Kaunas University of Technology

Faculty of Mechanical Engineering and Design

The Development of Image Analysis Method for Automated Textile Quality Control System

Master's Final Degree Project

Induja Ravichandran

Project author

Assoc.Prof. Jurgita Domskiene

Supervisor

Kaunas, 2021

Kaunas University of Technology
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Industrial Engineering and Management (6211EX018)

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Supervisor

Assoc.Prof. Rūta Rimašauskienė
Reviewer

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Induja Ravichandran

The Development Of Image Analysis Method for Automated Textile Quality Control System

Declaration of Academic Integrity

I confirm that the final project of mine, Induja Ravichandran, on the topic "The Development of Image Analysis Method for Automated Textile Quality Control System" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarised from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by Law) have been paid to anyone for any contribution to this project.

I fully and completely understand that any discovery of any manifestations/case/facts of dishonesty inevitably results in me incurring a penalty according to the procedure(s) effective at Kaunas University of Technology.

Induja Ravichandran	
(name and surname filled in by hand)	(signature)

Kaunas University of Technology

Faculty of Mechanical Engineering and Design

Task of the Master's final degree project

Given to the student – Induja Ravichandran

1. Title of the project –

The Development of Image Analysis Method for Automated Textile Quality Control System

(In English)

Vaizdų analizės metodo kūrimas automatinei tekstilės kokybės kontrolės sistemai

(In Lithuanian)

2. Aim and tasks of the project –

The aim:

To develop image analysis method for textile quality evaluation, based on 4-point grading system and to analyse possibilities to use the proposed system for automated quality control and management.

Tasks:

1.To prepare image analysis methodical using Image-J software for textile quality measurement.

2.To measure the textile defects and grade them with respect to 4-point grading system.

3. To estimate possibilities and to use the proposed system for the Analysis of defects in different pattern and colour knitted fabrics.

4.To analyse possibilities to use image analysis system for automated textile quality control and production quality management

3. Initial data of the project –

NA

4. Main requirements and conditions –

Four knitted fabric sample of different pattern and colour, Epson Scanner, *Image-J* Software

Project author	Induja Ravichandran		06.11.2020
	(Name, Surname)	*(Signature)*	*(Date)*
Supervisor	Jurgita Domskiene		06.11.2020
	(Name, Surname)	*(Signature)*	*(Date)*
Head of study field programs	Regita Bendikienė		06.11.2020
	(Name, Surname)	*(Signature)*	*(Date)*

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Keywords: Fabric quality inspection, image analysis, image acquisition.

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Summary

Production industry plays a significant role in contributing to the global economy market; the real challenge of these industries is to sustain their position in the market. The industry‘s value and place in the market are determined with the quality of the product it produces. The quality of the final product is very significant in any industry, and the same applies to the textile industry.

This project focuses on the quality inspection techniques in the textile industry by analysing some of the defects present in the fabric with *Image J* as image analysis software and also on how the industry can improve its quality inspection technique. To study the quality inspection technique practically an industrial visit to Penguin Apparel (P) Ltd, Madurai India was made. The company was using textile fabric quality inspecting machine working according to ASTM D 5430-04 standard. The defects of textile fabric were compared with the standard four-point system based on which the material is accepted or rejected in the quality department.

With the knowledge on the quality inspecting machines, for the research the defects were simulated in a Laboratory set up on four knitted fabric and scanned with V370 Epson scanner. The simulated faults (coloured defects, holes and oil stains) were initially measured manually. The scanned image of the fabric surface with defect was prepared for using the *Image J* software, where defects were measured and graded according to the defect shape and size. The results of image analysis were compared with the manually measured defect, which showed that both measurements had little variations.

Proposed quality inspection process with adopted image analysis technique can be a part of an automated quality inspection process of textile production and sewing company. Implementing automated systems for the production and quality management could boost profit and growth rate of the company, and it targets on increasing its efficiency rate in the market with minor defects in future. Proposed image analysis technique can be replicated in large scale production; for the measurement images in a large screen can be used, and defects can be easily predicted with the human eye also. Further, quality inspection supplemented by image analysis eliminates human error and makes the process more fast, reducing time and also cutting labour costs. Automation of quality control and production could contribute to increasing the profit and efficiency of the chosen company.

Ravichandran, Induja. Vaizdų analizės metodo kūrimas automatinei tekstilės kokybės kontrolės sistemai. Magistro baigiamasis projektas, Assoc.Prof. Jurgita Domskiene; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

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Kaunas, 2021. 56 p.

Santrauka

Gamybos pramonė vaidina svarbų vaidmenį prisidedant prie pasaulinės ekonomikos, todėl pramonės stiprios pozicijos rinkoje yra labai varbios. Gamybos įmonės vertę ir pozicijas rinkoje lemia jos gaminamos produkcijos kokybė. Galutinio produkto kokybė yra labai reikšminga bet kuriai pramonės šakai, ypatingai aktuali tekstilės pramonei.

Šiame projekte tekstilės medžiagos kokybės kontrolei, siūloma naudoti *Image J* vaizdų analizės programinę įrangą, kuri padeda fiksuoti ir analizuoti tekstilės medžiagos defektus ir pagerinti kokybės tikrinimo procesą. Norint susipažinti su tekstilės medžiagų kokybės tikrinimo procedūromis, buvo aplankyta „Penguin Apparel (P) Ltd“, Madurajus įmonė (Indija). Bendrovėje naudojama tekstilės kokybės tikrinimo mašiną, suderinta su standarto ASTM D 5430-04 procedūra. Užfiksuoti medžiagos defektai yra vertinami remiantis standartine keturių taškų sistema, kurios rezultato pagrindu kokybės skyriuje priimamas sprendimas, ar medžiagos kokybė yra priimtina, ar medžiaga yra atmetama kaip nekokybiška.

Remiantis žiniomis apie tekstilės kokybės tikrinimo procesą, moksliniam tyrimui medžiagų defektai buvo imituoti laboratorijoje, o-keturių megztų medžiagų vaizdai buvo užfiksuoti naudojant V370 Epson skaitytuvą. Imituoti medžiagos defektai (spalvos defektai, skylės ir aliejaus dėmės) pirmiausia buvo matuojami rankiniu būdu. Vaizdų analizės metodas buvo taikomas skaitmeniniams medžiagos paviršiaus vaizdams, kurie buvo analizuojami naudojant *Image J* programinę įrangą, defektai buvo matuojami ir rūšiuojami pagal defekto formą ir dydį. Vaizdų analizės rezultatai buvo palyginti su rankiniu būdu išmatuotais defektų parametrais, o analizė parodė, kad abiejų matavimo būdų rezultatai skiriasi nežymiai.

Siūlomas tekstilės medžiagų kokybės tikrinimo sistema, kai pritaikomas vaizdų analizės metodas, gali būti pritaikoma kaip automatizuotos tekstilės gamybos ir siuvimo įmonės kokybės tikrinimo proceso dalis. Siūlomą idėją pritaikius įmonėje, galima padidinti bendrovės pelną ir augimo tempą, o ateityje padidinti bendrą veiklos efektyvumą. Siūlomą vaizdų analizės metodą galima pritaikyti masinėje gamyboje: matavimui galima naudoti medžiagos vaizdus dideliame ekrane, kas padeda lengviau fiksuoti defektus. Be to, medžiagų kokybės tikrinimo procesą papildžius vaizdų analize, sumažinama žmogaus klaidų galimybė, procesas greitėja trumpėja gamyboslaikas ir sumažėja darbo sąnaudos. Įgyvendinus siūlomąmetodą, tikimasi padidinti pasirinktos įmonės pelną ir veiklos efektyvumą.

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Introduction

Quality of a product determines the standard of the company manufacturing it, with good quality the market value of a brand shoots high and desired by people to buy it. Textile industry needs better quality products to be produced to meet its customers satisfaction. Since textile products are the need of the people for daily use, and longevity of fabric is desired by all for which there is a requirement of quality assurance. For meeting this standard, quality inspection machine needs to be prioritised, for evaluating if the product manufactured meets the standard of quality or not. Since ages, the quality inspection has been carried out manually, practically it is not possible to expect a perfect product with human inspection, and human cannot work flawlessly for a prolonged period, end-user satisfaction is a challenge. Generally, the defects occur in the fabric with stages of the manufacturing process like cutting, sewing, etc. Scientists came with the application of automated intelligence which featured vision in looms as an intelligent fabric defect detecting tool. After automation, visual inspection made the process smooth; further, it reduced labour cost for the department of quality inspection and improved the quality. Recently the introduction of industry 4.0 has contributed to making the process easier with the Internet of Things (IOT) for the manufacturing unit. The quality inspection tools have been automated by capturing the images and storing the data of the detailed inspection history. The material can be traced with its product code and traced all its manufacturing details to its quality of acceptance; the cloud platform has made this storage of information easier. The textile industry not only manufactures products for clothing but also for many other vital areas like furniture, conveyor belts, medical garments and for many other fields. Fabric quality inspection in some industries has been carried out with inspecting tool with lights over the machine to view it, and here it’s a human who visually inspects the flaws and prepares the fabric inspection chart, which later is evaluated according to the standard grading systems like 4-points system, 6-point system, 10-point system etc.

In this report, Penguin Apparel (P) Ltd, India is considered to study the process of quality inspection mechanism. The company is developing slowly with its mechanism of manufacturing and quality inspection. With its development, it demands more kinds of products to be manufactured. Since their demands are increasing from their customers, the efficiency of the company should be improved. Therefore, the limitations in the quality inspection process need to be improvised and enhance the productivity and quality of the product.

Aim of the project:

To develop an image analysis method for textile quality evaluation, based on the 4-point grading system and to analyse possibilities to use the proposed approach for automated quality control and management.

Tasks of the project:

1. To prepare image analysis methodical using *Image-J* software for textile quality measurement.
2. To measure the textile defects and grade them concerning 4-point grading system.
3. To estimate possibilities and to use the proposed system for the Analysis of defects in different pattern and colour knitted fabrics.
4. To analyse possibilities to use image analysis system for automated textile quality control and product quality management.

1. The relevance of the research

1.1. Background

Quality control is an imperative component of modern manufacturing, and the textile industry is no different from any industry in this respect. Textile quality inspection is done by the fabric inspection machine operated by workers. Practically it is not possible to expect a perfect product with human inspection, and even humans can't work flawlessly for a prolonged period, and end-user satisfaction was not met [6]. The competitive market in today's cut-throat competition has to meet the category of good quality to be in the race of the business globally.

Textile Industry covers a significant percentage in the industries contributing to the world economy, material brand, and quality makes a substantial impact on the global market strategy. Many efforts through automation engineering and scientific methods are emerging every day to make the product efficiently and collectively leading to an increase in the profit of the industry altogether by eliminating the error neglected in quality inspection techniques.

Generally, the inspection of the material is carried out by quality department supervisors who are expert in examining the flaws. Although the review of the fabric is performed by skilled people, the first quality is only 60%. The inspection of the material generally has a fabric width of 1.60-2.00 m, which is inspected at a speed of 10m/min. The average human eye at times fails in identifying at this carried speed due to fatigue and other obstacles; perfection can not be expected all the time from an inspection made by human eyes [3].

