“Each to their own”? An investigation into the effect of spacing on laid-thread couching as used in textile conservation

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Abstract

Laid-thread couching is a common stitched technique within textile conservation. It is used to support damaged fabrics onto a stronger support material. Due to its long-standing use, little research has been undertaken to quantify some its “known” characteristics. This project investigated the effect of varying the spacing of lines of laid-thread couching. Current literature, and a survey of practicing textile conservators, indicated that few details about laid-thread couching are published in case-studies, but a small number of in-depth research projects into stitched treatments have been undertaken in the past 10 years. Through the survey, cotton was chosen as the most appropriate thread to treat a presented “object”. Tensile-testing revealed variable characteristics between cotton threads from different thread manufacturers. Samples of the “object” were conserved with cotton thread, with different densities of laid-thread couching. Elongation and recovery from fixed-load testing was recorded over several weeks. This project found that thread choice was more important than spacing, as patterns in elongation and recovery were linked to the characteristics of cotton. Several samples were subjected to Digital Image Correlation, which demonstrated patterns of strain around the damaged and conserved areas. This technique proved useful, but requires further research before its full potential for use in textile conservation is completely realised.

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List of Abbreviations

AIC – American Institute of Conservation

CCI – Canadian Conservation Institute

CRE – Constant Rate of Extension

CTC – Centre for Textile Conservation, University of Glasgow

DIC – Digital Image Correlation

ICOM-CC – International Council of Museums, Conservation Committee

ICOM – UK Institute of Conservation

N – Newtons

TMRP – Tapestry Monitoring Research Project

Chapter 1: Introduction

The idea of "Does spacing matter?" came from a pair of curtains hanging in Calke Abbey, a National Trust property in rural Derbyshire. The curtains, which were several metres long, had been conserved with laid-thread couching in many areas. The lines of couching had been spaced equidistantly, even though the couching at the top of the curtain carried more weight than couching at the bottom…"Does it matter?" was the question which sprung to mind.

This project builds from the work of Sarah Benson who, in 2013, investigated different stitching threads used for laid-thread couching treatments.[1] Stitching style was highlighted as a suitable area of future research. This project also borrows techniques used by "The Tapestry Monitoring Research Project". A personal interest in the lack of didactic material available regarding couching also encouraged this focused topic.

1.1 What is laid-thread couching?

Laid-thread couching is one of the most common stitch techniques used in textile conservation. Its primary function is to attach an area of damage or loss to a stronger support material. Laid-thread couching is worked in lines, and each line is worked in two stages. Once a thread is secured into a strong area of the object, a short length of

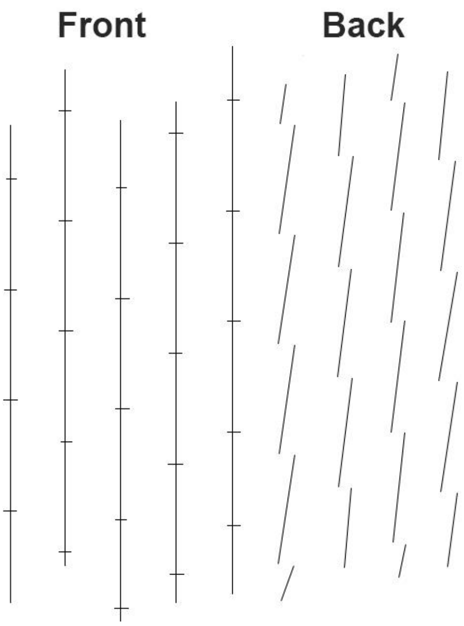

Figure 1.1: Illustration of the appearance of lines of laid thread couching from the front and back of treatment. Hannah Sutherland, 2016.

[1] Sarah Benson,"'Like with like':A comparison of natural and synthetic stitching threads used in textile conservation," unpublished MPhil dissertation, 2013, University of Glasgow.

thread is laid across the surface of the object along the grain. Small horizontal stitches are worked back up this line of thread securing it down. The lines themselves, and the horizontal stitches, are intentionally staggered to ensure the stitches are not all anchored onto the same weft or warp, see figure 1.1. The decision to use laid-thread couching over another method of stitching depends on the individual state of the object to be treated.

1.2 A Brief History of Laid-Thread Couching in Textile Conservation

The Getty book *Changing Views of Textile Conservation* offers many insights in to the beginnings of textile conservation by way of a range of articles from the 1950s onwards.[2] It details workshops set up during the early 20th century with the intention of preserving textiles, notably flags in North America and royal textiles or religious vestments in Europe.[3] [4] Tapestry restoration and conservation are also discussed.[5] All of these early workshops relied on skilled workers using techniques akin to construction to mend items, such as darning or reweaving tapestries and re-stitching loose beadwork.

Early discussions of laid-thread couching have been found dating to 1931, when Lady Meade-Featherstonhaugh, of Uppark House, employed an embroiderer from the Royal School of Needlework to assist in the preservation of 18th century curtains. This work is best summarized in Christopher Rowell's article published within *Textiles in Trust.*[6] His paper draws on two key sources – Lady Meade-Featherstonhaugh's memoir, *Uppark and its People,* written in 1964, and also transcripts of her diaries from 1931-1940.[7] [8]

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[2] Mary M.Brooks and Dinah Eastop (eds), *Changing Views of Textile Conservation,(*Los Angeles: The Getty Conservation Institute, 2011).

[3] Deborah Lee Trupin,"Flag conservation then and now," in Changing Views of Textile Conservation*, (*Los Angeles: The Getty Conservation Institute, 2011),48-58.

[4] P.A. Semechkin,"Workshop for the repair of antique needlework': On this history of the decorative arts section of the central state restoration workshops 1919-1934," Changing Views of Textile Conservation*, (*Los Angeles: The Getty Conservation Institute, 2011),19-30.

[5] Marike Temmink-van Dijkhuizen,"Textiles in all conditions: Opinions about restoration and conservation from changing perspectives," Changing Views of Textile Conservation*,(*Los Angeles: The Getty Conservation Institute, 2011), 31-36.

[6] Christopher Rowell,"Conservation traditions at Uppark: Lady Meade-Featherstonhaugh as a textile conservator," (London: Archetype Publications Ltd., 1997),96-107.

[7] Lady Meade-Featherstonhaugh and Oliver Warner, *Uppark and its People,* 1988 ed.,(London: National Trust, 1964).

[8] Lady Meade-Featherstonhaugh,*1931-1940 Mss. Diary*, Transcript by Margaret Davidson, 1979. (National Trust Archive, Polesden Lacey, Surrey.)

This variation of laid-thread couching used two needles and two threads; one to work the first laid line and one to work the horizontal stitches. This is more akin to couching as it is used in embroidery where one thread catches down another.[9] This work again builds on traditions of using known textile techniques in conservation treatments.

The use of traditional hand sewing, such as laid-thread couching has always continued within textile conservation. This long history of use is what may make it a difficult topic to research. It is such a common treatment that some may not see the benefit of researching it further. This position is summarized well by Johanna Nilsson,

> *…I am researching topics which are well known to those working with conservation. What colleagues might regard as common sense and obvious knowledge through tradition, and therefore unnecessary to survey, is to me characterized by a lack of scientific knowledge…the weakness of common sense is that many believe something to be true, and it is not the basis for what may be true.*[10]

This research project will provide quantitative data for some elements of textile conservation which are under-researched. It will also be of benefit to future conservators by recording the current collective knowledge regarding laid-thread couching in textile conservation.

1.3. Research questions

The following questions were formulated to allow the development of structured data, which could be used to understand the relationship between spacing of lines of laid-thread couching and the suitability of the support treatment.

- Does the spacing of laid-thread couching lines affect the strength of a treatment overall?
- Is there a "best practice" way of considering the spacing of couching?

[9] Readers Digest, *Complete Guide to Needlework,* (London: The Reader's Digest Association Ltd, 1981),32.

[10] Johanna Nilsson,"Ageing and Conservation of Silk: Evaluation of three support materials using artificially aged silk," Gothenburg Studies in Conservation, vol. 37 (2015):40, https://gupea.ub.gu.se/handle/2077/40524.

- Is it possible to use Digital Image Correlation (DIC) to understand the strain in an area of laid-thread couching?
- How can conservators effectively communicate about laid-thread couching treatments?

1.4. Research objectives

These objectives were developed in order to ensure the above questions could be answered.

- Carry out a literature review on the use of laid-thread couching within textile conservation, especially looking for literature which details treatment specifications.
- Create and share a questionnaire on the spacing of laid-thread couching. Analysis of this questionnaire should highlight considerations for spacing decisions and opinions regarding ideal spacing.
- Carry out tensile testing of chosen support thread to understand its physical properties.
- Make a series of stitched samples, replicating normal laid-thread couching, but spacing the lines at different densities.
- Use samples to carry out fixed-load tensile testing to quantitatively measure extension and recovery.
- Experiment with DIC to see if it can be used to measure strain in laid-thread couching treatments.
- Use stereo-magnification to identify changes in deformation patterns between various spaces of laid-thread couching lines.

1.5. Report Outline

Chapter 2 investigates the previous research carried out in this area through a literature review. C**hapter 3** fills some gaps in this literature by asking textile conservators about their methods. **Chapters 4-5** examine the physical properties of cotton fibres and how these properties can be understood using different testing methods. This is done through fibre research and tensile testing. **Chapter 6** gives the main experimental methodology for fixed-load tensile testing conserved samples.

Chapter 7 outlines the potential for using DIC to understand the strain inflicted on these samples from laid-thread couching. **Chapter 8** summarizes results from chapters 6 and 7. **The final chapter, 9,** analyses the project findings and how these findings relate to the textile conservation profession. This chapter also shows outlines potential areas of future research.

Chapter 2: Literature Review

The main aim of this literature review is to collect and discuss sources currently available relating to the spacing of laid-thread couching. These include instruction sheets, case studies and experiment-based research. Understanding the current literature ensured this project sat within an established, yet under-researched, field.

2.1. Didactic information on laid-thread couching

The Canadian Conservation Institute (CCI) have produced a series of "Notes" covering a wide range of conservation themes and issues. One of these is an introduction to stitches used in textile conservation.[11] This paper, written in 1986, but updated in 2008, calls laid-thread couching "self-couching". This term refers to the fact that the same thread works both the main line and the catching stitches. The technique is explained through a simple diagram and a few lines of text. Another introduction comes from "Textile Museum Services".[12] This leaflet, available from their website, suggests lines of laid-thread couching should be used sparingly and that horizontal catch stitches should be small to minimise visibility. Here, hand-drawn illustrations are less clear than the simpler designs from CCI. Spacing of 3mm-5mm is recommended, but no reasons are given for this ideal. Neither document comments on thread choice or how far beyond the area of damage laid-thread couching should go.

Early textile conservation publications give some information about the use of laid-thread couching. Leene, writing in 1972, brought together multiple textile conservation articles[13]. Leene advises how the stitch is formed and gives an illustration. She cites Emery's *The Primary Structures of Fabrics* as the source of the information[14]. Emery's book discusses fabric structure rather than conservation; classifying laid-thread couching as embroidery. Finch and Putnam describe the use of laid-thread couching in their book *Caring for Textiles*, but do not offer details of thread

[11] "Stitches used in Textile Conservation," Canadian Conservation Institute, http://canada.pch.gc.ca/eng/1439925170837. Accessed May 16th, 2016.
[12] "Conservation Stitching Guide," Museum Textile Services, [PDF], www.museumtextiles.com/uploads/7/.../conservation_stitching_guide.pdf, (accessed January 30, 2016).
[13] Jentina Leene, *Textile Conservation,* (London: Butterworth, 1972).
[14] Irene Emery, *The primary structure of fabrics,* (Washington, DC: The Textile Museum, 1966),247.

choice beyond a comment on the importance of it being aesthetically pleasing.[15] Landi, writing in 1985, gives more information regarding the spacing, urging the reader to vary their spacing as required by the structural and aesthetic needs of the object.[16] Descriptions given in these three works are only as useful as the skill of the conservator to understand what these needs are for the object in question. The authors do not refer to previous conservation sources and it is assumed their advice is based on experience.

2.2. Couching discussed in case studies

The most detailed, published, discussion of a laid-thread couching treatment is Berkouwer's paper on the treatment of a large wall hanging from Ham House.[17] This paper, presented at an ICON Textile Group Spring Forum, gives details on the spacing of couching and the pattern of couching used on a large textile. She discusses the choice to use different densities of laid-thread couching lines (10mm, 20mm or 40mm), depending on the condition of a particular area. This forethought allows future conservators to add in lines of stitching should they be needed, whilst continuing with the pattern already in use. This useful idea may be the reason why such detail about the laid-thread couching was given.

Most published case studies focus on another part of treatment and pass over laid-thread couching with a low-key "it was couched". The author conducted a brief survey of 20 case studies which mentioned couching; fifteen noted the thread used, but only one gave information on spacing (see discussion of Glover's paper below). An annotated bibliography of surveyed articles is presented in appendix 1. This finding agrees with Nilsson's discussion that "Information is lacking [in conservation literature] concerning… the spacing or length of the stitch…".[18]

Glover, writing about the conservation of sixteenth-century funeral cope, noted a 4mm spacing between her lines of couching on a velvet panel; spacing for other

[15] Karen Finch and Greta Putnam, *Caring for Textiles,* (London: Barrie and Jenkins Ltd., 1977),74.
[16] Sheila Landi, *The Textile Conservator's Manual*, (Oxford: Butterworth-Heinemann, 1992),117.
[17] May Berkouwer,"The conservation treatment of the seventeenth-century wall hangings in the Queen's Antechamber at Ham House," ICON Textile Group Spring Forum 2014, [CD-ROM],46-59.
[18] Nilsson, Gothenburg Studies in Conservation, (2015).

sections was not noted.[19] This article was published in *Costume,* a journal aimed at those with an interest in fashion history. Another conservation report presented in this journal does not offer a spacing but does state that the aim with laid-thread couching was to give as much support as possible without adding too many new stitch holes into the object.[20] Conservators may feel a greater need to give details when presenting to a non-conservation audience.

Occasionally authors opt to give detailed comments on their laid-thread couching technique. Kite discusses choosing to use a straight needle rather than a curved needle to carry out laid-thread couching on a cope.[21] It was felt that curved needles gave less control over stitch placement, whereas a straight needle could be true through the many layers present in the cope.

Discussing laid-thread couching within tapestry conservation, Gill points out that lines placed too far apart can create a noticeable difference in a stitched and unstitched area.[22] In this instance it would seem that the shadow created by couching is cause for concern, rather than the stitches themselves.

2.3. Couching discussed out of case studies

Several articles discuss stitching as a stand-alone subject; focusing on the technique or on stitching vs. adhesive, rather than linking the technique to specific object. Geijer, writing in 1963, suggests that both stitching and adhesive could produce unsatisfactory results if applied with “excessive zeal”.[23] She goes on to stress that the fewer stitches the better, advocating a “gently does it” approach. Jedrzejewska gives an unbiased view of the advantages and disadvantages of both stitching and adhesives. [24] In

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[19] Jean M. Glover,"The Conservation of a Sixteenth-Century Spanish Funeral Cope," Costume, vol. 19, no. 1 (1985):30-39. DOI: 10.1179/cos.1985.19.1.30.
[20] Susan Payne et. al.,“A seventeenth-century doublet from Scotland,” Costume, vol 45 (2011):39-62, DOI:10.1179/174963011X12978768537537.
[21] Marion Kite,“The Conservation of the Jesse Cope,” Textile History, 20 (1989):235-243.
[22] Kathryn Gill,“Couching Stitch Patterns – Avoiding the “Tram Line” Effect,” in M.Leader ed. Tapestry conservation: maintaining the woven picture, postprints of The Institute of Conservation Textile Group Forum, 2006, 30-34.
[23] Agnes Geijer, “Preservation of textile objects” in Recent Advances in Conservation: Contributions to the IIC Rome Conference, 1961, Ed. Garry Thomson (London: Butterworths, 1963), 185-189.
[24] Hanna Jedrzejewska, "Problems in the Conservation of Textiles: Needle verus Adhesive (1981)," in Changing Views of Textile Conservation, eds Mary M. Brooks and Dinah D. Eastop, (Los Angeles: Getty Conservation Institute, 2011), 148-152.

relation to stitched support she comments how threads should move with the textile and follow their woven structure. Flury-Lemberg includes a detailed illustration of laid-thread couching stitches, but fails to refer to it in the text of her article on "Conservation with Needle and Thread". [25] She refers to the technique as "laid stitch". None detail a favoured or advised spacing.

2.4. Physical properties of laid-thread couching treatments

Ballard gives a detailed introduction to fibre properties in her paper submitted to the 11th International Council of Museums – Conservation Committee Triennial (ICOM-CC).[26] She identifies how fibres are impacted by changes in humidity when hanging, and outlines how fibres go through a known cycle of elongation before breaking.[27] She also illustrates the "yield points" of several fibres; this is the point at which a fibre's ability to return to its original length after stretching is diminished, (see chapter 5.1 for details).[28] Writing from a conservation perspective allows a connection between scientific facts and conservation issues. The main issue pertinent to this research project is that the top section of a textile is subject to the greatest load and therefore will elongate the most in a given situation.[29] A useful glossary of terms regarding elongation and recovery in fibres is given in a different paper by Ballard from the same year.[30] Ellis cites the work of Ballard in her 1997 investigation into the tensile strength of silk and polyester yarns.[31] Ellis concludes that fibre strength, yarn tex, yarn ply and the presence of a dye are all influencing factors on the strength of a yarn. In turn, Benson cites the work of Ellis as a starting point for her research in 2013.[32] Benson looked at different threads used to carry out laid-thread couching, by examining the

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[25] Mechthild Flury-Lemberg, "Conservation with Needle and Thread," in Changing Views of Textile Conservation, ed. Dinah Eastop and Mary Brooks, (Los Angeles: The Getty Conservation Institute, 2011), 171.
[26] Mary Ballard,"Hanging Out: Strength, Elongation and Relative Humidity: Some Physical Properties of Textile Fibres," ICOM-CC 11th Triennial, Edinburgh, (1995),665-669.
[27] Ibid.
[28] Ibid.
[29] Ibid.
[30] Mary W. Ballard,"How backings work: The effect of textile properties on appearance," in Lining and Backing: The Support of Paintings, Paper and Textiles, (London: UK Institute of Conservation, 1995),34-39.
[31] Shirley Ellis,"A preliminary investigation of the tensile properties of yarns used for textile conservation," Textile Conservation Newsletter, Spring Supplement (1997):1-20.
[32] Benson, 16.

treatment of natural fibre samples with both natural and synthetic threads.[33] These samples were subjected to a fixed-load experiment for a period of two weeks, after which they were examined using high-magnification images and scanning electron microscopy (SEM). Results from the fixed-load experiments indicated that even light loads would cause distortion when left for a long period of time, regardless of thread choice. Benson found that polyester threads gave the highest damage result. Many areas of further research were indicated, including stitching layouts and stitching technique. Her work was also shared through publication in the postprints for ICOM-CC 17th Triennial in 2013.[34]

Between 2005 and 2010 extensive research was carried out by Nilsson at the Institute of Conservation, University of Gothenburg, to create a methodology for evaluating textile conservation treatments.[35] Her research culminated in the publication of five papers between 2010 and 2015.[36] [37] [38] [39] [40] The papers are available as appendices of Nilsson's dissertation through the University of Gothenburg.[41] The introduction included in this file takes the form of a literature review; it is particularly valuable for understanding the intentions of textile conservation as a field, and the various

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[34] Sarah Benson, Frances Lennard and Margaret Smith,"'Like-with-like': A comparison of natural and synthetic stitching threads used in textile conservation," in ICOM-CC 17th Triennial Conference Preprints, Melbourne, 15-19 September 2014, ed. J. Bridgeland (Paris: International Council of Museums, 2014).9pp.

[35] Johanna Nilsson,"In Search of Scientific Methods for Conservation of Historic Silk Costumes," Gothenburg Studies in Conservation, 25 (2010):pp104, conservation.gu.se/.../1309/1309145_nilsson_2010_conservation_of_historic_silk.pdf, accessed May 10, 2016.

[36]Johanna Nilsson,"A survey of the most common support methods used on historic costumes and a preliminary investigation of tests assessing the quality of conserved fabrics," in *Scientific Analysis of Ancient and Historic Textiles*, eds. Rob Janaway and Paul Wyeth, (London: Archetype Publications, 2005),79-85.

[37] Johanna Nilsson et.al.,"The validation of artificial ageing method for silk textile using markers for chemical and physical properties of seventeenth century silk," Studies in Conservation, vol. 55 (2010):55-65.

[38] Francisco Vilaplana et.al.,"Analytical markers for the degradation of historic and artificially aged silk in different environments," Analytical and Bioanalytical Chemistry, vol. 407, 5 (2015):1433-1449, DOI 10.100 7/s002 16-014-8361-z.

[39] Johanna Nilsson, "Evaluation of Stitched Support Methods for the Remedial Conservation of Historic Silk Costumes," e-conservation journal 3 (2015), DOI: 10.18236/econs3.201506.

[40] Johanna Nilsson and Östen Axelsson,"Attributes of aesthetic quality used by textile conservators, evaluating conservation interventions on museum costumes," Perceptual and Motor Skills, vol. 121 (2015):199-218, DOI 10.2466/27.24.PMS.121c10x7.

[41] Nilsson, Gothenburg Studies in Conservation,(2015).

decisions required in conservation scenarios [42]. Whilst Nilsson's work focused on current practice in Sweden, conservators from around the world were consulted through a survey.[43] The main experiments relevant to this project are shared through Nilsson's fourth paper and a short film.[44] [45] While the film documents her making and testing the samples, illustrations in the paper are more useful for those wanting to replicate the research. The experiments involved the treatment of artificially aged, damaged, silk – one group with laid-thread couching, one group with brick-couching and the final group with a crepeline overlay. Samples were subjected to tensile testing to understand the changing strength of the samples as they were damaged and conserved. Some of the stitching was removed after testing to examine deformation and damage of the samples in detail. Nilsson found that none of the treatments came close to restoring the complete strength of the aged, undamaged silk; they averaged 20% of original strength, with strength calculated from maximum force at break.[46] This figure should be taken alongside the finding that the aged, damaged, unconserved silk had on average 5% of original strength. Nilsson recommended crepeline patches for supporting damaged silk, but also found that laid-thread couching was the best treatment for returning some strength to a hanging item.[47]

All of these investigative projects demonstrate a desire to fully understand treatments which for so long have been the "bread and butter" of textile conservation work. All projects outlined the need for future research within the area of stitched conservation treatments.

2.5. Conclusions

Sources available relating to laid-thread couching vary in quality and in content. Critical investigation of it as a treatment is rare and articles giving exact details on spacing are few. Those sharing their spacing ideals do not quantify their reasoning. Conservators

[42] Ibid, 21-41.
[43] Nilsson,(2005).
[44] Nilsson, e-conservation journal, (2010).
[45] Johanna Nilsson,"Stitching support methods using laid couching, brick couching and crepeline attached by running stitch," [YouTube film], https://www.youtube.com/watch?v=eoogh96C7eI, (accessed May 12, 2016).
[46] Nilsson, e-conservation journal, (2010).
[47] Nilsson, Gothenburg Studies in Conservation, (2010).

who publish without research to back up their claims are not necessarily producing incorrect information; they are working off real-life experience rather than a specific set of data gained in an experimental way. Most didactic publications agree that each object needs to be addressed differently, and treatment carried out according to the individual needs of the object. Advice on factors which could aid conservators in making treatment decisions are often omitted.

The literature review raised the following questions:

- What are some of the considerations taken into account when a conservator decides to carry out a laid-thread couching treatment?
- Why are details of stitched treatments not published often, when details on other treatments, for example adhesive, are easily accessed?

In order to fill in these gaps, a survey was conducted of practising textile conservators. This survey addressed these issues and also encouraged conservators to put forward any case-studies they have worked on which discussed couching in detail.

Chapter 3: Questionnaire

3.1 Introduction

A questionnaire was sent out to textile conservators around the world. The questions aimed to collect the following information:

- Factors impacting laid-thread couching space choice.
- Suggestions of line spacing and thread types which could be used for tensile-testing experiments with historic sample.
- Investigate if early training impacted choices of thread or spacing.
- Opinions on lack of published details on laid-thread couching.

3.2 The Questionnaire

The questionnaire was created on SurveyMonkey®, an online platform allowing it to be shared easily and filled in quickly. Five questions were asked, most of which required a check box or few word answer. Space was left at the end for any further comments. The questionnaire was personally emailed to 44 conservators and also shared through the ConsDistList – an international email network for conservation professionals.[48] Participants were encouraged to share the questionnaire where possible. In total 29 of those who were emailed completed the questionnaire, with a further 22 finding the questionnaire through colleagues or the ConsDistLists, giving a total of 51 responses. See appendix 2 for a copy of the questionnaire and appendix 3 for comment responses.

3.3. Respondent Answers

Respondents were found to currently be working in twelve different countries as outlined in table 3.1.

[48] Hannah Sutherland, "Survey on laid-thread couching," May 3, 2016, http://cool.conservation-us.org/byform/mailing-lists/cdl/2016/0512.html, (accessed June 6, 2016).

Table 3.1: Respondents' current places of work

Europe: 33	North America: 11	Other: 6	Total
Scotland 7 England 22 Norway 1 Ireland 1 Holland 1 Germany 1	Canada (west) 2 Canada (east) 4 USA (mid-west) 2 USA (east coast) 2 USA (west coast) 1	New Zealand 1 Australia 3 Singapore 1 India 1	50 One participant did not give this information.

Due to the disproportionate numbers of UK conservators it is difficult to make comparisons between UK practices and those of other locations, as there are not enough respondents to be representative. The data will therefore be examined as a whole group.

Question 1

At what establishment/s did you carry out the majority of your early textile conservation training?

Several Respondents noted a university course and an early job post. In these instances, both have been recorded.

Table 3.2: Respondents' training establishments

University Programmes	Textile Conservation Centre, Hampton Court	12
	Centre for Textile Conservation, Glasgow	6
	V&A/Royal College of Art Conservation Programme	4
	Textile Conservation Centre, Southampton	2
	University of Delaware	2
	University of Alberta	1
	Abegg Stiftung	1
	Queen's University, Ontario	1
	Centre de Conservation du Quebec	1

	University of Applied Arts Vienna	1
	Fashion Institute of Technology, New York	1
	University of Florence	1
	Unspecified university programme	2
Museums	British museum	7
	American museum	4
	Canadian museum	2
	Australian museum	2
	German museum	1
	Unspecified museum	3
Other	National Trust	2
	Private studio apprenticeship	2
	Unspecified job post	1
	No majority	1

The high numbers of conservators having trained within the UK is likely due to the author's knowledge of these professionals and access to ICON's conservation register[49]. The varied responses show the range of routes into the conservation profession. Many have trained in one country and subsequently trained or worked in another. This may be indicative of the small number of courses specialising in textile conservation. Many of the training programmes listed in table 3.2 are only represented by one respondent. It would therefore not be appropriate to consider the information gathered as representative of the programme. This means no accurate conclusions can be drawn on the impact of early training on spacing of laid thread couching.

[49] "Conservation Register," ICON, (2016), http://www.conservationregister.com/, (accessed June 2, 2016).

Question 2

When considering using laid-thread couching on an object what are your key considerations when deciding how spaced apart to make your lines of couching? Please mark as many as necessary.

Table 3.3: Respondents' considerations

Fragility of object	51
Size of loss	42
Weight of object to be supported	31
Importance of a minimally visible treatment	27
Flexibility required from treatment	23
Type of stitching thread	21
Fibre of object	19
Time available to complete treatment	9
Spacing comfortable working to	9
Other	20

Most respondents chose three or four statements. 100% of respondents indicated that the fragility of the object would be a key consideration, with the size of the loss was also deemed important. Issues relating to the conservator personally were the lowest scoring (time available to complete treatment, space comfortable working to). This focus on the object, rather than the worker, ties into much of the literature regarding tailoring treatment to the individual object.

Twenty respondents gave additional considerations in response to this question. These can be grouped into six categories:

1. **Type of Damage**: Is the hole in an otherwise sound area of substrate or is the area generally weak? Does the rip/hole follow the weft, warp or bias? How much of the object is affected by the damage? Are there any loose threads requiring support?
2. **Nature of fabric**: What is the weave pattern of the fabric? ie. potential to blend in stitching. What is the thread count of the fabric? All comments suggested that the

coarser the substrate yarns, and the lower the thread count, the further apart they were space their lines.

3. **Couching as part of an overall treatment**: Is couching the primary or secondary treatment? ie. is the main treatment an adhesive, with small areas of stitching? Is the whole object being stitching with lines of laid-thread couching or just a small area? Are any overlays (net, crepeline etc.) being used?
4. **Object future:** Is the object going to be hanging or flat? Is the fabric part of an upholstered item?
5. **Support material choice:** What support fabric is being used? What thread is being used to stitch with? A finer thread may warrant more lines closer together.
6. **Resources:** Not just time, but also budget and the need to use materials available in the studio.

Question 3

As a student I have found it difficult to find detailed information regarding couching within published articles. Would you consider any of the following to be reasons for this lack of detail? Please mark as many as necessary.

Table 3.4: Potential reasons for lack of publication

A	It is unnecessary: couching is very variable and dependant on the object, so exacting instructions are not as transferable as other treatments	32
B	The spacing of couching is personal preference; it doesn't matter what person A did because person B would probably have worked it slightly differently	17
C	Couching is a common treatment; other conservators are not interested in getting explicit details	13
D	Not publishing this information limits the chance of untrained persons attempting repairs themselves	6
	Other	27

Most respondents gave two answers to this question. Twenty-seven gave additional thoughts; most expanded on the respondent’s initial answer/s.

Many “Other” comments discussed the experience level of a textile conservator and could be seen as an expansion on answers A, B or C. Respondents noted the high number of variables in this decision, but that these variables are processed as a gut-reaction, rather than a calculated formula taken from literature. In summary they state that each textile conservator is taught how to work laid-thread couching stitch whilst training. She/He will then accumulate different experience from different objects; this contributes to their individual decision-making process when deciding how to space lines of couching. This was expended upon by several respondents who felt that learning about laid-thread couching was best conducted in practice rather than in theory, and under the guidance of someone who had experience of working on many objects.

Several respondents considered why laid-thread couching is not published in journals. Reasons given included that journals tend to cover new or innovative technologies, neither of which would cover laid-thread couching, and that journals tend to focus on the scientific rather than the purely practical.

One respondent added that conservators tended to turn to those around them if they needed guidance with a spacing issue and would not necessarily think of searching journals.

Question 4

Do you think that you have developed a preferred line spacing over your career?

Table 3.5: Overall breakdown of yes/no answers

Yes	15
No	36

Table 3.6: Breakdown of "Yes" answers by group

	Overall	Private practice	Based in institution
% yes	30%	50%	25%

Around 29% of respondents confirmed they had developed a preferred spacing. Due to the limitations of investigating by training programme, this data was broken into private practice and intuition-based respondents, to see if this had any bearing. Private practice may had had a higher percentage of "yes" answers as this may make estimates for work simpler: timing for stitched treatments can be more accurately predicted. This was a small sample group (just 10 from 51), so it could be coincidental; a different group of 10 could give a very different answer.

Of those who said that they had developed a preferred spacing only one person gave an exact figure: 5mm. Others gave a range, ie. 4-6mm. All given measurements were between 2mm and 10mm. Two respondents stated they worked on a grid system and used divisions of that grid depending on the damage, ie. working at a 10mm spacing and then 5mm or 2.5mm in some areas. Some respondents stated a set spacing for a particular type of object they came into regular contact with.

Question 5

You are presented with a c.1900 cotton infants gown with a horizontal split in the skirt. The gown will be mounted on a mannequin for long-term display. The fabric itself is medium weight and stable. How far apart would you consider spacing out your lines of couching, and what threads would you consider using?

Both parts to this question allowed a free-form answer. Where a range was stated (ie. 3-5mm), all measurements in that range were counted (ie. 3mm, 4mm and 5mm) to cover all possibilities. If more than one thread was stated, all were noted.

Figures 3.1 and 3.2 were presented in the questionnaire.

Figure 3.1, Above: Detail of split in skirt.

Figure 3.2, Right: Infant gown.

Table 3.7: Proposed threads for hypothetical treatment

Proposed Threads	
Cotton (very fine or lace weight)	27
Hair Silk	10
Stabiltex®/Tetex®[50]	13
Güterman Mara (100, 150 or 220) (polyester)	10
Güterman Skala (polyester)	8
Silk Monofilament	6
Other very fine polyester	4
Silk pulled from crepeline	1
Embroidery Floss (fibre not specified)	1
Very fine linen	1

[50] Brand names for a woven, sheer, lightweight, polyester fabric from which individual yarns can be drawn.

Table 3.8: Proposed spacing for hypothetical treatments

Proposed Spacing	
2mm	3
3mm	10
4mm	10
5mm	22
6mm	11
7mm	7
8mm	6
9mm	4
10mm	7

All measurements given were between 2mm and 10mm, as Q4. One respondent proposed to work lines of laid-thread couching over the area of damage, but use running stitches in the surrounding areas.[51] Another stated that they would work out a grid system and then use proportions of that as appropriate. One respondent stated that they would space lines at 3-4mm if using very fine cotton, but would make them closer if using hair silk "as it is weaker"[52]. Several respondents stated that cotton of a suitable fineness was sometimes unavailable. Comments were also made that Stabiltex® and Skala can be too shiny.

If all variants of polyester thread were counted as one, then polyester would have been the most popular. The high number of different weights and brands meant they these were counted as different types for this experiment. As many respondents were specific about the same type of cotton, this was chosen as the thread to be used in later experimentation. Four respondents gave details:

- 200/2 dtex mercerised lacemaker's cotton thread (Lacis brand from USA)
- 185/2 cotton.
- 100s cotton.
- Egyptian cotton.

[51] Respondent #43, Appendix 3, p.103.
[52] Respondent #49, Appendix 3, p103.

Table 3.9: Thread choice by region

	UK	North America	Europe	Other
Silk	7	5	1	2
Cotton	13	7	1	4
Tetex	10	1		2
Skala	5	3		
Mara	8		1	1
Other polyester	2	1		
Other	Fine linen 1			

Thread choice was looked at by location, as examined by Sarah Benson.[53] This concurs with Benson's findings that Mara is still more popular in the UK than elsewhere. The popularity of cotton across each region-group remained high. Two conservators working in Europe declined to give thread choices based on photographs alone.

Question 6

If you have written or come across any case studies giving details on the spacing of laid couching I would be very interested to hear about them.

The following articles and chapters were highlighted:

- "Couching Stitch Patterns" by Kathryn Gill, in *Tapestry Conservation,* edited by Frances Lennard and Maria Hayward.[54]
- "Hand stitches used in textile conservation" from AIC.[55]
- The PhD research of Joanna Nilsson.

[53] Benson, 19.
[54] Gill, 30-34.
[55] "TSG: Laid and Couched Stitch," American Institute of Conservation, [2014 digitization of 1995 edition], http://www.conservation-wiki.com/wiki/TSG:Laid_and_Couched_Stitch,(accessed May 30, 2016).

- "The conservation treatment of the seventeenth-century wall-hangings in the Queens's Antechamber a Ham House" by May Berkouwer. Paper presented at the 2014 ICON Textile Group Spring Forum.[56]

Three respondents commented that this was something they did not look for or that spacing was not something they tended to record in detail.

Final Comments

Twenty-two respondents expanded their answers with further comments. Common themes included personal stitching preferences and the overall value of experience.

Stitching as part of a treatment:

> Comments were made about the scope of the treatment; where some opted to use the same spacing for a whole object, others were more open to varying spacing depending on the damage. The idea of having one spacing for stronger areas and another, closer, spacing for weaker areas was given. This included the use of an alternative stitch, such as running stitch, alongside lines of laid-thread couching. The size and regularity of the catching stitches (those perpendicular to the laid line) was mentioned as being a factor which can impact treatment and spacing. The size of the curved needle chosen was noted to impact spacing choice.

Teaching laid-thread couching:

> One respondent stated that "…while practicing [laid thread couching, the students] look…under the microscope so as to understand what happens if they pull the thread too tightly…"[57]. This method was supported by other comments which noted how being taught overly prescriptive methods was not useful as it did not allow for the wide scope of a range of objects.

The value of experience:

> The fact that couching is subjective came up several times in this section. The general opinion is that every section of damage is different and therefore each

[56] Berkouwer.
[57] Respondent 46, Appendix 3, p.107.

couching treatment is different. This also links in to the fact that each conservator's accumulated experience is different. This gives, as one respondent said, "huge variation in working practice"[58]. One respondent stated how experience came from not only practice, but also the observation of treated objects over time.[59]

Several conservators used this section to highlight areas in which they would like to see more research carried out. These areas included:

- The importance of staggering lines of laid thread couching as sometimes this is not possible due to location of damage.
- Different methods of couching, including the size of the perpendicular stitches and the use of brick couching.
- The distance lines of laid-thread couching should be taken into the strong surrounding area.

3.4 Aims Summary

Factors impacting laid-thread couching space choice:

There are many factors impacting laid-threading couching space choice. Those identified during this survey are:

- Fragility of object – strong with isolated damage vs. inherently weak etc.
- Size of loss – large holes, small slits etc.
- Type of damage – holes, splits, abrasion, loose wefts/warps.
- Fibre of object.
- Nature of fabric – weave structure, thread count.
- Object future – hung, laid flat, upholstered.
- Weight of object to be supported – heavy or light, load-bearing.
- Importance of a minimally visible treatment.
- Flexibility required from treatment.
- Other concurrent, or prior, treatment – adhesive, patches or complete backing.
- Spacing comfortable working to.

[58] Respondent 16, Appendix 3, p.105.
[59] Respondent 17, Appendix 3, p.105.

- Support material and type of stitching thread.
- Available resources – time, space, threads, staffing.

These finds reiterate the importance of understanding an object as a whole before starting treatment: not only what the object is made of, but also how it is to be stored or displayed in the future. The "gut feeling" mentioned by several respondents can be defined as sophisticated decision making based on great experience. Several elements in the decision making process can be highlighted as external factors: those which are potentially out of the conservator's control. These include available resources and prior treatments carried out on the object.

Suggestions of line spacing and thread types which could be used for experiments:

Spacing of 5mm was the most popular. Twelve people gave a measurement of exactly 5mm whilst a further seven gave bracketed figures which included 5mm, ie. 3-5mm or 5-6mm. All respondents gave answers between 2mm and 10mm. The practical experiments will look at different spacings within that range.

Polyester and cotton both scored highly. The vast range of polyester threads mentioned meant that when they were broken into type cotton was the most popular. Most of those who suggested cotton defined it as "very fine" or "lace weight". These are both terms which will meant different things to different conservators. Further research will be carried out to choose a suitable, fine, cotton thread.

Investigate if early training impacted choices of thread or spacing

Little correlation is evident between place of training and spacing or thread choice. In order to give this information a survey would require a greater number of respondents and for the questionnaire to be aimed at graduates from particular programmes.

The scope of this survey can only identify that individual experiences will impact personal preferences and recommendations for different objects; each respondent to the survey has been exposed to different objects and discussed their treatments with different people. These factors will have ultimately affected their individual accrued experience.

Opinions on lack of published details on laid-thread couching:

Answers to question three can be summarized to conclude that it is unlikely that qualified conservators would regularly search out information about other conservator's stitched treatments. Conservators are likely to have a personal discussion with another conservator about spacing decisions rather than look for written didactic information. Conservators are always learning and developing their skills; anything too didactic may suggest a finite number of situations for laid-thread couching to appear in. The number of variables to consider would make succinct, detailed, writing difficult.

3.5 Conclusions

The range of answers demonstrate how each individual object requires thorough consideration before treatment begins. Comments towards the end of the questionnaire indicate how these many decisions become more automatic as each conservator becomes more experienced. Experience is difficult to explain in a quantitative matter. For many respondents in the survey there appears to be a point in their career where they rely less on colleagues for assistance in making complex choices about thread choice and spacing, and perhaps other colleagues would rely on them for guidance. This pattern of using colleagues for advice and support was highlighted by a few respondents as to why they do not publish, or indeed look for, details on laid-thread couching.

The next stage of the project investigated the differences between weights of cotton mentioned in the questionnaire, and why Egyptian cotton is specifically noted for use in conservation.