1.2. Fabric defect analysis

Fabric is obtained by natural and artificial ways, its interwoven network of fibres woven together. Yarn is obtained by natural components like wool, flax, cotton, hemp etc. These yarn are then made into textiles by the process of weaving, knitting etc. These processes have been done in many ways in ancient time using traditional handlooms. With evolution, technology was implemented, and industries started to manufacture fabric in large scale and in many forms and varieties [3].

1.2.1. Fabric defects

In the textile industry, production of these fabrics was achieved with the help of machines but how about the defects, quality, and accuracy of the finished product. It is interesting to know that mostly in industries, 85% of the finished product is met with defects. Due to this defect in the manufactured goods, lead to a heavy loss in the industry. Approximately 40-45% of the price of the manufactured goods dropped down every second of the production [9].

The defects analysed during the inspection by the quality department supervisor is noted down in a chart after evaluating the material. These materials are later to be approved by the person in charge of the quality department to finalize if it is to be accepted for the final product or rejected.

Defects in fabrics occur due to external factors like force, friction, bending, straining and other forces resulting in flaws like piling, gloss and wrinkle formation. When the fabric cloth is of multicoloured patterns, and other designs were part of the material, machines were unable to identify the defects, different kinds of filters were used to rectify them [5]. Some of the common defects are present in the image, as shown here in Fig .1.

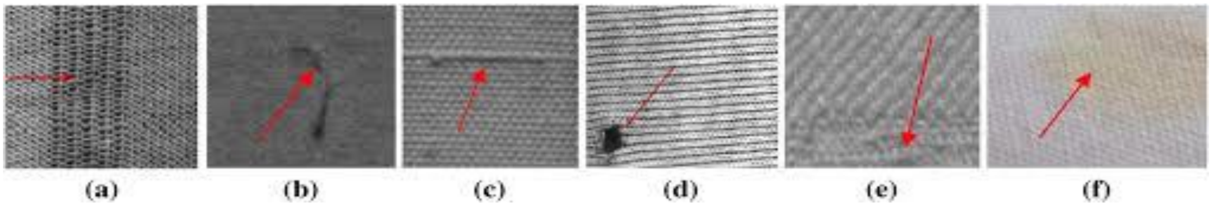


Fig. 1. Defects namely (a) needle breaking, (b) weft curling, (c) slub, (d) hole, (e) stitching (f) rust stains [1]

Fabric inspection reveals countless defects ranging from drop stitches to colour shading variation. The scale of defects makes it clear the garment manufacturer will have to cut around the issues to use the fabric, wasting material in the process. Fig .1 shows some of the common defects present in the fabric inspection; however, there are negligible other kinds of defects. A human eye due to optical illusion and other constraints may not be able to identify the defects with precision and can't be blamed as well [1].
At times the defects are very hard to detect and need to be filtered after the scanning process, threshold adjustment, binary filters, RGB adjustment are some of the techniques used to view the defects easily (Fig.2). In the thresholding process, the fabric image is scanned and converted to 8-bit bitmap, and later the greyscales are adjusted from 0 (black) to 255 (white) [2].

a) b)

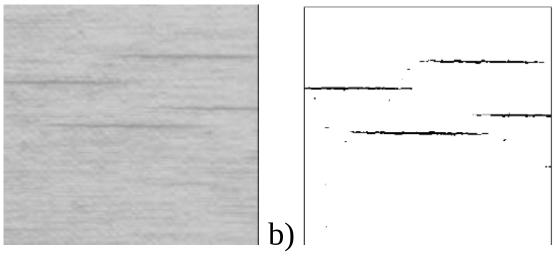


Fig. 2. a) Fabric with flaw b) fabric after thresholding [8].

The adjusting threshold value is a critical process while obtaining the image of the fabric for identifying defects. The adjustment needs to be done until the flaw is visible is clear and visible to decipher; however some alternatives can be adapted to achieve the threshold function; Value of pixels when higher than fixed greyscale is considered to be faulty pixels. This step of function is desired since it facilitates visual inspection by human eyes easily after the application of this system.

For assessing wrinkling, AATCC method is used, which is based on visual inspection and comparison of the fabric. The wrinkle evaluation is graded 5 for deeply crumpled and grade 1, with complete smooth surface fabric [4]. The fabric density is one of the kinds of defects found in woven fabrics, which stands as one of the most relative parameters for quality control. It is the number of warps or wefts in a unit length of 2. Some of the methods of identifying fabric density are pattern recognition, Fourier transform, line profile method etc. In Fourier transform, peaks are used to observe the periodicity and directionality of a period structure; however, this method is limited due to its filtering processes in space or frequency domain. Also, automatic determination deteriorates the benefits of image analysis. Fourier transform is limited to unadorned fabric hence not recommended for real-time application [8]. In pattern recognition, the fabric image needs to be pre-processed, and it analyses only plain weave just as in Fourier transform method. In line profile method, the process is considered to be more effective as it can be applied to various weaves and adorned fabrics, and the process does not require a pre-filtering process to determine repetition. The fabric image needs to be pre-processed, and it analyses only plain weave just as in Fourier transform method. The line method is simple and faster considering the calculation, but the process has a drawback by the requirement of vertical and horizontal axes of the image to be aligned with the warp and weft direction of the fabric [11].

1.3. Image acquisition system

Many research and methodology has been presented about the automation of fabric analysis recently and was based on the low resolution of images acquired under only reflective light hence came with limitations. A hardware system has been discussed here to capture the images of the fabric for testing [5]. The process of capturing the image with automatic visual inspection consists of three processes, namely, image acquisition, calibration and Analysis. The first step towards the capturing of the image process is to use an area camera arranged in two-dimensional arrangement CCD or with a line scan camera with a one-dimensional arrangement of CCD. Some basic set up have been shown in Fig .3.

Fig. 3. CCD camera setup for image acquisition of fabric image[3]

Fig .3 shows the CCD setup with light sources from two exposure angles. Though the setup has an exposure of light from two sources, the image captured has setback like image blurring. The main cause of this issue comes because of the inspection speed, restriction of inspection range etc. For these kinds of issues, line scan camera with fast image acquisition speed, low signal noise and a high resolution of 7000 pixels or above is used. To capture a perfect quality of image, the width of light is very important also according to the electromagnetic spectrum; the human eyes can view radiations ranging from 400-700 nm wavelength [6].

Light illumination from an LED (Light Emitting Diode), is preferred more since it facilitates view like human eyes, LED lights are updated with new technologies now and then and most preferably line LED is used. For effective use of LED lighting, the width of light has to be prefered by the formula as given below [7].

Light width [mm] = illuminated area + ($2 \times$ camera working distance)..[7]

To identify defected and defect-free fabric, infrared light and high frame camera are used in structural lighting systems. Fig 4. shows some of the prototypes of lighting for the fabric inspection, resolution of the image come better with good exposure of light, and the angle of reflection is one of the major factors influencing the clarity of the material, the backlighting concept in these prototypes are given to make the fabric easy for defect inspection without ghosting images at background [25].

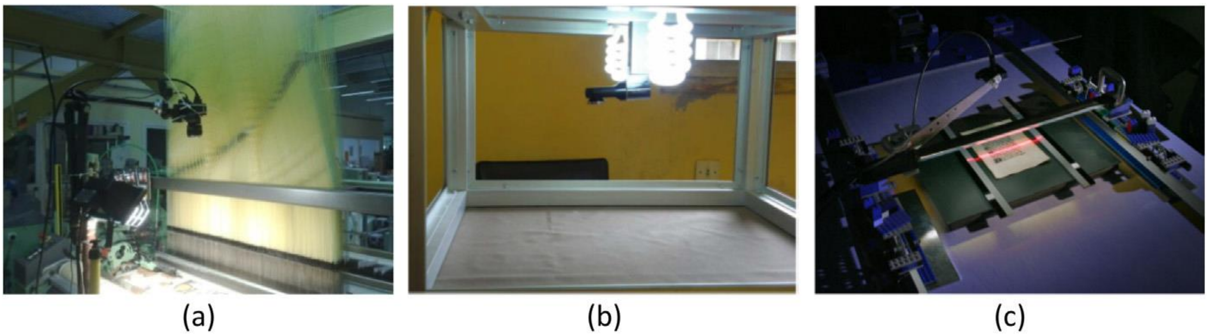


Fig. 4. (a) Halogen light source, (b) fluorescent light source[8] (c) linear light source[7]

To reduce the threshold range in the fabric image exposed, special lighting properties are used. Some of those special conditions are high-frequency fluorescent or halogen lamp, etc. In the automated inspection, it is necessary to have a high-quality camera with proper focus. There are basically two categories of lightning technique, bright field and dark field, in the former one the camera takes major imitated rays hence it is called the bright field, and it is understood that the later receives minor reflected rays [7].

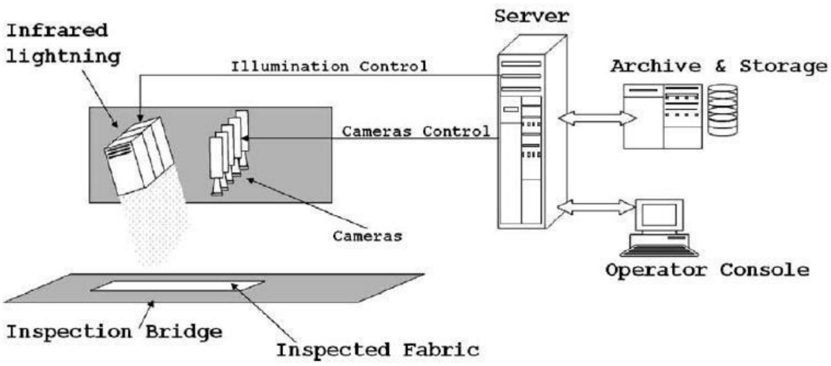


Fig. 5. Configuration of a typical automation inspection system[8]

Dark in the field is used for magnifying minute defects. There are some defects which can only be detected using darkfield lighting. As seen in Fig.5. infrared light is used instead of normal lighting, and the reason behind was to capture images insensitive to external exposure of lights around it. Hense some of the analog cameras have infrared sensitivity.

To conclude about the lighting and cameras, a high resolution of camera and light with intense exposure would be required.

1.4. Fabric inspection machines

The manufacturing sector of the textile industry has been automated, and the production efficiency of the industry improved, however still many types of flaws occur during production, sometimes the defects are not recognized. To eliminate these defects, the industry introduced automation technology for the purpose of quality inspection. The evolution of the fabric quality inspection machines kept emerging in the market, and still, automation is contributing to the process in a more innovative way The evolution of the textile industry along with the latest technology came up with the integrated automated technology, which made the inspecting process easier and highly accurate with improved fabric detection rate and quality. Some of the latest automated technologies have been discussed in this section.

1.4.1. Polymaster IM

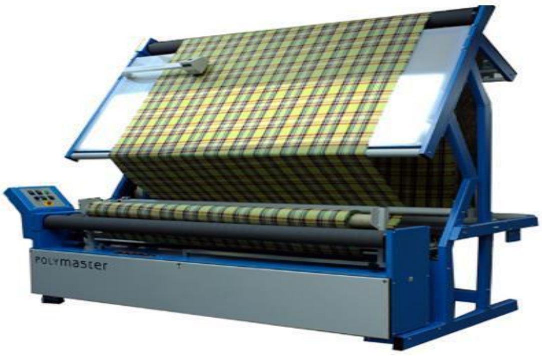


Fig. 6. Polymaster I [12]

Polymaster IM is a full inspection Machine, which is apt to meet the needs of fabric quality assessment without the traditional over-complication. It is quite easy to operate and at a price that is easy to invest on and return the same. This Polymaster allows the individual to specify the unit, size and options with customisations according to our requirement. It comes with automatic edge guidance, digital cloth counter and light at an inclined position which has to be provided externally. The operator uses basic pedal operation to switch on and off the machine. The digital counter counts the fabric length inspected [6].

1.4.2. Polymaster IMR

The IMR is a machine that is capable of inspecting a full-size material and also there is add on advantage for the inspector to have a close look of the material. This IMR lets the operator work safely in hands as the fabric gets rolled in the powered rollers behind them with automated edge cutting technology. This machine is available in compact forms and comes with overhead lighting for the supervisor to detect the flaws. The speed of the material rolling here can be regulated accordingly [5].

Fig. 7. Polymaster IMR[11]

1.4.3. Ramson‘s checker

Ramson‘s checker is a machine which can visually inspect the defects in the fabric material; this is a more developed machine that the machines discussed before in this section. The inspecting machine has more features compared to the later; it holds an illuminating light brighter enough to expose the flaws on the rolling fabric. The gearbox on the front is used to regulate the speed and measure the length of the fabric entered here. This machine is being used globally all over for the purpose of inspection. After the inspection of the material, the defects are measured and noted in the fabric inspection chart and later sent to the next level of the quality department for calculating defect points, which is compared with the 4-point inspection system according to ASTM D 5430-04 standards and then material is evaluated by the supervisor.

Fig. 8. Ramson‘s checker

The measurement of defects is classified as length or width direction through which the defects are classified. Something to be noted here is though this machine came with updated technology, it only considers major defect and minor flaws are not assigned any penalty points. Some of the mills still grade the fabrics are first quality and second quality and don‘t feel comfortable in terming the fabric with penalty points. The second quality assignment is just passed or fails classification, whereas, in point analysis terms, it is graded as penalty points awarded per 100 square yards [6].

1.4.4. Automatic inspection system

a) I-TEX

It is an automatic fabric inspection machine which is based on a visual inspection system with embedded algorithms that are replicas of the human visual analysis system. This machine can detect defects as minute as 0.5 [mm] on fabric with dimensional width of 330 [cm]. Also, this system has a unique system of catching flaws occurring in the production stages like improper dyeing, finishing, and coatings on any fabric [3].

b) PLC-controlled digital display

This automated system proposed contains fabric inspection machine which has a PLC-controlled digital display and web software that enables the controller to execute the reports simultaneously those of produced by this system, purifies reports and lets the report to be viewed on computer screens as soon as the inspection is done. This integrated machine assures rolls of fabric, multiple bundles with the same orders are displayed on one monitor. This makes the fabric easy to be evaluated under the four-point inspection system, which is identified and used by many top textile industries for quality control [13].

c) Cyclops

Defects can be identified at the primary stages like weaving and cyclops is one such fabric inspecting machine which can evaluate fabric directly at weaving stage, the on-loom inspection mechanism sends an immediate signal to the microprocessor in case of detecting the defect, and also it holds the machine by shutting off until the weaver confirms the elimination of the flaw [12].

With the evolution of industry 4.0, there has been many innovations in quality inspection techniques, and cloud platform has been an add on advantage for the storage administration of data and IOT accelerates the automation process in the inspection mechanism, in future labour employed for each process will gradually be reduced and complete automation is not far away [26].

1.5. Concluding the literature review by indicating the future work

The various author‘s opinion on the improvement of efficiency of the production process and the need for development in the quality control of the fabric through automated inspection was reviewed. With the help of these works, one of the system ASTM -D5430 applied on Ramson‘s Checker quality inspecting machine, which is used in the ,‘‘Penguin apparel industry‘‘ we find the company’s performance, and the inspection improvement method is proposed using a dedicated software tool *Image-J*.

2. Industrial visit to the company

This project work which emphasises on the quality inspection comes with the process of analysing some of the defects present in the fabric. To explore and know real-time work-based experience about the project, an industrial visit to a small scale company ,Penguin Apparel Pvt Ltd was made, this company is a textile company which produces garments. This company was founded on 1990, it started with ready-made garment factory with 40 sewing machines, however with its substantial growth and improvement by modernised machines in its production line and incorporating the latest technologies, now the company has over 1800 sewing machinery and other ancillary equipment with its branch company, Penguin Garments(P) Ltd & Peacock Apparels (P) Ltd. The company Penguin Apparel (P) Ltd is in D-53, Industrial Estate, Kappalur, Madurai, Tamil Nadu, India. Since it is a small scale company, it produces limited varieties of garment product.

Initially, the information about the company and quality control process are collected by interview with the director and working employee of the company. Some of the information on the quality control process and methods used along with the fabric inspection chart was obtained from the Manager of the company, quality control sector.

2.1. About the company

The company has its manufacturing unit near the city capital, which makes it easy to export its trade since transportation is easy and convenient. Table 2.1. describes the necessary information about the company

Table. 1. Information about the company

CIN	U18101TN1990PTC019054
Date of Incorporation	16 Apr 1990
Status	Active
Company Category	A company limited by shares
CEO of Company	Mariappan Ayasamy
Company Class	Private
Business Activity	Manufacturing (Textiles)
Authorized Capital	24.0 lakhs
Paid-up Capital	18.0 lakhs
Paid-up Capital %	75.0
Employees	1001-5000
Registered State	Tamil Nadu
Registration Number	19054
Registration Date	16 Apr 1990
Customers	Local and International

2.2. Machinery available in the company

The machines used in the company is discussed in this section with their specifications and details. The machinery of a company is very important since it contributes to the assets of the company, which determines the quality and standard of the company in the global market on producing quality goods.

a) Cutting

The process of cutting and spreading requirements differ from one fabric to the other; this company uses Lectra automatic fabric cutting machine, Lectra computerised pattern making system is used to cut the fabric. Since the introduction of automation in the company, they deliver the exceptional output and cut quality end product regardless of fabric type or ply-height.

b) Sewing

The company focuses on the sewing unit a lot since one stitch fail can land in defected material at the end. The company has automated the complete sewing process by modern and new equipment, like Durkopp Adler, Juki, Kanzai, Imato and Brother Japan which has helped the company to ensure an optimal working flow and to provide time for adding value to the final product.

c) Embroidery

The embroidery divisions in the company have sophisticated automated multi-head machines using CAD/CAM designing, enabling for large scale execution of intricate embroidery which has up to 9 colours.

d) Washing

The company uses Tonello branded washing machine to wash the garments, which consumes less water contributing to less ecological impact. Also, after the process is over the residual water is recycled using biological bacteria, and the purified harmless water is used for watering plants and keep the green environment, leading to sustainable development in future.

e) Finishing

The end product that is the final look of the garment is the most critical factor leading to purchase decision. The highest priority is given here, to support this they use automatic machines like form finishers to provide a perfect finishing to the garments.

2.3. Identifying the issue with the company

The industrial visit aimed mainly to investigate the quality control department of the company. When investigated about the products of the company, it had limited designs and products for its customers which makes this company lack in a competitive market. The company has paid 75 % of its capital investment which was due to its continuous manufacturing in its basic designs and garments that were repeatedly manufactured. As observed from the products of the company, it does not simulate or design women's attire and the latest design models for kids and men. The company aims only at constant or same growth rate with no rise and down in its profit share. On investigating the problem, the quality department had the answer for not manufacturing creative designs and latest fashion textiles in the unit due to the fear of delivering low-quality goods which could lead the company down the hill [23][24].

2.4. Products made in the company

The company has customers starting from local areas to international exports. This gradual increase in the customer list was due to its quality product made with better machinery in the unit for production. Fig.9. shows some of the products made in the industry. Though the products made in the company are not of different kinds and modern designs, it aimed at exporting limited products in fine quality to the customers [24].

Fig. 9. Some of the available products in the company a. kids wear shirts b. kids outerwear c. workwear tops d. men‘s outerwear e. formal shirts f. trousers

2.5. Quality control of the company

The company aims to deliver quality ready-made garments with timely delivery to meet customer’s requirement. The Legal statutory by Government bodies have approved this company with good standard. Some of the certificates the company holds due to its standards are International Management System Standards like ISO 9001 and ISO 14001[24]. The quality control department functions by analysing the defects on the fabric with the ASTM D 5430-04 standards. The detailed inspection of quality control is presented in this chapter. The sheet of cloth manufactured in the industry are made in surplus amount and stored in the inspection room to be tested for quality check (Fig.10)

Fig. 10. Rolled fabrics in the quality inspection room

The rolled fabric is installed inside the fabric inspection machine. The company uses Ramson’s checkmate (Fig.11). The checker stands here and examines flaws under the light to view the defects easily and grade them according to their quality. The identified flaws and other details are noted in the fabric inspection chart, which then has to be examined by the department supervisor.

Fig. 11. Ramson's checkmate

The supervisor, after reviewing the fabric inspection chart, evaluates the points to be assigned for the quality inspection, here the company uses Four-Point system for quality evaluation. 4 Points System: According to this method, defect points are identified out in 100 square yards. Later, according to the total points, the fabric is accepted or rejected. The optimum points awarded for acceptable quality is 40, crossing which the material gets denied. Overall the current level of efficiency with the Ramson's checkmate is satisfactory to the level of distribution at the constrained time as of now, however if the inspection process could be done in a more easier way and less time would lead to inspecting the fabric in a much faster way and deliver more goods before the time assigned for the delivery.

Table. 2. Assignment of points in the four-points system [17]

Defects length	**Points**
Up to 3 inch	1
3" – 6."	2
6" – 9."	3
Above 9"	4

Defects length for holes and openings	**Points**
1 "or less than 1."	2
Above 1"	4

According to the four-point system, the fabric gets evaluated, hence the company receives a lot of waste due to rejection at a quality level. However, sometimes due to optical illusions and human fatigue, the defects are unable to be identified quickly, and this makes the final quality level of the product low in standard thus making the company behind the competitors [25]. This is one of the reasons for the company to not manufacture other kinds of textile materials. The problems of the company are taken into consideration. The quality inspection is performed in an automated way with image analysis software which can eliminate the quality issues of the company and boost in manufacturing a different kind of garments and make the company a part of the market competition instead of lacking behind.

3. Experimental part

A detailed analysis of investigating the defects under the dedicated software *Image J* in an exemplified form is presented in this section. The prime goal of this experimental part of the project is:

1. To identify colour defects on different fabric quality;
2. To identify oil stains on repellent material and oil stains on absorbent materials;
3. To detect the holes in the fabric and measure the dimension of the same;
4. To find the grade for the analysed defect to standard ASTM D 5430-04.