Chapter 4: Material Analysis

4.1 Introduction

The survey of textile conservators showed fine cotton as the most popular supporting thread. This result matches with the idea of "like-with-like" explored by Benson.[60] Very few respondents gave additional information regarding weight of cotton. The aims of this chapter are to:

- Understand the make-up and characteristics of cotton – why does it make a good support thread?
- Look in detail at the fabric to be supported.
- Identify the differences between the three potential support threads.

This chapter will introduce cotton as a fibre and qualitatively analyse the threads. Examining these materials at a microscopic level will help provide supporting information for the analysis of later tensile testing.

4.2 Cotton

Cotton is a natural, plant fibre, grown on plants of the genus Gossypium.[61] Fibres grows as seed hair inside the boll of the plant.[62] Limited space inside each boll stops fibres growing straight.[63] At this stage they are a moist tube. When the bolls burst the fibres dry out, causing their lumen (the central hole) to collapse. This drying causing them to curl and twist, giving the characteristic cotton fibre shape.[64] After picking bolls are ginned: a process to separate the fibres from their grit-like seeds; fibres can then be spun.[65] Cotton fibres vary between 11µm to 22µm in width.[66]

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[60] Benson, 10.
[61] J. Gordon Cook, *Handbook of Textile Fibres: Volume 1 – Natural Fibres*, 5th Ed. 1984, (Oxford: Woodhead Publishing Limited, 2012),39.
[62] EPG. Gohl and LD. Vilensky, *Textile Science: An Explanation of Fibre Properties,* 2nd Ed. 1983, (Melbourne: Longman Cheshire Ltd., 1985),41.
[63] Cook, 43.
[64] Ibid
[65] Cook, 49-52.
[66] Gohl and Vilensky, 41.

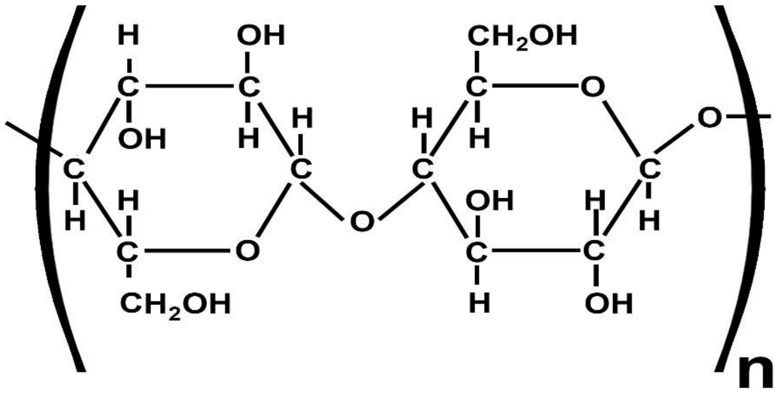


Figure 4.1: Cellulose monomer. ©Hannah Sutherland, 2016.

Cotton is almost 99% cellulose once in yarn or thread form. Natural waxes form the rest. These help with lubrication during spinning.[67] Figure 4.1 shows the cotton monomer. Cotton is between 65% and 70% crystalline.[68] In this formation polymers are uniformly structured; they are very strong, but rigid. Polymers in the amorphous region are more loosely structured, with little linear pattern (see figure 4.2). This region is more malleable. The combination of structured and un-structured regions allows cotton to stretch a small amount before it will break.[69] This quality is useful in textile conservation as it allows cotton to move slightly in support of an object or to react to a change in environmental conditions.

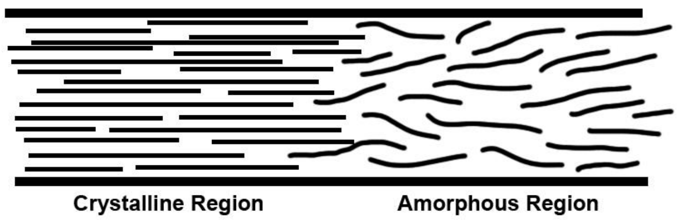


Figure 4.2: Formation of crystalline regions and amorphous regions. ©Hannah Sutherland, 2016.

Cotton varies in quality depending on growing conditions. High quality if often noted by a long fibre length. Rich nutrients deposited by the Nile during annual flooding produces excellent growing conditions for cotton plants. Egyptian cotton is therefore

[67] Cook, 69.
[68] Gohl and Vilensky, 45.
[69] Cook, 65.

well-known for having some of the longest fibres.[70] Long fibres produce a strong yarn as the fibres have a greater area of overlap, allowing them to grip together well.[71] This makes threads which are both very fine and strong.

4.3 "Object" – Cotton Infant's Gown

This cotton gown (figure 4.3) was purchased from eBay™, prior to the questionnaire being sent out. It was chosen as it was known to have been worn, washed and handled regularly. The skirt section of this gown will be used as the "object" in testing procedures. Due to the gown's age and use it is likely that the inherent strength of the fabric will vary in different parts of the fabric. This is still useful for testing as these qualities make it a useful reflection of an artefact found in a heritage collection. By using the skirt only, the variation should be minor as there is no visual deformation in this area caused by wear.

The gown is assumed to date from the first half of the 20th century. Fibre confirmed through microscopy. There are 32 wefts and 32 warps per 10mm.

Figure 4.3: Cotton Infant's gown.

[70] Cook, 49.
[71] Cook, 85.

Figure 4.4 shows clear variation in yarn thickness, both in the weft and the warp. This is to do with the way in which the yarns were spun. Figure 4.5 shows how the warp threads (and wefts) have set into their woven state. This is called secondary creep and could impact tensile testing.[72] This is because a certain amount of load will be taken up with straightening out the wave, before any stress is exerted on the yarn itself. Figure 4.6 shows several fibres removed from the gown warp. The highly twisted nature shows a matured cotton fibre, which has undergone only basic processing.[73]

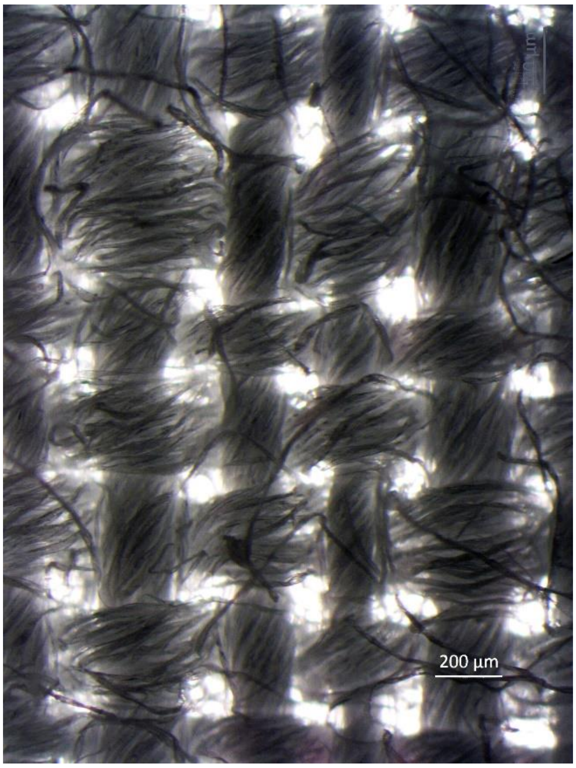


Figure 4.4: Detail of weave structure. Warps are vertical.

Figure 4.5: Warp pulled from gown fabric.

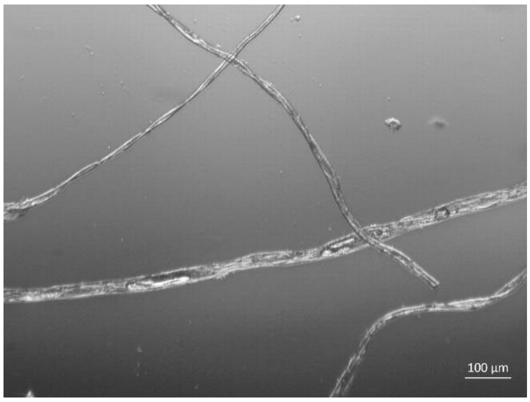


Figure 4.6: Cotton fibres from gown.

4.4 Threads

Before carrying out tensile testing it was important to clarify terminology and identification methods used in the thread industry. The term “lace weight” was used ten times in questionnaire responses. Only two weights of thread were given - 185/2 and 200/2. One resource, which discusses lacemaking threads, notes over 1800 types

[72] Ágnes Timár-Balázsy and Dinah Eastop, *Chemical Principles of Textile Conservation*, (Oxford: Butterworth-Heinemann, 1998),14.
[73] Cook, 60.

of thread.[74] Of these only some will be suitable for textile conservation, mainly due to their thickness. The thickness of a thread is denoted by an identifying number or code. There are two methods of identification, known as Fixed Weight Systems and Fixed Length Systems.

- Fixed Weight Systems – the length of thread required to reach a set weight.
- Fixed Length Systems – the weight of thread required to reach a fixed length.[75]

The two thread weights mentioned (185/2 and 200/2) have been calculated using a Fixed Weight System. This is standard for cotton. There are two versions of this system: the English (or imperial) count, denoted with Ne, and the metric count, denoted with Nm.

- Ne – Number of hanks (840yds) per pound.
- Nm – Number of hanks (1000m) per kilo.

In both systems, the higher the first number, the finer the thread. [76] As neither of these weights were given with their denoting letters it is difficult to assess how they may relate to threads chosen for this project as, for example, Ne 185/2 would not equal Nm 185/2. The second number indicates how many yarns are plyed together.[77]

4.5. Chosen Threads

The three threads shortlisted for this project are:

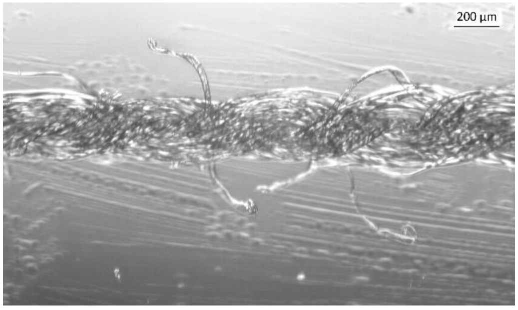
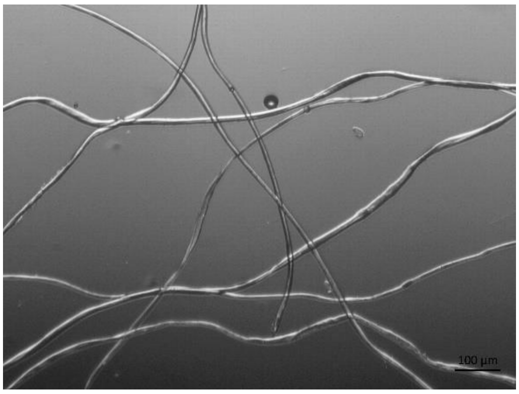
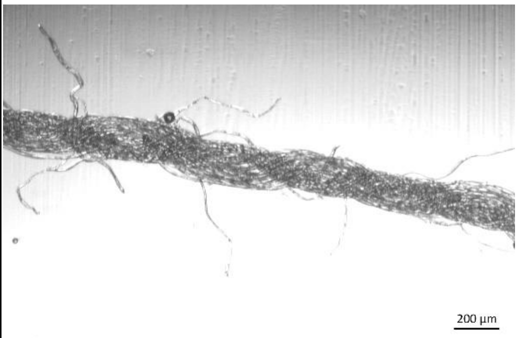
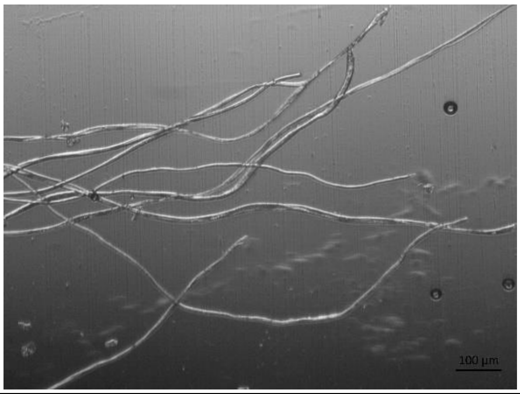
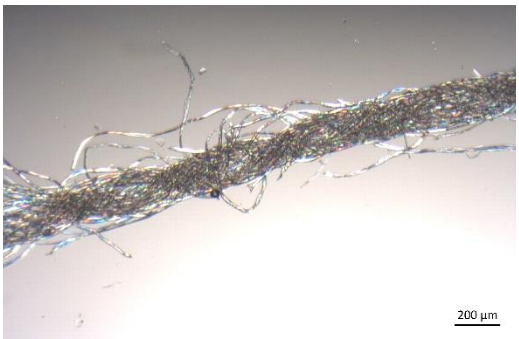
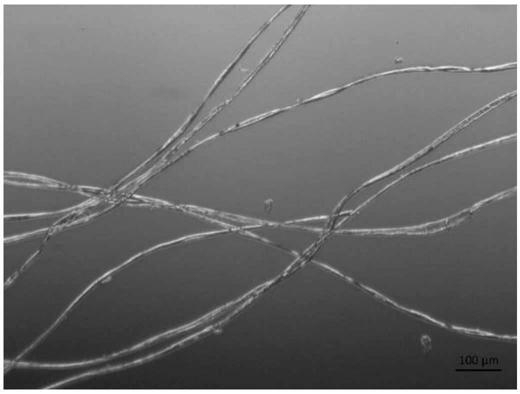
- Kantklosgaren Egyptian Cotton (Gegazeerd) Ne 170/2 (Belgian brand)
- Kantklosgaren Egyptian Cotton Ne 160/2 (Belgian brand)
- Fil au Chinois Egyptian Cotton 120/2 (French brand)

These threads are different to those mentioned in the survey, but are very fine threads and would be suitable for use in textile conservation. Thread availability meant that the exact threads mentioned could be sourced. "Gegazeerd" means that the cotton

[74] Brenda Paternoster, *Threads for Lace Edition 6,* (Kent: Brenda Paternoster, 2015).
[75] "Thread Numbering," Coats Industrial, http://www.coatsindustrial.com/en/information-hub/apparel-expertise/thread-numbering,(accessed June 22, 2016).
[76] Ibid.
[77] "Numbering systems – more than figures," Güterman, https://www.guetermann.com/shop/en/view/content/Industry_Numbering_System?node=Industry-Numbering-System, (accessed June 22, 2016).

has been gassed.[78] This finishing process passes thread through a flame to incinerate stray fibres, making the thread smoother overall. This finish is popular for lace-making threads .[79]

Table 4.1: Morphological comparison of threads

Thread	Yarns	Fibres
120/2		
160/2		
170/2		

[78] Personal communication with Maureen Rijkers, Capsicum Textile Shop, June 2016.
[79] Paternoster, 4.

Table 4.1 shows that the thickest thread (120/2) has fibres which are much smoother than the other two threads. This smooth appearance is typical of a process called mercerization. During mercerization yarns are dipped into a bath of caustic soda which causes them to swell rapidly. The swelling smooths out many of the natural twists present in cotton fibres. Drying under tension retains this smoothness.[80] Most stitching threads are mercerized to improve strength and lustre. It is possible that all three threads were mercerized, but it is most obvious on the fibres of thread 120/2. There are alternative methods of mercerization, which could affect the mechanical properties of cotton differently.[81]

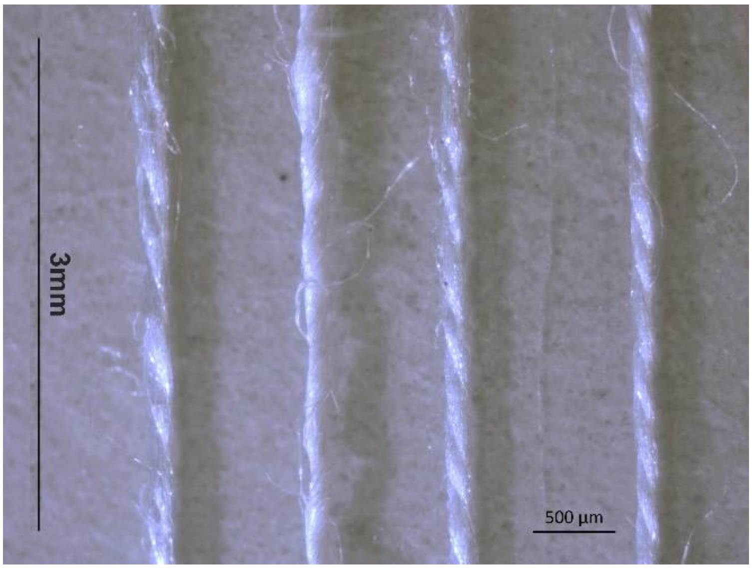


Figure 4.7: Comparison of stitching threads with gown warp.
Left - right: 120/2, gown warp, 160/2 and 170/2.

Figure 4.7 shows the visual difference between the three stitching threads and a warp from the gown. The finest thread (Ne 170/2) has the most twists/mm. It is also the smoothest due to the gassing process.

All stitching threads have been “Z” spun and “S” plyed. The gown warp has been “Z” spun.

[80] Cook, 67.

[81] SM Aboul-Fadl et.al.,. "Effect of mercerization on the relation between single fibre mechanical properties and fine structure for different cotton species," Textile Research Journal, vol. 55, issue 8 (1985): 461-469, doi: 10.1177/004051758505500803.

4.6 Conclusion

Fibre identification confirmed that all stitching threads, and the gown, are 100% cotton. Comparing the thickness of the threads also confirmed that the higher the first number in thread labelling, the finer the thread.

The next stage involved tensile testing of all three threads to ensure a well informed choice of final thread. Due to its mercerization, and potentially different processing methods (due to brand difference), the thickest thread (120/2) was likely to not conform to patterns set by the other two threads. Gassing cotton, as with 170/2, was unlikely to impact results as this is an aesthetic treatment rather than a chemical alteration. When tensile testing warps from the gown it was expected that there would be great variation in results due to the difference in yarn thickness, as noted in figure 4.4. Warps were tested as this is the element of the fabric structure which lines of laid-thread couching emulate – the vertical threads.

Chapter 5: Tensile testing pre-tests

The aims of this chapter are to:

- Outline what tensile testing is and how it can help demonstrate physical properties of threads.
- Use tensile testing to produce quantitative data for each short-listed thread and warps from the gown.
- Use this data to pick the most appropriate thread for the fixed-load experiments.

5.1 Tensile Testing

Tensile testing is a method of producing quantitative data regarding the load-elongation or stress-strain characteristics of a material.[82] A linear force is applied to a sample in order to deform it. This deformation can be measured and recorded in different ways. Several similar terms describe different elements of tensile testing and the results gained.

Extension: the increase in length of the original test sample (given in units of length).[83]

Elongation: the increase in length of the original test sample as a ratio to the initial length (given as a percentage).[84]

Stress: the force applied to a test sample in relation to its cross-sectional area.[85]

$$Stress = \frac{\text{force applied}}{\text{cross} - \text{sectional area}}$$

[82] Mary Ballard,"Mechanical Properties: Preview and Review," The Textile Conservation Newsletter, No. 28 (Spring 1995):14-28.
[83] British Standard, Determination of maximum force and elongation at maximum force using the strip method, BS EN ISO 13934-1:2013, (London: BSI, 2013).
[84] Ibid.
[85] B.P. Saville, Physical testing of textiles, 2009 reprint, (Cambridge: Woodhead Publishing Ltd., 1999), 116.
[85] Ibid.

Strain: the change in length of the original test sample as a fraction of original length.[86]

$$Strain = \frac{\text{extension}}{\text{initial length}}$$

Tenacity: the specific stress as it corresponds with the maximum force on a force/extension curve.[87]

Tensile strength: the maximum force required to break a test sample.[88]

For this research project it is important to understand how the fibres will react to stress being placed on them. This can be visually shown on a graph comparing the load (stress) to the deformation (strain). Figure 5.1 shows typical regions of a hypothetical load-deformation curve. Fibres are visco-elastic, meaning they have traits of both plastic (viscous) and elastic materials.[89] In the elastic region fibres stretch slightly due to chain molecules sliding past each other in the polymer.[90] They can return to their normal position if the load is released (elastic quality). If the load is released after the

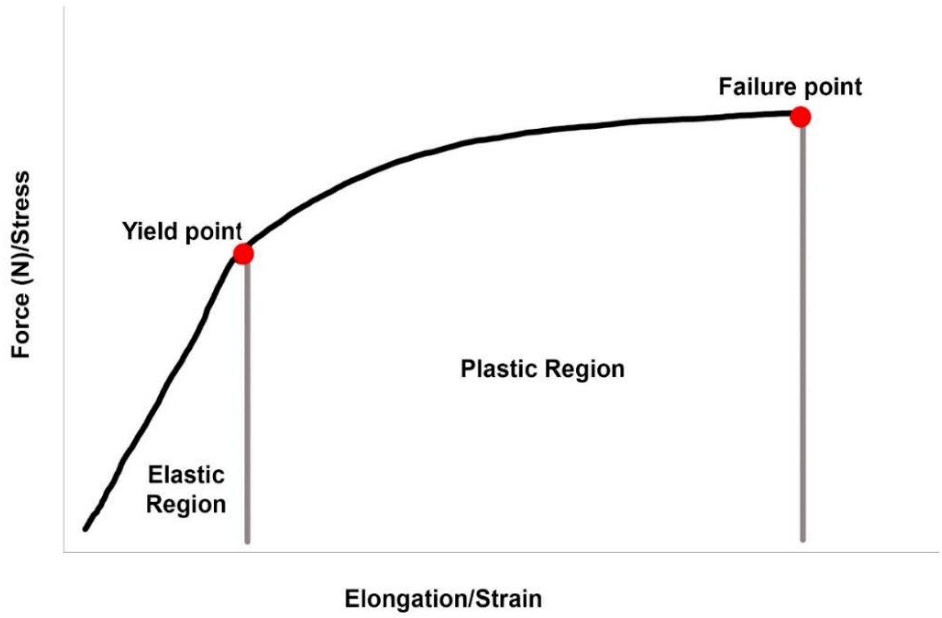


Figure 5.1: Hypothetical load/deformation curve. ©Hannah Sutherland, 2016.

[86] Saville, 116-117. [note: Saville uses elongation in his equation, as he states elongation is expressed in units of length not as a percentage. Extension has been used here to reflect the definition of extension as used in BS EN ISO 13934-1.)
[87] Ibid.
[88] Ibid.
[89] Timár-Balázsy and Eastop, 14.
[90] Ibid.

yield point, a fibre or a thread will be permanently deformed[91] (plastic quality). The yield point of a fibre depends on the ratio of crystalline to amorphous regions. The higher the percentage of amorphous regions the higher the affinity for elastic stretching. Due to cotton's high crystallinity it has a very small plastic region.

The following experimental methodology is based on the work of Shirley Ellis and Sarah Benson.[92] [93] Suppliers can be found in appendix 4.

5.2 Equipment set-up

Following British Standards, a Constant-Rate-of-Extension (CRE) machine was used to conduct the tensile testing.[94] The machine has two clamps; a fixed lower clamp and a moveable upper clamp. This allows for the upper clamp to move at a pre-defined constant rate. Bluehill software was used to create a method which allowed for the input of each thread's tex value (see below). The pull of the upper clamp can be pre-determined. To enable valid comparisons of the results to previous work (Benson) a rate of 10mm per minute was chosen.[95]

5.3 Sample preparation

Threads were held in paper frames to ensure each tested thread was positioned into the clamps under the same tension. This follows British Standard guidelines.[96] Fifteen replicates of each stitching thread, as well as 15 replicates of gown warps, were tested. This large group was chosen to account for the potential great variation in gown warps. It was important to measure the tenacity of each sample. For this, tex had to be measured. Tex is a measure of linear density, based on the weight of 1000m of a given thread. [97] It is more reliable than measuring yarn thickness, as this is difficult to do accurately. Measurement by mechanical methods can compress the yarns, potentially

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[91] Margaret J. Smith, Thomas Hugh Flowers and Frances Lennard,"Mechanical properties of wool and cotton yarns used in the twenty-first century tapestry: Preparing for the future by understanding the present," Studies in Conservation, vol. 60 (2015):375-383.
[92] Shirley Ellis,"A preliminary investigation of the tensile properties of yarns used in textile conservation," Textile Conservation Newsletter, Spring Supplement (1997):1-20.
[93] Benson, 40-43.
[94] British Standard, "Determination of breaking force and elongation at break of individual fibres," BS EN ISO 5079:1996, (London: BSI, 1996).
[95] Benson, 42.
[96] British Standard BS EN ISO 5079:1996.
[97] Saville, 77.

giving smaller than true values.[98] Any method visually measuring a thread could call into question the true outline of the yarn; surface fibres can "blur" the edges.[99]

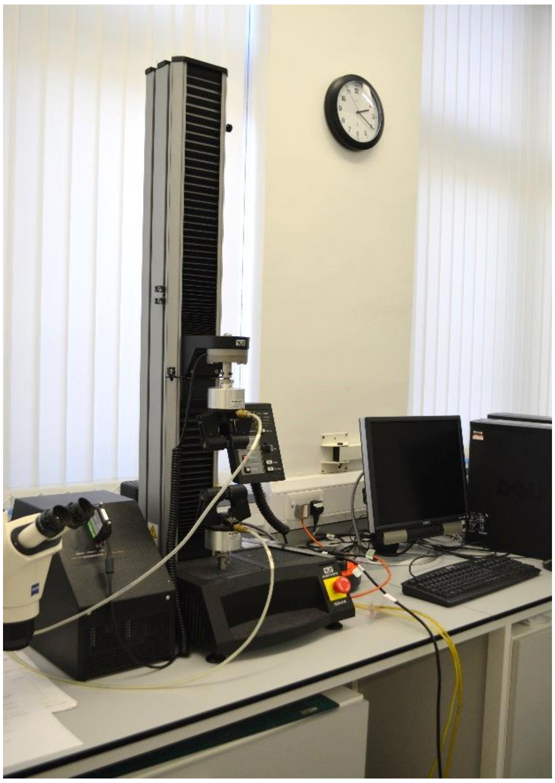

Figure 5.2: Instron 5544 tensile tester and computer with Bluehill software.

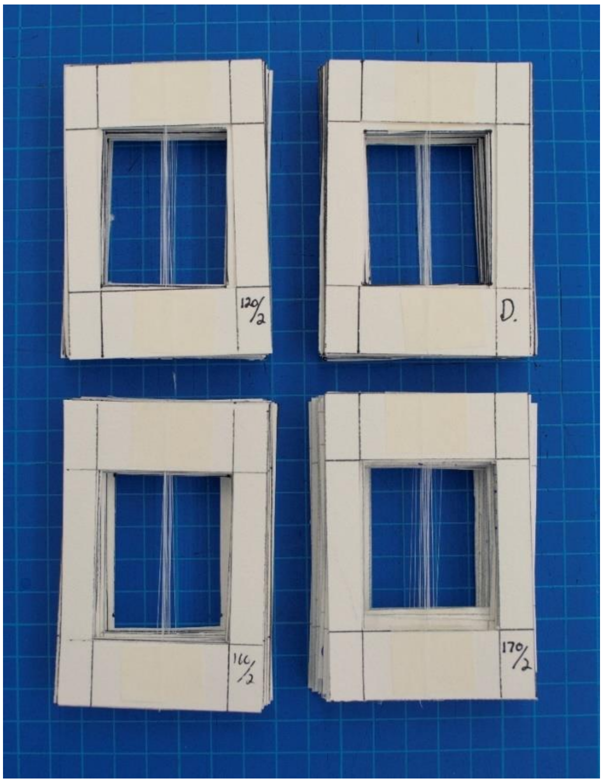

Figure 5.3: Samples prepared for tensile testing.

To calculate the tex of each thread, 5m samples were weighed from each reel. Warps were taken from the gown fabric for comparison. Tex for the warps is less accurate than the tex for the stitching threads, as several short lengths had to be taken to reach 5m. Slight tension was used in order to lessen the crimped effect, noted in figure 4.5. Threads were weighed on a Sartorius BP121S™ four figure balance with closed top. This ensured small particulates did not inhibit reading accuracy. Table 5.1 outlines these results and the tex values.

[98] Saville, 77.
[99] Ibid.

	Sample 1	Sample 2	Sample 3	Sample 4	Average	≈ Weight of 1000m	**Tex**
Gown warp	0.0795g	0.0785g	0.074g	0.0825	0.0786g	15.72g	**15.72**
120/2	0.0533g	0.0511g	0.051g	0.0525g	0.0520g	10.4g	**10.4**
160/2	0.0393g	0.0393g	0.039g	0.0401g	0.0392g	7.84g	**7.84**
170/2	0.036g	0.0363g	0.0364	0.0365g	0.0363g	7.26g	**7.26**
185/2	This weight was used by Sarah Benson for her experiments						

Table 5.1: Tex calculations for short-listed threads

Tex is related to weight therefore it was expected that the finer threads would have a lower tex. A measurement for 185/2 cotton has been included here to compare with the thread used by Benson.[100]

5.4 Testing

A "method" is the information inserted into the Bluehill software, ie. specifying the tex value and pull speed. A different method was used per sample set. Once the sample

Figure 5.4: Sample clamped in position before testing.

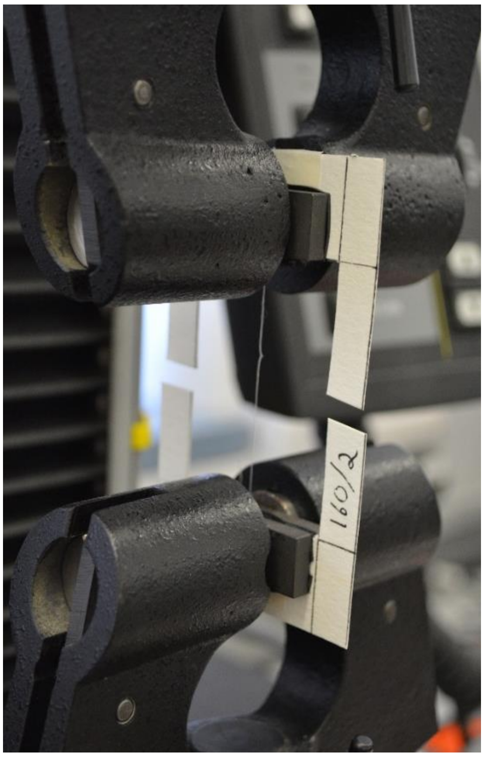

Figure 5.5: Sample clamped in position after testing.

[100] Benson, 41.

was positioned in the clamps, the carrier was cut to allow the thread to be pulled, see figures 5.3 and 5.4. Samples which snapped within 3mm of the clamps, or failed to register breakage, were disregarded and repeated.

5.5. Statistical Analysis

Experimental testing gave the following outputs: load, tensile extension and tenacity. Measurements were recorded every 0.1 seconds, until break-point was reached. Extension (mm) and load (N) were most important for providing stress/strain curves. Raw data from the Bluehill software was transferred into Microsoft® Windows Excel 2016. Here, extension and load values could be normalised. This involved recalculating measurements to ensure all datasets began at 0, making all sets comparable. Means for maximum load, tenacity and elongation at break-point are automatically calculated by the Bluehill software. Standard deviation for each data set is also calculated. This is show on error bars below.

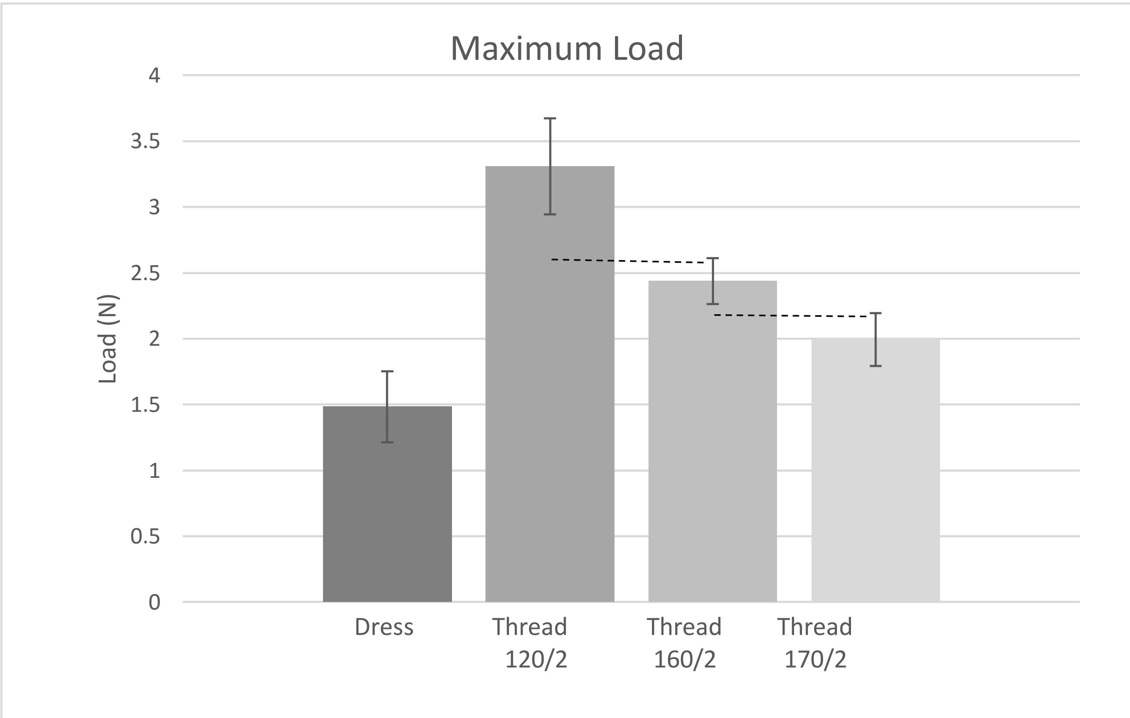

Figure 5.6: Comparing maximum load at breaking point of all four tested threads – values are mean for 15 replicates.

Figure 5.6 gives mean maximum load, at break, values for each data set. This set of data is as predicted: the warps are the weakest, with the threads getting weaker as they get finer. The gown warps are weak due to age and the fine threads are weaker because there are less fibres to hold together. 160/2 and 170/2 are closest in value. This may be because they come from the same manufacturer, or that the three threads are not sequential, ie. threads at weights 130/2, 140/2, 150/2 would fit between 120/2 and 160/2.

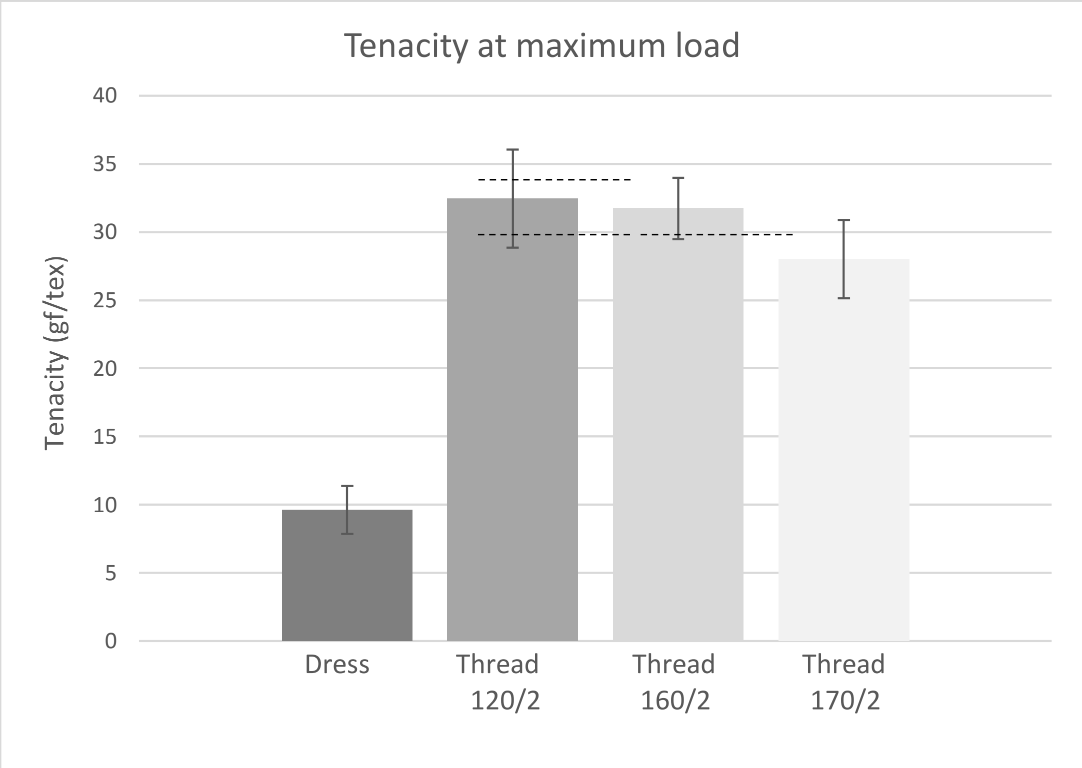

Figure 5.7: Comparing tenacity at maximum load of all four threads tested - values are mean for all replicates.

Tenacity gives comparable values for different thicknesses of thread. The three stitching threads have almost identical tenacity, with all values falling between 26 and 34gf/tex. As all three are modern and made with Egyptian cotton fibres this is to be expected. The dotted lines indicate how there is a particular similarity between 120/2 and 160/2, because the standard deviation of 160/2 falls within that of 120/2. The gown warps have a much lower tenacity. This is, at least partly, to do with fibre age. The warp was only spun, not spun and plyed as stitching threads are. In stitching threads, some force is taken up with pulling on this ply before any fibre damage occurs.

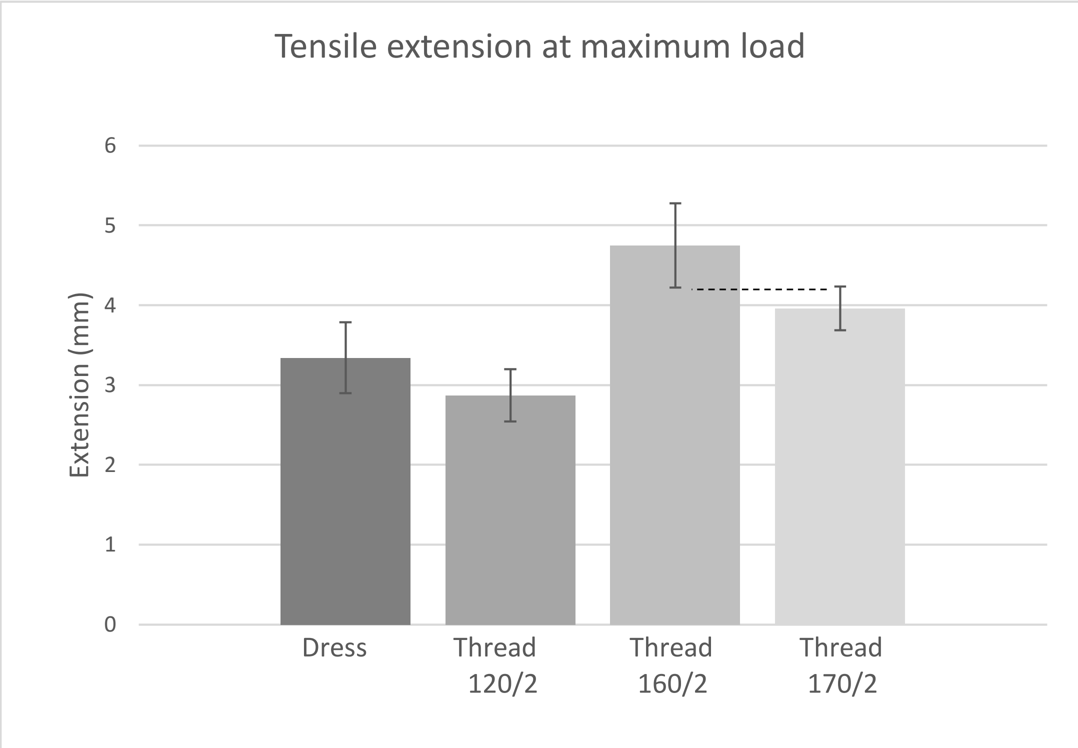

Figure 5.8: Comparing tensile extension at maximum load of all four threads tested values are mean for all replicates.

Figure 5.8 shows the impact that different manufacturing processes have on the physical properties of stitching threads. The 120/2 thread had been mercerized, as discussed in chapter 4. These results suggest that mercerization may decrease elasticity. A decrease in elasticity suggests an increase in crystalline regions within a fibre. Due to the threads being from different manufacturers, it is difficult to say for certain whether it was mercerization, or another manufacturing process, making the difference.