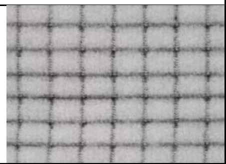
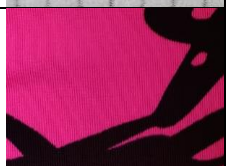
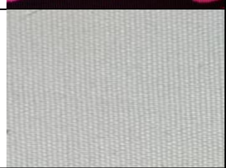
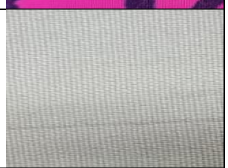
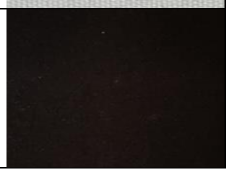
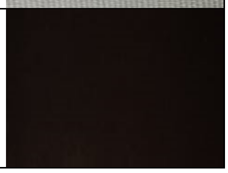
3.1. Sample preparation method

3.1.1. Textile characteristics

Fig. 12. Knitted fabric samples

For the Experiment analysis, various types of knitted fabric were chosen (Fig.12.) The sample fabric is cut in a dimension of 21×29.7 cm (A4 paper size) from the whole lot. The samples are of different kind of composition and properties (Table.3)

Table. 3. Characteristics of knitted fabric

Fabric label	Structure	Composition	Front view	Rearview
F1	Knitted structure with a pile	100% polyester		
F2	Knitted structure with print	96% polyester 4 % lycra		
F3	Knitted structure	96% polyester 4 % lycra		
F4	Knitted structure	96% polyester 4% lycra		

3.1.2. Defect simulation

For the experiments, the defects were made manually (Table.4) in the laboratory environment and observed for all possible outcome.

Table. 4. Manually made defects for the experiment part

Defect Label	Defect type and Description	Defect Size /Size Range
D1 H	Colour defect – lines in different position were made by contrast marker on the surface of knitted material horizontally	A horizontal line of 50 [mm]
D1 V	Colour defect – lines in different position were made by contrast marker on the surface of knitted material vertically	A vertical line of 50 [mm]
D2 10	Holes in fabric-holes in a material is made using scissors by cutting out circular shapes	Hole diameter 10 [mm]
D2 15		Hole diameter 15 [mm]
D2 20		Hole diameter 20 [mm]
DO 1	Oil stain- oil is spilt on the fabric using a dropper	Area diameter average (10-20) [mm]
DO 2		Area diameter average (20-30) [mm]
DO 3		Area diameter average (30-40) [mm]

The selected material has to be wrinkle-free with a good shape to attain this; we use an iron box and gently press the material with care and make it steam pressed (Fig.13).

Fig. 13. Making the fabric wrinkle-free

3.1.3. Colour defect simulation

1. Use a light marker pen, for material with dark texture and bright coloured material, let us use a black marker.
2. For dark fabric material which is fabric F4, let us use white marker or correction pen.
3. Using a ruler let us make the coloured mark of 50 [mm] line on the fabric material using a ruler(Fig. 14). The defects are marked as D1 V and D1 H according to Table .4.

Fig. 14. Ruler used to mark the defects

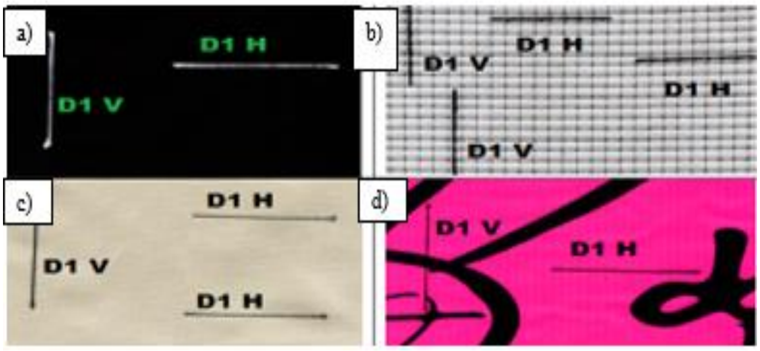


Fig. 15. Coloured defects; a) F4 with D1 V and D1 H; b) F1 with D1 V and D1 H; c) F3 with D1 V and D1 H; d) F2 with D1 H and D1 V

3.1.4. Simulation of oil stain

To make an oil stain on the material, let us use a dropper to drop oil and make stains dropwise. Elastic material cloth has a natural way of expelling the oil on it, let us verify it with a small experiment. For the stains, 100% synthetic oil for an industrial sewing machine was used.

a) Mini experiment on elastic material

1. Take a little amount of oil with the help of a dropper, as shown in Fig .16.
2. Drop it in the testing material in a desired shape and size (Fig .17).

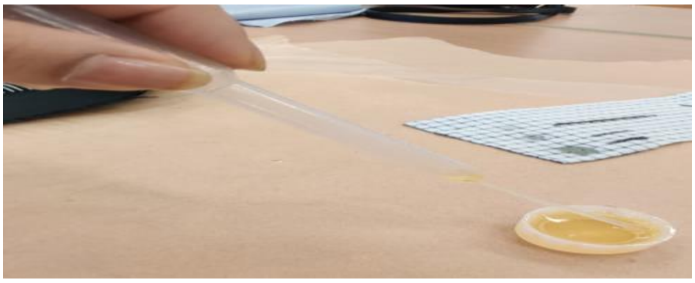


Fig. 16. Filling the dropper with oil

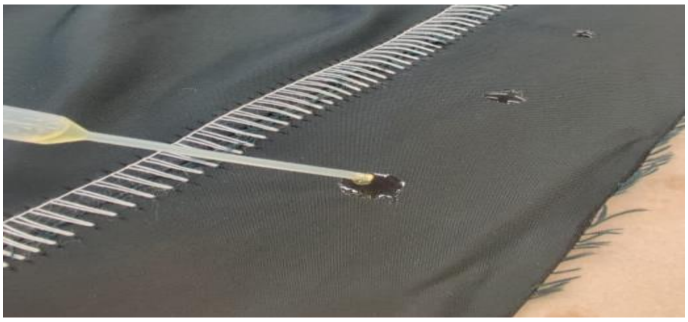


Fig. 17. Dropping oil to make stains

3. The dropped oil on the fabric makes droplets like this, let us absorb the excess oil using an absorbent paper (Fig.18).

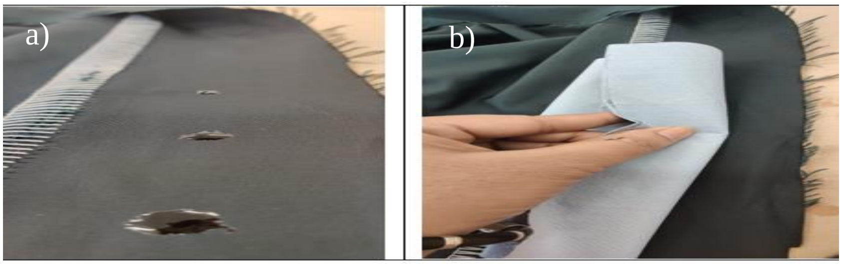


Fig. 18. a) Oil stains in b) removing excess oil

4. This material does not absorb any oil stains as it repels oil also, its absorbable with paper as we see in the figure below, the oil stains vanish as soon as the form is used or even when its dropped. When let to dry, it does not make much difference as the material repels the oil (Fig .19).

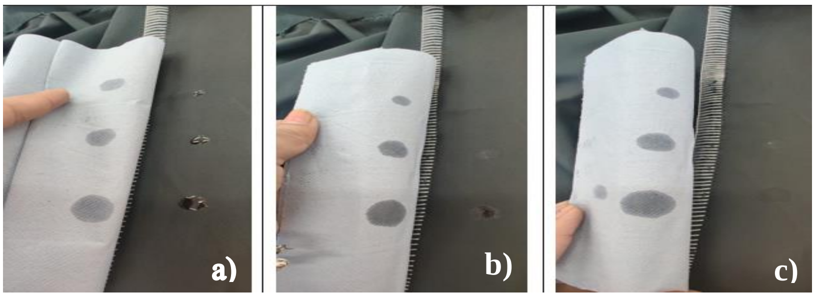


Fig. 19. Oil droplets a) first absorption b) getting absorbed finely; c) complete absorption

The oil droplets put on the fabric material stays for a while and after some time gets dried off, and after absorbing with a tissue, no stain persists on the material which shows that this material is repelling oil hence no stains.

b) Oil stain in other materials

As seen in mini-experiment, let us try the same experiment in other fabric materials. The fabric material (F1 and F3) here gets absorbed with oil stain forming some visible stains(Fig .20), the oil stains here flows throughout the material due to its viscous nature and forms irregular shape and defects marked with respect to Table.4 and the other two materials F2 and F4 repel the stain formed, and no stain is detected in them.

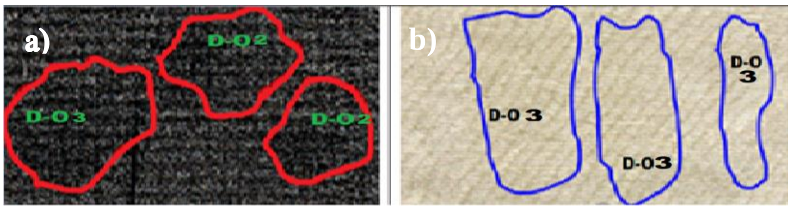


Fig. 20. Deformed stains obtained; a) F3 with oil stains DO3, DO2 and DO2; b) F4 with all three DO3 stains

3.1.5. Holes in fabric

In this section, holes are cut out from the fabric to analyse the defect under image analysis. The defect here is made using scissors in different sets of dimension on all the fabric (Fig .21) and defects marked with respect to Table .4.

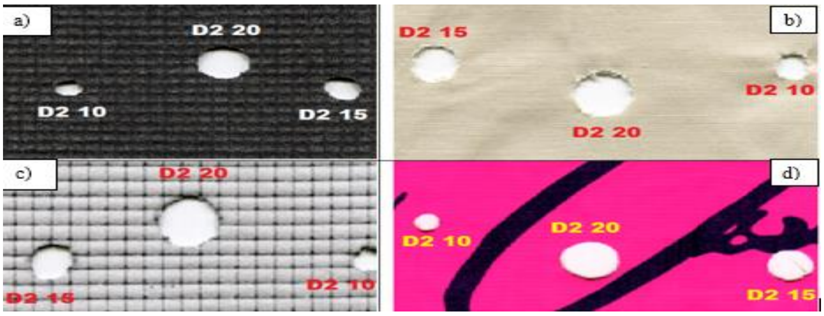


Fig. 21. Holes made as defects; a) F3 with defects of D2 10, D2 20 and D2 15; b) F4 with defects of D2 15, D2 20 and D2 10; c) F1 with defects of D2 15, D2 20 and D2 10; d) F2 with defects of D2 10, D2 20 and D2 15.