5.6 Stitching threads

A mean force-extension curve from each data set was not possible, as the variety in time taken to break meant that mean values could not be gathered for all time-points. A "typical" curve for each set of data is shown below. All results can be found in appendix 6.

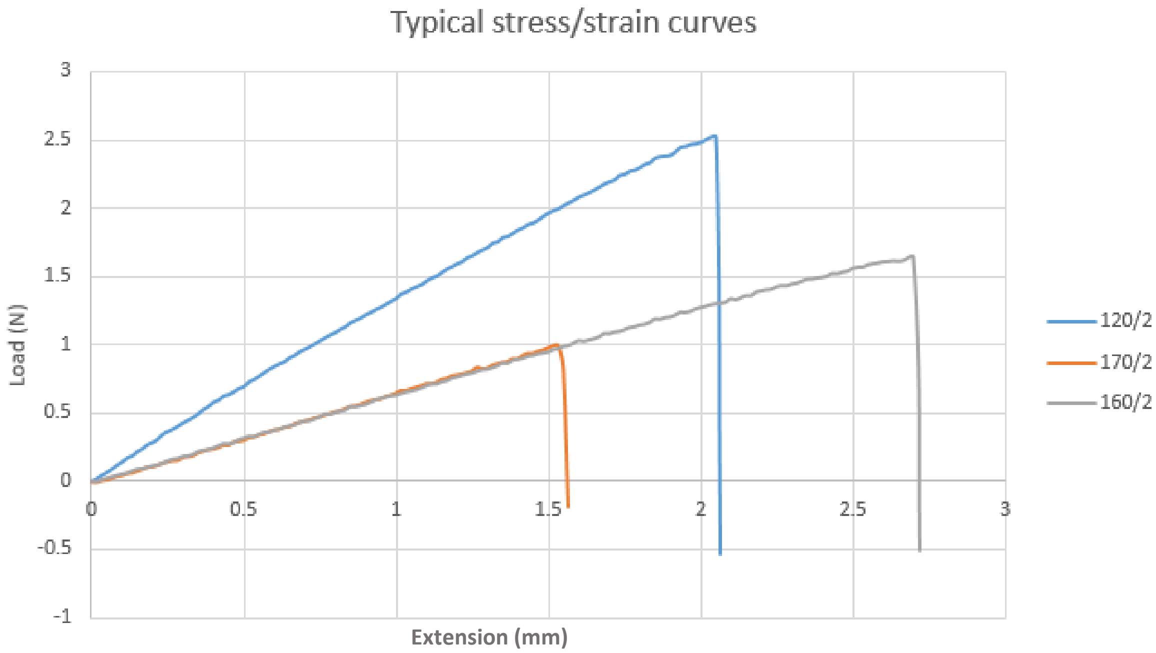

Figure 5.9: Force/extension curves for three chosen stitching threads.

Figure 5.9 reinforced the fact that the two Belgian threads have different physical properties to the French thread. Both 160/2 and 170/2 (Belgian) follow the same degree of elastic stretching. If 120/2 had been from the same manufacturer, all three threads are likely to have followed this same angle. As discussed above, mercerization has produced a less stretchy, but stronger thread, as it carried a larger load before break. This could suggest that mercerization encourages the crystallising of some amorphous regions. Drying under tension may also remove some of the inherent stretch in the yarn. This would limit future stretching. In this case, the thickness of the thread may have made it stronger, as more fibres are present.

5.7 Gown warps

Figure 5.7 shows all 15 warp replicates from the gown to demonstrate the range possible in historic fibres and threads. It is known that as fibres age and deteriorate they get weaker.[101] The range of elongation in particular shows how difficult it is to know how one part of a historic textile will react compared to another. It is also possible that some of this variation came from varying warp thickness (figure 4.4): areas with thicker warps may be stronger than those with thinner warps.

Figure 5.10: Force/elongation curves for all tested warp threads.

5.7 Conclusions

This chapter has provided a foundation for further tensile testing and highlighted the difference between contemporary and historic fibres. It has shown the potential differences in physical properties of thread made by different companies.

Quantitative data for each thread has given an insight into their physical properties. From the gained data, the most suitable thread choice is the 170/2. This thread was shown to be the weakest. Due to its fineness, it is also an obvious choice if tensile testing was unavailable. Traditionally, treatments should be weaker than the fabric

[101] Ellis, 1.

they are supporting. The concept of “weaker” is difficult to define quantitatively. Modern stitching threads, just being new, are likely to be stronger than a historic object. With laid-thread couching it is also important to consider the strength of multiple threads working together, rather than individual strands.

Chapter 6: Tensile testing – Fixed load experimental methodology

6.1 Introduction

This chapter outlines this project's main experimental phase. Conserved "object" samples (cotton gown) will be used to understand if, and how, the spacing of lines of laid-thread couching impacts the effectiveness of each treatment. This experiment is drawn from the work of Landi[102] and Benson[103].

The aims of this experiment are:

- To produce quantitative data on the extension and recovery of conserved artefact samples.
- To identify differences between results based on the spacing of lines of laid-thread couching.

6.2 Sample production

Twenty conserved samples were prepared for this experiment: five replicates of each of four spacing variations. All fabrics and thread used for the experiments was left in the same room as the experiments were conducted in, to allow them to reach equilibrium with the room's ambient conditions. Each sample was fixed in position with bar magnets onto a magnetic notice board.

6.2.1 Spacing of laid-thread couching lines

All spacings given in the questionnaire were between 2mm and 10mm, with 5mm being most popular.[104] Four spacings were chosen for this experiment: 3mm, 5mm, 7mm and 9mm. A pattern, based off that of Benson and British Standard 13934-1:2013.[105] [106] , was drawn up to ensure that each sample set followed the same basic size and shape. Samples were cut in the warp direction, as this is the usual direction of force for hanging objects, see figure 6.1 and 6.2. Warps were removed from the edges

[102] Sheila Landi,"The Arguments For and Against the Use of Synthetic Fibres for Sewing in Textile Conservation," in *20th Century Materials, Testing and Textile Conservation*, (Harpers Ferry: Harpers Ferry Regional Textile Group, 1988),47-51.
[103] Benson, 49-51.
[104] See page 21.
[105] BS EN ISO 13934-1:2013.
[106] Benson, 45.

to ensure no further fraying took place. The grip lines ensure that each sample has the same amount of fabric between the top magnet and the weight. Support fabric (also cotton) was cut 45mm x 80mm, see figure 6.3. See appendix 5 for each exact patterns. Each sample was cut in half and stitched onto the support fabric with lines of laid-thread couching. The 170/2 thread chosen in chapter 5 was used for all samples. Four samples of gown fabric, without damage or conservation, were cut out as a control. Samples are presented in appendix 11.

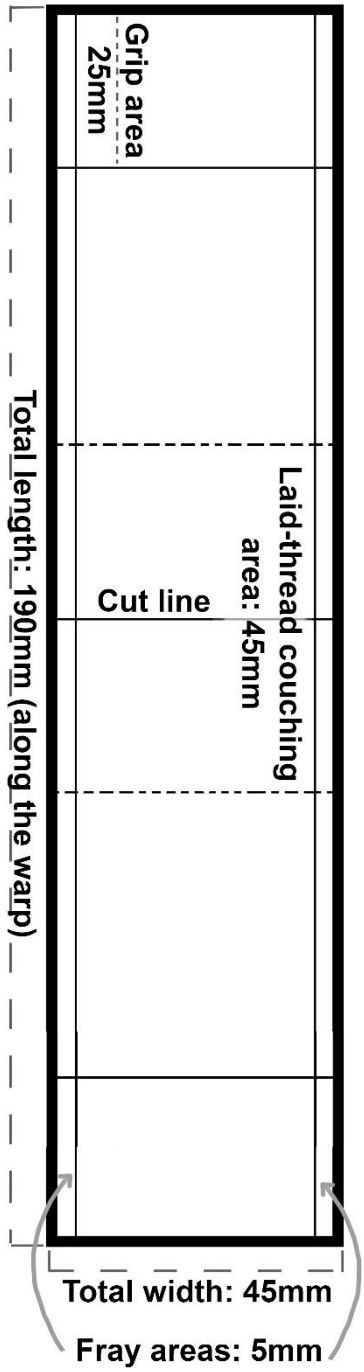

Figure 6.1, Above: Warp direction on gown.

Figure 6.2, Right: Basic sample pattern.

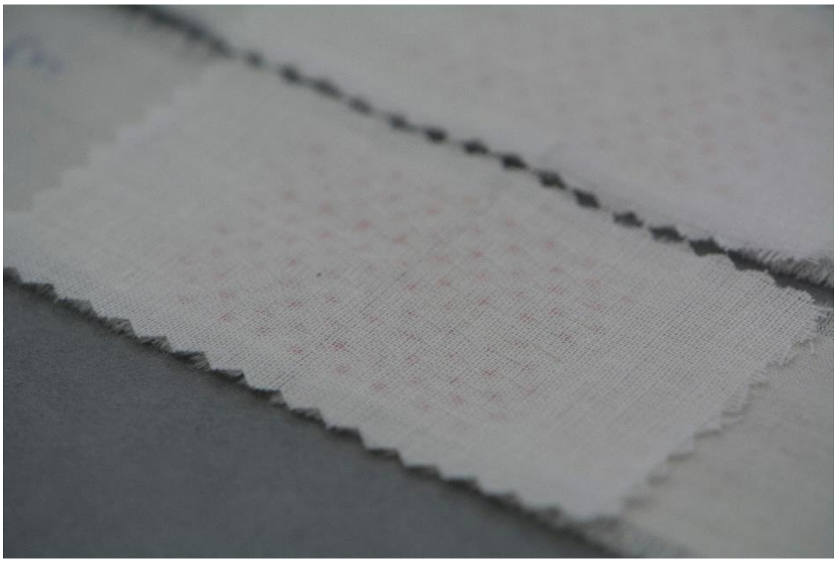

Figure 6.3: Reverse of sample showing support fabric.

Figure 6.4: All samples in place on the magnetic board.

6.2.2 Equipment for testing

Bar magnets and bulldog-clips carrying weights ensured force was spread equally across each sample, see figure 6.4. The weight used was 30g. This is smaller than used by Benson, as her work concluded that “point of damage is more affected by the length of time of loading as opposed to the load amount.”[107] Samples were hung for three weeks, rather than Benson’s two. Force exerted onto an object treatment is likely to be from the weight of the object itself, ie. a surface decoration, rather than a sudden pull; therefore, a lighter weight over a longer time may be more realistic of museum conditions.

6.3 Variables

The desired variable in this experiment is the spacing of laid-thread couching lines. Other variables have been managed as far as possible:

- The author personally stitched all samples, using the same size needle and same lighting conditions. This removes the potential of different tensions, from different hands, confusing results.
- All stitch points were marked on the sample prior to stitching. This ensures that each laid-line has the same number of catching stitches.
- All samples were hung with the start and finishing stitches in the lower half.

Some variables are beyond the control of this experiment:

- The magnetic board is subject to changing humidity and temperature. This often reflects the outside weather conditions and the number of people using the space. This highly fluctuating environment does not reflect ideal museum conditions, but is more like conditions found in historic houses, where conditions are harder to stabilize.
- It is unknown exactly how the chosen support thread was produced. These production methods may alter results compared to a different manufacturer.
- It is unknown how old the gown fabric is and exactly how it has been washed or handled in the past.

[107] Benson, 92.

6.4 Methods of evaluation

Two method of evaluation will be used to understand the results of this experiment: quantitative and qualitative.

6.4.1 Quantitative: Extension and recovery

Understanding extension and recovery are important as they relate to how a treatment may react to display and storage. Four key measurement stages were chosen:

- Extension: On the final day (day 21) the overall length of each sample was taken. This is the measurement between the two grip lines.
- Initial recovery: Immediately after removal of the weight overall length was taken.
- 48 hours unweighted: After the weights were removed, samples were left horizontal for 48 hours. Overall length was taken again.
- 1 month unweighted: As above after 1 month.

These four measurements were compared to the initial length of each sample prior to hanging. A good result was hypothesized as one where little extension occurred and the initial length was regained after 48 hours. A bad result was hypothesized as one with a large extension, and with little recovery at the final stage. It was also hypothesized that the closer the lines of laid-thread couching, the less extension there will be: having more lines decreases the amount of force exerted on each line. Statistical analysis was used to check data for reliability.

6.4.2 Quantitative: Stereo-magnification

Photography through the stereo-microscope allowed detailed images to be taken of the surface of the samples. Weave distortion between the different sample groups could then be compared. It was hoped that comparing these images with those taken with digital-image-correlation technology (see chapters 7 and 8) it would be possible to link points of high strain to physical markers within a treatment.

6.5 Conclusion

This experiment has demonstrated that is it possible to replicate the experiments of Benson and Landi in order to understand different characteristics of laid-thread couching treatments. Results of the experiment will be covered in chapter 8.

Chapter 7: Digital Image Correlation

7.1 Introduction

This chapter discusses the potential of using DIC to detect areas under most strain in laid-thread couching treatments. This chapter aims to:

- Introduce the technology of DIC
- Investigate the use of DIC in textile conservation
- Outline the experimental methodology for using DIC within this project.

7.1.1 What is DIC?

DIC is an imaging technique which tracks the changes in surface geometry of an object through correlation of a deformed surface with its undeformed state. [108] Therefore, the measured deformation can be processed to give further information regarding the impact of a specific load on a material (e.g. self-load) or even the effect of environmental condition such as temperature or humidity. DIC is, in principle, non-invasive and non-destructive which makes it suitable for use in sensitive applications such as with historic objects. All key papers covering early developments of the technique are cited by D. Lecompte et.al., 2006.[109]

7.1.2 How does DIC work?

DIC works by comparing digital images of material at different stages of deformation. The starting image, known as the reference image, and the comparison image are read by the correlation algorithm as pattern of grey scale. Each image is virtually partitioned into a grid of "interrogation cells" or subsets.[110] To assist the computer software in identifying grey scale, a speckle pattern is applied to the surface of the material to be

[108] Janice M. Dulieu-Barton et.al.,"Deformation and strain measurement techniques for the inspection of damage in works of art," Reviews in Conservation, no. 6 (2005):63-71.
[109] D. Lecompte et. al.,"Quality assessment of speckle patterns for digital image correlation," Optics and Lasers in Engineering, vol. 44, issue 11 (November 2006):1132-1145, doi:10.1016/j.optlaseng.2005.10.004.
[110] G. Crammond, S.W. Boyd and J.M. Dulieu-Barton,"Speckle pattern quality assessment for digital image correlation," Optics and Lasers in Engineering, vol. 51, issue 12 (December 2013):1368-1378, doi:10.1016/j.optlaseng.2013.03.014.

tested.[111] Computer software looks for where the subset on the deformed image has the best matching results on the reference image. The movement required to superimpose the second image subset onto the reference image is what is measured as strain, see figure 7.1.

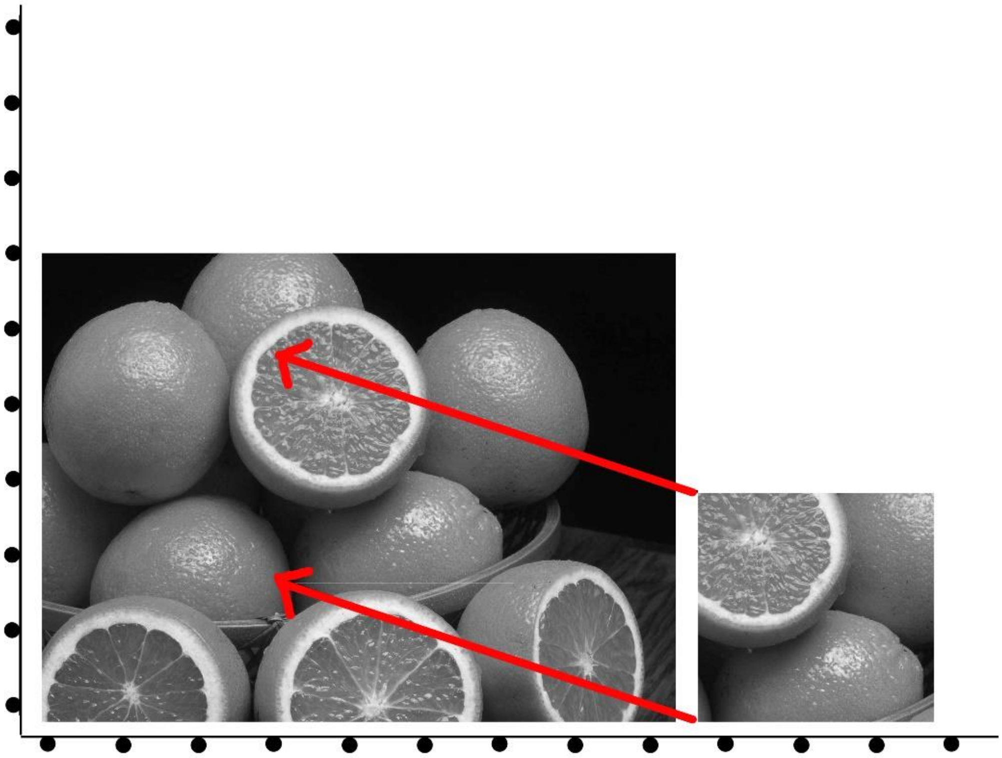

Figure 7.1: Example of required movement to overlay one image onto another. ©Wikicommons/ Hannah Sutherland, 2016.

By post-processing the deformation data from individual subsets, it is possible to compute important engineering properties such as different strain components all over the region of interest. Different components of strain can be evaluated considering vertical (y-axis) or horizontal (x-axis) directions, see figure 7.2.

[111] Sven Bossuyt,"Optimized patterns for digital image correlation," in Proceedings of the 2012 Annual Conference on Experimental and Applied Mechanics, Vol.3: Imaging Methods for Novel Materials and Challenging Application, eds. Helena Jin, Cesar Scimmarella, Cosme Furlong and Sanichiro Yoshida, (New York: Springer-Verlag, 2013),239-254.

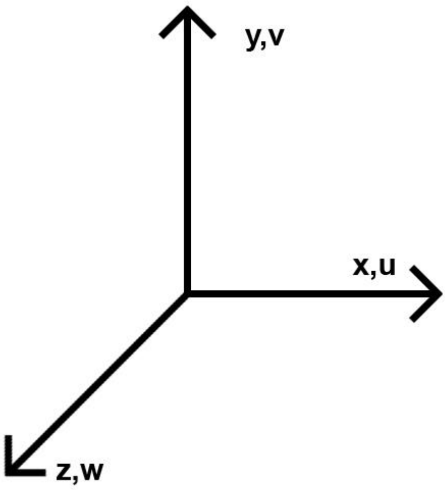

Figure 7.2: Axis of movement, where x,y,z are positive movement and u,v,w are negative (opposite) movement. ©Hannah Sutherland, 2016.

7.2 DIC in Textile Conservation

DIC is relatively new to textile conservation. It was used by the Tapestry Monitoring Research Project (TMRP) team at Southampton University from 2007 to 2010, but early developments within other fields have been reported on since 1982.[112] The TMRP investigated if and how DIC could be used to identify patterns of strain within hanging tapestries. A useful project overview was presented at the ICOM-CC 16th Triennial.[113]

A follow-on project has recently restarted at Glasgow University opening potential for future updates on their work. This technology may be useful in identifying strain across laid-thread couching treatments if it can identify the spread and location of strain across a treated surface.

7.3 Experimentation Methodology

7.3.1 Equipment

Equipment used was provided by the material testing lab at the University of Glasgow's School of Engineering. The set-up included a pair of charged couple device (CCD) cameras and two lamps. The cameras were controlled by VIC-SNAP 2010 software. Computer modelling with DIC was carried out by VIC-3D 2010 software. Both

[112] T.C. Chu, W.H. Peters, W.F. Ranson and M.A. Sutton,"Application of digital correlation methods to rigid body mechanics," Proceedings of 1982 Fall Meeting of the Society for Experimental Stress Analysis, 73-77.
[113] Frances Lennard et.al.,"Strain monitoring of tapestries: Results of a three-year research project", ICOM-CC 16th Triennial Conference, Lisbon, 19-23 September 2011, 8pp.

of these computer programmes and instructional information is available from Correlated Solutions.[114]

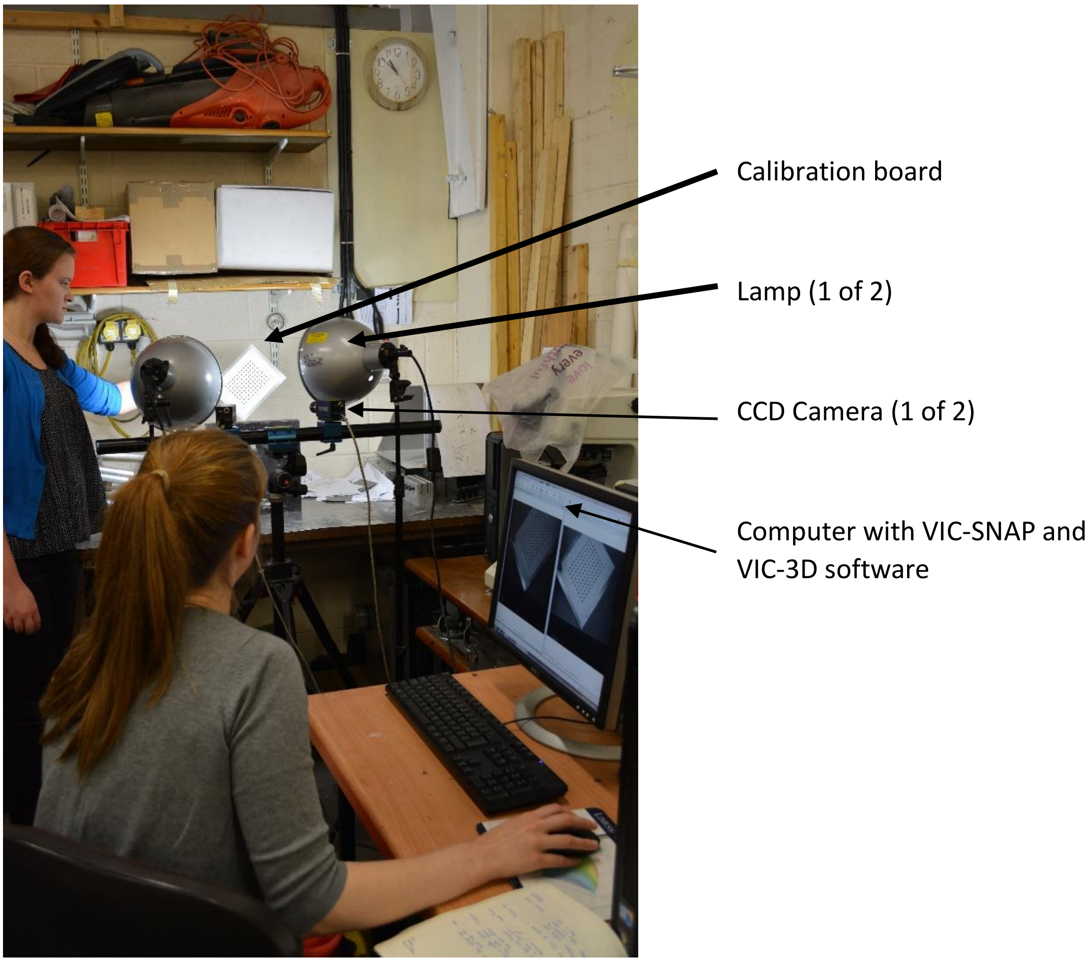

Figure 7.3: Myself and Cecelia Voss carrying out calibration. Equipment as shown by arrows. ©Hannah Sutherland/ Hannah Vickers, 2016.

7.3.2 Sample Production

Samples to be examined using DIC were made in the same way as samples produced for the fixed-load experiments. Due to time limits only two different spacings were chosen – 9mm and 5mm. Two samples of each spacing were prepared. A speckle pattern was applied with a Sharpie® Fine Tip pen, in accordance with the VIC-3D

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[114] "Products," Correlated Solutions, (2016),http://correlatedsolutions.com/products/,(accessed July 13th, 2016).

software manufacturer guidance.[115] Weights of 100g and 200g were prepared. These were chosen to represent a high stress on the treatment, without reaching breaking point. It was hoped this high stress would incite a large enough movement for the computer to capture.

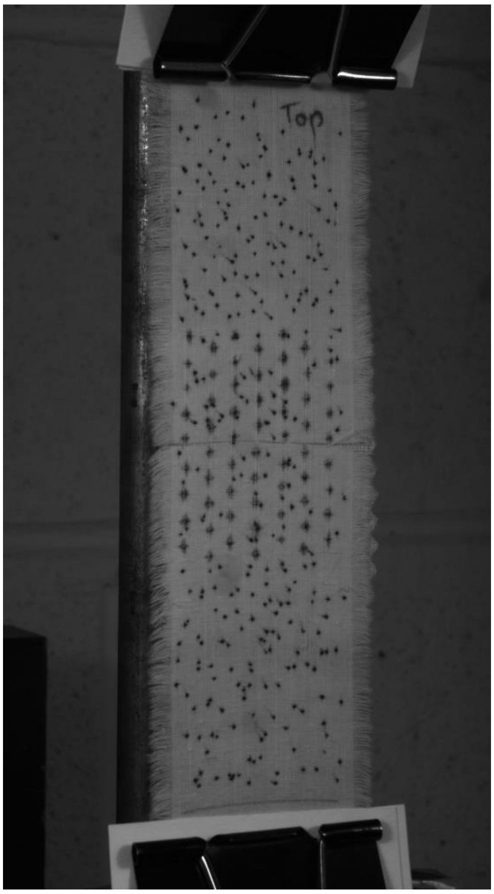

Figure 7.4.: Ink pen speckle pattern example.

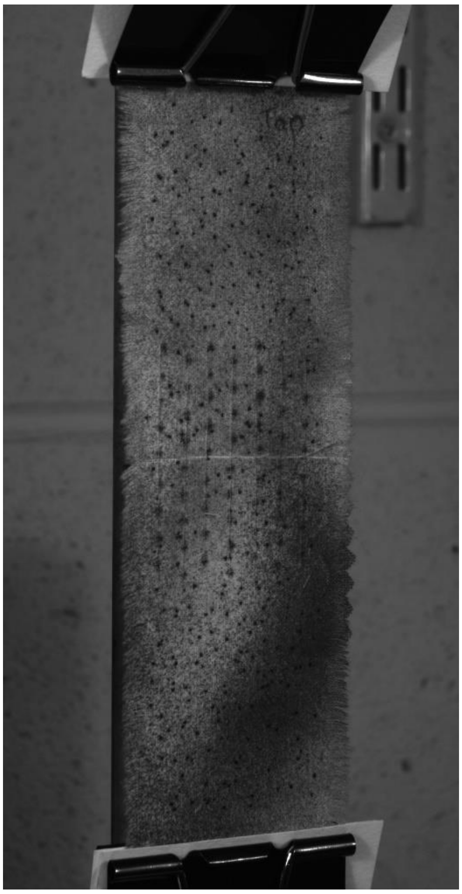

Figure 7.5: Spray paint with ink speckle pattern example.

7.3.3 Experiments

Two phases of testing were undertaken. Appendix 8 gives a step-by-step guide for taking images and processing them to produce results comparable to this experiment.

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115 Correlated Solutions, "VIC-3D 2007: Testing Guide,"[PDF] classes.engr.oregonstate.edu/mime/winter2009/.../**VIC**-3D%20Testing%20Guide.pdf, (accessed July 1, 2016),47.

Test phase 1: Speckle applied with pen. 100g weight applied. 1 image/second over 30 seconds, see figure 7.6.

Test phase 2: Additional speckle applied with matte black spray paint. 200g weight applied. 1 image/second over 30 seconds, see figure 7.7.

During each test the weight was applied at the 3-4 second mark. This ensured that the starting image had no weight, but that the final image did. Additional speckle and weight was applied during the second phase as initial results appeared inconclusive. It was hoped to see if more speckles aided recording of strain. Greater weight added to ensure movement was large enough to be recorded.

7.4 Experiment Evaluation

This experiment was carried out to understand if DIC could be used to understand strain across laid-thread couching treatments. In brief; yes, it can. There are two main issues to be addressed if further research is to be carried out successfully.

Weighting:

When samples are weighted, when hanging, they twist. Use of tensile testing equipment, as in Chapter 5, would stop unwanted movement. Samples should first be tested to breaking point separate from DIC experiments. Replicates should then be tested, whilst being recorded with DIC, and taken to just below the known breaking point, to record linear strain.

Speckle Size:

Issues arising in this project regarding speckle pattern are further discussed on page 70. The importance of "correct" speckle pattern has been debated by several authors regarding interpretation and accuracy of DIC strain maps.[116] [117] Several options are available, including ink, paint and roller-stamps.[118] The use of paint or spray paint is potentially problematic for use with textiles, as it may alter the fabrics' physical properties. The amount of paint used vs. the fineness of the textile

[116] Crammond, Boyd and Dulieu-Barton.
[117] Bossuyt.
[118] "The VIC Speckle Application Kit," (2016), http://correlatedsolutions.com/speckle-kit/, (accessed July 7, 2016).

would have to be considered on a case-by-case basis. Ink, either as a pen or applied with a stamp, would be preferable for future experiments. Testing different speckle patterns would give more information regarding the most useful pattern for textiles. Testing of different textile surfaces, to understand if their inherent texture gives enough contrast, is also recommended. A useful bibliography regarding speckle pattern formation and evaluation can be found by Jianguo Zhu et.al.[119]

7.5 Conclusion

The benefits of DIC for textile conservation purposes rely on the inclusion within the project team of an engineer who understands the results of the tests and can accurately interpret them. Taking images and processing them is simple, if time-consuming. Taking the resulting strain-maps and relating them back to the original sample is difficult without a good grasp of the technology and the equations upon which the technology is based.

Experiment results are discussed in detail within chapter 8.

[119] Jianguo Zhu, Gaoshen Yan, Guanglong He and Lei Chen,"Fabrication and optimization of micro-scale speckle patterns for digital image correlation," Measurement Science and Technology, vol.27, no.1 (2015), http://dx.doi.org/10.1088/0957-0233/27/1/015203.

Chapter 8: Results

This chapter summarizes both the quantitative and the qualitative results from the fixed load tests and DIC experiments.

In this chapter sample groups are referred to as “the Xmm group”, where X denotes the spacing of laid-thread couching.

This chapter aims to:

- Highlight patterns and irregularities in the results.
- Link patterns and irregularities to variables in the experiments.

8.1 Fixed Load Tensile Testing

The fixed load tensile testing produced quantitative data regarding extension and recovery over four stages. Photography with a macro lens and camera-adapted stereo-magnification allows for qualitative analysis also. Complete measurements can be found in appendix 7.

8.1.1 Results Summary

All samples recovered to within 1.4mm of original length after 48 hours in a horizontal position. Deformation of gown weft was noted around upper ends of each laid-thread couching line. Deformation was particularly noticeable on the support fabric weft in the 9mm group. These results are as expected: the wider the spacing of laid-thread couching, the longer the initial extension of the sample

8.1.2 Quantitative Analysis

All samples were 140mm long at the beginning of testing. This was used as a baseline for calculating extension. The largest initial extension was found in the 9mm group: 4mm. The smallest initial extension was to be found in the 3mm group where one sample recorded no movement.

Table 8.1 gives the standard deviation (SD) for each set of data at each measuring point.

Table 8.1: SD of extension, per group, at each measuring stage

	Initial Extension	Initial Recovery	48 Hours Unweighted	1 Month Unweighted
3mm	0.4mm	0.3mm	0.3mm	0mm
5mm	1.1mm	0.7mm	0.2mm	0mm
7mm	0.8mm	0.8mm	0.7mm	0.2mm
9mm	0.7mm	0.8mm	0.7mm	0.6mm
Control	1.3mm	0.9mm	0.5mm	0.5mm

SD is a marker of how spread out a set of data is: the higher the SD the more varied the data set.[120] An ideal SD result would be 0, as all samples within the group would have reacted in the same way. As they all fall below 1% (1.4mm) of the overall sample

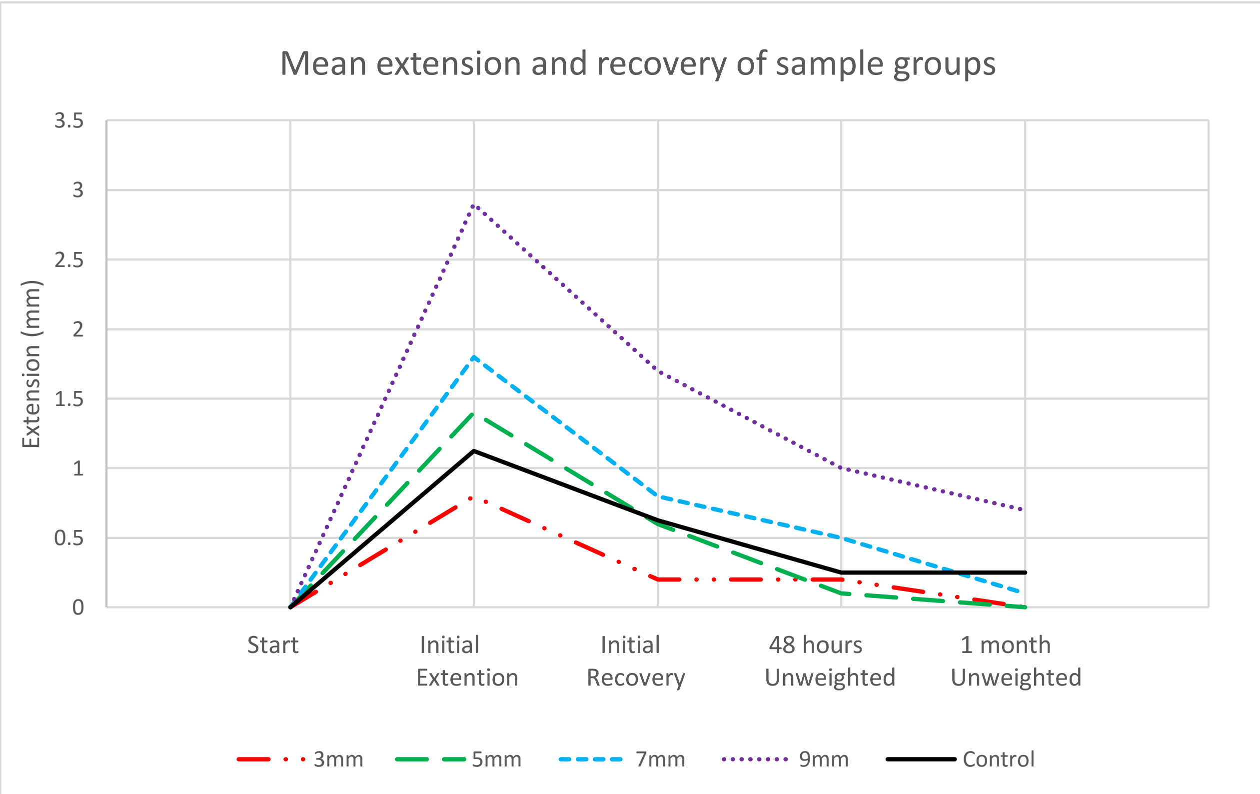


Figure 8.1: Elongation and recovery (mean) of each data set.

[120] "Standard Deviation," BBC Maths Bitesize, (2016), http://www.bbc.co.uk/bitesize/standard/maths_ii/statistics/standard_deviation/revision/1/,(accessed July 5, 2016).

length, this indicates little variation within each group, which in turn allows for mean values to be used confidently.

Figure 8.1 plots the mean values for each set of data. All samples returned to within 1% of the original length (1.4mm) after 48 hours of being horizontal (unweighted). The four sets of conserved samples follow the predicted pattern, with a slight overlap between the 48-hour recovery of the 3mm and 5mm groups. This is likely to do with the small number of samples the mean was drawn from. The data set which does not fit with the pattern of the rest is that of the control group. This group had greater extension than the 3mm group. This result may be linked to the heterogeneous nature of the warp threads, as established in chapter 4: the samples in the 3mm group may just have been stronger than those used as the control. A larger replicate number may have improved the accuracy of this result, by drawing data from a wider pool.

Figure 8.1 shows that as the samples recover, the five lines get closer together, indicating that as the samples recover they all move back towards the same point regardless of initial extension. The groups which elongated the most, also recovered the most. The SD of all samples at each stage (table 8.2), confirms this as the SD can be seen to get smaller. If all samples recovered a fixed amount, then SD would stay similar across all three recorded points. This can be seen in figure 8.1: the wider the spacing of laid-thread couching, the steeper the angle of initial recovery. This is a reflection of the nature of cotton fibres to stretch slightly and recover[121].

	Initial Extension	Initial recovery	48 hours unweighted	1 month unweighted
SD	1.1mm	0.8mm	0.6mm	0.4mm

Table 8.2: SD for all samples at each measuring stage.

8.1.3. Reliability of Result

Statistics can be carried out to understand if two sets of data are statistically similar to each other; in this instance the spacing of the laid-thread couching against the extension at a given stage. The given value is called a *p-value*. When the p-value is value is <0.05 the data is strongly (>95%) in agreement with the hypothesis. From the

[121] Cook, 65.

graph in figure 8.1, it can be deduced that the wider the spacing, the greater the extension. Calculating a p-value for each stage of extension and recovery can statistically prove this deduction, see table 8.3.

Table 8.3: Mean data used for calculating p-values, and p-values calculated.

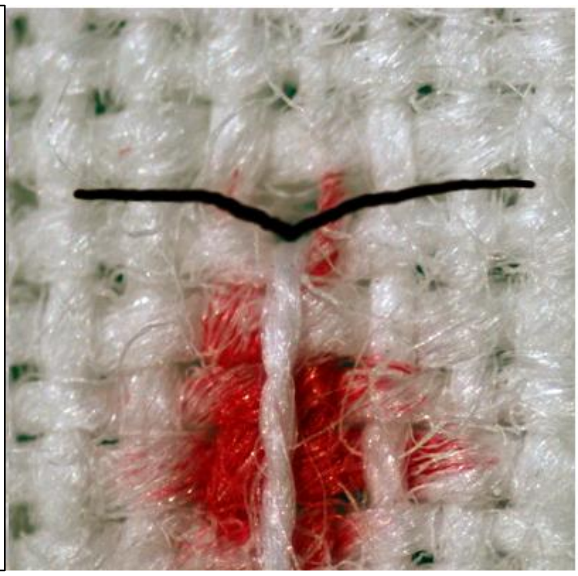
Spacing	Extension at each measuring point			
	Initial Extension	Initial Recovery	48 hours unweighted	1 Month Unweighted
3mm	0.8mm	0.2mm	0.2mm	0mm
5mm	1.4mm	0.6mm	0.1mm	0mm
7mm	1.8mm	0.8mm	0.5mm	0.1mm
9mm	2.9mm	1.7mm	1mm	0.7mm
	p= 0.008	p= 0.007	p= 0.008	p=0.008

As all p-values are <0.01, the data supports (>99%) the deduction as correct.

8.1.4. Qualitative Analysis

Photography through stereo-magnification has allowed an in-detail view of weft deformation. This deformation was noted by Benson and therefore expected to some degree.[122] Figures 8.2 and 8.3 shows these predicted, and gained, deformations.

Image removed



Left: Figure 8.2: Benson's deformation of cotton "object" with lace-cotton laid-thread couching. 5mm spacing. ©Sarah Benson, 2013. (Black lines added to show deformation).
Right: Figure 8.3: Deformation from 3mm group. (Black lines added to show deformation).

[122] Benson, 86-91.

Using the known spacing of the lines of laid-thread couching as a scale, the splits made between the upper and lower sections of the samples can be estimated with some accuracy.