3.2. Image analysis

3.2.1. Image acquisition tool

Generally, the image acquisition system for analysing the fabric has been done using the CCD (charged-couples device) camera, with optimal optical resolution [7]. Images are captured using a resolution of 351*351 pixels with a pixel depth of 8 bits (256 shades of grey). The CCD cameras have to be accompanied with fluorescent lights for better resolution, and this mechanism is mostly carried out in a dark room [7]. (Fig .22)

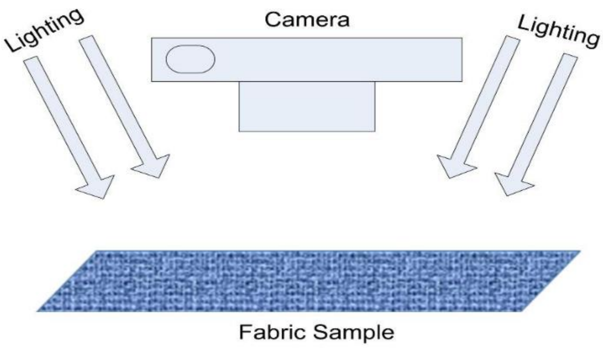


Fig. 22. CCD camera with fluorescent light-capturing fabric image

This process of accumulating the image sometimes fails in capturing the image with the original resolution, since there are chances of image dispersion due to the intensity of light, exposed and with quality of the camera. To eliminate this kind of abnormalities capturing the images, Epson scanner V370 is used to scan the material with built-in transparency unit for easy scanning and also operates on a high optical resolution of 4800 dpi Moreover, CCD (charged-coupled device) technology and ready scan LED technology makes this scanner give high quality and precision images. (Fig .22).

Fig. 23. V370 Epson scanner

For the experimental purpose, we use this(Fig.23) scanner since the sample size is (21 × 29.7) cm that is of an A4 sheet paper dimension. After scanning these images, the fabric is analysed with the help of Image J software, where the fabric material is analysed with different kind of filters for easy analysing technique.

3.2.2. Image analysis method

1. Scan the fabric with the help of a scanner, we used V370 Epson scanner with 600 pixels dpi and load the images in the system in jpg format for a better quality of an image.
2. Open *Image J* software and load the image here for the analysing process.
3. Identify the defected area in the fabric, and use tools given in the software to measure the defects.
4. For parameters of defects D1 H and D1 V, use the tool as shown below to identify the length of the defect.

Fig. 24. A tool to measure the length of colour defects

Use this tool to measure the dimension of the defected length by extending the line of dimensional line over the defect as shown below and then go to analyse section where measure option will be available.

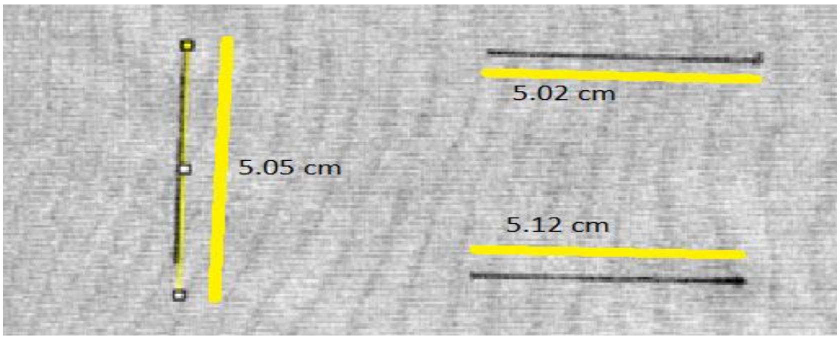
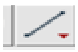


Fig. 25. Measurement of defected Lines

5. For defects with holes, D2 use the tool given here(Fig .26).

Fig. 26. A tool to measure holes

Use this tool to measure the dimension of the hole, extend the circle over the defected hole you want to analyse and measure the area of defected flaws (Fig 27).The radius of the circle can be found by using this  tool, the diameter is found using this method, and half of it would give a radius

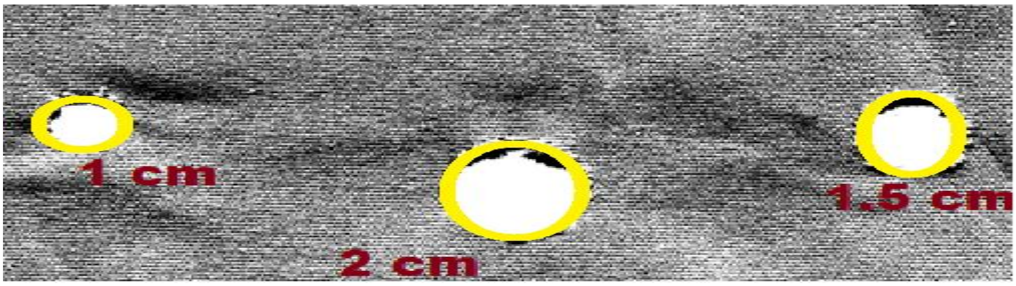


Fig. 27. Measurement of D2 voids

6. Some of the defects can be measured by taking outline for the image, for defects such as oil stains D3-O, use the tool as given here:

Fig. 28. A tool to measure irregular defects

Use this  tool to calculate the area in pixels

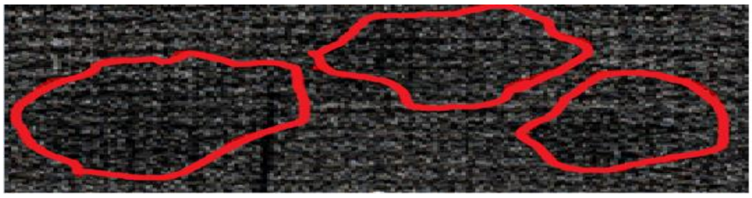


Fig. 29. Measurement of D3-O oil stains

7. The primary image or the original image view of fabric surface shows better results in case of holes and contrast lines, therefore for some types of fabric and defects, it is necessary to use image modification in order to get the right image of the defect. In this case, it is possible to adjust the colour threshold for better identification of stains of oils especially in dark colour samples(Fig .29)

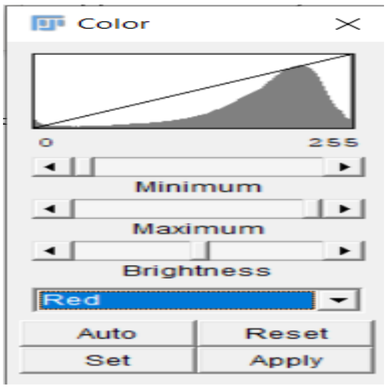


Fig. 30. Adjusting threshold

Identification of flaws from the primary image is sometimes difficult to analyse due to the complexity of the design, texture and colour of the material. Material with dark and thick material can be converted to a binary image with a binary filter option, applying this can lead to easy detection voids and contrast defects. The navigation to set this filter is depicted (Fig .31).

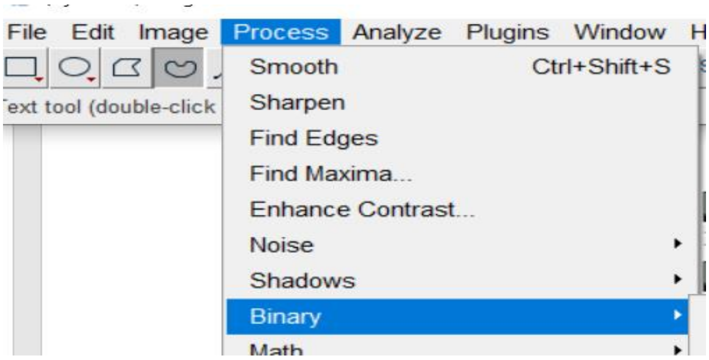


Fig. 31. Converting primary image to binary images

For defect evaluation, each type of simulated defect was measured three times, and the values were captured in a table for the comparison. The values are taken average for having a precise value of the defect and also to ensure that the defects noted are accurate.

3.2.3. Image calibration

Summarised measured value of the detected flaws is obtained with all necessary values needed for measurement. The software *Image J* can produce results in pixels and also in the dimension we need; however, dimensions in both pixels can be obtained with a change in settings. At first, the dimensional value in changed from pixels to millimeters in the unit under setting scale followed by measurement of the defects as we saw in this section of image acquisition (Fig.32).

Let us calculate the coefficient of calibration for image of pixels, let the known distance be 500 mm i.e = 5 cm ;Pixel value of cm to pixel for 5 cm = 188.97 pixels

189 pixel = 500 mm (5 cm)

1 pixel = let it be ‘X’ ,

‘X’= 500/18

Therefore ‘X’= 2.6 mm , (1 pixel = 0.026 cm)Coefficient of Callibration of Pixel= 0.026
And 1 pixel = (2.54 / 96) cm ,‘‘0.026458333 centimeters in a pixel’[18]

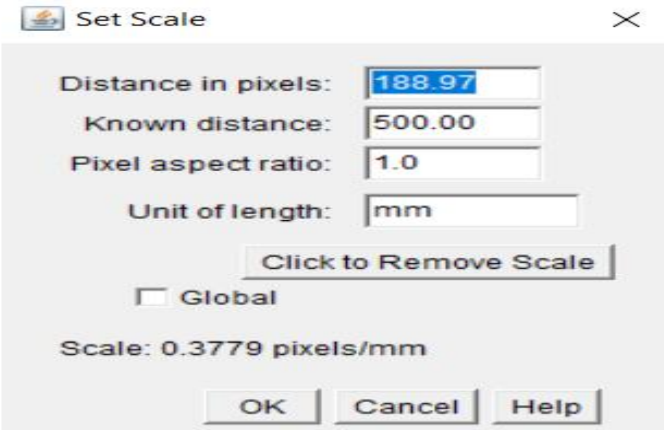


Fig. 32. Setting scale to desired dimensional preference

3.2.4. Four-point analysis of fabric according to standard ASTM D 5430-04

The 4 point analysis of fabric is made by using the detected flaws measurement, and it is converted into inches, and then according to the category, they are awarded points of defected length. Mostly the 4 point defect analysis is done for defects with holes or openings and flaws made of lengthy defects. Flaws up to 3 inches are given point of “1” and holes with more than 1 inch or less than 1 inch is given “2” points. In this section, the process of awarding the defected points is given here, and each fabric is assigned the total defect points taking into the consideration of both the defects formed by holes and lengthy flaws put together. If the total defect points exceed 40, the material gets rejected [17].