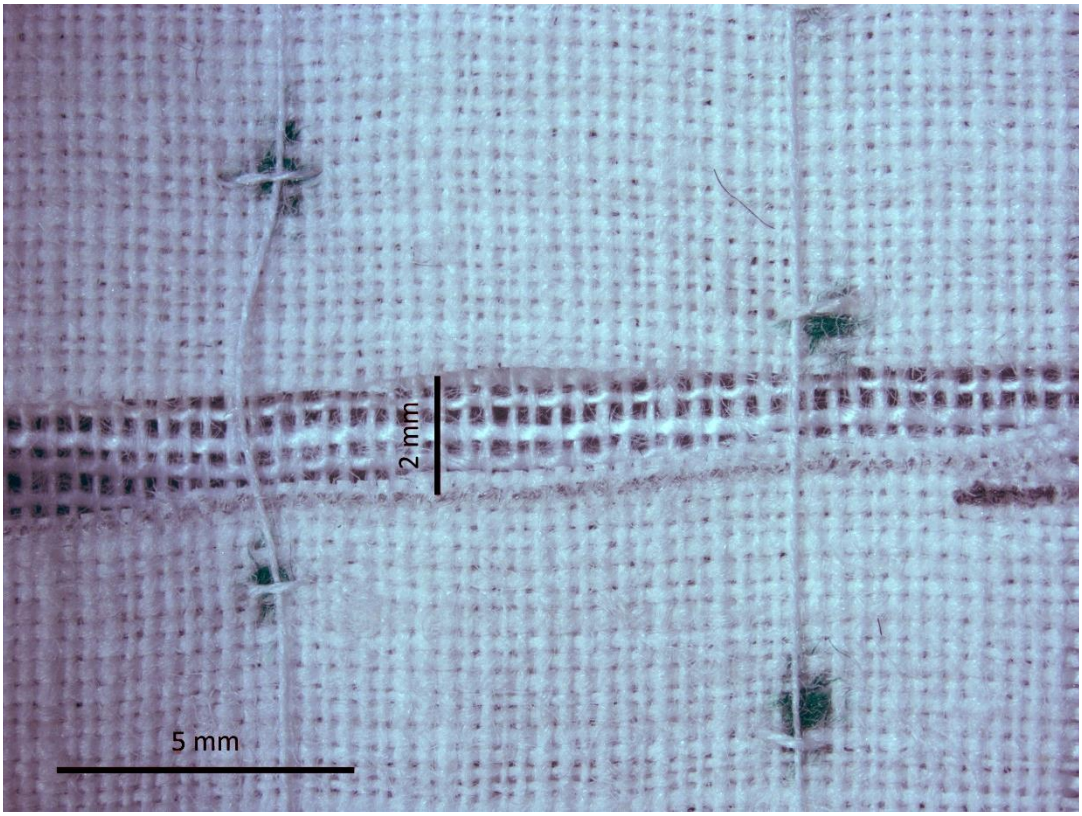


Figure 8.4: Detail of split between upper and lower sections of 9mm sample no.5.

Some extension can be seen in the support threads. Figure 8.4 shows the sample with the largest extension. The left-hand support thread is bowing where it has been pulled during hanging and not recovered to the same degree as the surrounding treatment. Cotton is homogeneous so if this happened to one thread is should have happened to other threads in this sample. It is therefore more likely that the issue arose from incorrect tension during initial stitching.

Slight deformation was noticeable along the upper end of each line of laid-thread couching. This was most apparent on the 9mm and 7mm group, where the wefts below the anchor weft were also slightly deformed, see figures 8.5 and 8.6. The 3mm group showed the least deformation. This indicates that where the load is spread over more lines of laid-thread couching, the impact of the load is less per line. Although all samples recovered overall, the deformation to individual wefts was not improved through removal of the weight, as shown in figure 8.7.

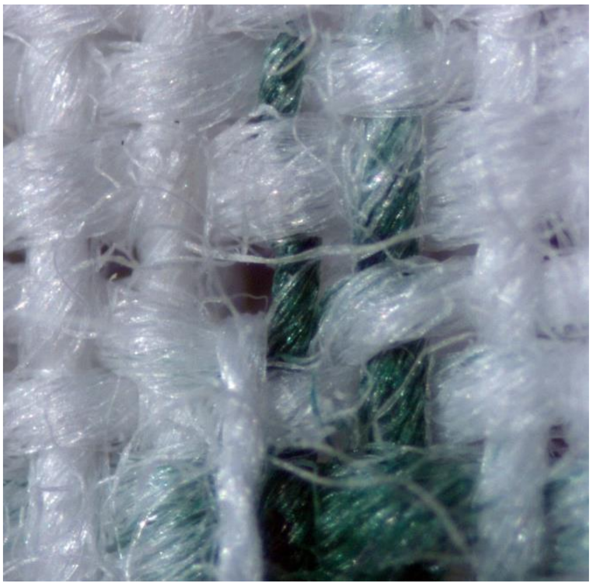


Figure 8.5a: Detail of 9mm sample, no. 5.

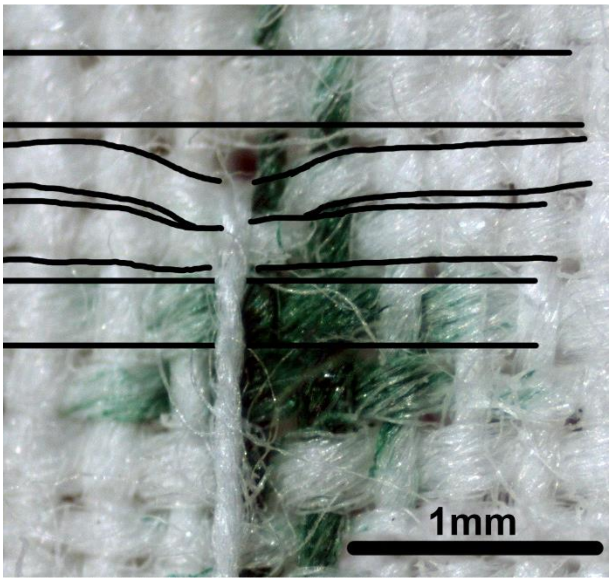


Figure 8.5b: As 8.5a with lines to indicate deformation.

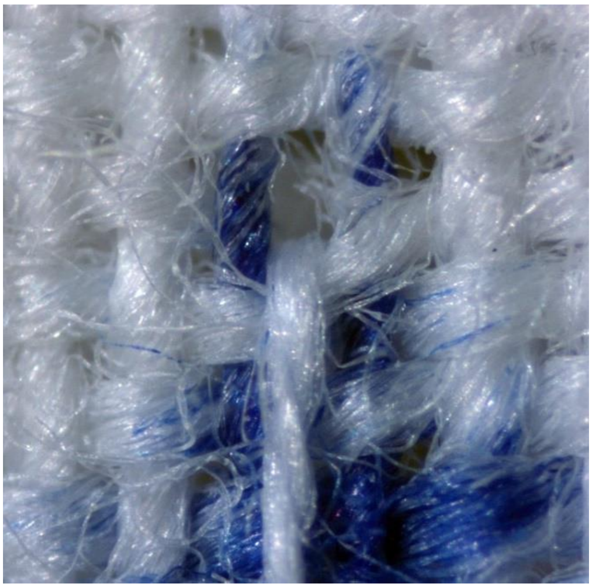


Figure 8.6a: Detail of 7mm sample, no. 4.

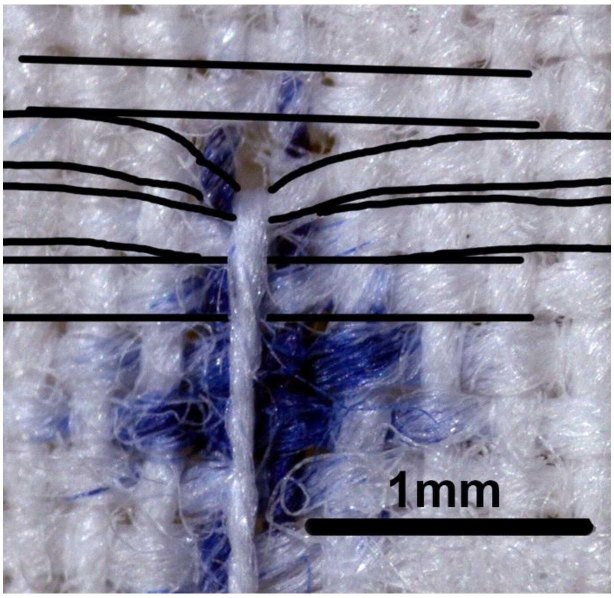


Figure 8.6b: As with 8.6a with lines to indicate deformation.

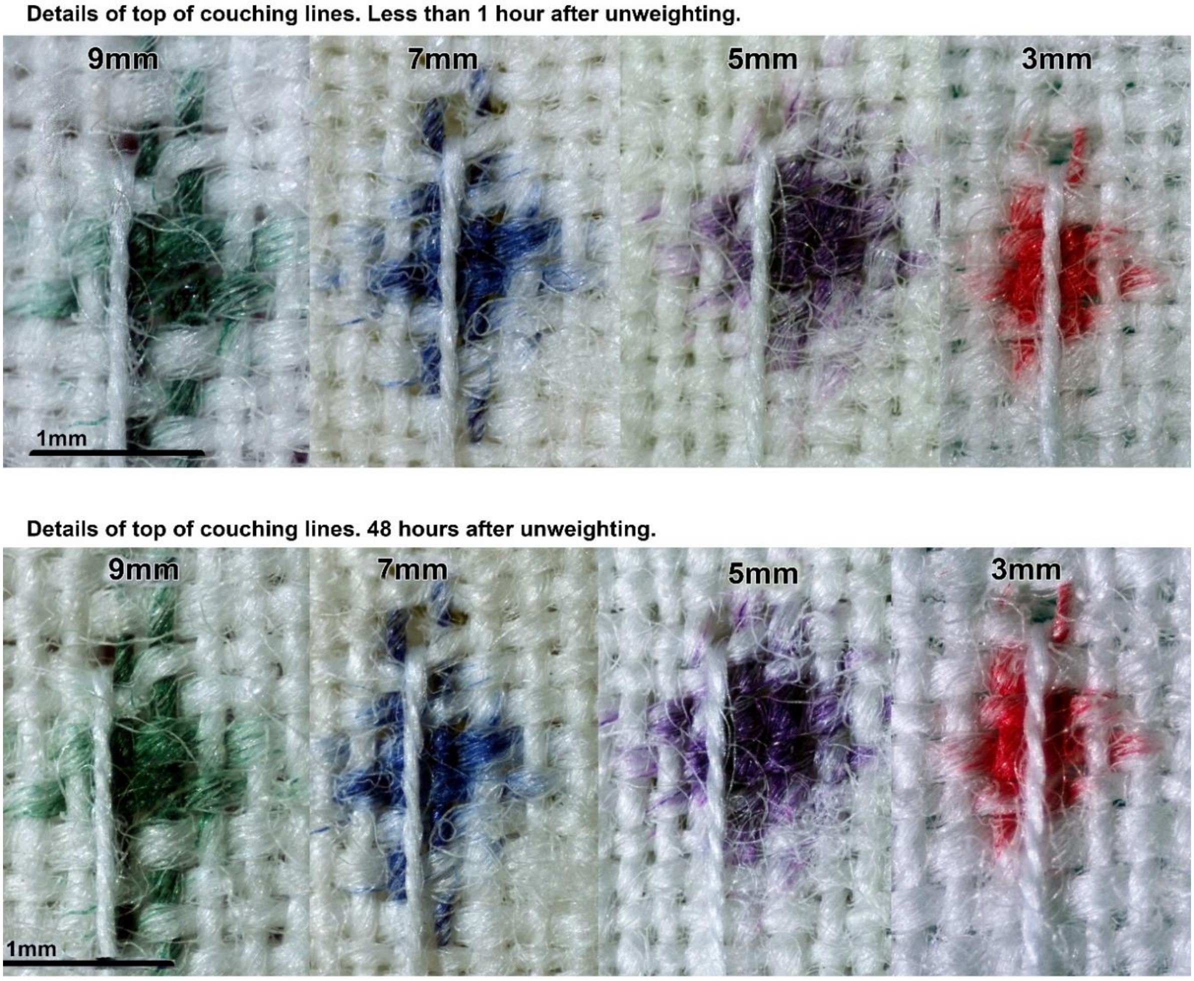


Figure 8.7: Montage of images demonstrative lack of change in weft deformation after recovery period.

The support fabric was also affected. Greater deformation was visible on the support fabric of samples with fewer lines of laid-thread couching, see figures 8.8 and 8.9. These images have been edited to give a higher contrast, to make these deformations easier to identify. The deformations are slight but clear, especially on the left-hand side of figure 8.9. The support fabric was of a less dense weave than the object: 26 wefts and 22 warps per 10mm, rather than 32 warps and wefts per 10mm. This difference is important to note as the loose or tight nature of a weave will impact how that fabric reacts to stresses. Loose weaves are likely to deform in ways which are visible without magnification. This is because individual yarns have more room to move within the fabric structure.

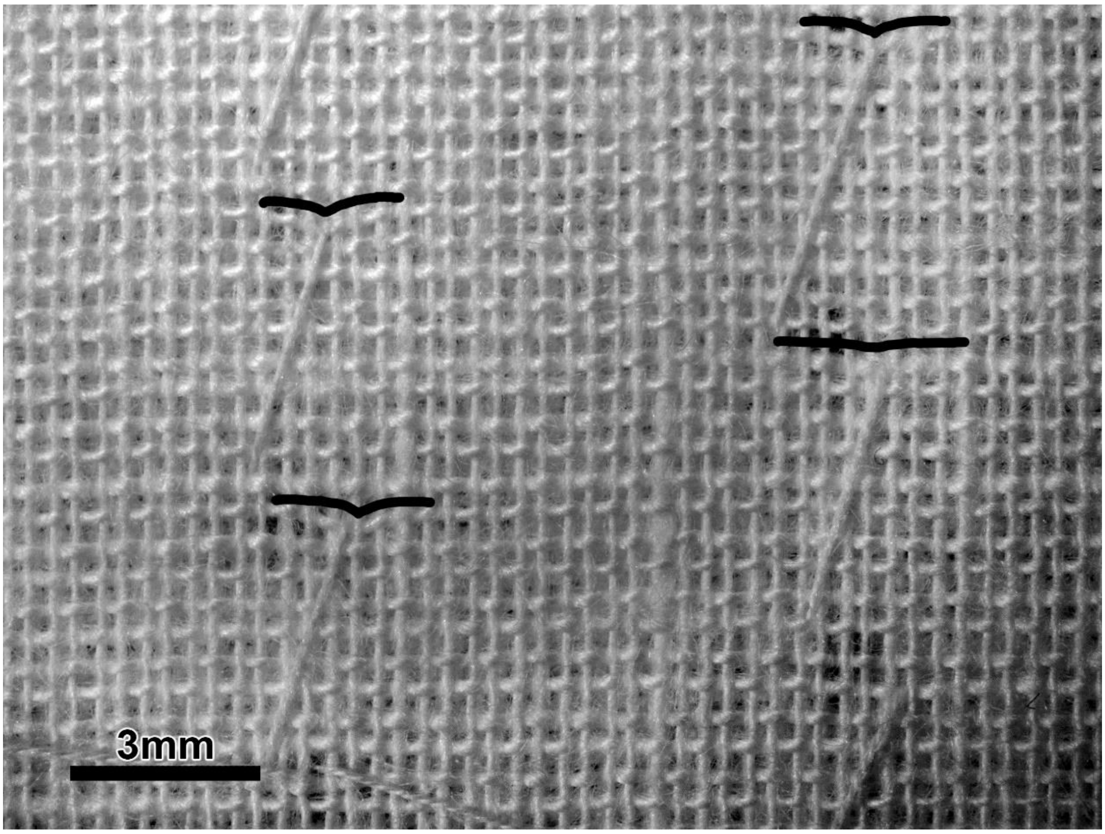


Figure 8.8: Reverse of a 9mm sample. Lines highlight points of deformation.

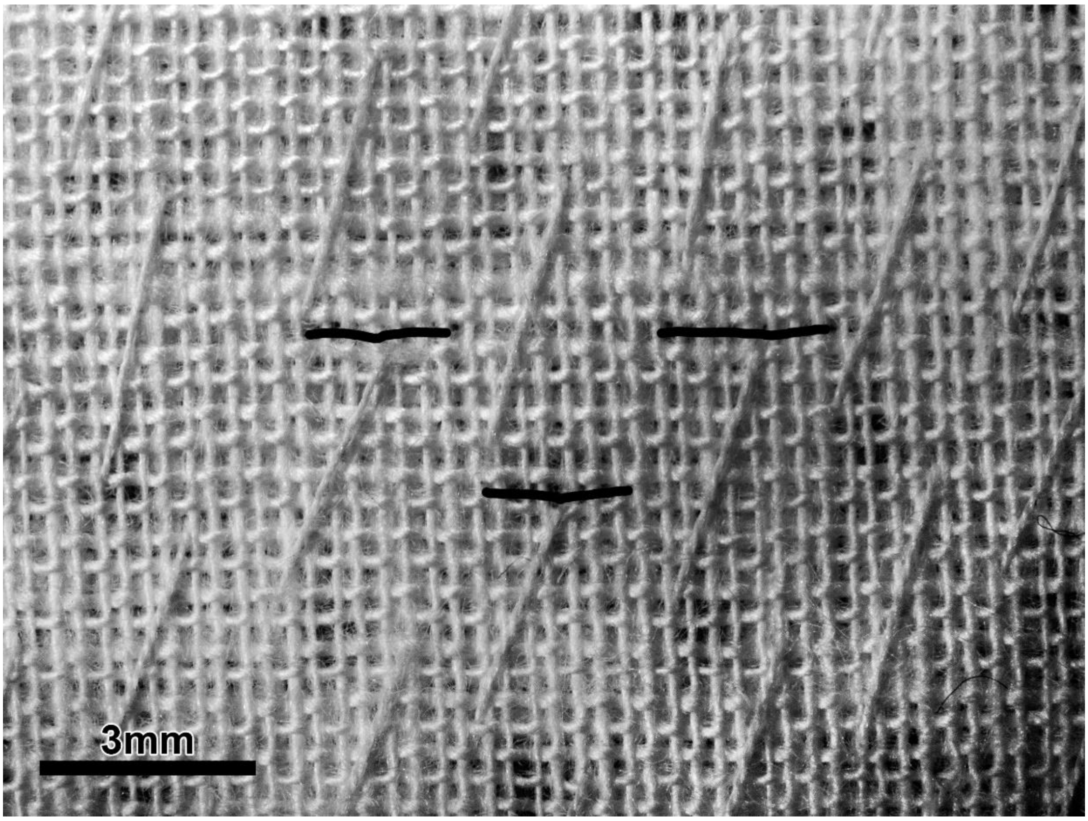


Figure 8.9: Reverse of a 3mm sample. Lines highlight points of deformation.

8.2 Digital Image Correlation Results

Due to the small number of samples investigated with DIC, the following results are stated with the intention of informing future research and pointing out flaws which could be improved upon. Some interesting patterns of strain have been noted, but until more replicates can be investigated these insights are not conclusive.

8.2.1. Data Interpretation

After initial processing the default display for strain results is a three-dimensional plot. These are known as strain maps. These maps can be turned to allow viewing from 360°, but they give more information than necessary for this research. For example, the large spikes at the edges in figure 8.10. In order to make data accessible for this project all plots were examined in 2D format. Choosing 2D formatting automatically superimposes the strain map onto the sample in question, see figure 8.9. This allows for easy identification of high-strain areas.

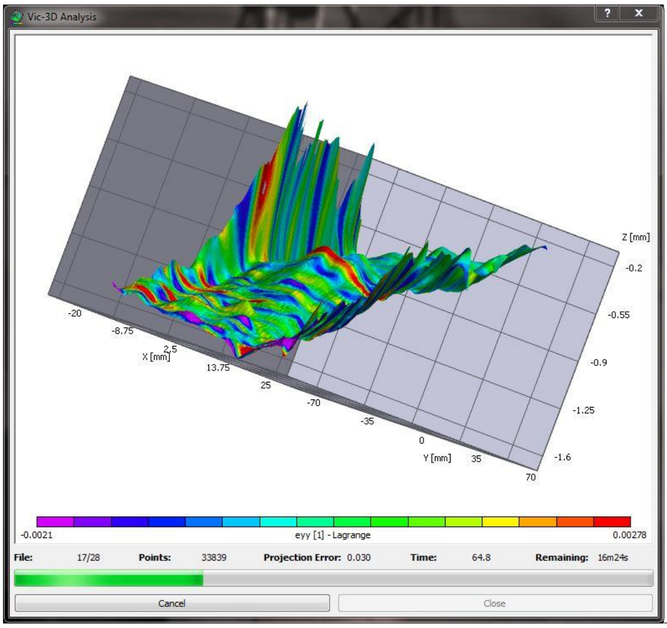


Figure 8.10: 3D plot example

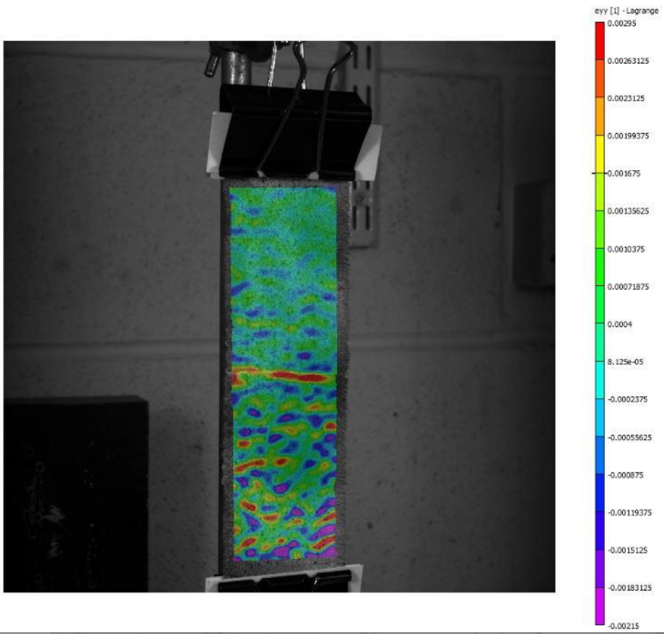
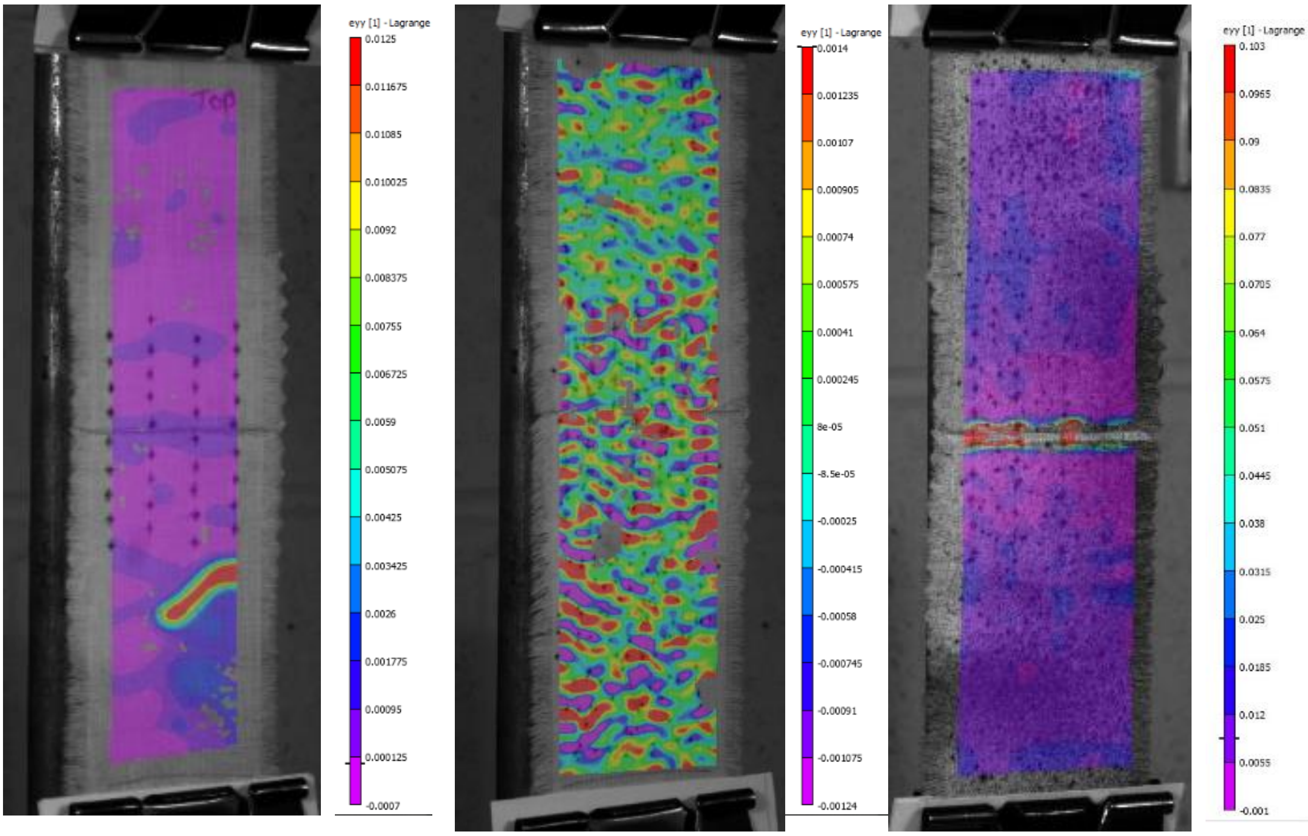


Figure 8.11: 2D plot example

8.2.2 Impact of speckle pattern on results

The speckle pattern can impact the results that are gained. An ideal speckle should exhibit fully random grey patterns, with wide intensity distribution and not be overly periodic.[123] One sample was tested three times, with three different speckle patterns during the course of the experiment.



Each sample was processed in the same manner, but three different results were gained. Out of the three images above, the image on the right gives the result that may have been expected: high strain around the area of high damage. This result is important for moving research forward as it demonstrates the issues discussed in chapter 7.4. This highlights the importance in applying the speckle pattern correctly, in order to gain trustworthy results.

[123] Correlated Solutions, 2007, 41-48.

8.2.3. Strain analysis

"Eey[1] Lagrange" was chosen to depict strain along the y-axis. This eliminates any sideways movements. Figures 8.15 – 8.17 show three results, cropped to the area of damage.

Figure 8.15: Test 4b: 9mm spacing, 200g weight, spray paint speckle.

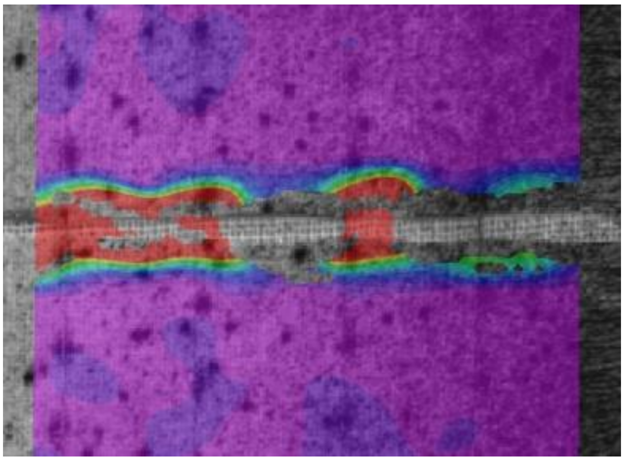


Figure 8.16: Test 3b: 9mm spacing, 200g weight, spray paint speckle– just after weight added.

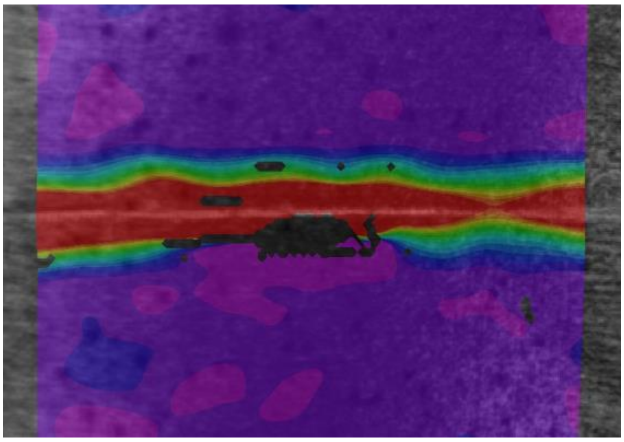
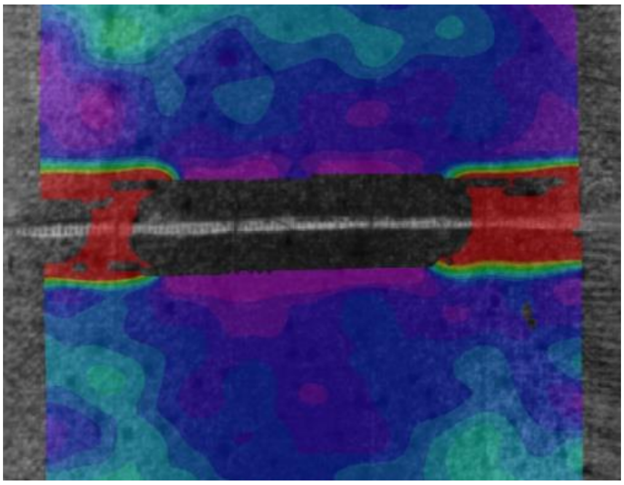


Figure 8.17: Test 3b: 9mm spacing, 200g weight, spray paint speckle– final image, after 30 seconds weighting.



Test numbers can be cross-referenced with images in appendix 9 to see full results.

Figures 8.15 to 8.17 show a high concentration of strain across the line of damage. This fast change of red through to blue indicates an area of heterogeneous nature[124]: these can be problem areas because different elements close together are moving in different ways. All three images demonstrate the issue of incorrect speckle patterns: no speckle = no data. As the "object" moves, the white support fabric cannot be read. Figure 8.16 is included as it is the image before information is lost across the centre of that particular sample. The shapes of the red, high strain, areas can be seen to shift depending on the location of the lines of laid-thread couching. This could be an interesting insight if it were not for the fact that the results were the complete opposite when a different speckle pattern was used. White lines have been added to indicated couching lines, black lines have been added to accentuate the shape of the high-strain area.

Figure 8.18. Test 3: 9mm spacing, 100g weight, pen speckle, final image, after 30 seconds weighting.

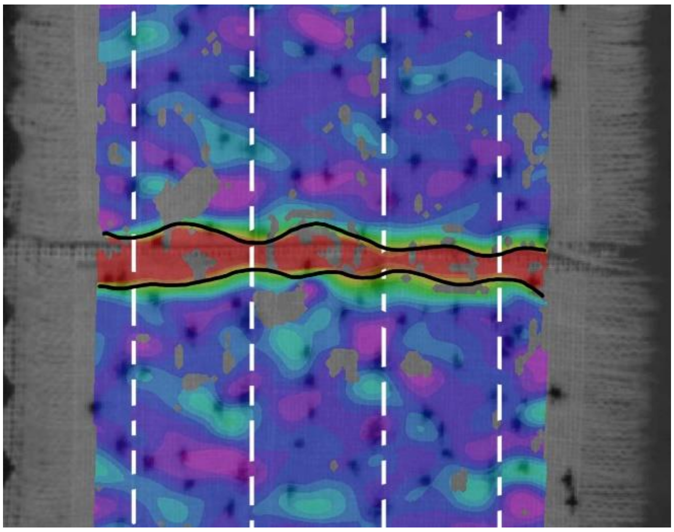
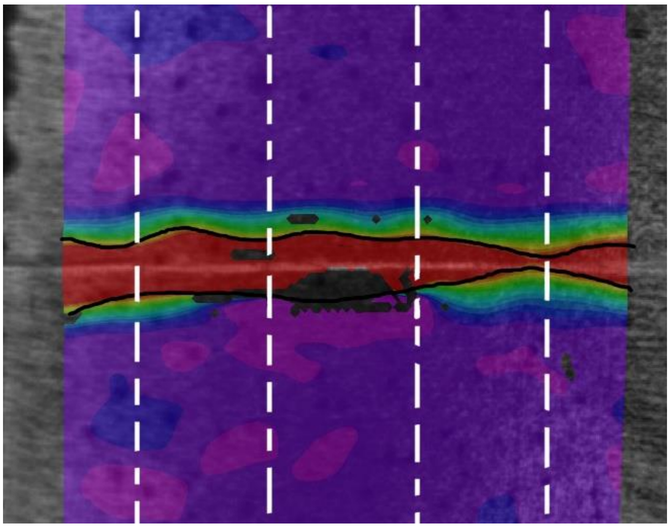


Figure 8.19: Test 4b: 9mm spacing, 200g weight, spray paint speckle, image taken just after weight was added.



[124] Discussion with Jafar Alsayednoor, School of Engineering, University of Glasgow.

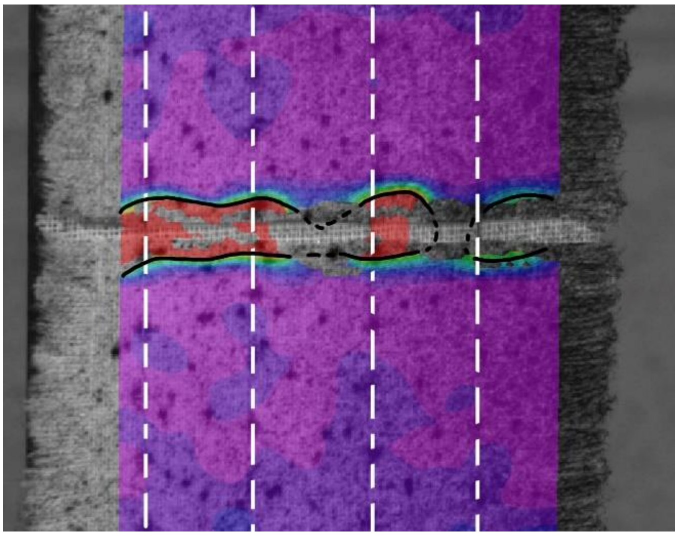


Figure 8.20: Test 4b: 9mm spacing, 200g weight, spray paint speckle, final image.

Figures 8.18 and 8.19 show a wider reaching strain in the gaps between the lines of laid-thread couching, whereas figure 8.20 shows a narrower strain at these points.

Little difference was noted between samples with 5mm spacing and those with 9mm spacing: the pattern of high strain across the area of damage was similar in most cases. Several results appear different to those already discussed, whilst still showing similar information. Figure 8.21 and 8.22 are both from the same group: they “should” produce a similar result. The red section on figure 8.21 reveals a strain of 0.2% whereas the red section on figure 8.22 reveals a strain of 9.3%. Without a larger

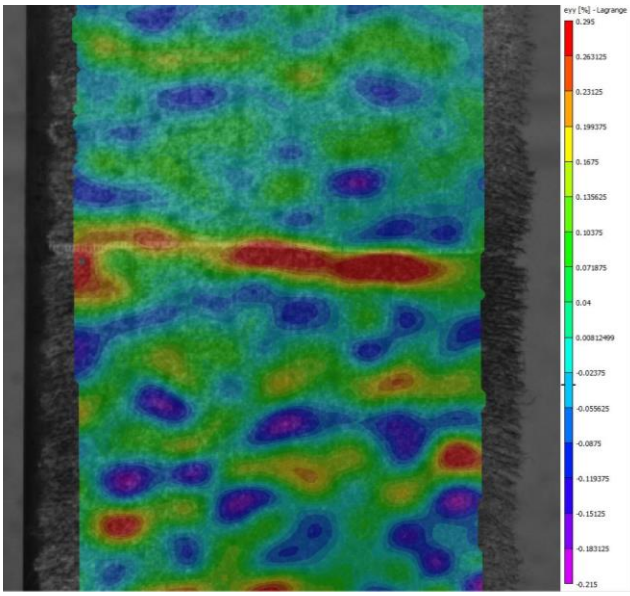


Figure 8.21: Test2b, 5mm, speckle with spray paint, weighted with 200g.

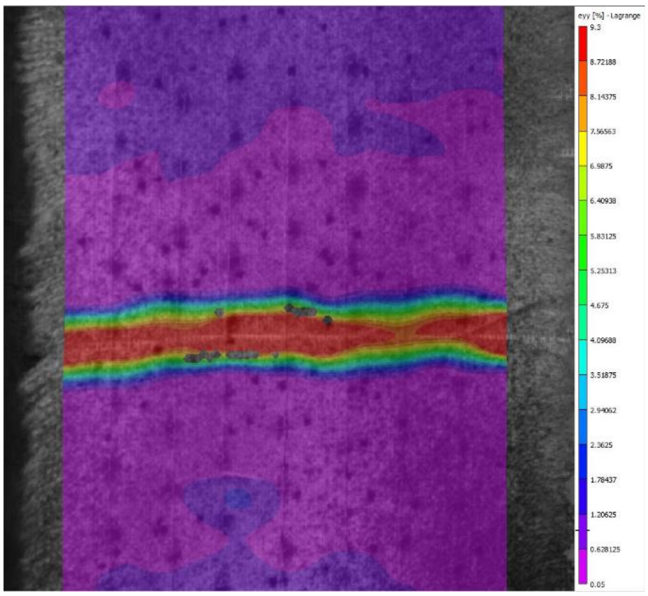


Figure 8.22: Test 1b, 5mm, speckle with spray paint, weighted with 200g.

replicate size, it is impossible to state if figure 8.21 is an anomaly or if there were other issues causing the difference in readings.

8.2.4. In-plane rotation

In-plane rotation was examined as it is a good way of understanding if an object and support treatment are acting as one. It calculates how much the surface is twisting during the weighting. If treatments and object are moving as one, then movement should be the same all over. In-plane rotation is given in a "phi [rad]" numerical value. The actual turn in degrees can be calculated using the following:

$$x = \frac{rad\ x\ 180}{\pi}$$

For the purposes of these experiments π was taken as 3.14.

Three patterns of rotation were found across the experiments.

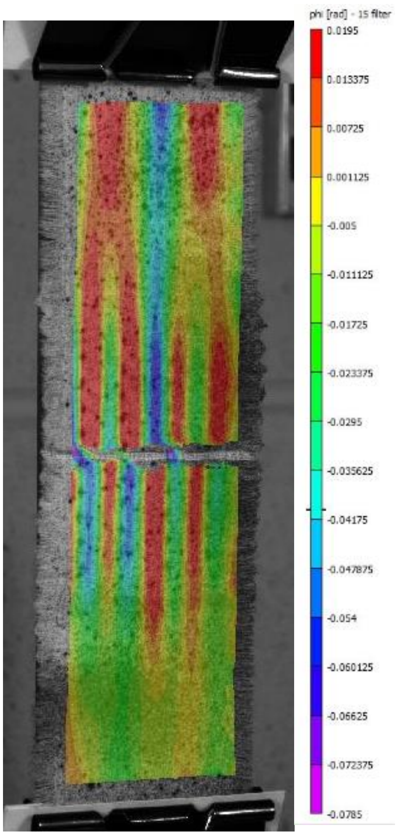


Figure 8.23: Test 4b, 5mm, speckle pattern with spray paint, 200g weight.

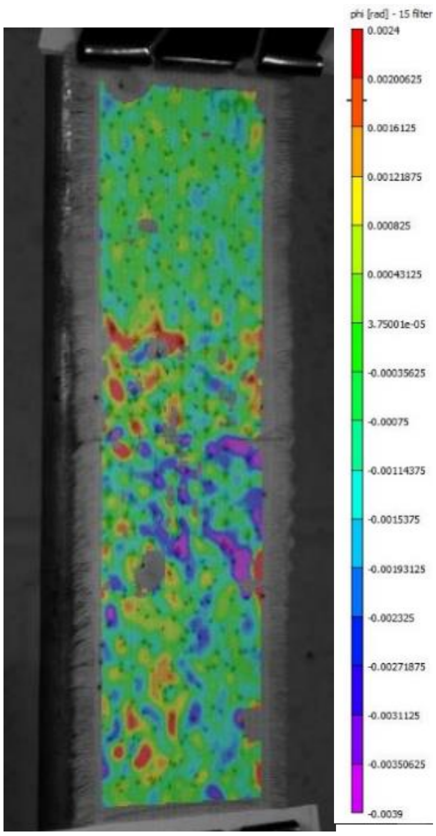


Figure 8.24: Test 1, 5mm, speckle with ink pen, 100g weight.

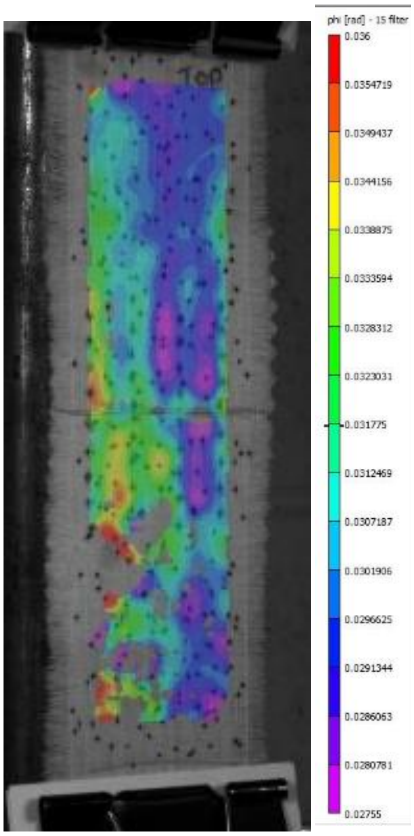


Figure 8.25: Test 4, 5mm, speckle pattern with ink pen, 100g weight.

1. Different levels of twist were apparent vertically, following the lines of laid-thread couching – figure 8.23.
2. Different levels of twist were apparent above and below the split – figure 8.24.
3. Different levels of twist were noted left and right – figure 8.25.

In-plane rotation has the potential to allow a more in-depth understanding of the way that treated materials move and how different support mechanisms alter the spread of strain over a damaged area. Due to figure 8.23 showing a sample with a better speckle pattern, this is the most likely pattern to reappear should the experiments be repeated. This sample was also subject to a greater force, which may have helped exaggerate movement.

8.2.5. DIC Summary

Two points relating to laid-thread couching in textile conservation can be formed from this experiment. Both should be followed up to prove their accuracy:

- High strain is tight around the area of damage: it does not spread out past a few millimetres of the damage. It was expected that some strain would have been noted around the tops of each laid-thread line as these are the points carrying the weight of the treatment.
- Weight-bearing splits can twist subtly, potentially causing further damage. The way in which a treatment moves with an object, or does not move, is important in textile conservation. If a treatment moves against an object, even in a very small way, this can have long-term impact on the success of the treatment.

Avenues of further, DIC related, research are highlighted in chapter 9.3. Video clips of several samples are presented in appendix 12.

Chapter 9: Conclusions

9.1 Research Summary

This project investigated the effect of varying the spacing of lines of laid-thread couching; just one of many possible variables within this treatment. Quantitative data from fixed-load tensile testing indicated that thread choice should be of greater concern than spacing. Although there was a larger initial extension with from the wider spacing sample groups, the ultimate recovery was very similar for all samples. This ability to recover is inherent in object fibres, but more so in the support materials as they are newer and have not potentially lost some of this ability. Understanding how the elongation and recovery of support materials may impact the elongation and recovery of an object is of upmost importance. Weft deformation was also caused by every top stitch in each line of laid-thread couching, regardless of spacing. The wider the spacing, the greater the deformation to support fabric wefts.

9.2 Answers to Research Questions

The research questions given in chapter 1.3 aided the focus of this project by providing smaller research areas to focus on at different points.

Does the spacing of laid-thread couching lines affect the strength of a treatment overall?

“Strength” is a difficult word to quantify as it is a relative term which varies depending on the needs of the object. A support treatment should aim, where possible, to make the textile as strong as it was before damage occurred. Preliminary tensile tests suggested that the stronger the stitching thread, the fewer lines are required to equal the strength of the object, or vice versa. More lines of stitching would require more new stitching holes into the object. It is almost impossible that a conservator would be able to conduct tensile testing on their object fabric in order to ensure that their chosen thread is weaker. The need to understand how “strong” or “weak” an object, or a treatment, is links well to a comment made during the questionnaire regarding the value of observing how treated objects fare over time.[125] Fixed-load testing did suggest that additional caution should be taken for fabrics of a more open-weave than tested here though. The support fabric (which was of a more open weave than the object) showed a much greater weft deformation when lines of laid-thread couching were placed further apart.

Is there a "best practice" way of approaching the spacing of laid-thread couching?

Gathering data from practicing textile conservators demonstrated that each conservator brings their own personal experience to the objects in their care. All spacing measurements given in response to the questionnaire were between 2mm and 10mm. This tight range indicates that there is a "standard" range of spacing values, and experience allows the conservator to choose the value for the individual project. Any approach more formulaic that this would not be able to take all the potential variables into account. "Best practice" is to approach each object individually.

Is it possible to use DIC to understand the strain in an area of laid-thread couching?

Yes – but further research is needed to fully uncover all of the technology's potential within textile conservation. This project aimed to investigate one parameter - hanging textiles with laid-thread couching. Other variables could, and should, be examined further as discussed in chapter 9.4.

How can conservators effectively communicate about laid-thread couching treatments?

Conservators are already discussing stitched treatments between colleagues. The lack of published information is appropriate as conservators do not routinely look for these details in published sources and, in turn, do not often publish them. Future communication between peers could be made more effective by encouraging regular reflection on past stitched treatments to understand how the treatments are aging, and use these are teaching tools.

[125] Respondent 17, Appendix 3, p.105.

9.3 Experiment Summaries

This investigation had a two-fold approach to laid-thread couching treatments: tensile testing and DIC.

9.3.1. Tensile Testing

Both stages of tensile testing built up a picture of the physical properties of laid-thread couching as a treatment, and the materials which it is conducted with. Leaving samples hanging for a longer period of time would have given results closer to those of potential museum display. The use of a sample which was not cut completely in half, so some warps were also supporting the object, may have also given a more accurate gauge of movement. Use of more stringent measuring tools may have aided in gathering subtler differences between replicates.

9.3.2. Digital Image Correlation

Results gained were individually interesting, but not representative of the whole group, due to the small replicate number. More replicates, with a more practiced speckle pattern, would give more reliable data and allow confident definitions of patterns of strain across laid-thread couching treatments.

DIC is a valuable tool to have access to in a research facility. At the time of writing there is no “DIY” method of carrying out experiments without purchasing expensive software. It is hoped that as more research is carried out, through the TMRP and future dissertations, more quantitative information will be passed along which can aid qualitative analysis of stitched treatments.

9.4 Further research:

All elements of this research project have potential for future research. Quantitative analysis of laid-thread couching is a large topic. Many points suggested by Benson are still to be explored.[126] Those unexplored by this project include:

- Analysis of deformation caused by different types of stitching, ie. running stitch vs. long and short stitch.

[126] Benson, 95 -96.

- Methodology for quantitatively analysing deformation/damage caused by treatment.

Tensile testing, both testing strands and fixed-load experiments, could lead into detailed research projects:

- Cotton threads from different manufacturers – how and why are they different?
- The distance away from damage laid-thread couching needs to be taken.

Further work on examining various textile treatments with DIC is especially recommended.

- Replication of this project's DIC work on a larger scale, allowing more samples with tighter variables, ie. the use of a printed speckle pattern and CRE tensile-testing equipment.
- The impact of speckle patterns on textile DIC results and the impact of speckle media (ie, spray paint vs. ink) on textile DIC results.
- The potential of macro-DIC analysis of detailed areas of a stitched treatment. Papers have been written discussing "micro-speckles"[127]; the combination of a macro lens and micro-speckles could allow for an in-depth look at very subtle patterns of strain around stitch-holes. This could, for example, allow a quantitative understanding of the deformation of wefts at the top of laid-thread couching.

9.5 Final Observations

This research project aimed to examine one variable in a treatment which has many, many variables. Results from this series of experiments should be read alongside the work of Benson and Nilsson to give well-rounded, research based, answers to some questions on laid-thread couching. Overall, this project has provided some solid data to back up "known" elements of textile conservation work.

The questionnaire and literature review sections of this project have compiled a useful set of information regarding how laid-thread couching is approached and examined in real-life, and research, situations. This information will be useful to students of textile

[127] Zhu et.al.

conservation, as a prompt for the elements they may need to take into account prior to beginning stitched treatments.

It is hoped that this discussion will continue, to allow wide-reaching reflection on the impact of laid-thread couching treatments on the objects they support.

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Appendix 1: Annotated Bibliography of Survey Articles

The following twenty articles were chosen during a library search of the term "Laid-thread couching". These were the first twenty where couching was mentioned in the main body of text. The annotations highlight the information given regarding laid-thread couching.

1. Beyer, Claudia. "Upholstery conservation in the Acton collection, Villa La Pietra, Florence." Joint Interim Meeting, ICOM-CC, Rome March 2010. https://www.icom-cc.org/54/document/upholstery-conservation-in-the-acton-collection/?action=Site_Downloads_Downloadfile&id=869. Accessed February 18, 2016.

- *"organzine silk thread" used to support areas of loss and splits to dyed patches of linen, with lines of laid-thread couching.*
- *Loose warps and wefts couched with silk.*
- *No spacing given.*

2. Blyth, Val. "The Indian vase carpet fragment: Decisions and discussions prior to conservation." V&A Conservation Journal, issue 31. (April 1999). http://www.vam.ac.uk/content/journals/conservation-journal/issue-31/the-indian-vase-carpet-fragment-decisions-and-discussions-prior-to-conservation/. Accessed February 17, 2016.

- *Curved needle and polyester thread used for laid-thread couching.*
- *No spacing given.*

3. Chewning, Cecelia and Harold F. Miland. "Treatment of an American 19th-century Upholstered Chair." Journal of the American Institute for Conservation, Vol. 32, No. 2. (Summer 1993): 119-128. http://www.jstor.org/stable/3179704.

- *"Couching" used to consolidate fraying – unclear if laid-thread or the couching down of existing yarns.*
- *Dyed cotton thread and a curved needle were used.*
- *Pattern of couching described as "random".*

4. Cogram, Albertina. "The conservation of fourteenth century chasuble." V&A Conservation Journal, Issue 17. (Autumn 1995). http://www.vam.ac.uk/content/journals/conservation-journal/issue-17/the-conservation-of-a-fourteenth-century-chasuble/. Accessed 18 February, 2016.

- *Laid-thread couching with Skala™ to attach support patches.*
- *No spacing given.*

5. Gentle, Nicola. "Treatment of an early 18th Century Indian chintz qanat." V&A Conservation Journal, Issue 11. (April 1994). http://www.vam.ac.uk/content/journals/conservation-journal/issue-11/treatment-of-an-early-18th-century-indian-chintz-qanat/. Accessed February 17, 2016.

- *Comments that laid-thread couching alone may worsen textile condition due to needle breaking through brittle woven areas.*
- *After an adhesive treatment, running stitch, in Skala, was used to fix the textile to a cotton support fabric. Then laid-thread couching, in pulled Stabiltex thread,*

was used to support "the most degraded and damaged and still vulnerable areas."

6. Glenn, Sarah. "Sleeves." V&A Conservation Blog. (September 13, 2011). http://www.vam.ac.uk/blog/conservation-blog/sleeves. Accessed January 30, 2016).
- *Introduces and discusses the technique of laid-thread couching.*
- *Laid-thread couching carried out in Skala™.*
- *No spacing given.*

7. Glover, Jean M. "The Conservation of a Sixteenth-Century Spanish Funeral Cope." Costume, vol. 19, no. 1 (1985): 30-39. DOI: 10.1179/cos.1985.19.1.30
- *Stab stitches used in some areas, 10mm apart, to secure motifs.*
- *Areas of loss and damage in the ground fabric were supported with lines of "self-couching in fine silk and loose strands of yellow floss silk by the same method".*
- *Velvet ground secured with "self-couching" across slits: black silk, 4mm intervals. Thread was "split then re-twisted into very fine but strong threads".*

8. Kite, Marion. "The Conservation of the Jesse Cope." Textile History, 20 (1989): 235-243.
- *Lines of couching used to mount fragments. These were laid diagonally in twill weave areas to minimise visibility of the threads.*
- *Some laid-thread couching carried out in pulled Stabiltex™.*
- *A straight needle, size 12, was "stabbed vertically through all layers of the fabric. A curved needle was not used as a diagonal penetration could have caused damage to fragile sections".*

9. Kite, Marion. "The Xmas Cake Dress." V&A Conservation Journal, Issue 18. (January 1996). http://www.vam.ac.uk/content/journals/conservation-journal/issue-18/the-xmas-cake-dress/. Accessed 17 February, 2016.
- *Dress was supported onto silk habotai using "couched repairs" in Skala™.*
- *Ribbon "couched" to support fabric using pulled Stabiltex™.*
- *No spacing given.*

10. Kite, Marion. "The Safavid cope." V&A Conservation Journal, Issue 49. http://www.vam.ac.uk/content/journals/conservation-journal/issue-49/the-safavid-cope/. Accessed on February 17, 2016.
- *Adhesive treatment used to "enable the couching to be kept to a minimum and limit the visual distraction of surface stitching."*
- *Fragments and splits "couched" to supporting linen fabric.*
- *No thread mentioned.*
- *No spacing given.*

11. Kite, Marion and Albertina Cogram. "Re-evaluation and retreatment: The reconservation and remounting of an English Court Mantua." Studies in

Conservation, Vol. 51, No. 2 (2006): 111-122.
http://www.jstor.org/stable/20619435.

- *"…silk support fabric and a couching technique" used to support damaged silk.*
- *Some discussion of previous conservation couching.*
- *Some stitching carried out in Stabiltex™.*
- *No spacing given.*

12. Kite, Marion and Audrey Hill. "The Conservation and Mounting of a Jinbaori." V&A Conservation Journal, Issue 27. (April 1998). http://www.vam.ac.uk/content/journals/conservation-journal/issue-27/the-conservation-and-mounting-of-a-jinbaori/. Accessed February 17, 2016).

- *Fine polyester thread used for laid-thread couching.*
- *Some areas "couched" to one of the interlining layers of construction.*
- *No spacing given.*

13. Leader, Marilyn. "Conservation of a crewelwork bed curtain." V&A Conservation Journal, issue 39. (Autumn 2001). http://www.vam.ac.uk/content/journals/conservation-journal/issue-39/the-conservation-of-a-crewelwork-bed-curtain/. Accessed February 17, 2016.

- *Splits and areas of loss were supported using lines of laid-thread couching in polyester thread.*
- *Cotton patches used for infills.*
- *No spacing given.*

14. Marko, Ksynia and Margaret Dobbie. "The conservation of an eighth century AD. Sleeveless coptic tunic." Studies in Conservation, Vol.27, No. 4. (November 1982): 154-160. http://www.jstor.org/stable/1506063.

- *Threads pulled from Stabiltex™ No.4 used for full stitch support including "couching".*
- *No spacing given.*

15. Müller, Sonja. "Conservation of the "May Primrose" wedding dress." V&A Conservation Journal, issue 23. (April 1997). http://www.vam.ac.uk/content/journals/conservation-journal/issue-23/conservation-of-the-may-primrose-wedding-dress./. Accessed February 17, 2016.

- *Waistband supported onto "a stronger silk and secured by couching."*
- *No thread or spacing given.*

16. Owens, Gillian. "Now you see it, now you don't: the conservation of a Turkey work chair." V&A Conservation Journal, Issue 12 (July 1994). http://www.vam.ac.uk/content/journals/conservation-journal/issue-12/now-you-see-it,-now-you-dont-the-conservation-of-a-turkey-work-chair/. Accessed February 17, 2016.

- *Polyester thread used for "couching down holes and weak areas".*
- *Discusses couching as "…a stitching technique much used in conservation now and in the past."*

- *Braid “couched” to dyed cotton tape.*
- *No spacing given.*

17. Owens, Gillian. "Ethics in Action - Conservation of King James II's wedding suit." V&A Conservation Journal, Issue 26 (January 1998). http://www.vam.ac.uk/content/journals/conservation-journal/issue-26/ethics-in-action-conservation-of-king-james-iis-wedding-suit/. Accessed February 17, 2016.

- *Some discussion of previous couching repairs.*
- *Japanese paper inserted between wool and lining and “couched in place”.*
- *No spacing given.*

18. Payne, Susan, David Wilcox, Tuula Pardoe and Ninya Mikhaila. “A seventeenth-century doublet from Scotland.” Costume, vol 45 (2011): 39-62, DOI:10.1179/174963011X12978768537537.

- *Patched supports stitched in placed with laid-thread couching.*
- *Laid-thread couching used to hold down*
- *No spacing given.*

19. Younger, Sophie. “Textile treatment on Mary Queen of Scots bed.” (November 13, 2014). http://youngerconservation.com/treatment/textile-treatment-mary-queen-scots-bed/. Accessed January 18, 2016.

- *Laid-thread couching lay-out described as “a comprehensive network of support and outline stitching.”*
- *Cotton support fabric.*
- *“Fine threads” used. No fibre given.*

20. Zoldowski, Abby. "The effects of long term display on previous treatment." Textile Speciality Group Postprints, Vol. 20 (2010): 102-113.

- *“…patches secured with rows of couching stitches…” in silk.*
- *No spacing given.*

Appendix 2: Questionnaire

University of Glasgow

VIA VERITAS VITA

The Use of Laid-Thread Couching in Textile Conservation

Consent to the use of data
University of Glasgow, College of Arts Research Ethics Committee

This questionnaire forms part of the research for my post-graduate dissertation, which is a requirement of the MPhil in Textile Conservation, University of Glasgow. My dissertation aims to build upon work started by Sarah Benson in 2013. A copy of Sarah's paper for ICOM-CC can be found here. My research will focus upon stitching styles, particularly if and how the spacing of laid-thread couching lines impacts the object to be supported. A literature review, tensile testing, weighted samples and digital image correlation (strain mapping) will also be employed as part of the wider project. This work is being supervised by Frances Lennard.

The aim of this survey is:
- to establish attitudes towards laid-couching spacing in the professional sector.
- to see if patterns of choice can be linked to training or country of work.
- to understand why little is published on couching.
- to gather suggestions for thread types to be used in the experiment.

Many thanks for you time,
Hannah Sutherland

* 1. I understand that Hannah Sutherland is collecting data in the form of completed questionnaires for use in an academic research project at the University of Glasgow. This research aims to examine current professional practice regarding laid-thread couching in textile conservation practice.

I give my consent to the use of data for this purpose on the understanding that the material may be used in future publications, both print and online, by ticking one of the boxes below

- ◯ I give permission to be quoted
- ◯ I give permission to be quoted anonymously
- ◯ Please do not quote me

1

Contact Information

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United Kingdom

University of Glasgow

VIA VERITAS VITA

The Use of Laid-Thread Couching in Textile Conservation

Participant Questions

* 2. Contact Information

Name

Institution/Company

City/Town

Country

Email Address

3. At what establishment/s did you carry out the majority of your early textile conservation training? This could be a university, museum, job post etc.

4. When considering using laid-thread couching on an object what are your key considerations when deciding how spaced apart to make your lines of couching? Please mark as many as necessary.

- ☐ Fragility of object
- ☐ Size of loss
- ☐ Fibre of object
- ☐ Flexibility required from treatment
- ☐ Time available to complete treatment
- ☐ Weight of object to be supported
- ☐ Type of stitching thread
- ☐ Importance of a minimally visible treatment
- ☐ The spacing I am comfortable working to
- ☐ Other (please specify)

5. As a student I have found it difficult to find detailed information regarding couching within published articles. Would you consider any of the following to be reasons for this lack of detail? Please mark as many as necessary.

- ☐ It is unnecessary: couching is very variable and dependant on the object, so exacting instructions are not as transferable as other treatments.
- ☐ Couching is a common treatment; other conservators are not interested in getting explicit details.
- ☐ Not publishing this information limits the chance of untrained persons attempting repairs themselves.
- ☐ The spacing of couching is personal preference; it doesn't matter what person A did because person B would probably have worked it slightly differently.
- ☐ Other suggestion

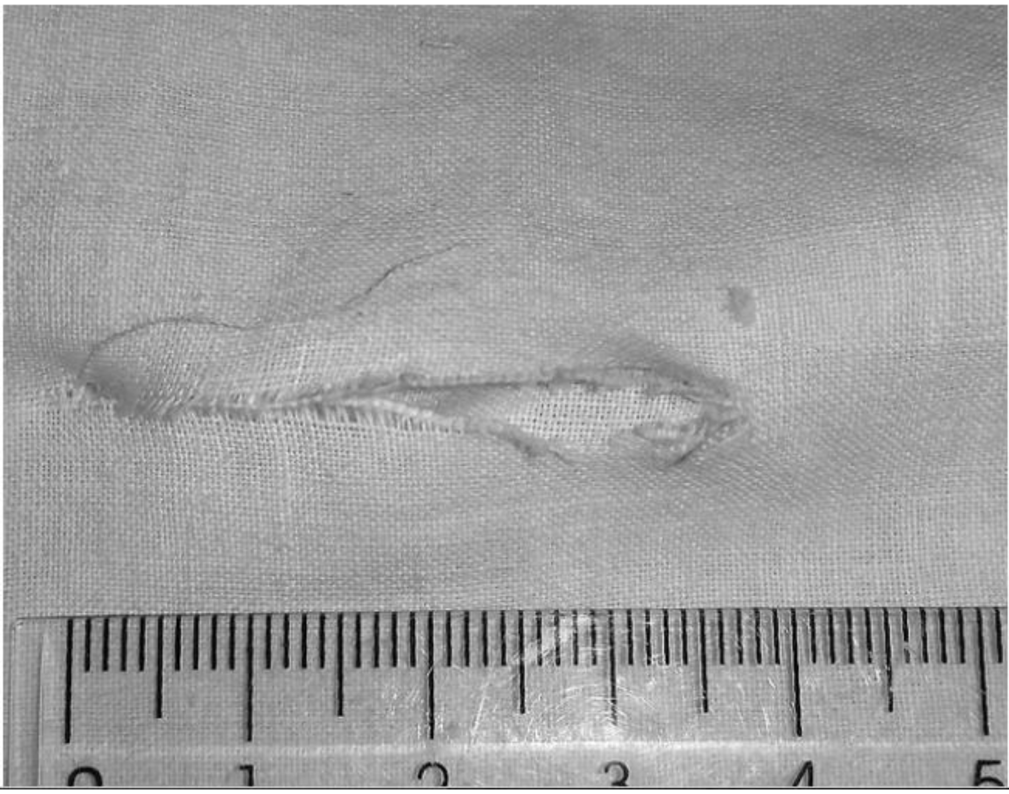
6. Do you think that you have developed a preferred line spacing over your career? for example "around 5mm apart".

- ○ Yes
- ○ No

If yes, please give a measurement.

7. You are presented with a c.1900 cotton infant's gown with a horizontal split in the skirt. The gown will be mounted on a mannequin for long-term display. The fabric itself is medium weight and stable. How

far apart would you consider spacing out your lines of couching, and what threads would you consider using?



Spacing

Threads

8. If you have written or come across any case studies giving details on the spacing of laid couching I would be very interested to hear about them. Please give details below:

9. Please feel free to make additional comments or thoughts below

Thank you for completing this questionnaire. At the end of the project a summary of the results will be sent out to all participants. Please feel free to share this questionnaire with anyone you feel may be interested. I am hoping to collect the opinions of a wide range of textile conservators from both private practice and institutions, as well as those who may have retired. I can be contacted at hannah.sutherland@hotmail.com if you require any further information on the project.

Appendix 3: Questionnaire Comments

The following comments were given to questions where an "other" or "comments" section was offered. Several responses have been omitted at the request of respondents. Respondents have only been identified by their response number. Several people viewed the survey but did not fill it in, hence some numbers are over 51 (the number of actual responses).

Question 2: When considering using laid-thread couching on an object what are your key considerations when deciding how spaced apart to make your lines of couching?

Respondent #3

Nature & type of support fabric, type of damage.

Respondent #4

If there are completely loose threads to hold down, this may affect my spacing (density and position) of laid-thread couching.

Respondent #5

Type of loss - for example i might choose a different spacing for an area of complete loss and an area where only the warp/weft is missing or an area of weakness vs loss, or even an isolated split in an area of overall strength vs a small split in a large area of overall structural damage

Respondent #6

Whether the damage is caused by disintegration of the fabric or is mechanical damage. How much of the object is affected: isolated area/s or more general weakness. What is the object's 'usage' in the future: self supporting/hanging/draped or to be completely supported/stitched on a board.

Respondent #7

Goes along with weight, the coarseness vs fineness of the textile. For finer textiles I will likely space closer than coarser textiles.

Respondent #11

Minimum stitching for maximum effect. Thread choice determines distance apart. Thread choice depends on visual impact and strength required - finer thread might require closer stitching, but thicker stronger threads will be more visible. Availability of threads, sometimes you just have to use what you have.

Respondent #14

I would probably also consider the thread count, and weave type: how it responds to being pierced with a needle. I would space them further if I thought too much piercing with the needle would be damaging and would discount the benefits of the couching.

Respondent #18

The direction of the tear/rip, with regards to the direction of the weaving of the original textile (e.g. is it ripped vertically or diagonally?). Also, my choice could depend on whether or not a backing is used, and if so, if I am adding only a small localized backing or backing the whole textile. Furthermore, my choice would also depend on whether or not I'm adding a type of facing also (e.g. like when 'sandwich'ing a textile between two layers of silk crepeline).

Respondent #25

The size of the weave (thread count) - do you mean that by weight? If I was working on a very finely woven textile I would use closer stitch lines to that of a hand spun, slubby textile.

Respondent #26

Weave of fabric being supported.

Respondent #29

Spacing appropriate for the object

Respondent #32

Spacing is dictated by the needs of the object, fragility, overall weakness. Aesthetics may be a consideration but this depends more on careful colour matching. The weave pattern of the base textile may also dictate spacing if many straight vertical lines create an undesirable affect. Examples of where close laid couching has saved a very fragile silk but in turn created a pattern in itself that obscures the underlying woven design can be seen at Uppark. Work carried out with every good intention by Lady Meade in the 1930s/40s

Respondent #33

If a secondary support method such as an adhesive treatment is used then couched spacing as a second layer of support may be more widely spaced than if the couching was the only method of support. Some of the above points are a consideration e.g. for thread choice, addition of general grid/ support lines but not for actual spacing choice

Respondent #37

The future use of the object when displayed. When hanging, there will be more strain than when an object will be presented laying down.

Respondent #38

I also consider any loose threads within the areas of loss/damage that may need to be secured in place by the stitching.

Respondent #43

Varies depending upon the area of damage. I increase the spacing on the more robust edges of the damage and in areas surrounding the damage I use about 6mm apart running stitches instead of couching.

Respondent #47

I think it's a lot to do with the type of damage - how many loose warps/wefts need to be secured, and how weak or strong the object is generally.

Respondent #49

If, for instance, the textile required a combination of an adhesive treatment and a stitching treatment, I might be inclined to use fewer laid thread couching stitches.

Respondent #52

I would expand 'time available' to resource constraints, e.g. budget; other key consideration future role of object, e.g. prep for storage or display (long term/short term); is object to be mounted onto a support form; is the object to be stitched to a support form, e.g. flat textile to fabric covered board; horizontal display/ vertical display, somewhere in between; reapplied to an upholstered form?

Respondent #56

The weave of the fabric and any surface features such as embroidery.

Question 3: As a student I have found it difficult to find detailed information regarding couching within published articles. Would you consider any of the following to be reasons for this lack of detail?

Respondent #3

None of the above - purely particle papers are not appropriate for publication in academic journals. Lack of time and inclination - busy conservators are unlikely to bother to publish something apparently 'mundane".

Respondent #4

Laid-thread couching (like other stitching techniques) have many variables, which may account for the lack of comprehensive research to date. Also, advanced technology may make it easier today to produce quantitative data. Another explanation could be that stitched support techniques' origin go back very early in our history, and thus they are considered non-scientifically, most of the time.

Respondent #5

I think there are very few publications which consider such practical papers. i also think that spacing would object specific and therefore not really transferable information as such.

Respondent #6

It is a common treatment and therefore it has probably not occurred to anyone to write a blow by blow account. Plus, no two objects are the same and each treatment is specific to one object. There are many variables: condition, support material; thread choice; future 'use' of object etc etc

Respondent #7

Perhaps because it is a fairly standard technique used for stabilization and maybe it is assumed once you learn how to do it you know it. Also, to some extent, with experience you gain a "feel" for it, for what needs to be done. What works and what doesn't. Not everything can be taught.

Respondent #10

I think it is a treatment conservators are comfortable with doing and feel confident to make their own judgements. Stitching and textiles are natural partners so possibly not questioned as much. Lack of time for conservators in practice to research because of other time pressures.

Respondent #11

I think the bigger question is thread choice, not distance apart.

Respondent #13

I don't recall being taught any specific rules about the spacing of couching; the choice of spacing is done on an object by object basis and as such it is very hard to impose a set of predetermined rules.

Respondent #14

I think conservators are reluctant to put their personal stitch methods into written form in case of criticism from other conservators. I've found it so hard to find this information too, in any form but verbal. I wish it was more available

Respondent #16

I would suggest that the high variability of loss/fabric/object is the reason there is no hard and fast 'this is how you couch' instruction.

Respondent #17

I feel that giving exacting instructions for couching is impossible. There are too many variables to be considered concerning material, state of deterioration, strain to be expected from display, choice of backing material

Respondent #20

When I was a student, I also very much found it difficult to find published information and details on common treatments including stitching stabilization. I believe this is due to the fact that for established conservators they are so common as to not warrant publication... In addition, textile conservators seem to rely a lot on verbal discussions/sharing of past experiences in the lab to determine treatments RATHER than following extensive published protocols.

Respondent #29

Couching us often different for different items and therefore difficult to generalize in a book.

Respondent #32

I think because it is a common method, assumptions are made as to its effectiveness. It is taken for granted. What is the alternative; rows of running stitch, darning ? These last are all possible and in fact can be both visually and structurally preferable depending on the object. The object dictates the methodology.

Respondent #33

It is not so much that conservators are not interested in writing about couching but rather articles focus on less commonplace treatments and developments

Respondent #35

Good photographic details with scales give a rough idea of spacing anyway

Respondent #36

I wouldn't say it is unnecessary but exacting instructions would not necessarily help as the needs and requirements of object vary each time. It is also not entirely personal preference dependant. It is a professional judgement one makes based on experience.

Respondent #37

Couching is a common treatment, but the ins and outs and the considerations on spacing, tension and thread type have to be gathered and developed through a lot of practice - much more so than through literature.

Respondent #38

I feel it may be a combination of the above. Although couching is variable and dependant on the object, any written instructions could be transferred

Respondent #43

Stitching of any kind is a technique that everyone is at least familar with and can relate to. It is seen as a basic technique that should be known and therefore possibly not questioned as it's been used for so long.

Respondent #45

Everyone does it a little differently often based on experience gained with each object.

Respondent #46

It is a very valid point, there are references online but not specifically on spacing. It might be missing because it requires practical expertise and just knowing the stitch is enough, it is more important to know how to use it and best learned under guidance.

Respondent #49

I think that in part the above 4 statements may be true, but it may also be that stitching treatments are part of a trained textile conservator's tool kit, much akin to a routine treatment such as surface or mechanical cleaning. All textile conservators have occasion to do it and the approach taken is customized to the particular textile. Also, published articles tend to focus on the 'new' or 'innovative' treatments, and stitching does not necessarily fall into this category.

Respondent #52

Are you aware of couching patterns in Lennard & Hayward 'Tapestry Conservation', pages 118 to 120 in particular

Respondent #56

It has been taught as a hands on skill by tutors or through working with other people.

Respondent #57

Variables are too great for a standardization but a general guide on the factors to look at would be helpful.

Question 4: Do you think that you have developed a preferred line spacing over your career?

(where respondents just gave a measurement this has been omitted, as it is reflected in the main data in chapter 3. These comments are those which gave information above and beyond a measurement.)

Respondent #3 - YES

My couching is based on a 10mm grid. I work out the 10mm grid lines and then use proportions of that as I feel necessary.

Respondent #25 - YES

3-4mm (dependant on textile and also thread count - maybe X number of yarns?

Respondent #30 - YES

5-7mm, depending on the damage - however, I do execute lines closer together in select locations if extra security is needed, or further apart to allow for design components.

Respondent #31 - YES

On average 5mm or 10mm for larger objects although it does depend on the condition of the object

Respondent #35 - YES

Around 5mm apart. If more intensive couching is needed I tend to stabilise the area with 5mm couching and go back and intersperse with a second batch, thereby making the couching about 2.5mm apart in the most needy areas.

Respondent #36 - NO

I ticked no as line spacing varies depending on objects but over the years on a large silk damask hanging with a support fabric of silk I tend to put couching lines about 7mm-8mm apart

Respondent #49 - NO

Each textile is assessed and may require a different approach. I do not see stitching treatments being so standardized.

Question 5: You are presented with a c.1900 cotton infant's gown with a horizontal split in the skirt. The gown will be mounted on a mannequin for long-term display. The fabric itself is medium weight and stable. How far apart would you consider spacing out your lines of couching, and what threads would you consider using?

(where respondents just gave a straightforward spacing or thread this has been omitted, as it is reflected in the main data in chapter 3. These comments are those which gave information above and beyond.)

Spacing:

Respondent #6

6 - 7 mm, line length 60 mm approx..

Respondent #43

Between 5 and 6mm within damage and running stitches 6mm apart in surrounding area.

Respondent #49

My rows of laid thread couching stitches would be approximately 3 - 4 mm apart if I was using a very fine cotton thread and perhaps a bit closer if I only had access to a very fine and weaker silk thread. I would start my rows of stitching slightly beyond the area of damage to secure the ends of the split.

Respondent #59

3 - 5 mm (to secure raw horizontal edges and confine loose weft thread).

Threads:

Respondent #5

2 ply hair silk, Skala, lace cotton if I could find one fine enough, probably not stabiltex as I don't think it would be strong enough, maybe depending on where in the split the skirt is and what the brief is (to be worn, definitely not, to go flat, maybe).

Respondent #10

Ultra fine cotton, polyester Stabiltex or even silk - looking for fineness and suitable strength.

Respondent #49

I would prefer to use a very fine cotton thread, but if that was not available, I would choose a fine silk thread.

Respondent #56

cotton, skala or stabiltex depending on what looked best.

Final Comments

Respondent #1

I think that this is one of those questions that have more than one "right" answer. There are a lot of different factors that go into spacing and thread selection but the end result of successfully supporting the object through its use-life can be achieved in more than one way.

Respondent #3

It well be worth contacting the elder generation of conservators to establish why & how couching was established, and does their training background have any influence here? Why was an established metallic thread embroidery technique so adapted? Also - style of couching as well as spacing - such as use of same needle hole for going through fabric & the brick formation of the over stitch.

Respondent #4

It would be very interesting to know more about the impact of staggering the end points of laid-thread couching, the varieties in this. Also, it would be useful to know about the impact of how far beyond the damage one takes the couching (into a stronger area, but is there an optimal distance?

Respondent #6

Laid couching is very difficult to be proscriptive about, the most important things are the area covered by the stitching (you do not want a closely worked area on an otherwise undamaged piece), the length of the stitches and the tension of the stitching.

Respondent #7

I really do think the "right" spacing comes with experience. After you've done it for awhile you get to know what works the best. Good luck!

Respondent #9

I spacing would also depend on the object as a whole and the extent of the damage elsewhere. I would want to keep to the same spacing for an entire object so I would work out what was most appropriate for all the areas of damage, with the option of doing a half space stitch if necessary but this would be more likely if I was doing quite a wide space to start with. I think it is also important to consider the role of support stitching particularly if dealing with isolated tears, this can be done in a different thread, usually thicker and works with the couching so that the finer thread is not put under so much strain.

Respondent #11

I use couching over areas of damage / loss / or edges - long/short stitches. Patch support = couching with a few stitches to hold the edge of the patch in place (unless it is too visually intrusive and no significant weight will be present, then it is possible to stitch around a loss with patch support behind and net overlay). Full support = couching over damage / loss / or edges + another stitch in stronger areas to hold the object to the support; wide spaced running stitches for flat surfaces / or staggered running if textile will be returned to a 3D shape, such as over upholstery, or where some stretch is required (straight stitch has no stretch, staggered stitches allow some stretch in all directions including the bias without damaging the object). Densely packed lines of couching make that area stronger than the surrounding unsupported textile so it is important find an satisfactory balance. Threads: - I NEVER use silk. - Pulled stabiltex for low visual impact - Mara most places, thickness depending on application - Skala on rare occasion where strength is required but I'm sure it has a cheese wire effect on the object threads at both ends of the laid line

Respondent #14

What a great project...I for one would really like more discussion on exact thread types and stitch methods, I find it very subjective!

Respondent #16

Methods for laid couching are highly variable and depend on the size and orientation of the loss/damage, the type of fabric and the preference of the conservator. I suspect that you will find huge variation in working practice.

Respondent #17

I am sorry that I can't answer the question based on the information provided. From the photo it is not obvious to me where on the skirt the damage is situated. This may in a small degree influence the choice of backing material and sewing thread. Is it higher up or lower down, how much weight does the repair have to support. I think the reason that nobody is writing about laid thread conservation is that this seemingly simple technique craves a lot of practice and observation of treated objects over time to 'master' it. I would always want to see the object itself and handle it before I gave any advice. That all said I wish you all the best with your project - couching well done is still one of the techniques that does little damage to objects and is reversible. :-)

Respondent #18

My answer to question 7 is more of a guess, because in real life I would have to see and manipulate (feel weight and fragility) the object to decide. Sometimes we think one thing seeing a photo, but then when we receive the object we change our minds.

Respondent #23

The Directory of Hand Stitches used in Textile Conservation distributed by the Textile Specialty Group, AIC covers the different couching stitches.

Respondent #25

Have you also considered the spacing of the stiches on the rows and staggering them compared to their neighbouring rows? Sometimes this is not possible due to the damaged textile. is there any research to show having the stitches inline does in fact cause damage? it would be interesting to see the research!

Respondent #27

With regards to spacing, the size of curved needle can determine the spacing used.

Respondent #32

The studio has just completed treatment on a set of very fragile early 17thc silk damask curtain linings from the Spangled Bed at Knole. These first required an overall support to allow safe handling, provided by adhesive film on silk crepeline, plus a further dyed silk support fabric, so the overall laid couching was worked through the three layers. The laid couching was first worked at a regular wide spacing across the entire surface of the damask and then closer lines were worked where very damaged areas required more support. The damask had to be strong enough to act as a curtain lining on a state bed on permanent display. Stitch templates were used so that everyone working on the linings followed the same pattern. I don't have the details with me but I have forwarded this survey to [NAME REMOVED] and she will have the measurements and details with regard to this particular example

Respondent #33

I would always try and adjust spacing across an area of damage on an overall weak object, moving from wider to closer from strong to weak areas. This would still be regulated i.e one spacing for strong areas, one for overall weak and one for very weak. I would stagger the lines so that they don't start at the same point so that a horizontal line of weakness is not created. Often couching is worked with grid lines which provide the overall stitched support while the couching itself is the localized support, though not in the case of your christening robe which seems only to have one small area of damage.

Respondents #36

In couching the size of the holding stitches also matters to me and it can affect the spacing of couching lines.

Respondent #39

@ transfer of treatment method: maybe it is possible to classify recommendations by object types + future use + handling personal. I find flow charts rather helpful in such cases.

Respondent #43

The spacing of the couching is definitely one aspect, but the finishing and the technique of the couching stitch can make a large difference on the success of the treatment as well.

Respondent #45

Couching is very subjective also depending on the thread that is used. I find the Skala Gutermann often to be too shiny whereas the hair silk seems to blend better.

Respondent #46

Spacing plays most significant role and is always the first thing that one decides while doing laid and couching but what is also very important is how it's executed. Whenever there is a new person learning the stitch, I ensure even while practicing they look it under the microscope so as to understand what happens if they pull the thread too tightly in the first place. The stress it causes in the fibres and also the patch at the back should have right amount of fullness.

Respondent #56

One of the things I was told early was that conservators started out with lines too closely spaced and had to learn to space them out. Choice of needle and whether there the textile is on a frame or has to be worked flat affect how far apart the lines can be spaced.