Length of the defect (diameter) = 2 × *r* ....(where *r* is the radius in [mm])..................[19]

1. Length of D2 10: diameter is 10.00 [mm] ....(then radius *r* is 5 [mm])
2. Length of D2 15: diameter is 15.00 [mm]..............(then radius *r* is 7.5 [mm])
3. Length of D2 20: diameter is 20.00 [mm]..............(then radius *r* is 10 [mm])

Here the defect length diameter is of manual calibration, and the 4 point analysis is made using this method and will be later checked with the image analysis section.

a) Fabric 1-(F1)

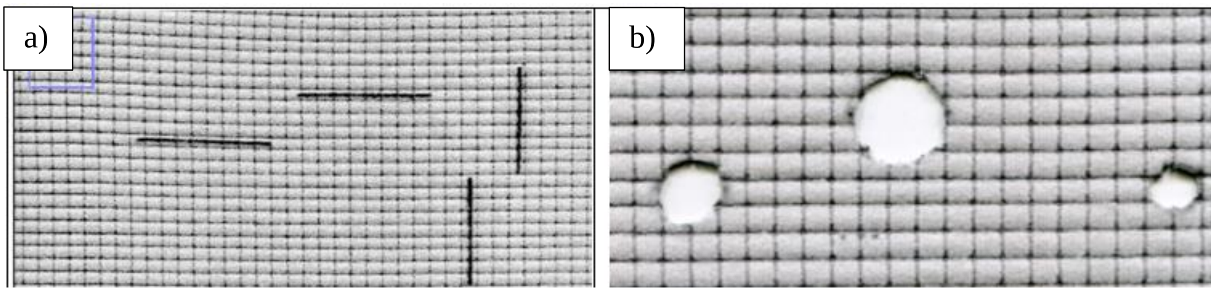


Fig. 33. F1 for four-point analysis a) colour defect; b) hole defects

Table. 5. Results obtained from 4 point analysis

Defect length (in cm)	**Points**
5.3 (2 inch)	1
5.12 (2 inch)	1
5.16 (2 inch)	1
5.03 (2 inch)	1
Length for holes and openings (inches)	**Points**
0.83<1	2
0.55<1	2
0.41<1	2

Total defect points: 1+1+1+1+6=10, hence this material comes under approved quality fabric since the total defect point is under 40

b) Fabric 2-(F2)

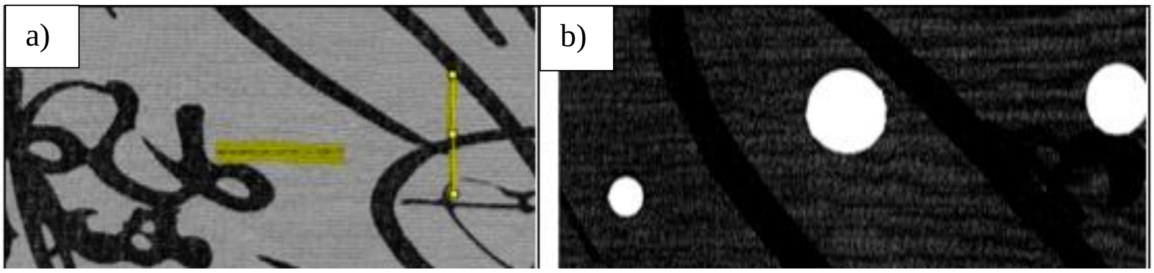


Fig. 34. F2 for four-point analysis a) colour defect; b) hole defect

Table. 6. Results obtained from 4 point analysis

Defect length (in cm)	**Points**
5.163 (2 inch)	1
5.161 (2 inch)	1
Defect length for holes and openings [inches]	**Points**
0.81<1	2
0.54<1	2
0.39<1	2

Total defect points: 1+1+6=8, hence this material comes under approved quality fabric since the total defect point is under 40

c) Fabric 3-(F3)

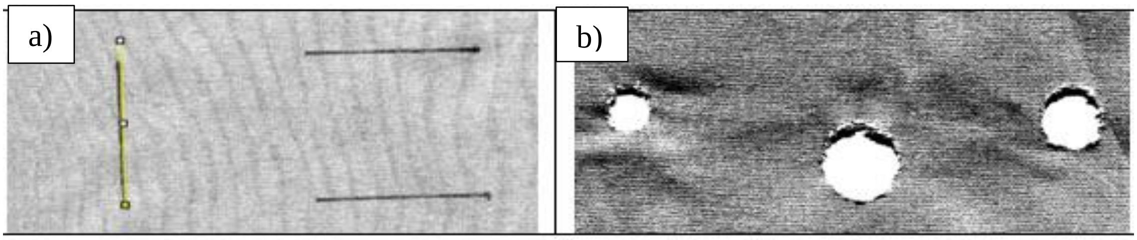


Fig. 35. F3 for four-point analysis a) colour defect; b) hole defect

Table. 7. Results obtained from 4 point analysis

Defect length (in cm)	**Points**
5 (2 inch)	1
5.25 (2 inch)	1
5.12 (2 inch)	1
Defects length for holes and openings (inches)	**Points**
0.81<1	2
0.56<1	2
0.40<1	2

Total defect points: 1+1+1+6=9, hence this material comes under approved quality fabric since the total defect point is under 40

d) Fabric 4-(F4)

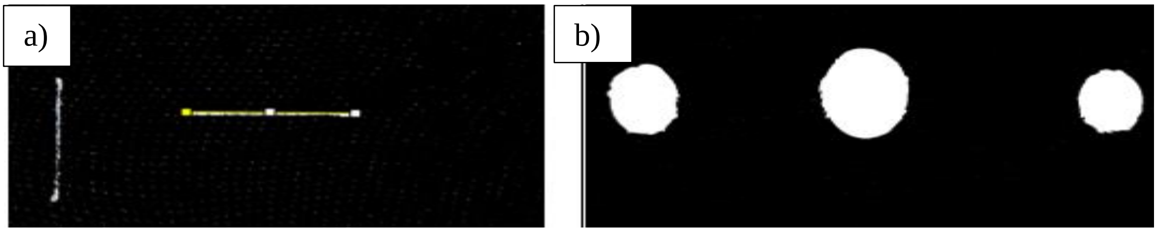


Fig. 36. F4 for four-point analysis a) colour defect; b) hole defect

Table. 8. Results obtained from 4 point analysis

Defect length(in cm)	**Points**
5 .036 (2 inch)	1
5.024 (2 inch)	1
Defects length for holes and openings (inches)	**Points**
0.80<1	2
0.55<1	2
0.41<1	2

Total defect points: 1+1+6=8, hence this material comes under approved quality fabric since the total defect point is under 40.

Hence the methodic part for grading the fabric through ASTM D-5430-04 has been discussed in this section, keeping this as reference the image analysis will be carried out. While carrying out the measurement process, some of the basic fundamentals considered in the calculation here are:

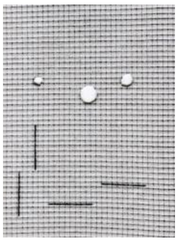
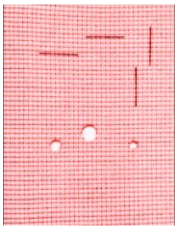
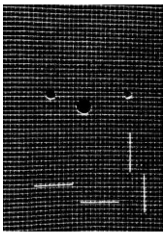
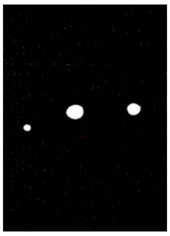
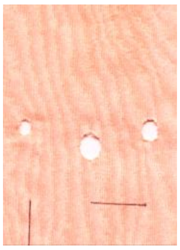
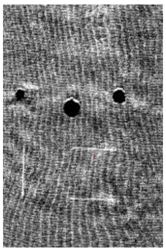
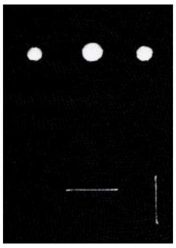
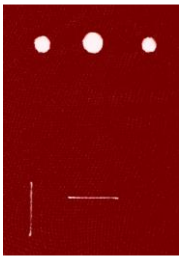
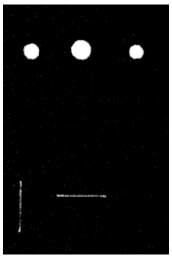
1. Radius = ½ (Diameter);
2. 100 [cm] = 1 metre[m];
   So, 10 [mm] = 1 [cm];
3. 1 pixel = 0.264 [mm];
4. 1 pixel = 0.0104 [inches] [19].

These are some of the conversions followed while calculating the evaluated defects

3.3. Experimental results and discussion

The size of defects is measured from the image and compared by the requirements of the standard ASTM D 5430-04. Test Methods for visually inspecting and grading fabrics are discussed in this section.

Table. 9. Samples of fabric after image filtering

Fabric label	Primary image (original scanned image)	Image after applying colour threshold function	Binary Image
F1			
F2			
F3			
F4			

The primary image sample is made of different kinds of composition (Table.3) and has negligible defects hidden inside it. Some defects are accurately visible by simply adjusting the threshold balance, while some into a binary image and greyscale adjustment give easy flaw detection for holes.

3.3.1. Analysis of the defects of sample F1

a) Coloured defect D1 H and D1 V analysis

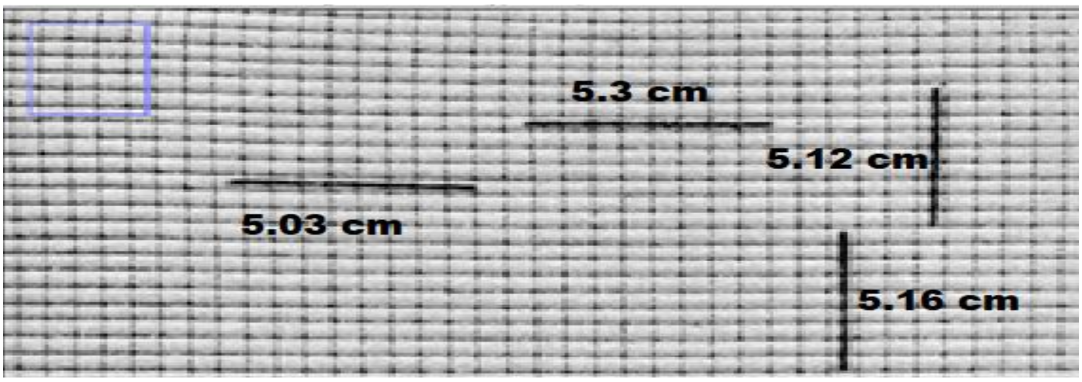


Fig. 37. Coloured defects under the scanner

The sample F1 is scanned for detecting coloured defects; Fig.37 shows defects made horizontally and vertically. These defects are lengthy and need to be measured using the tool discussed in the image analysis method.

Table. 10. Results obtained from the sample with coloured defect image analysis

Label	Sample defect length (mm)	Image defect length in pixels				Length in mm(image analysis)				Grade
		1	2	3	Average	1	2	3	Average	
D1 V	51.2	212	190	192	198	56	50.2	50.8	52.3	1
D1 V	51.6	202	205	196	201	53.4	54.2	51.5	53	1
D1 H	53	197	206	215	206	52.1	54.04	56.8	54.3	1
D1 H	50.3	188	196	195	193	49.7	51.8	51.5	51	1

In Fig .37, there are two horizontal and two vertical coloured defects, which is measured using the tool as discussed under section 3.2.2; also the fabric is graded with 1 according to standard ASTM D 5430-04 four-point fabric. As we can see from Fig.37, the background of the material is white, and the defect is visible in black colour, adjusting colour threshold is not required for this material. However, to make sure that other kinds of flaws do not erupt out of the material, it's very much recommended to pass the colour threshold filter process. Binary image of this material can clearly show the flaw since the coloured defect is black in colour(Table 9-F1).
From Fig.38, the graph shows the comparison between defected length measured in the fabric sample and image analysis performed by *Image J* software analysis. The graph clearly shows that the analysed length by image analysis and manual measurement is relatively the same, and an accurate result of the length is shown by the average of the pixels analysed by image analysis. For the results

to be the accurate and precise manual measurement from the Table .10 is taken as reference and compared with distances which are calculated three times as seen in the table and then taken average, then these pixel distance are converted into [mm] dimensions from the reference; manually inspected length is taken in [mm].

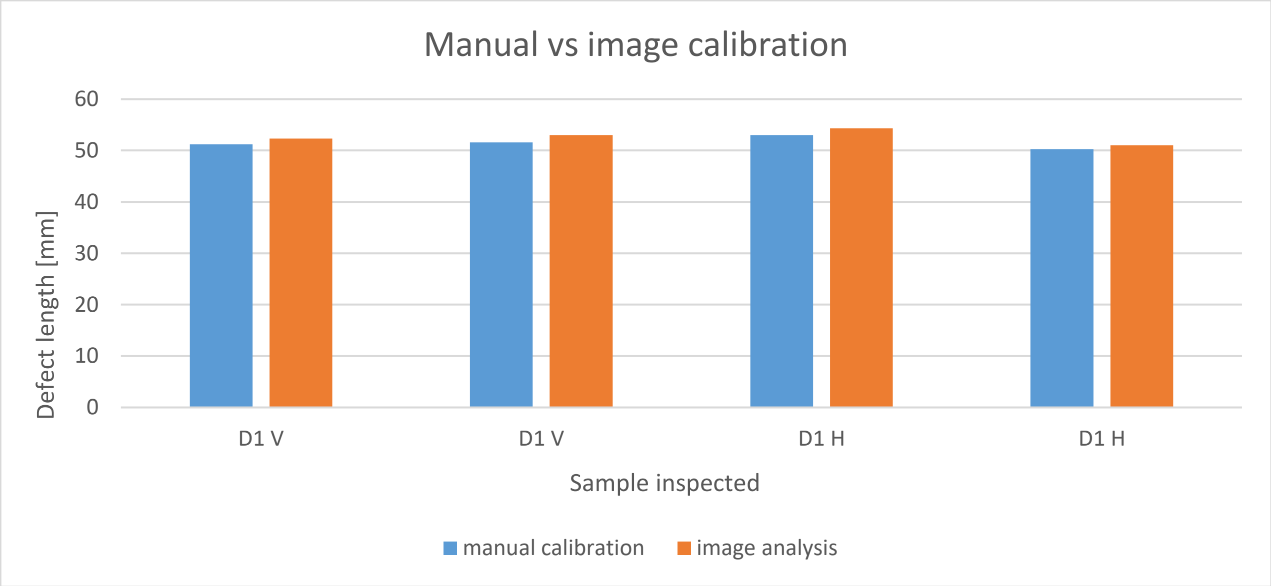


Fig. 38. Comparison between defected length measured in real fabric sample and under image analysis

b) Defected holes analysis

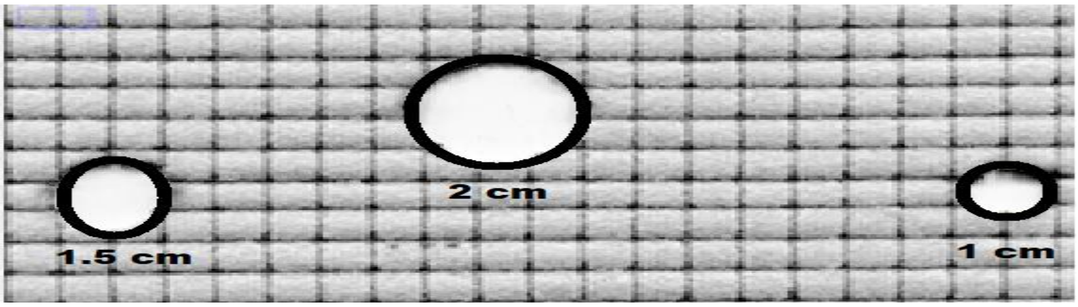


Fig. 39. Defected holes under the scanner

As seen in the last section, the no. of pixels and distance is analysed and detected by the software we use. Now that the Analysis is about the holes in the fabric, three holes are shown in the Analysis, (Fig. 39) the holes (left to right) has diameters of 15[mm], 10[mm] and 20[mm]; which is emphasised using circular boundary in Fig.39.

For manual calibration of the hole here, we need to calculate the void space as shown below:

Area of circle = πr^2...(where π=3.14 and r is the radius in [mm]) [19]

1. Area of D2 10 : 3.14 × 5 × 5 = 78.5 [mm] (radius r is 5 [mm])
2. Area of D2 15 : 3.14 × 7.5 ×7.5 = 176.62 [mm] (radius r is 7.5 [mm])
3. Area of D2 20 : 3.14 × 10 × 10 = 314 [mm] (radius r is 10 [mm])

Table. 11. Results obtained from the void analysis

Label	Diameter [mm]	The area manual calibration [mm]	The area by image analysis		Length of holes under image analysis(pixels)				Length in inches	Grade
			pixels	[mm]	1	2	3	Average		
D2 20	20	314	1240	328.2	81.3	79.3	79	80.10	0.83	2
D2 15	15	176.62	713.3	188.7	52.9	54.9	53	53.77	0.55	2
D2 10	10	78.5	305.3	80.7	39.9	40.1	38	39.4	0.41	2

The three holes were made manually, and the measured radius of the hole is known, now to calibrate the area of the void as calculated in this section the known radius is taken; later the image analysis tool is used to calculate three multiple results of the area of the void space to obtain precise results. The result of image analysis is obtained in pixels, later then converted into the dimension of [mm]. To show the comparison of the manual inspection and calibration from the software, a graph is plotted here Fig.41, which shows that the difference between defect diameter measured in sample and image is small.

Here, there are three holes which are measured using the tool, as discussed under section 3.2.2. Also, the fabric is graded with 2, as defected holes with flaws up to 1 inch is given this grade, according to standard ASTM D 5430-04 four-point fabric analysis.

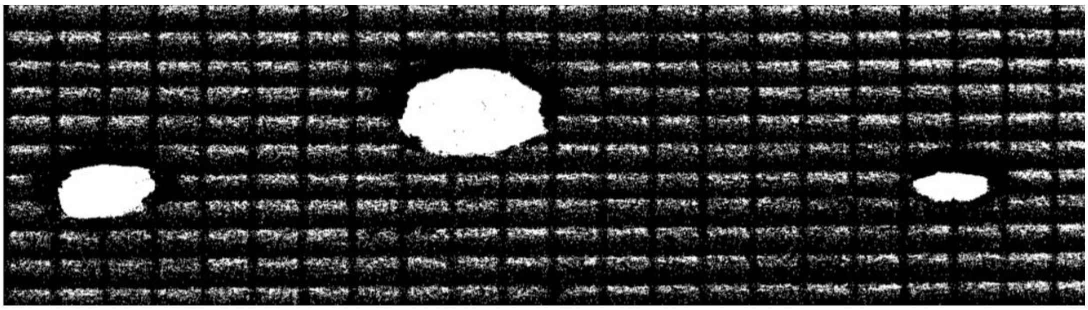


Fig. 40. Holes in fabric analysed adjusting the threshold level

The other easy method of analysing the defects in the fabric is to adjust the threshold level by the software which can easily detect any void or deformities in the material examined and with the help of the background colour change the deformed structure shows noticeable results of being different thus resulting in the void or holes in the tested sample, the fabric is changed to 8-bit type from RGB for better image analysis and a better result; however, the method illustrated in Fig.40 can also be used.

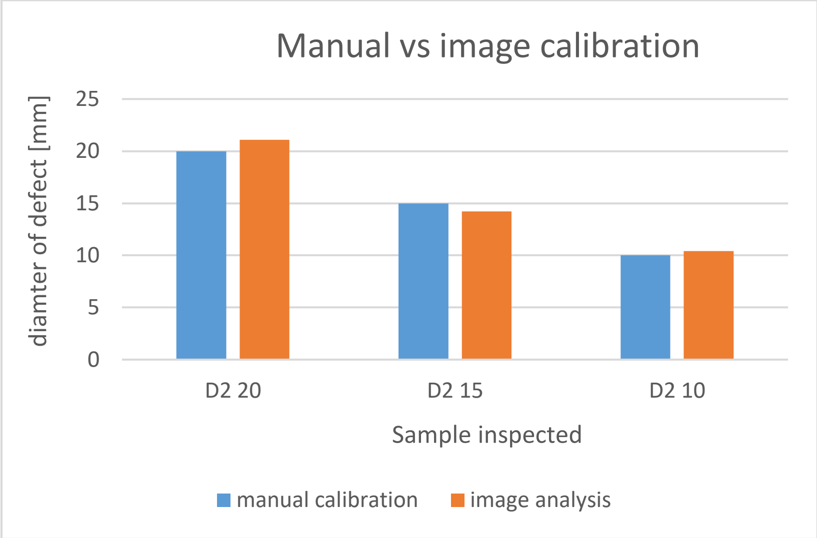


Fig. 41. Comparison between defect length diameter measured in real fabric sample and image analysis

c) Oil stain analysis

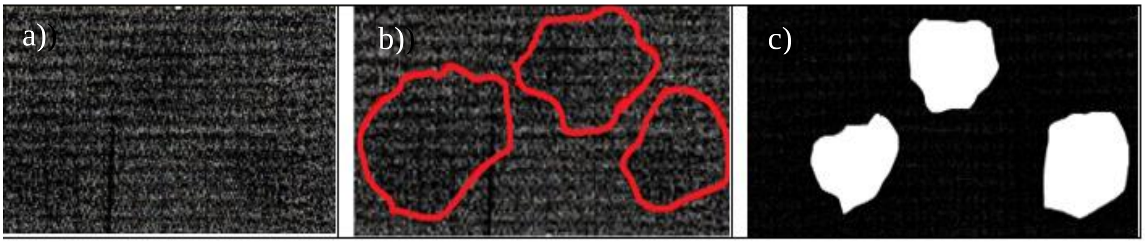


Fig. 42. Oil stained a) observed under scanner; b) stains bordered; c) structure eroded in the software

The scanned fabric sample is taken for Analysis under software, and the oiled area has put a boundary with the clear boundary line, the fabric is changed to 8-bit type from RGB for better image analysis, and the periphery of the oiled area is calculated to estimate the area of the stain. The oil stain is measured(Fig.42); the length of the stain is considered here for the inspection of the defect with reference to standard grading. The oil stains are to be measured using the length tool; the measurements are made horizontally and vertically over the stains. Multiple measurements are taken, and then the biggest length of the defect is considered for the Analysis.

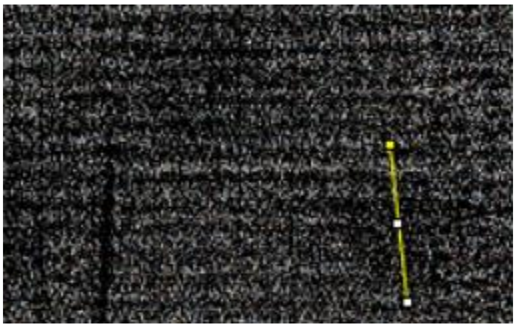


Fig. 43. Measuring the length of the oil stain

Table. 12. Results obtained from oil stain analysis

Label	Stain length (mm)	Length in pixel after image calibration				Length in mm(image analysis)				Grade
		1	2	3	Average	1	2	3	Average	
D3O	45	190	165	175	176.6	50.2	43.6	46.3	46.7	1
D2O	29.5	111	120	109	113.3	29.3	31.75	28.8	29.95	1
D2O	30	108	116	124	116	28.5	30.69	32.8	32.8	1

After dripping the oil on the fabric, it tends to spread due to its viscous nature, and this leads to the irregular shape of stain and the stain is deep in the centre region than at the boundary area. When the material was observed after some time, let in room temperature, the colours slowly started to disappear and lightened due to absorption [21].