Appendix 4: Suppliers List

Cotton Threads:

Claire's Lace
85 North Poulner Road
Ringwood
Hampshire
BH24 3LA
United Kingdom

01425 483450

Fil au Chinios Egyptian Cotton 120/2 - £7.50
http://www.claireslace.co.uk/shop/index.php?id_product=391&controller=product

Egyptian Cotton (Flemish) 160/2 - £7.50
http://www.claireslace.co.uk/shop/index.php?id_product=318&controller=product

Egyptian Cotton (Flemish) 170/2. Used from studio store, but also available here:
http://www.claireslace.co.uk/shop/index.php?id_product=319&controller=product

Support Fabric:

Whaleys (Bradford) LTD.
Harris Court
Great Horton
Bradford
West Yorkshire
BD7 4EQ
England
Telephone: +44 (0) 1274 576718
Fax: +44 (0) 1274 521309
Email: info@whaleysltd.co.uk

Fine Bleached Cotton 91cm Wide - £2.46/m excl. VAT (£2.09 when buying over 3m, £1.63/m when buying over 10m)
http://www.whaleys-bradford.ltd.uk/fine-bleached-cotton

Needles for stitching samples:

Sutranox
CH-1002 Lausanne, Switzerland
http://www.unimed.ch/en/products/standard-products/surgical-suture-needles/

Suture Needles – "Round 3/8" (25mm)"
REF: 8211-00 Kalt

Digital Image Correlation Equipment:

Correlated Solutions, Inc.
121 Dutchman Blvd.
Columbia, SC 29063 – USA
Phone: +1 (803) 926-7272
Fax: +1 (803) 749-7569

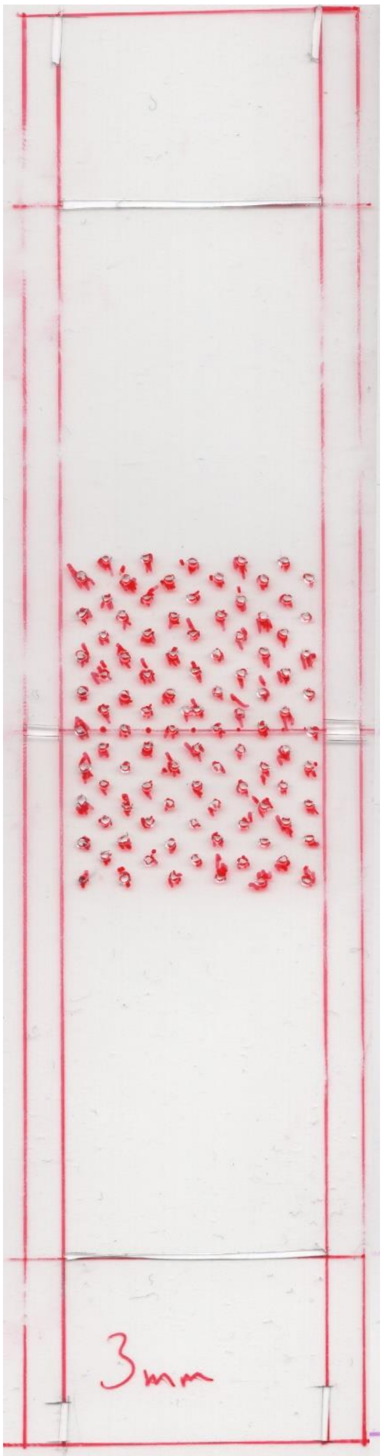
Software:
VIC-SNAP™ 2009
VIC-3D™ 2010
http://correlatedsolutions.com/products/

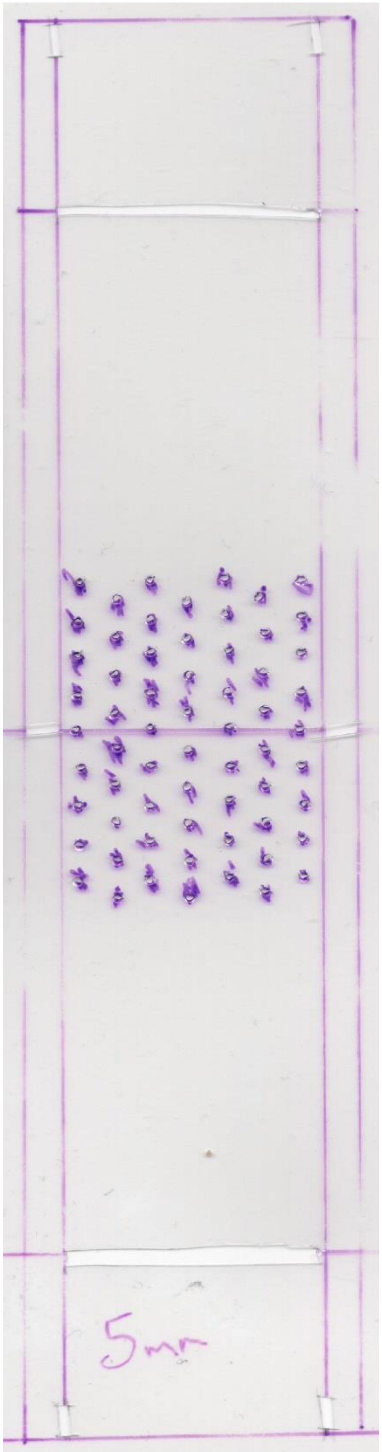
Quotes available on request for most recent versions.

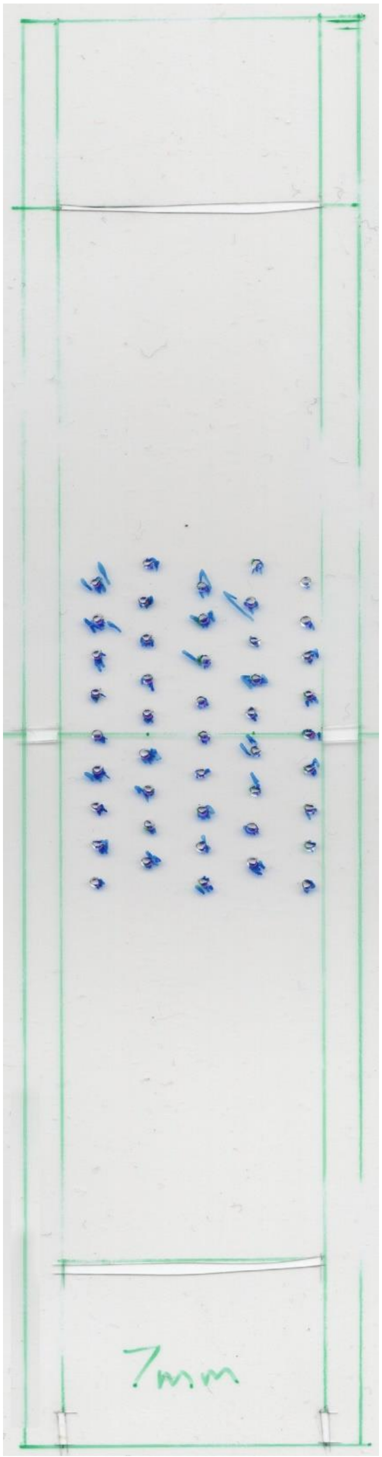
CCD Cameras from Limess (German).
http://www.limess.com/en/.

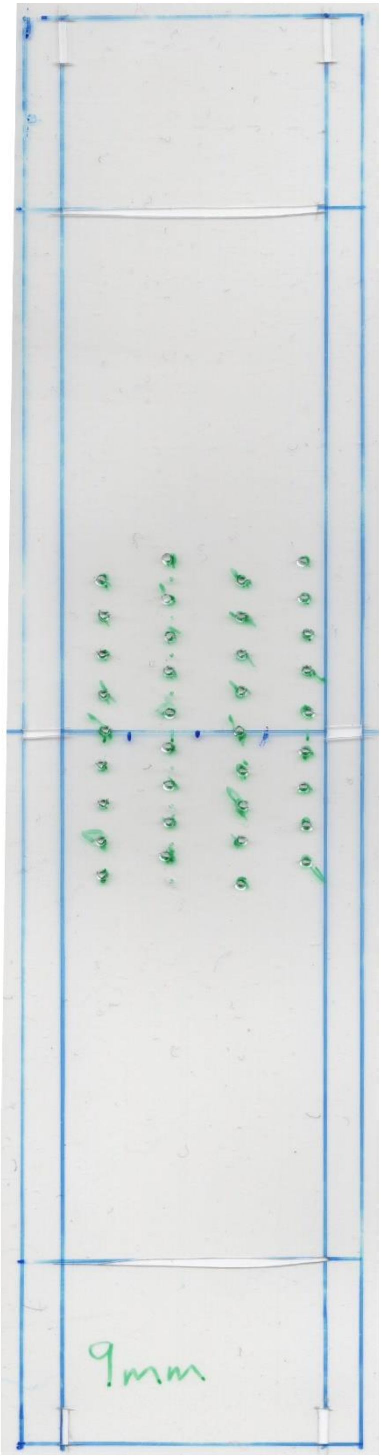
Appendix 5: Stitching Patterns

A pattern for each width of spacing was drawn up. Holes were cut to allow grip lines to be drawn in place and ensure the correct number of warps were removed from the edges. These images are full size.



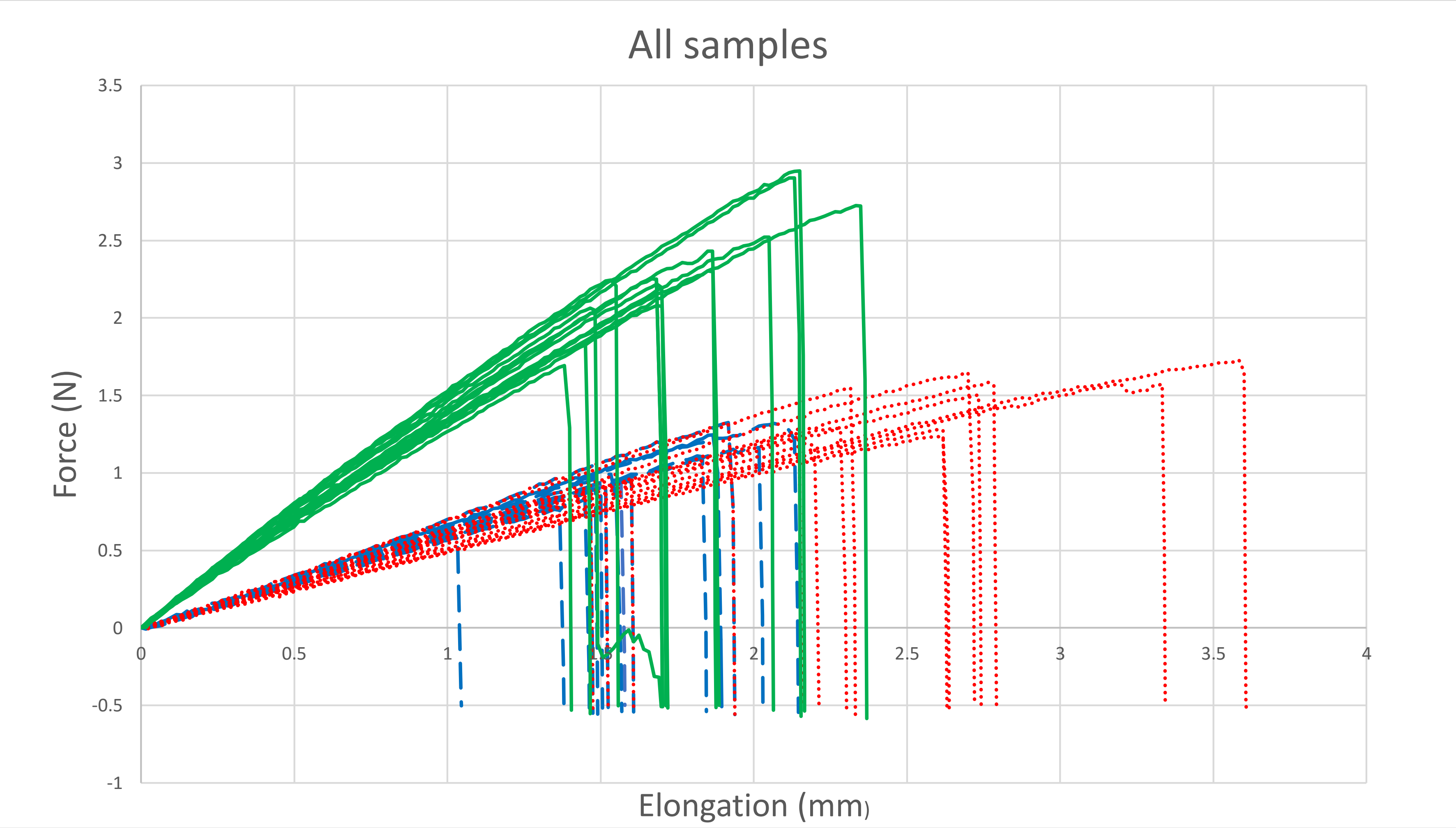



7mm

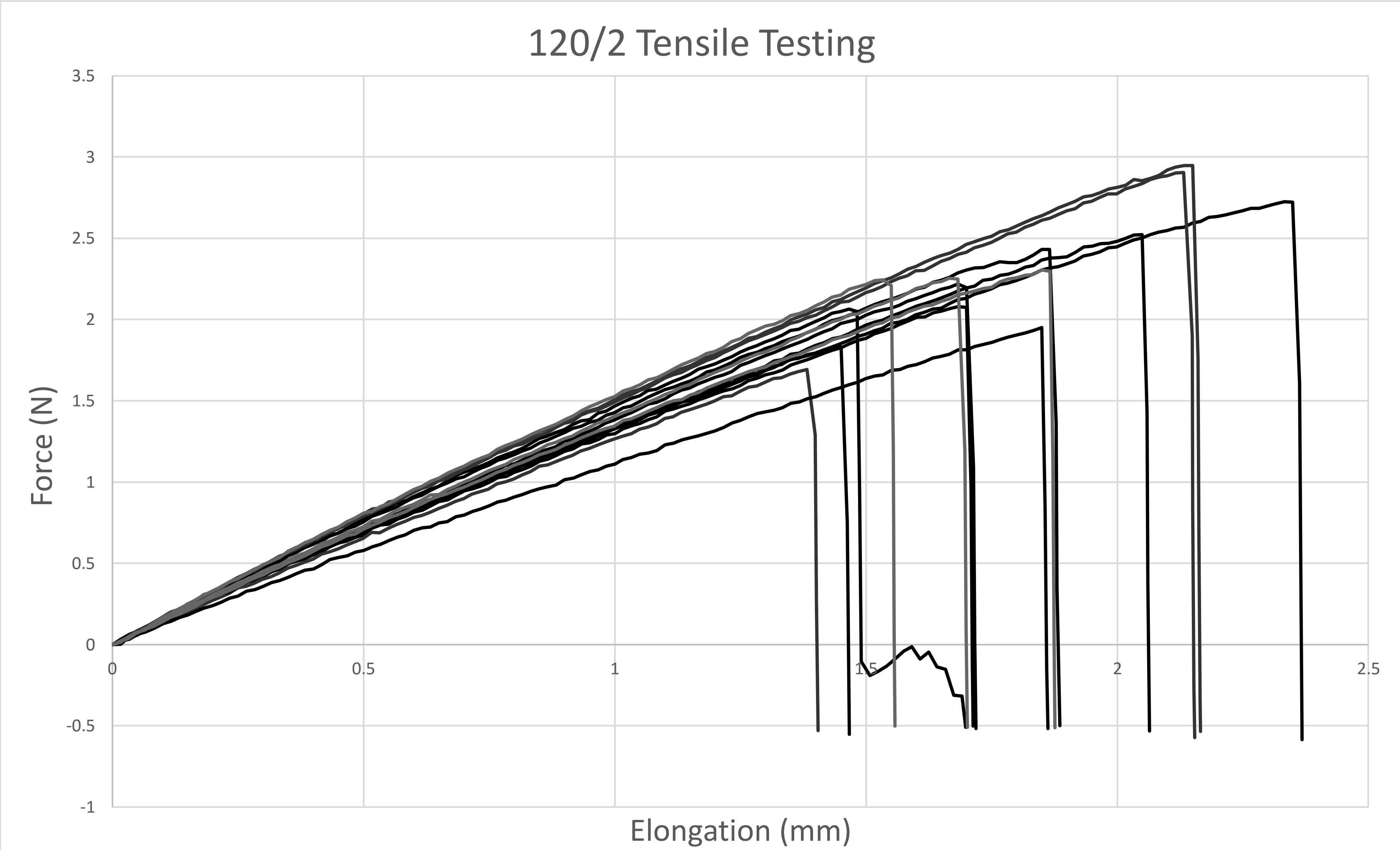

9mm

Appendix 6: Tensile Testing Results

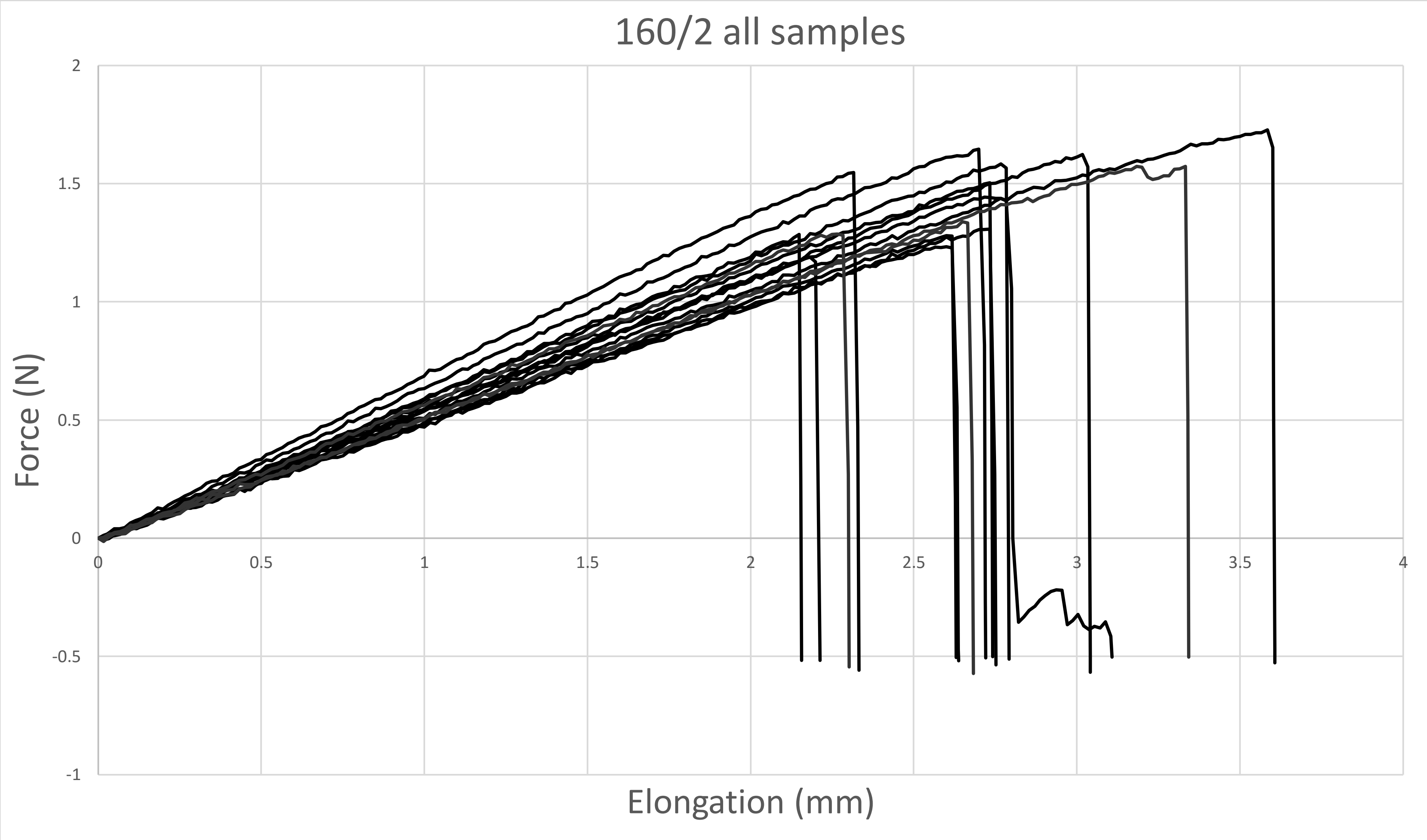
Force/Elongation curve for all three threads. Placing all data on one graph allows for a comparison of angle of elongation. These results are then broken up over the following pages.
Green/Solid line: 120/2. Red/Dotted line: 160/2. Blue/Dashed line: 170/2



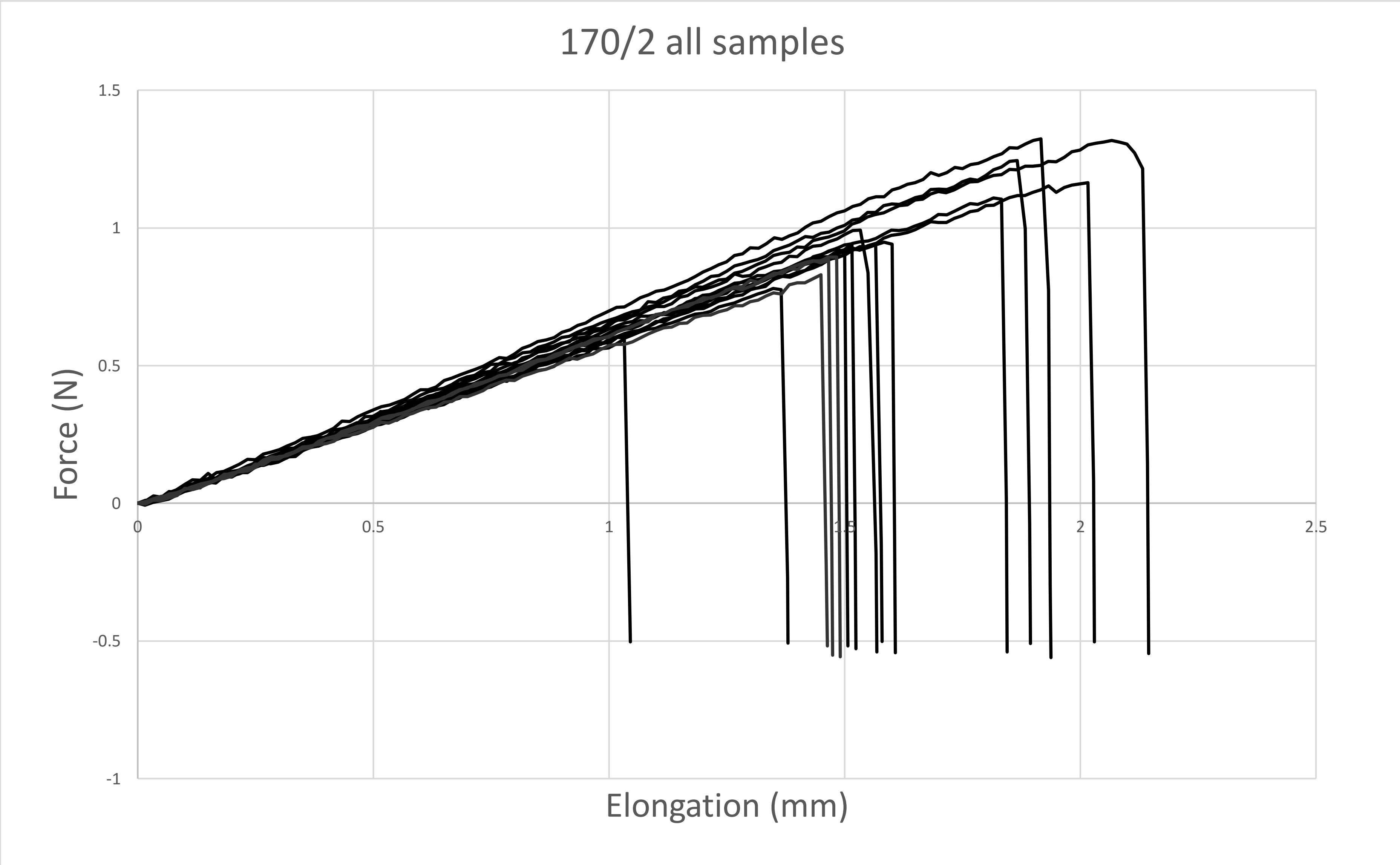
Force/Elongation curves for all 120/2 samples



Force/Elongation curves for all 160/2 samples



Force/Elongation curves for all 170/2 samples



Appendix 7: Fixed Load Data

The following data was gained from the fixed load experiments. This data was used to produce the results given in chapter 8 and guide conclusions made in chapter 9.
All measurements were taken with a tape measure, so can only be accurate to 0.5mm.

Sample Group		Visual*	Length at: Initial Elongation (mm)	Initial Recovery (mm)	48 hours unweighted (mm)	1 month unweighted (mm)
3mm	1	Best	141	140.5	140	140
	2		140	140	140	140
	3	Worst	141	140	140.5	140
	4		141	140.5	141	140
	5		141	140	140	140
5mm	1		141	140	140	140
	2		140	140	140	140
	3		141	140.5	140	140
	4		143	141.5	140.5	140
	5	**	142	141	140	140
7mm	1	Best	142	140.5	140	140
	2		141	140	140	140
	3		141	140	140	140
	4	Worst	143	142	141.5	140
	5		142	141	141	140.5
9mm	1		143	141.5	141	140.5
	2		142.5	141	141	140.5
	3		143	143	142	141.5
	4	Best	142	141	140	140
	5	Worst	144	142	141	141
Control	1	N/A	140	140	140	140
	2		140.5	140.5	140	140
	3		143	142	141	141
	4		141	140	140	140

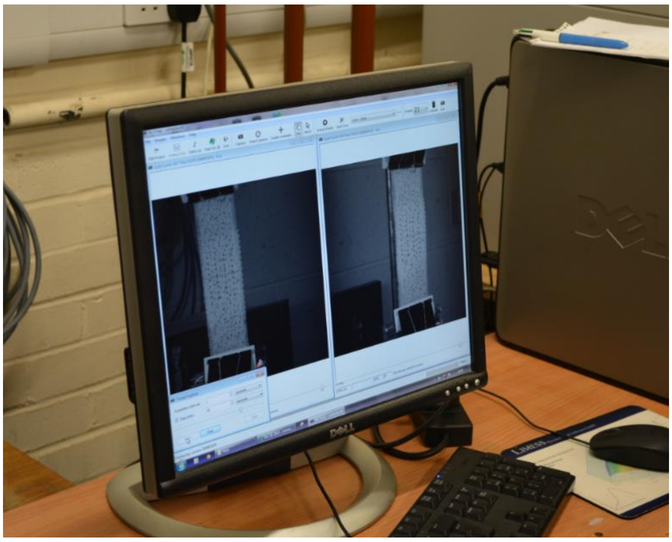
*Those samples which exhibited the largest and smallest gapping across the damage were chosen for photography through stereo-magnification.

**All samples were very similar; therefore, a random sample was chosen for photography.

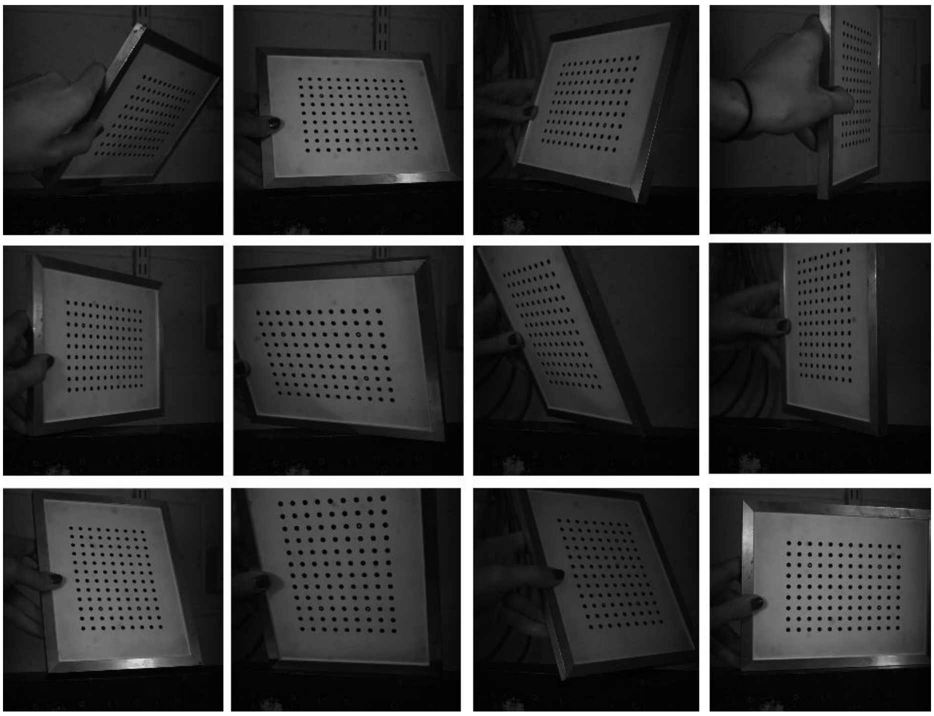
Appendix 8: Digital Image Correlation Instructions

These instructions are a step-by-step guide as to how the results given in chapter 8 were gained. It is advised that DIC is undertaken under the supervision of a person trained in the both the set-up of the hardware and the running of the software.

1. Turn on lights and cameras. Open Vic-SNAP. Cameras should automatically display in two screens. Place sample in position to ensure cameras are in focus and at the right distance from the sample.

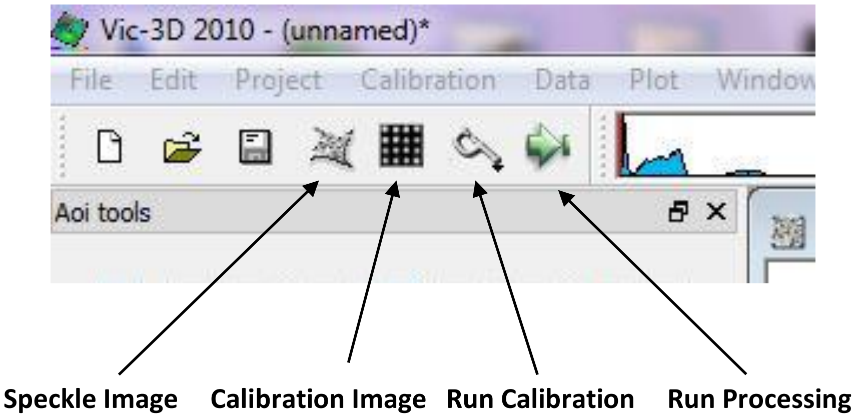


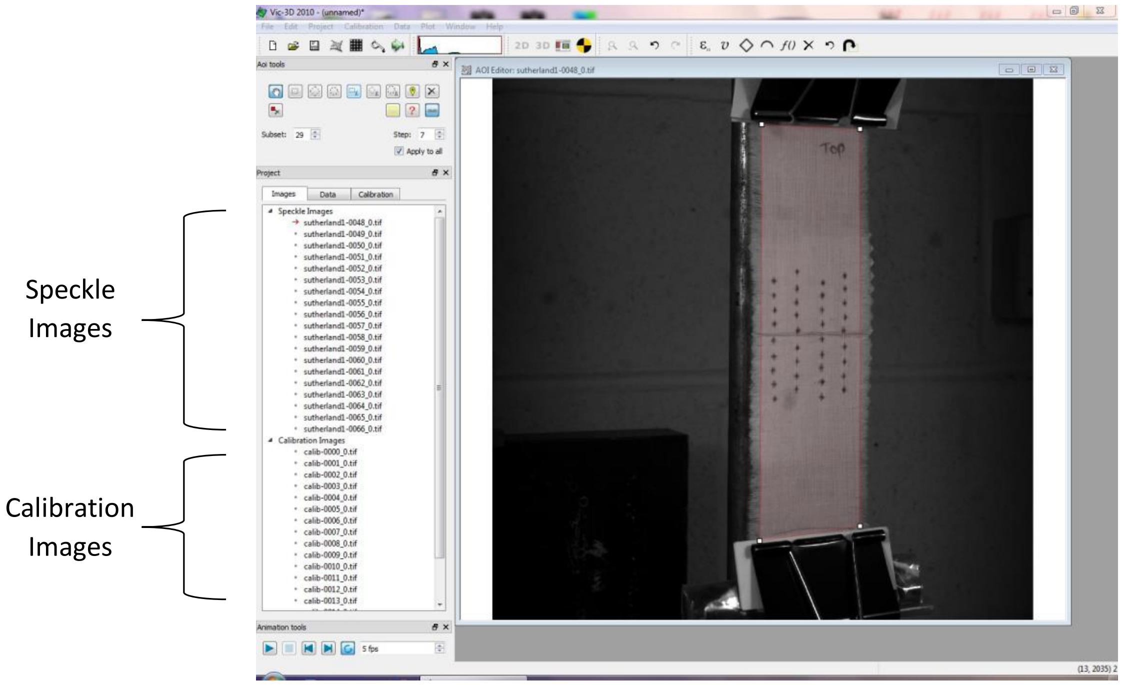
2. Remove the sample and replace with calibration board.
3. Using the “Manual Capture” button take several photographs of the calibration board at different angles: 18-20 images is a suitable number. Each position of the



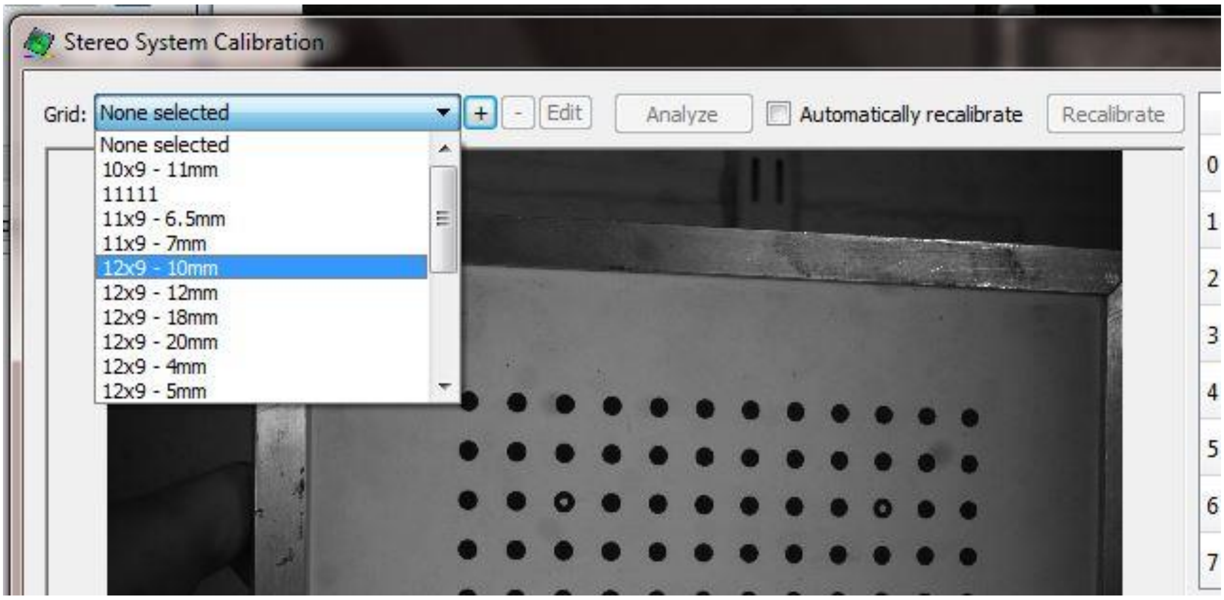
board should be repeated at different angles. This image demonstrates some possible positions:

4. Hang sample in position. Select "Timed Capture". Choose number of images to capture and the total length of time, ie. 1 photo per second for 30 seconds or 10 photos a second for 1 minute, depending on the expected movement. Once the photos have been captured close the capture box and open 3D VIC.
5. Select "Speckle Image" option. Highlight the set of images previously taken to open. Ensure to open all images: there will be two of each – one from left camera and one from right camera.
6. Select "Calibration Image" option. Highlight the calibration images previously taken to open. Both the "Speckle" and "Calibration" images will appear in the left-hand column as a list of files.

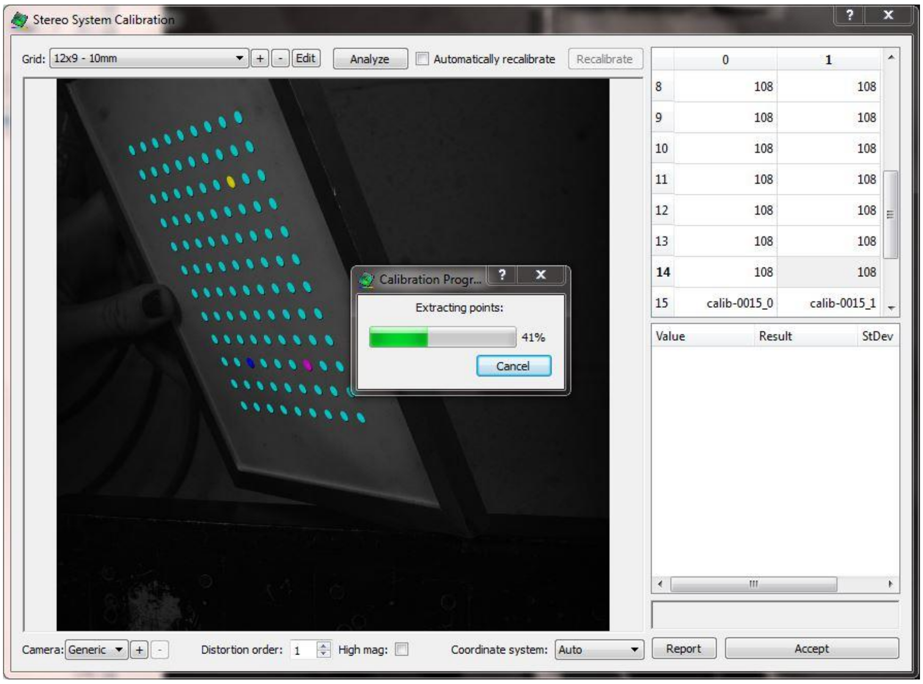




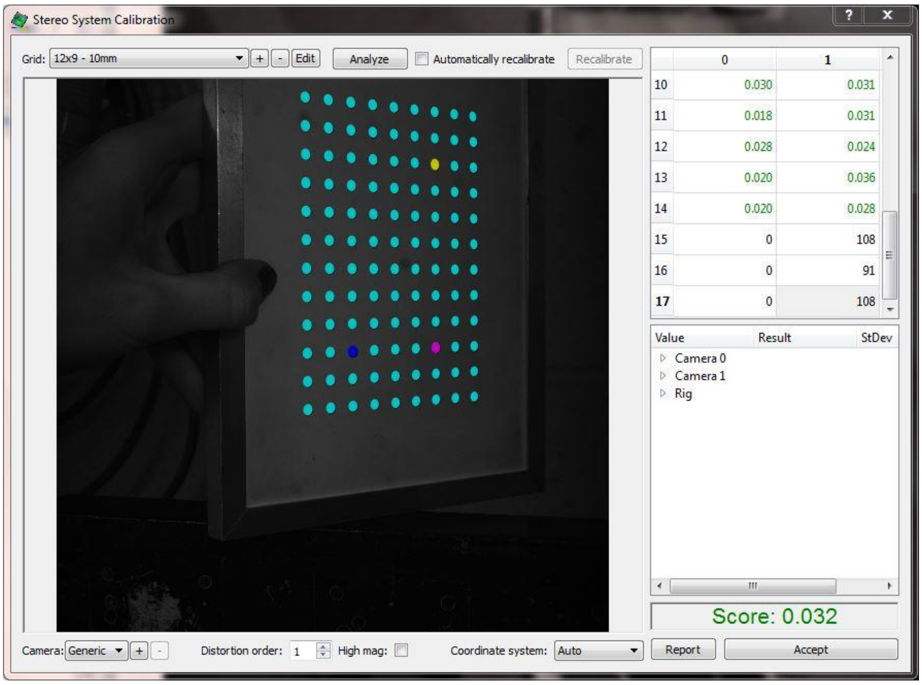
7. Select “Run Calibration”. This will open the “Stereo System Calibration” window. Choose the correct scale of calibration board. In this case 12 dots x 9 dots at 10mm apart. This information can be found on the reserve of the board.



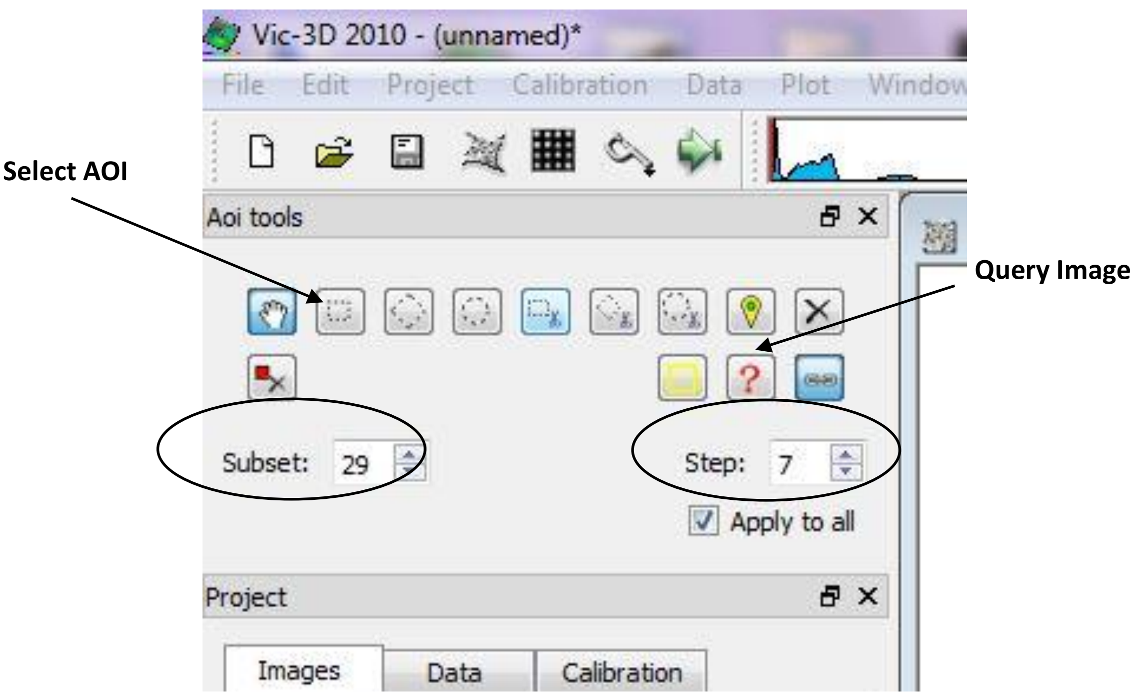
8. Once this option is selection the “Analyze” option will become active. Click analyse to run system calibration.
9. Calibration will take between 30 seconds and 1 minutes, depending on the number of images. In progress the window appears as such:

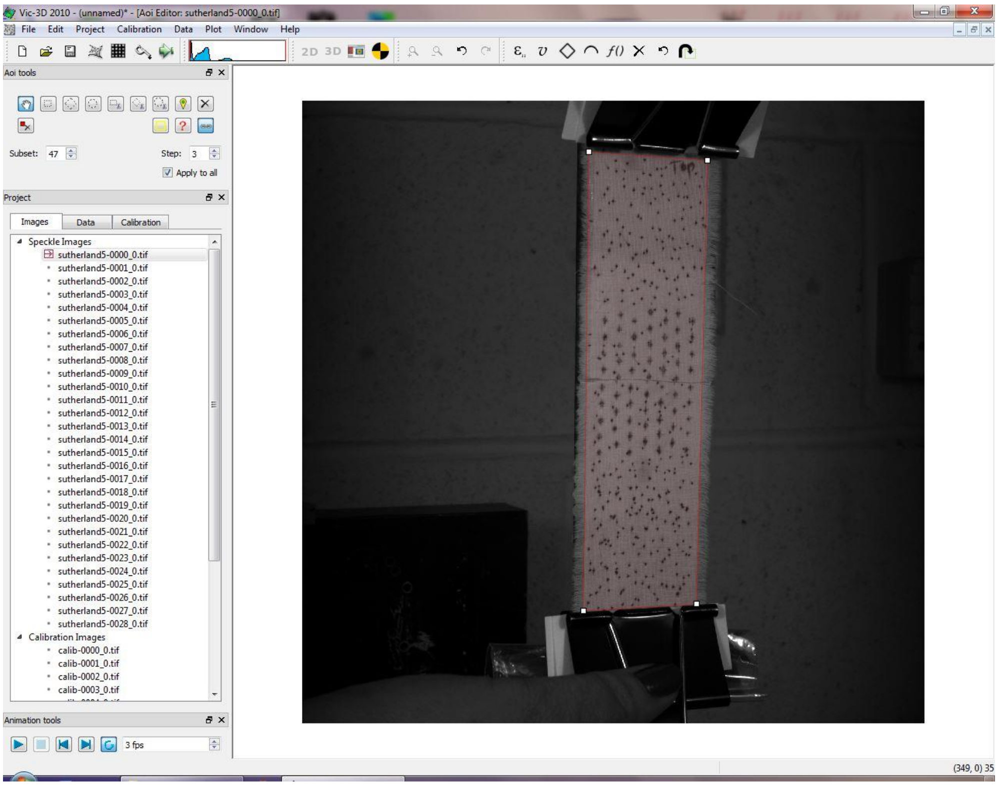


10. After calibration is complete a number will appear in the lower-right hand corner. If this number is smaller than 0.2 it is acceptable. Unacceptable results will appear in red. If the result is unacceptable it means that the system will not produce accurate results. Repeat the photography and processing of the calibration board. Ensure all the dots can be seen in each image, as this will help give good calibration. The below image shows a completed, acceptable calibration. Once happy with the result, click "Accept".



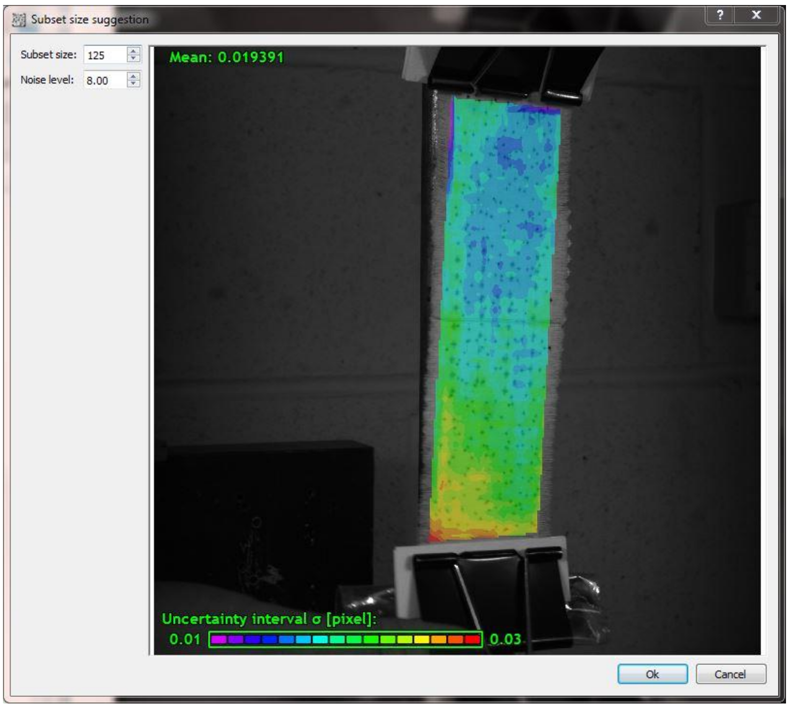
11. Open the first speckle image. Select the "Area of Interest" tool. This allows a polygon to be drawn on the image, selecting the area of the image to be processed.





12. Pick the area. Each corner can be altered once the initial rectangle has been drawn.

13. “Query” the image by selecting the red “?” (see point 11).
    The will bring up a colour image, as below. The computer software will judge a suitable “Subset”” and “Step” size. Then click OK. The Subset and Step size can be altered in the tool areas, as noted in step 11.



14. The higher the subset number, the larger the size of the boxes.

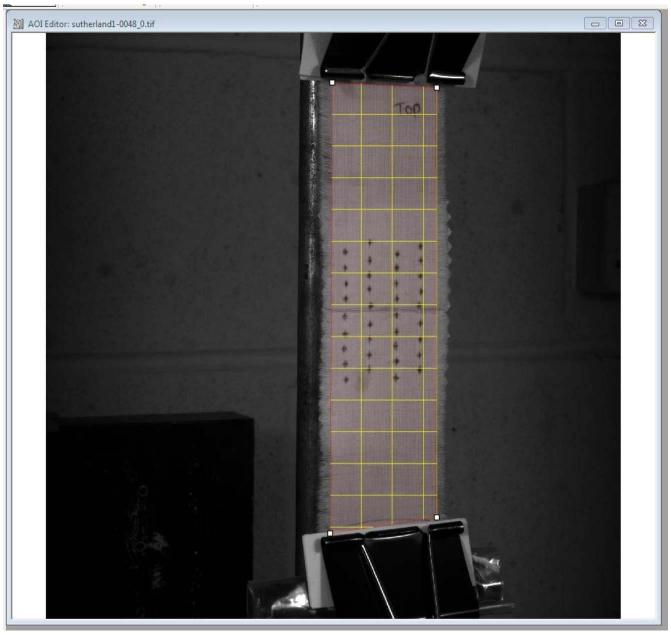
Step size relates to the number of pixels which are examined.

Step 1 = every pixel examined.

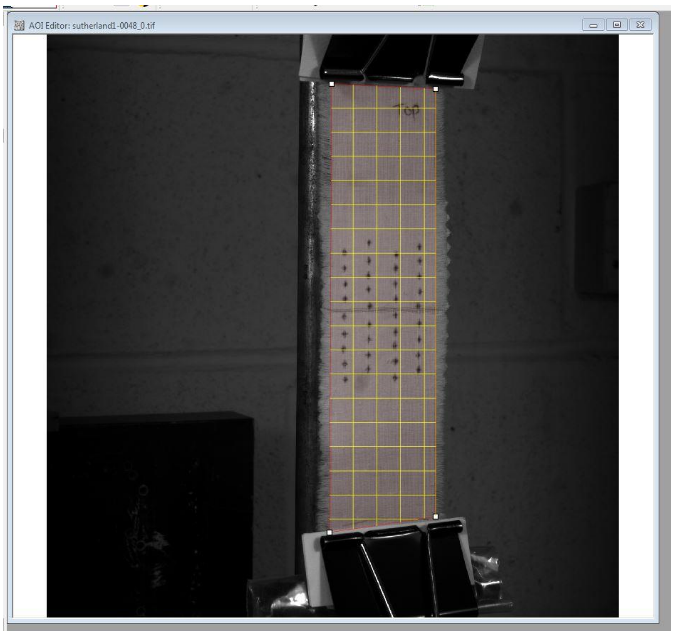
Step 2= every other pixel examined.

Step 5 = every fifth pixel examined.

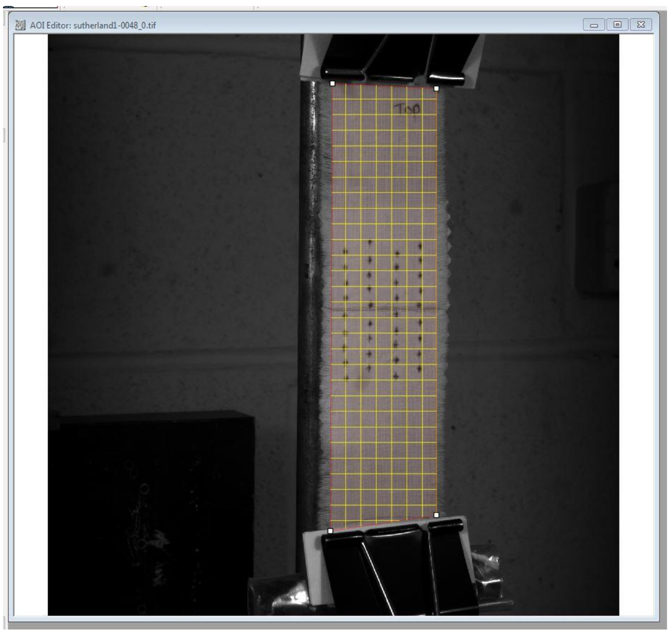
Subset: 119



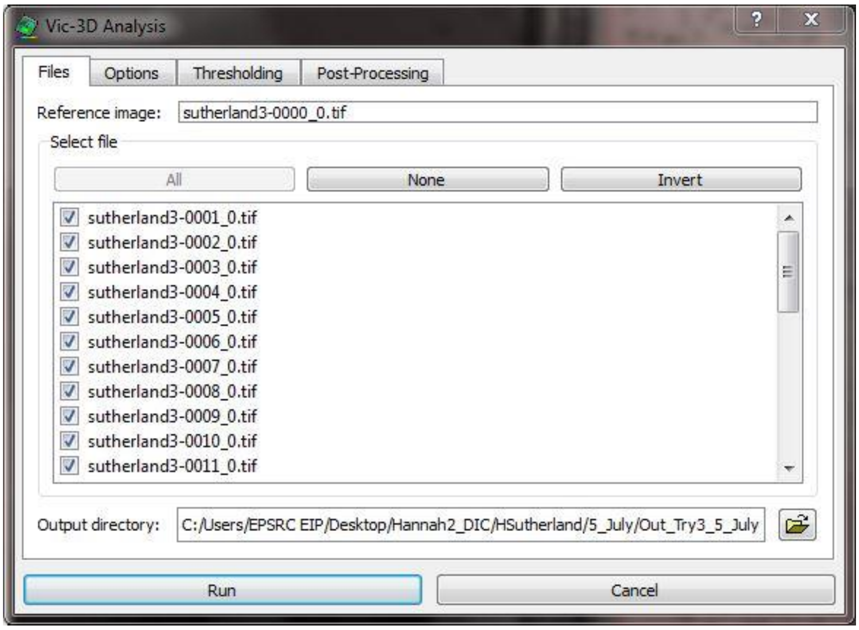
Subset: 85



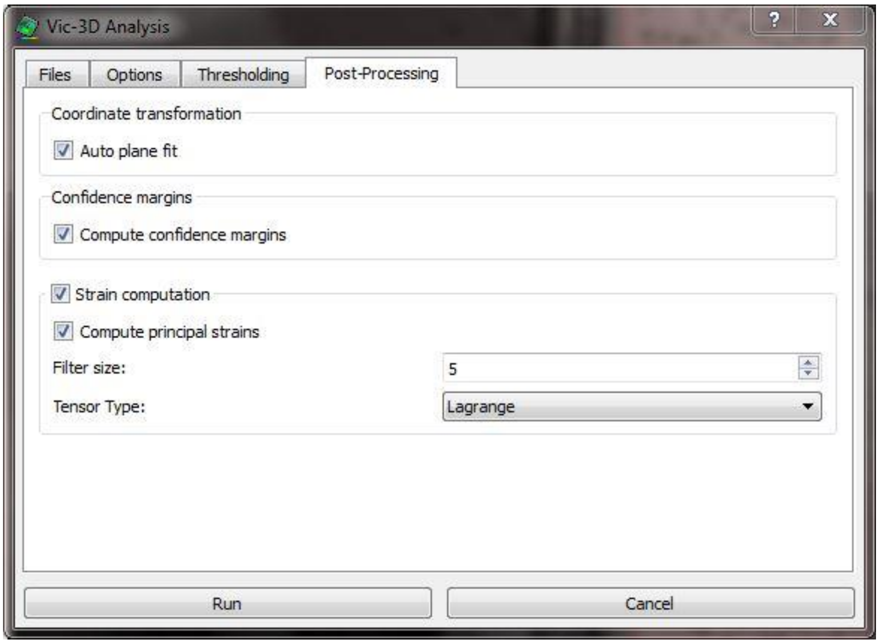
Subset: 55



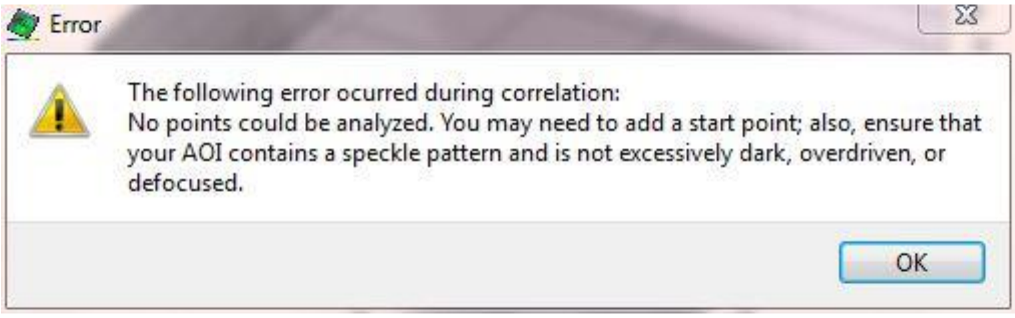
15. Once subset and step size are confirmed, select the “Run Processing” button, (green arrow marked in steo 6). This will open up the following box:



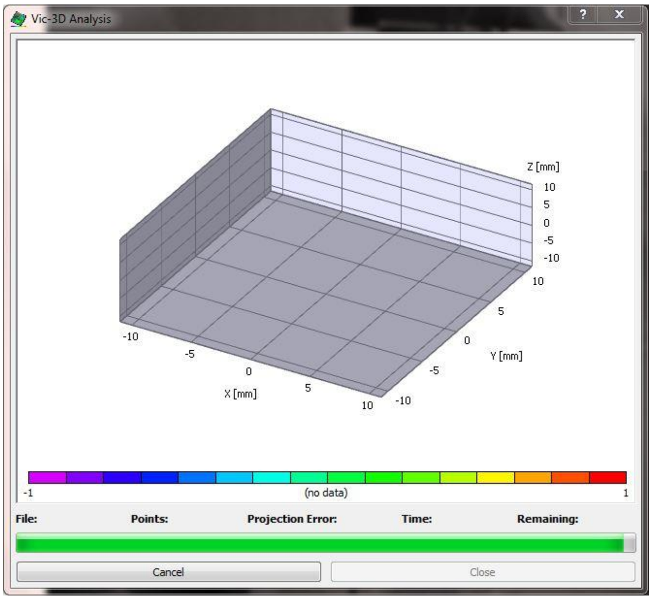
16. Within the “Post-Processing” tab the boxes should be ticked as shown in the above image. Then select the “Run” option.

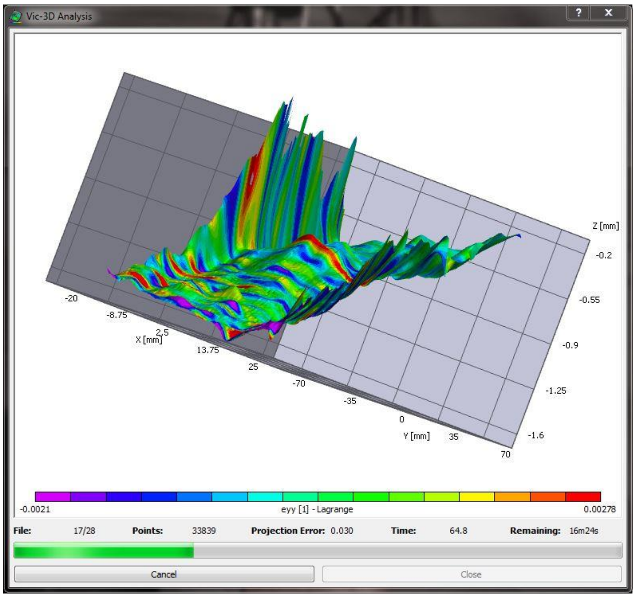


17. Occasionally the following error message will appear. Altering the subset size, step size or placement of AOI will remove this.

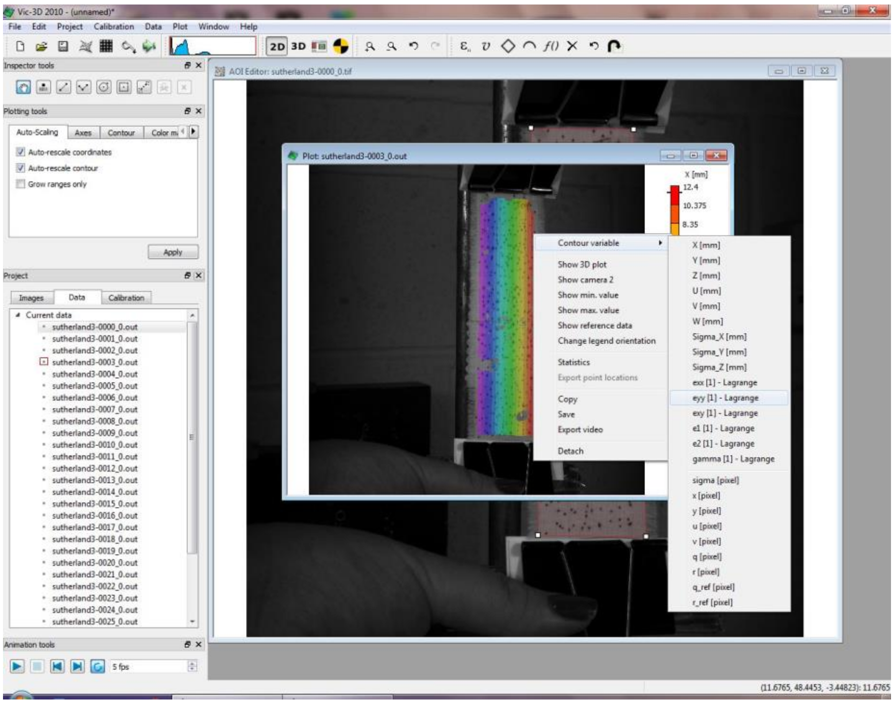


18. The following two images are screenshots of the analysis in-progress. A three-dimensional contour image is the default setting.

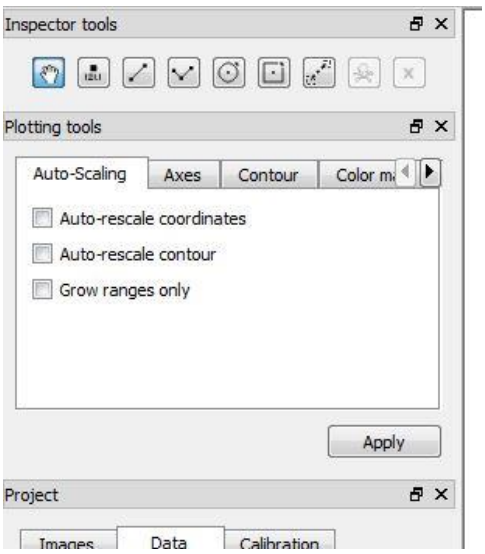


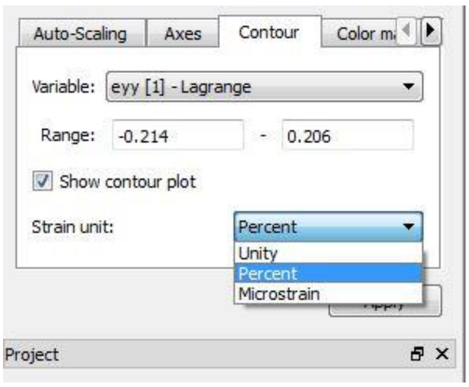


19. The processing stage can take varying lengths of time to complete. Processing for this project took between 5 and 50 minutes, depending on subset size. The larger the subset size, the longer processing will take. The more images to be processed, the longer processing will take,
20. Once complete, close the processing box. Under the “Data” tab in the left-hand column, double-click on any image to open up the movement data.
21. Right-click on the image and choose “Shoe 2D Plot”. This will superimpose the data onto the photograph. Right-click on the image and choose “Contour Variable”, the choose “eyy [1] -Lagrange”. This option shows the strain along the y-axis.



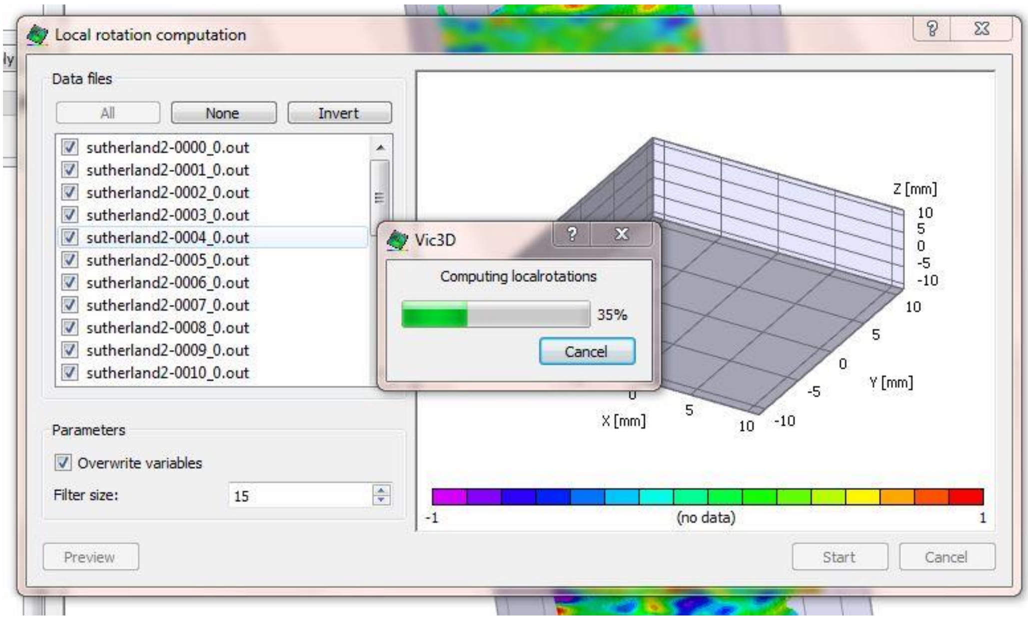
22. In the left-hand column turn off-auto scaling and change settings to “Percent”. This places all images onto the same scale, making them more easily comparable. Changing the strain to % allows it to be understood more easily in real-life scenarios.



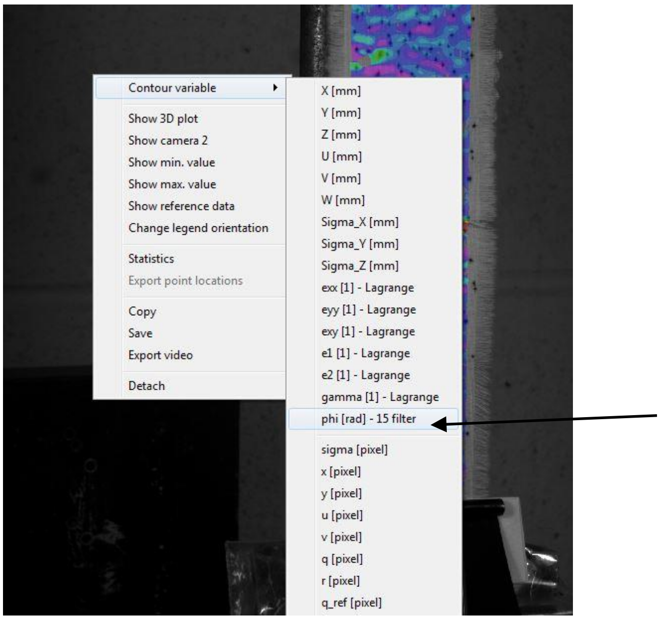


23. In-plane rotation can be calculated by selecting the "Calculate In-plane rotation" tool. Then press "Start".

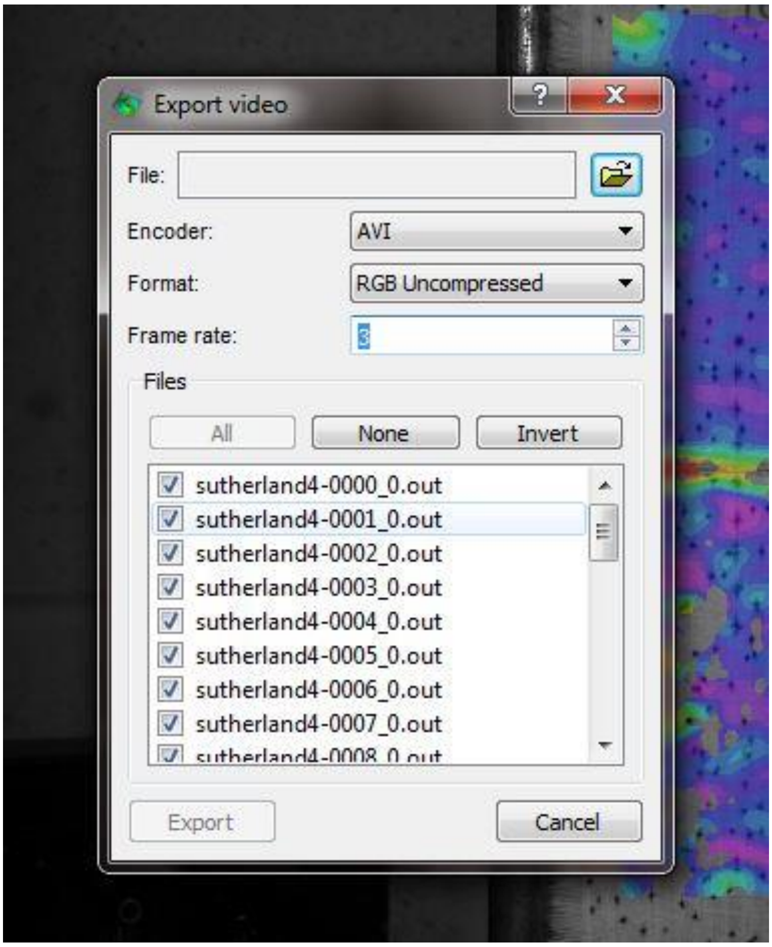
Calculate in-plane rotation



24. After calculation in-plane rotation can be shown by choosing the "phi (rad)" option as shown below.



25. Images at any stage can be captured by saving individual images. Print-screen can also allow for "in-progress" images to be recorded. Right-clicking on an image will allow for the export of a video showing the changes in strain over the course of the experiment. Frame rate indicates how many images will show per second. The lower the frame-rate the slower the images will play.
    Several examples of videos can be found on the CD-ROM at the back of the hard-copy of this dissertation.



Appendix 9: Digital Image Correlation Images

The following pages give the results for y-axis strain and in-plane rotation for each of the two experiment runs, of each of the four samples.

Alongside the in-plane rotation image is a “rotation parameter” given in degrees. This is the calculation of the upper (red/orange) and lower (pink/purple) phi[rad] values indicated by the scale with each image. A positive number indicates a clockwise rotation.

The following equation was used to calculate the rotation:

$$x^{\circ} = \frac{\mathrm{rad\ x\ 180}}{\pi}$$

3.14 was used in place of pi (π) to allow for simple calculation of data.

Test 1: 5mm

Experiment run 1: Speckle with pen. 100g weight. 1 photo/second for 30 seconds. July 5th 2016.

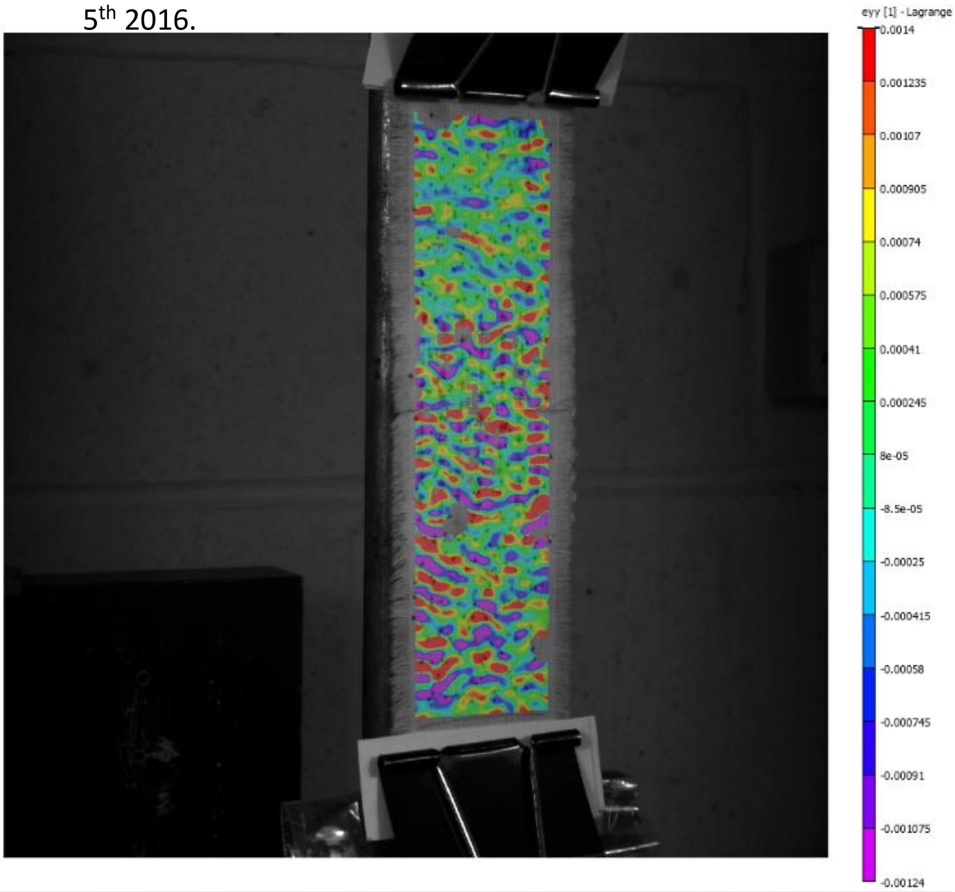


Figure A7.1: Y-axis strain map.

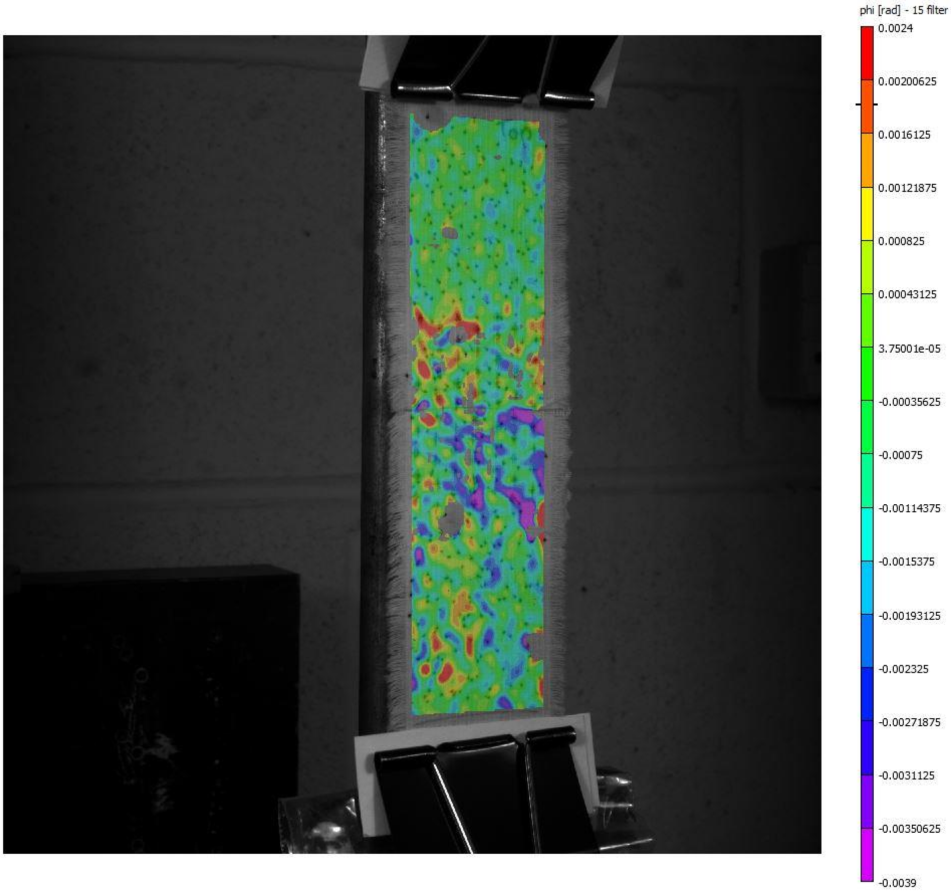
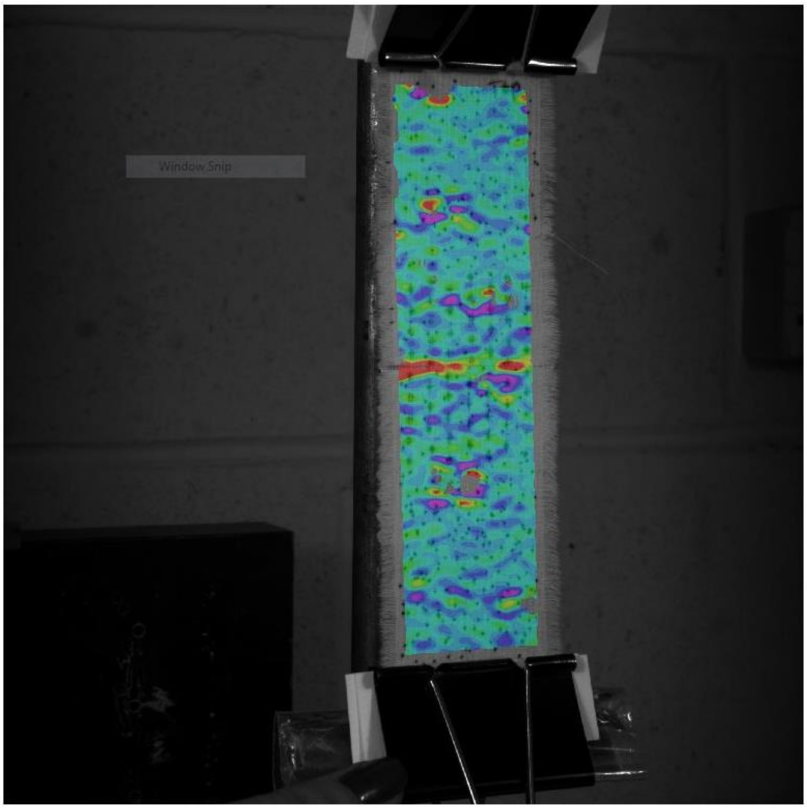


Figure A7.2: In-plane rotation map.

Rotation parameter: 0.137° to -0.224°

Test 2: 5mm

Experiment run 1: Speckle with pen. 100g weight. 1 photo/second for 30 seconds. July 5th 2016.



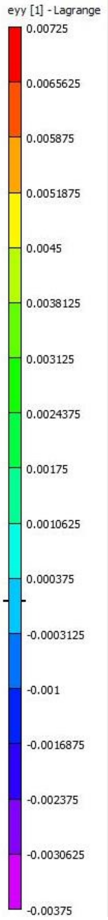
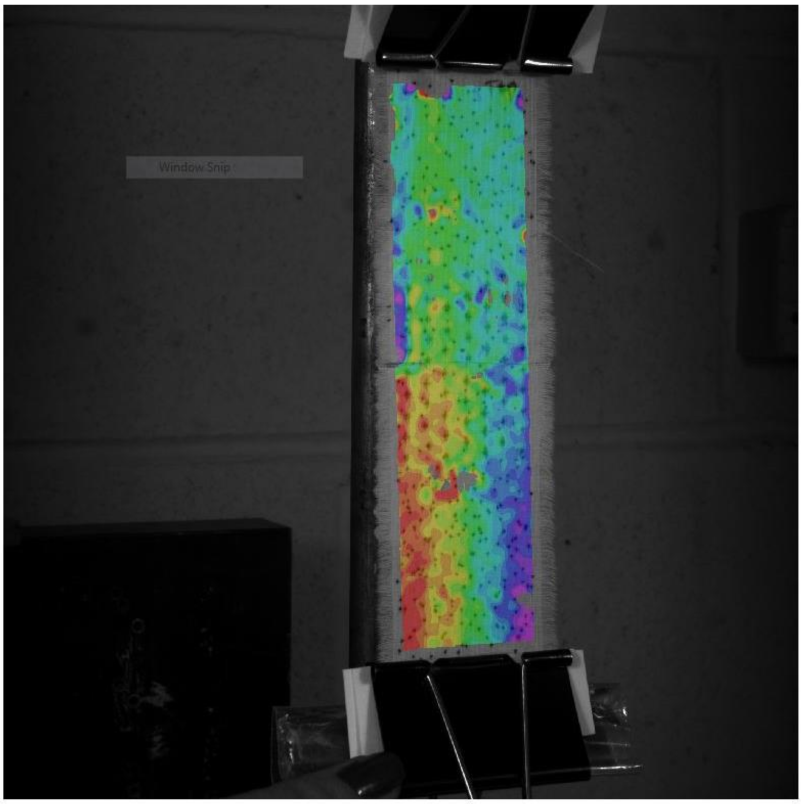


Figure A7.3: Y-axis strain map.



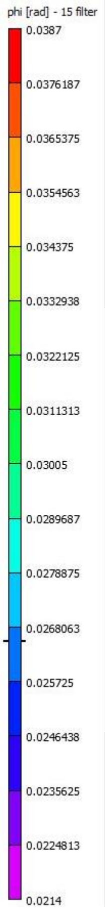


Figure A7.4: In-plane rotation map.

Rotation parameters: 2.218° to 0.712°

Test 3: 9mm

Experiment run 1: Speckle with pen. 100g weight. 1 photo/second for 30 seconds. July 5th 2016.

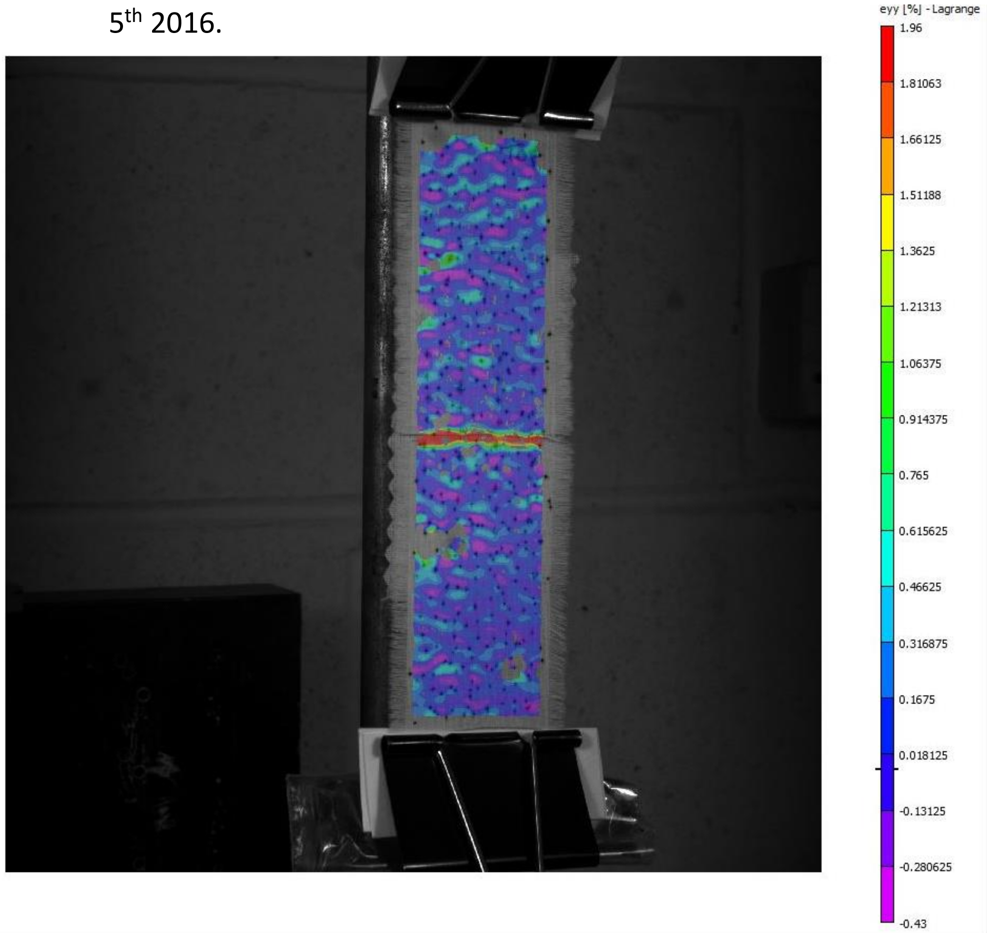


Figure A7.5: Y-axis strain map.

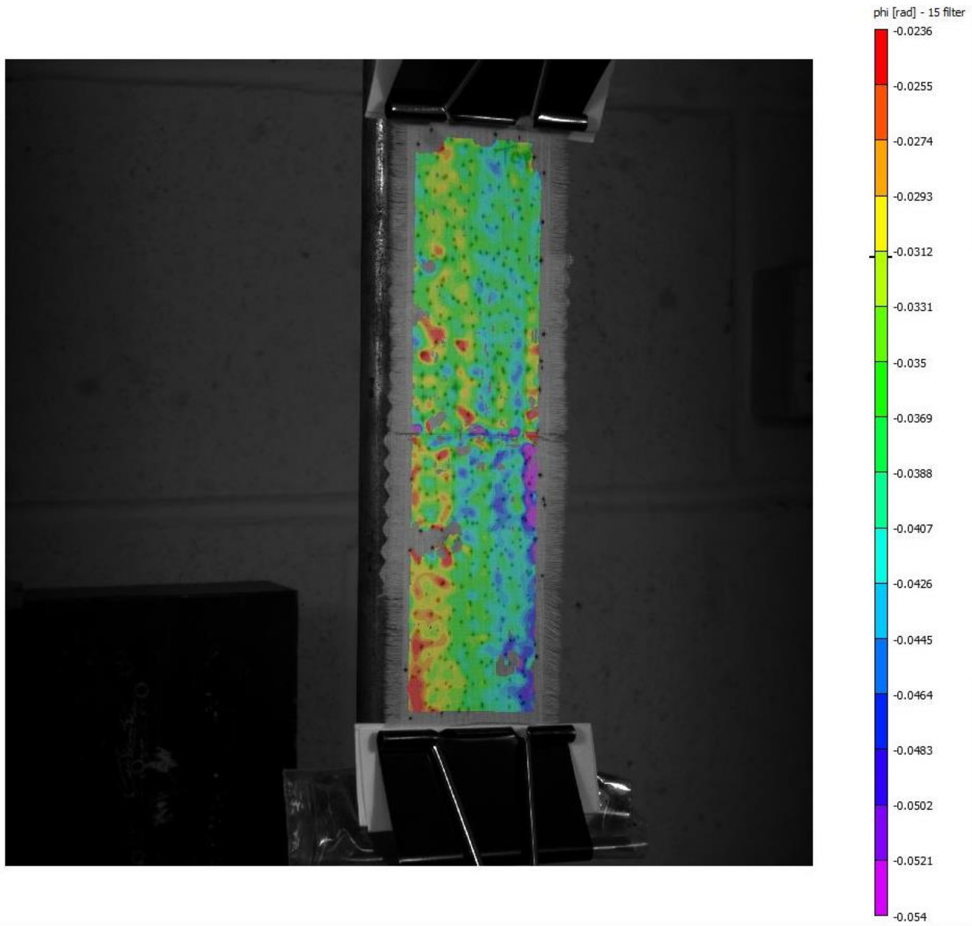


Figure A7.6: In-plane rotation map.

Rotation parameters: -1.35° to -3.09°

Test 4: 9mm

Experiment run 1: Speckle with pen. 100g weight. 1 photo/second for 30 seconds. July 5th 2016.

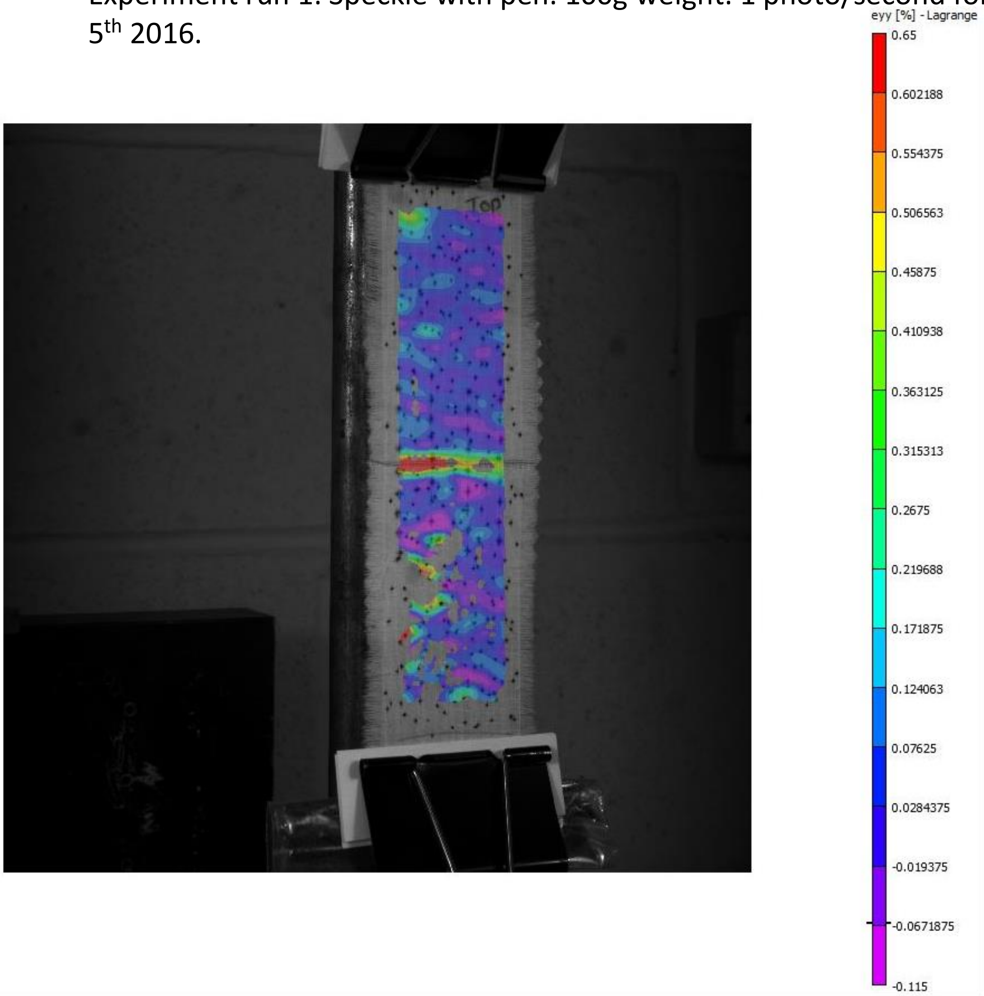


Figure A7.7: Y-axis strain map.

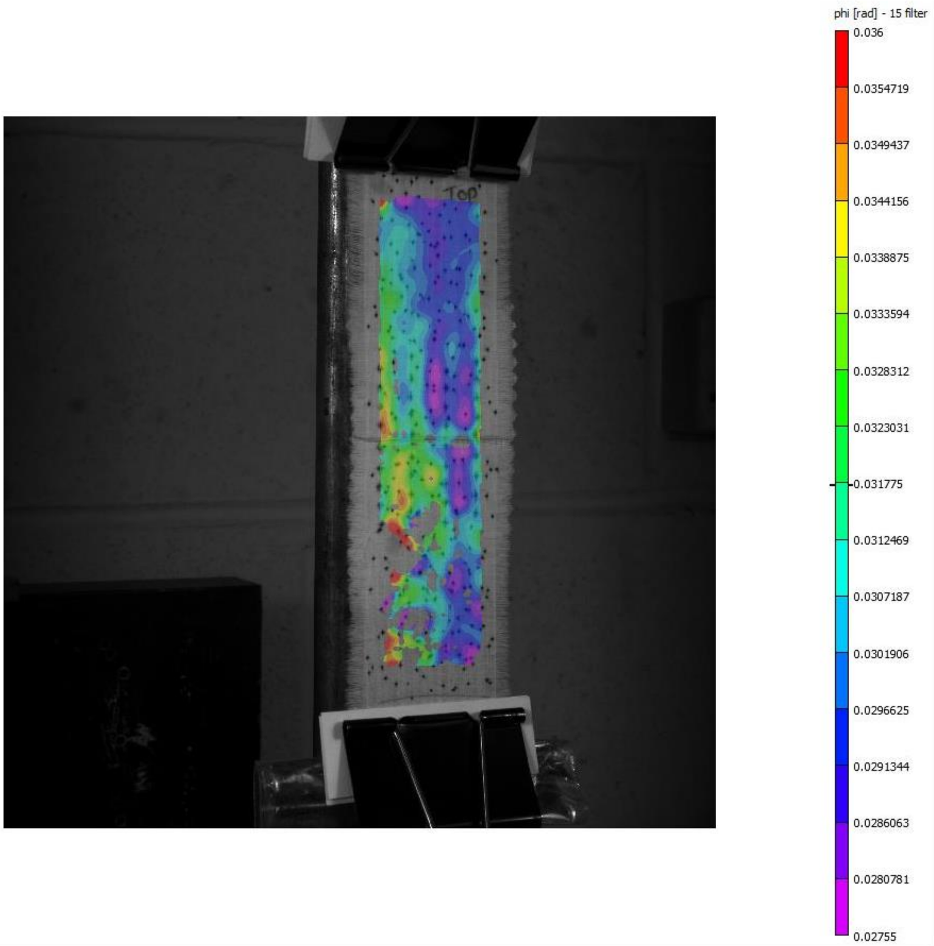


Figure A7.8: In-plane rotation map.

Rotation parameters:

2.064° to 1.579°

Test 1b: 5mm

Experiment run 2: Speckle with pen and spray. 200g weight. 1 photo/second for 30 seconds. July 6th 2016.

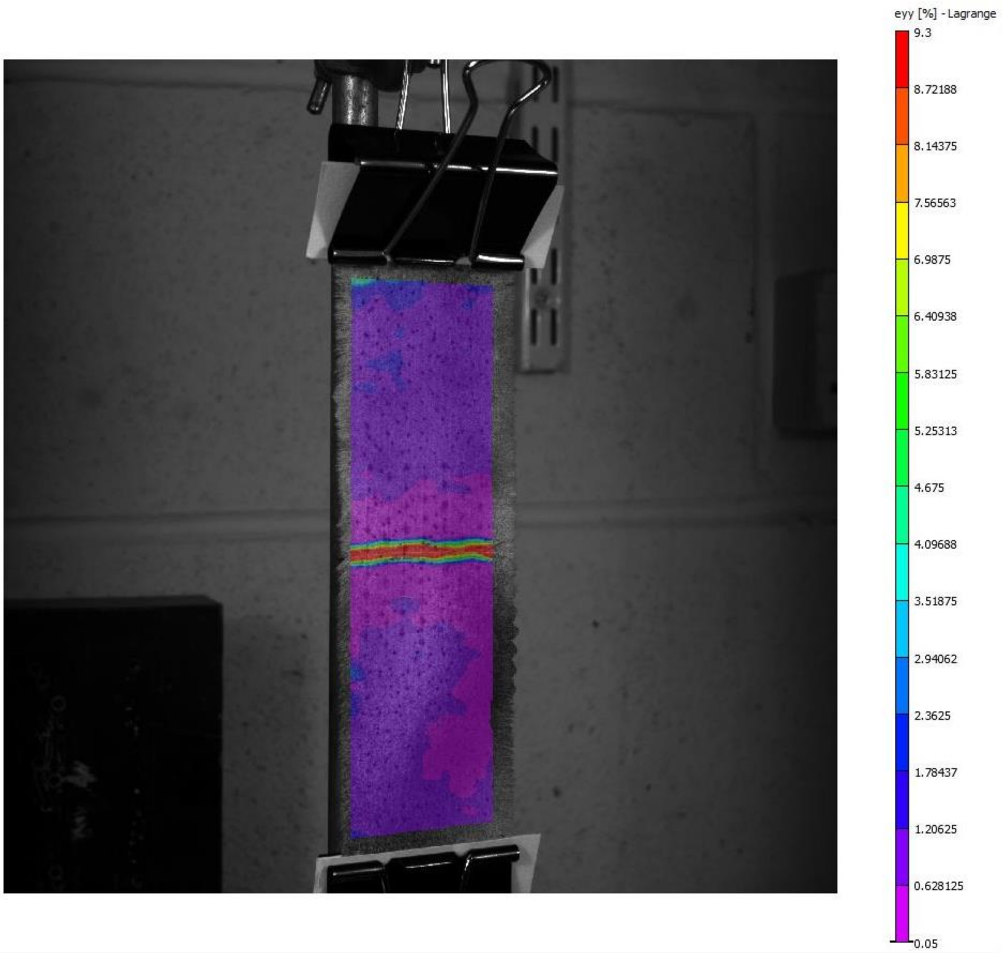


Figure A7.9: Y-axis strain map.

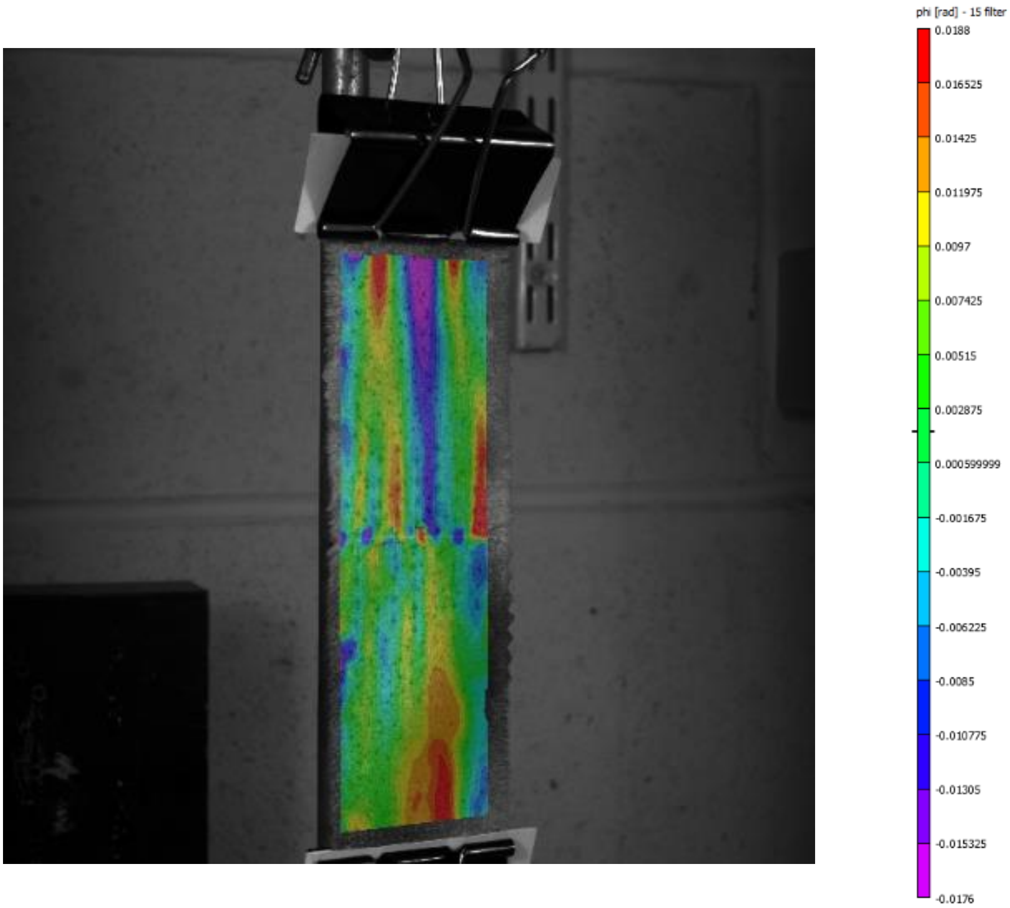


Figure A7.10: In-plane rotation map.

Rotation parameters:

1.078° to -1.009°

Test 2b: 5mm

Experiment run 2: Speckle with pen and spray. 200g weight. 1 photo/second for 30 seconds. July 6th 2016.

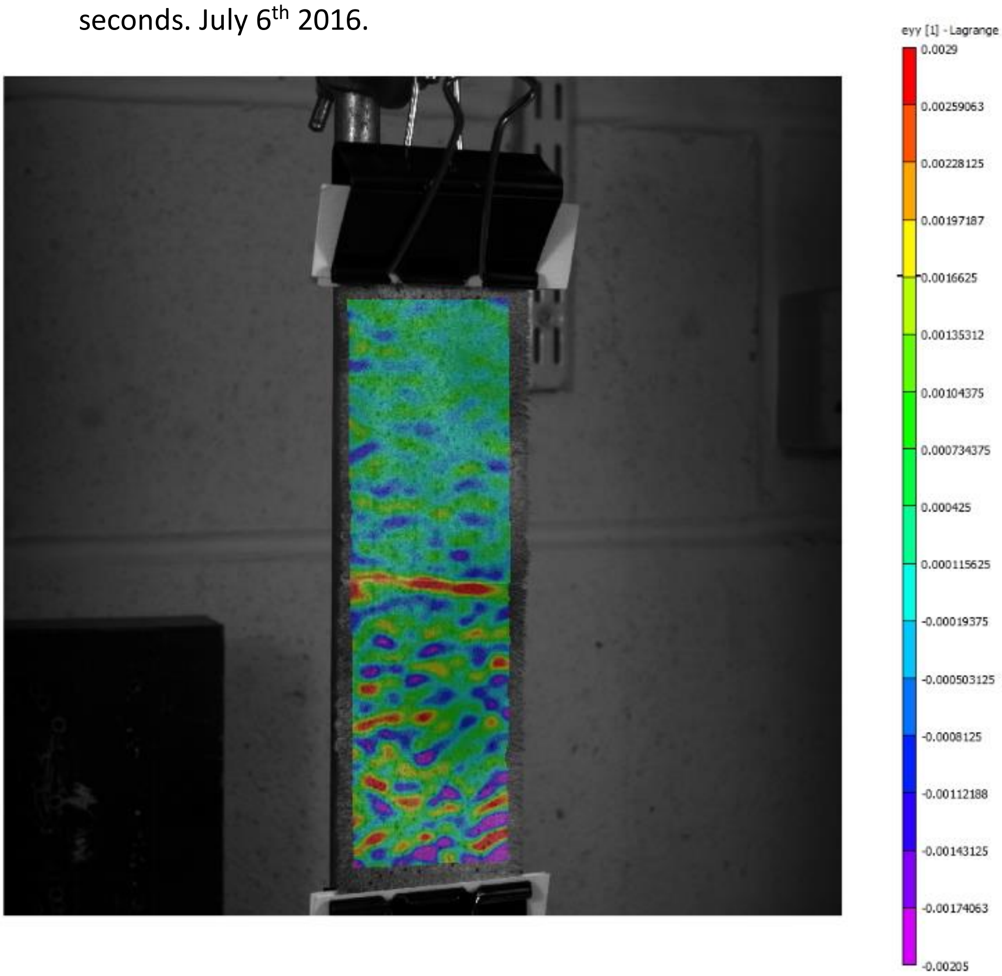


Figure A7.11: Y-axis strain map.

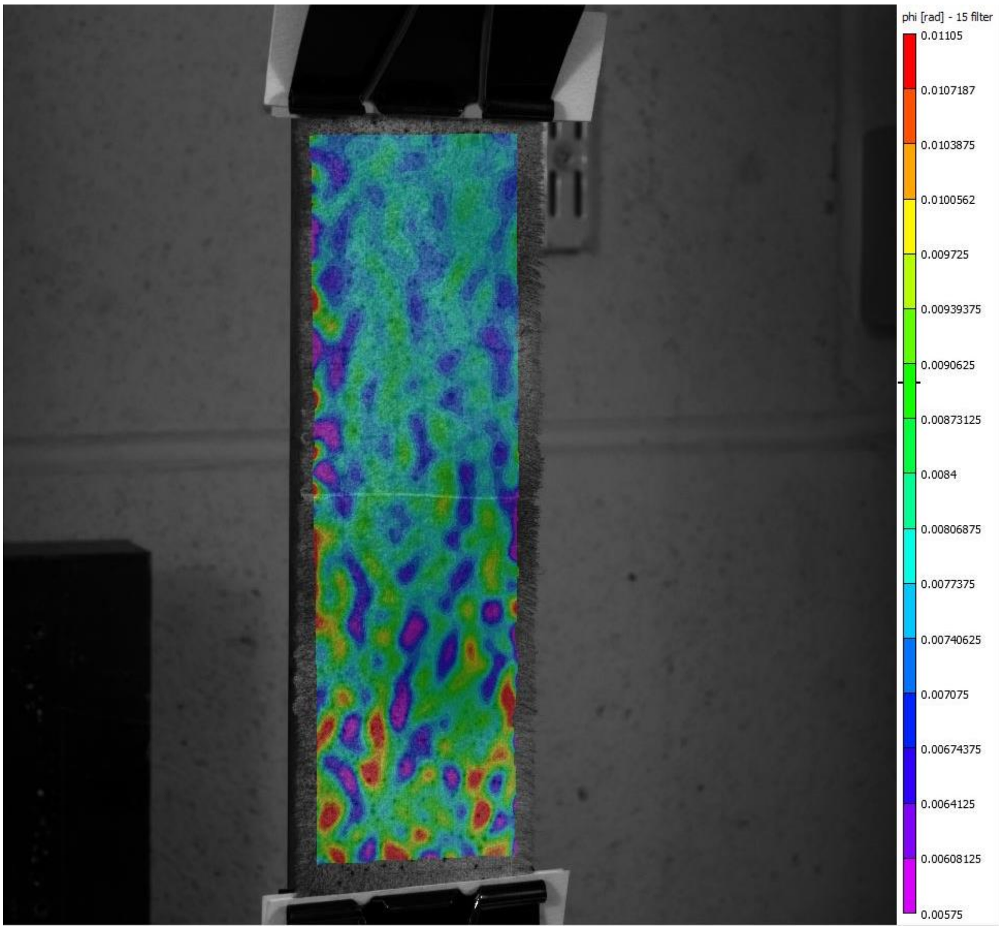


Figure A7.12: In-plane rotation map.

Rotation parameters: 0.634° to 0.329°

Test 3b: 9mm

Experiment run 2: Speckle with pen and spray. 200g weight. 1 photo/second for 30 seconds. July 6th 2016.

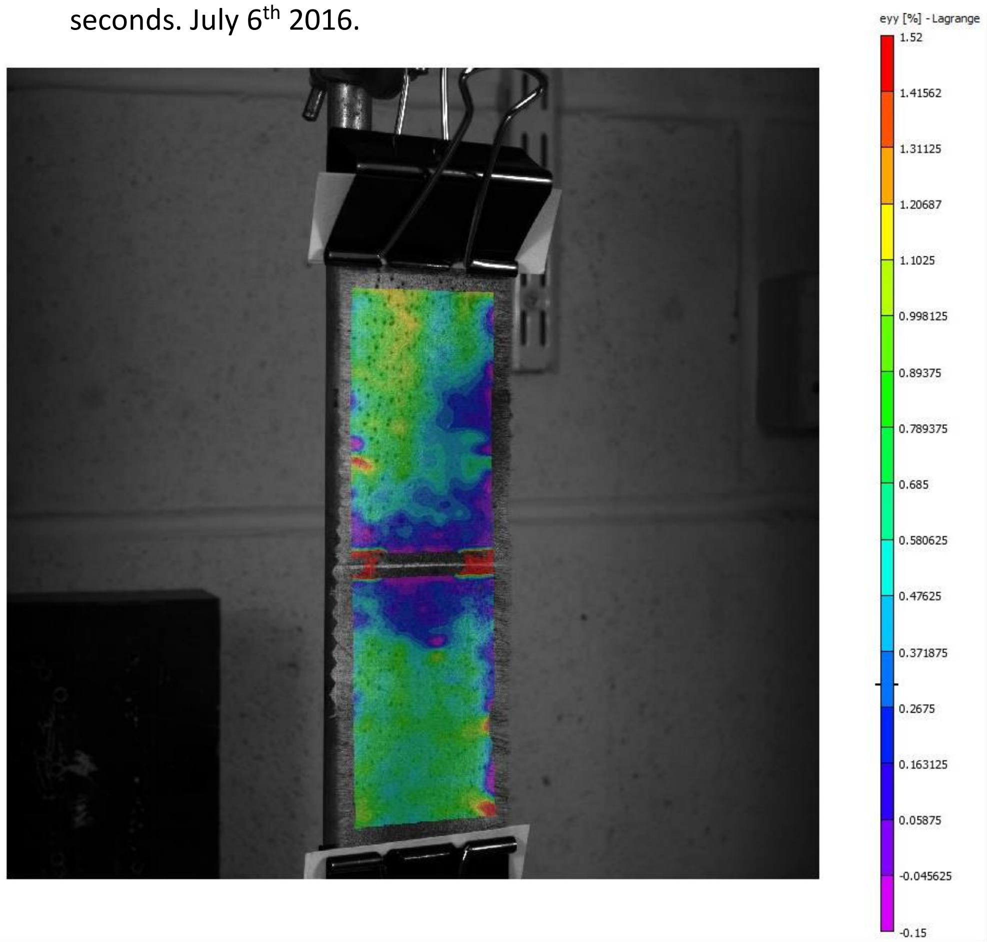


Figure A7.13: Y-axis strain map.

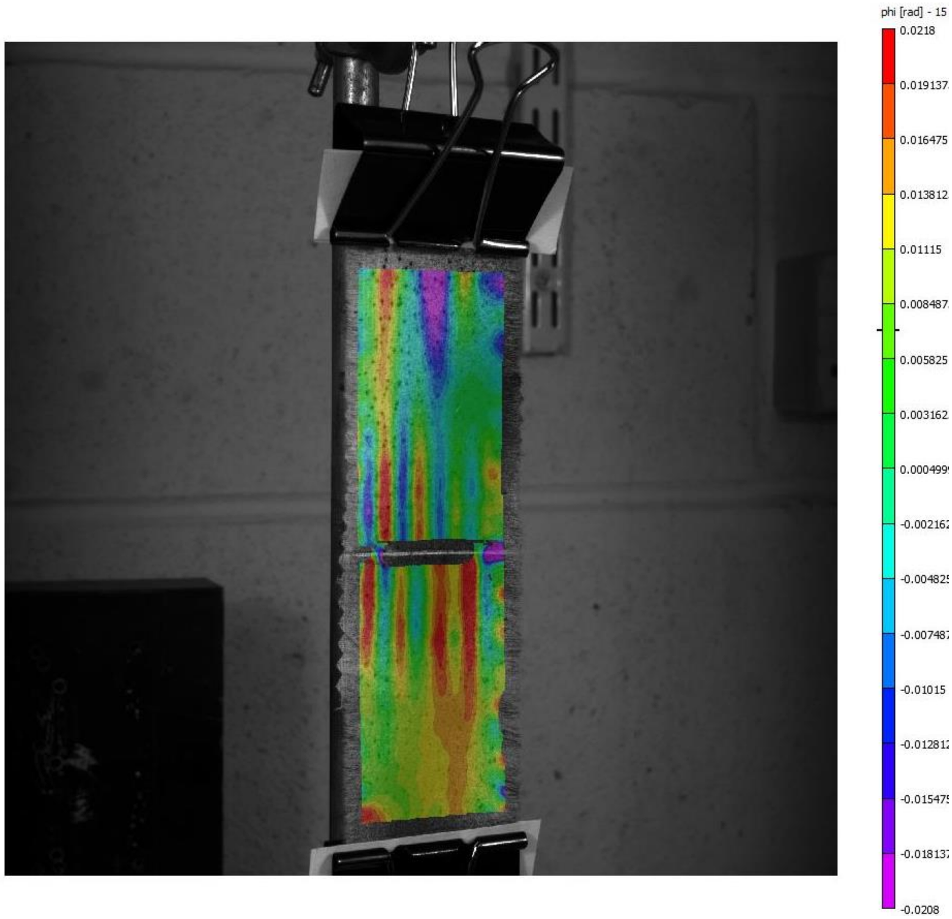


Figure A7.14: In-plane rotation map.

Rotation parameters:

1.249° to -0.604°

Test 4b: 9mm

Experiment run 2: Speckle with pen and spray. 200g weight. 1 photo/second for 30 seconds. July 6th 2016.

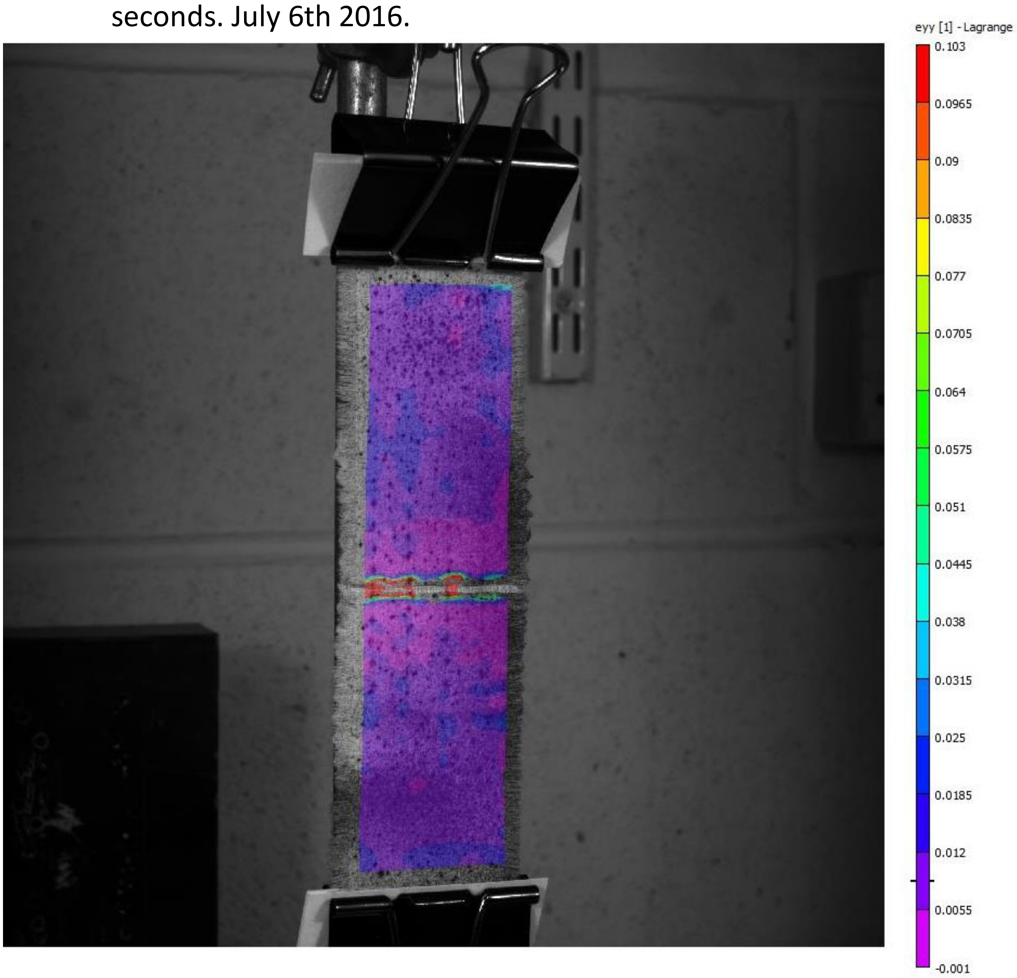


Figure A7.15: Y-axis strain map.

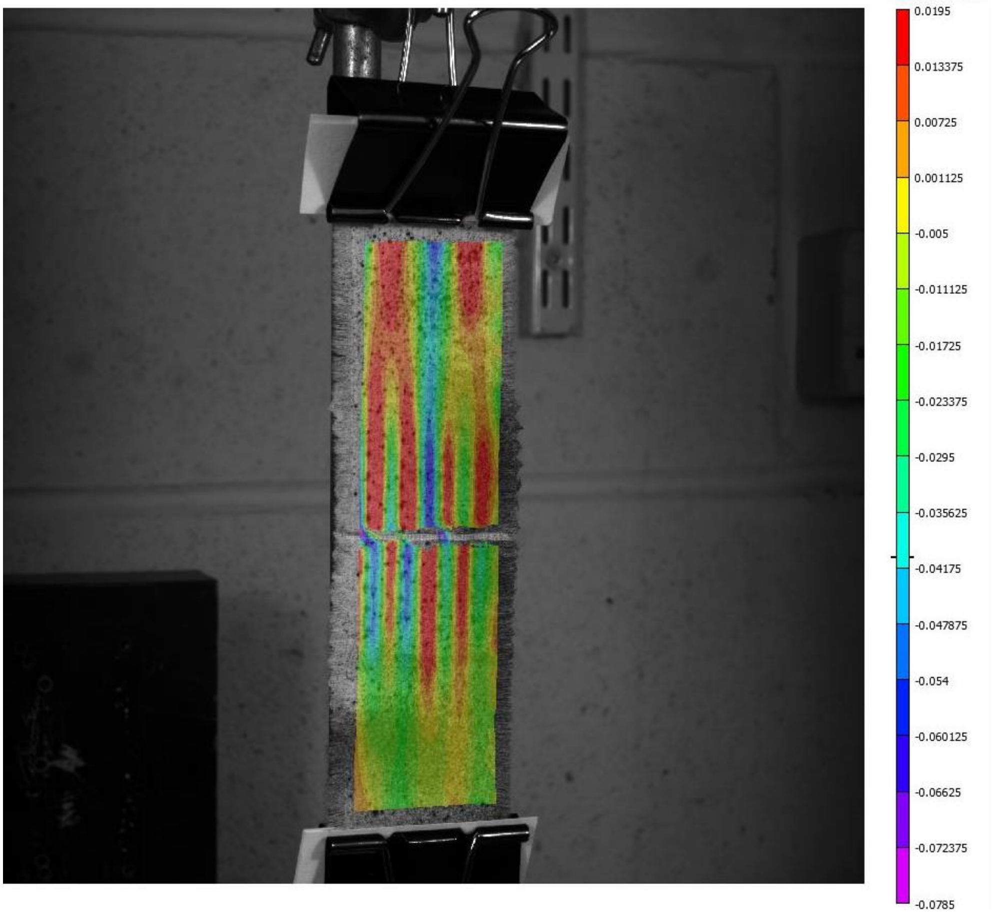


Figure A7.16: In-plane rotation map.

Rotation parameters:

1.118° to -4.5°

University of Glasgow

RISK ASSESSMENT FORM

School: Culture and Creative Arts	**Section:** Centre For Textile Conservation and Technical Art History	**Location:** Robertson Building, Level 3	**Reference No:** R___________	**Related COSHH Form (if applicable):** n/a

Description of activity:

Practical work relating to dissertation activity: "Each to their own"? An investigation of spacing in laid thread couching

- Cutting fabric – scissors, scalpels, glass weights
- Ironing fabric - iron
- Weighing scuba weights – electric scale
- Using Tensile Testing equipment – Instron machine with hydraulic clamps and PC set up
- Using Digital Image Correlation equipment – camera, lights and PC set up

Persons at risk:
Students, staff and visitors to the CTC

Is operator training/supervision required? If yes, please specify: Yes for Tensile Testing – initial instruction, then always working with a second person.

Hazards/ Risks	Current controls	Are these adequate?	What action is required if not adequately controlled?
Cuts from scissors and craft knives	Proper use and storage after use. Using cutting mats and rulers with handles to avoid slipping	YES	
Broken glass weights	Disposal of broken glass into broken boxes in Wet and Chemical Labs. Clearing area around breakage.	YES	

Trips in studio	All bags and coats stored away from working space. Keeping wires and trolleys out of walk ways. Checking route before moving through studio when carrying anything.	**YES**	
Electrical equipment	Check plug and PAT test before use. Ensure equipment is in the "off" position before plugging in. Unplug equipment when not in use.	**YES**	
Broken needles and pins	Dispose of in the sharps pin in the Chemical Lab. Ensure all parts have been recovered from area.	**YES**	
Lone working	Avoid if possible. Ensure other students are in the studio. Don't use appliances.	**YES**	
Instron machine	Complete training with M.Smith. Wear close-toed shoes. Work with a second person. Do not rush. Do not use if staff are not in building.	**YES**	
Digital Image Correlation equipment	Ensure all electric outlets are turned off after use. Only use when technician is in studio.	**YES**	

Completed by (print name and position, and sign): Hannah Sutherland, Student	**Date: 25/05/2016**
Approved by (print name and position, and sign):	**Date:** 01. 06.2016

Appendix 11: Sample Examples

These four samples were used for various parts of the experiment:

1. Undamaged, unconserved sample.
2. 3mm conserved sample.
3. 9mm conserved sample
4. 9mm conserved sample with ink pen and spray paint sample.

Appendix 12: DIC Videos

The four videos on the CD-ROM highlight the potential for demonstrating strain through computer modelling.

1. 5mm, ink pen speckle, 100g. eyy-strain.
2. 9mm, ink pen speckle, 100g. In-plane rotation.
3. 5mm, ink pen and spray paint speckle, 100g.. In-plane rotation.
4. 9mm, ink pen and spray paint speckle, 100g. eyy-strain.