In some cases, the stains were disappeared, leaving no traces of flaws. It is recommended scanning the material only after it gets dried sufficiently without fresh oil stains. Some fabrics have the natural way of repelling oil stains, as discussed in section 3.1.4. once the material is scanned marked the boundary of the stain, as shown in Fig .43(b). The graph (Fig.44) shows the variation of the manually inspected dimension and length analysed by *Image J* software. According to the ASTM D 5430-04, four-point grading the lengthy defect till 3 inches and up to 75 [mm] is awarded a point of 1.

The oil stain defect is analysed by measuring the length of the oil stain, as seen in the image acquisition method. Though the area of the oil stain in calculated, to grade the fabric the measurement of the length of the oil stain is essential and hence a three continuous measurement of the lengthy defect is calculated and compared with the manually inspected length of the stain later depicted in the graph.

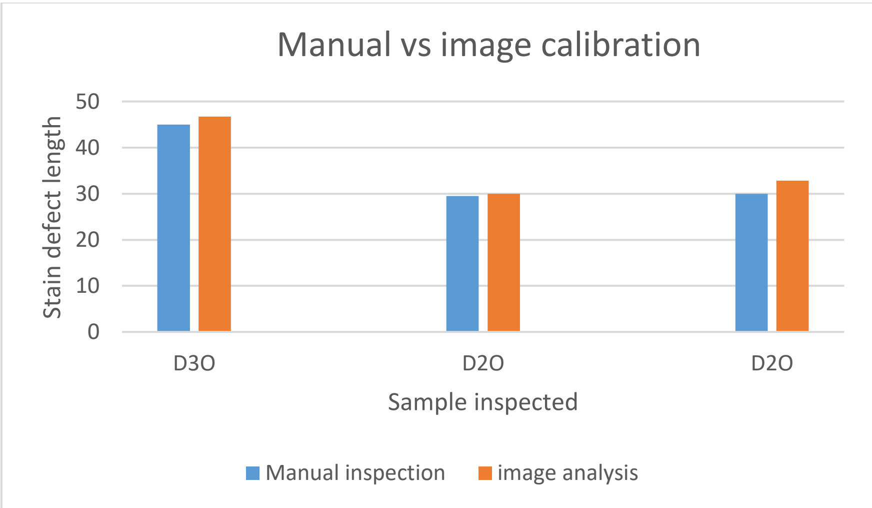


Fig. 44. Comparison between stain defect length measured in real fabric sample and image analysis

3.3.2. Analysis of the defect of sample F2

a) Coloured defect analysis

The fabric here for Analysis is first converted into 8-bit type since the colour of the fabric is pink, which is neither white nor black, so the conversion of this coloured fabric type to 8-bit is the primary requirement.

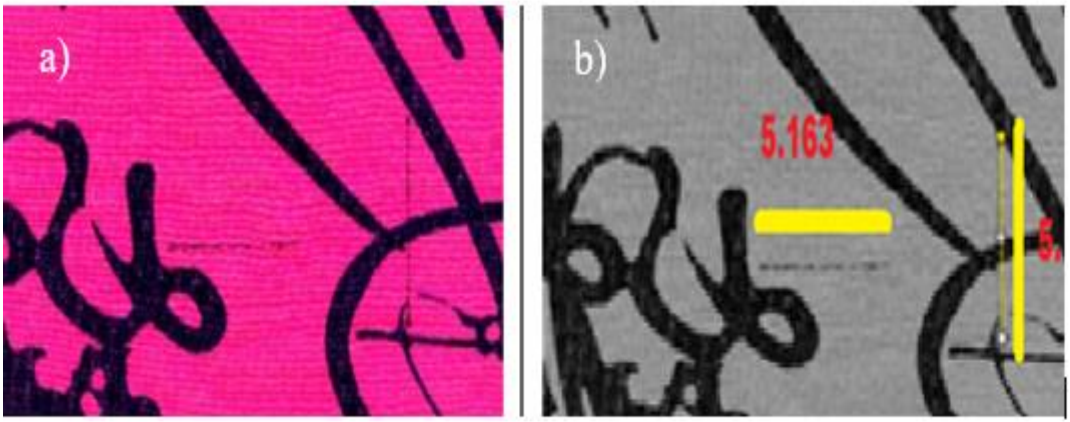


Fig. 45. Coloured defect a) primary image; b) binary image

The lined coloured defects are taken for Analysis, these defects are seen as black lines, but since the fabric also has some designs in the material, it becomes difficult to detect the fabric however the lined defects are shown differently with the design since it stands out as a unique kind of deformities among the design present in the fabric.

Table. 13. Results obtained from the coloured Analysis

Label	Sample defect length (mm)	Image defect length in pixels				Length in mm (image analysis)				Grade
		1	2	3	Average	1	2	3	Average	
D1 H	51.6	193	195	192	193.3	51.0	51.5	50.8	51.1	1
D1 V	50.3	187	186	188	187	49.4	49.2	49.7	49.4	1

In Fig.45, there is one horizontal and one vertical coloured defects, which is measured using the tool as discussed under section 3.2.2. Also, the fabric is graded with 1 according to standard ASTM D 5430-04 four-point fabric analysis. As we can see from Fig.45 the material is pink in colour and highly contrasted, adjusting colour threshold is required for this material. To make sure that other kinds of flaws do not erupt out of the material, it's very much recommended to pass the binary filter process. Binary image of this material can clearly show the defect precisely (Table 9-F2).

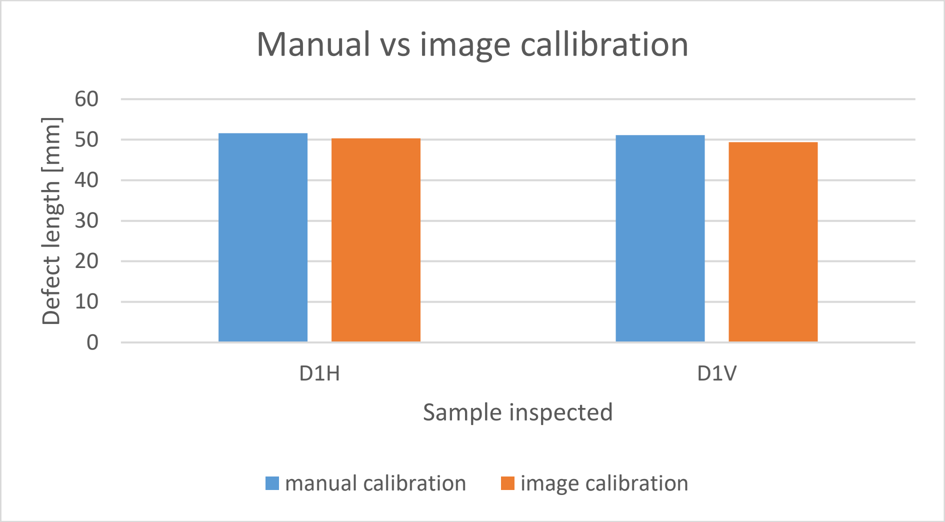


Fig. 46. Comparison between defected length measured in real fabric sample and under image analysis

From Fig.46, the graph shows the comparison between defect length measured in the fabric sample and image analysis performed by *Image J* software analysis. The graph clearly shows that the analysed length by image analysis and manual measurement is relatively the same. Moreover, an accurate result of the length is shown by the average of the pixels analysed by image analysis. For the results to be the accurate and precise manual measurement from the Table.13 is taken as reference and compared with distances which are calculated three times as seen in the table and then taken average, then these pixel distance are converted into [mm] dimensions from the reference; manually inspected length is taken in [mm].

b) Defected holes analysis

Now that the analysis is about the holes in the fabric, three holes are shown in the analysis, Fig .47). The holes (left to right) has diameters of 10 [mm], 20 [mm] and 15 [mm]; which is emphasised using circular boundary in the Fig 3.36.

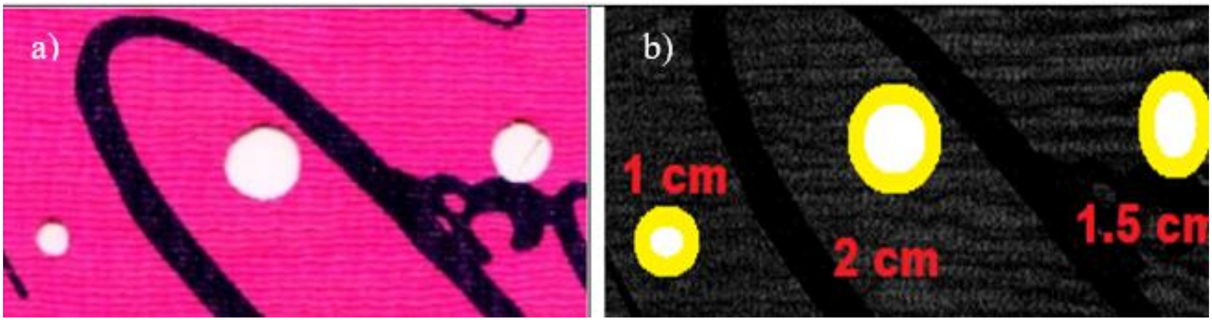


Fig. 47. Defected holes under scanner a) before; b) after binary filter

For manual calibration of the hole here, we need to calculate the void space as shown below:
Area of circle = πr^2..(where π=3.14 and r is the radius in [mm]) [19]

4. Area of D2 10 : 3.14 × 5 × 5 = 78.5 [mm] (radius r is 5 [mm])
5. Area of D2 15 : 3.14 × 7.5 ×7.5 = 176.62 [mm] (radius r is 7.5 [mm])
6. Area of D2 20 : 3.14 × 10 × 10 = 314 [mm] (radius r is 10 [mm])

Table. 14. Results obtained from the void analysis

Label	Diameter [mm]	The area manual calibration [mm]	The area by image analysis		Length of holes under image analysis(pixels)				Length in inches	Grade
			pixels	[mm]	1	2	3	Average		
D2 20	20	314	1238	327.5	79.9	79.3	76	78.4	0.81	2
D2 15	15	176.62	698.5	184.8	50.9	52.8	52	51.9	0.54	2
D2 10	10	78.5	310.3	82.10	38.9	39.1	37	38.3	0.39	2

Here, there are three holes, which is measured using the tool, as discussed under section 3.2.2. Also, the fabric is graded with 2, according to standard ASTM D 5430-04 four-point fabric analysis. As we can see from Fig.47 the material is pink in colour and highly contrasted, adjusting colour threshold is required for this material. To make sure that other kinds of flaws do not erupt out of the material, it's very much recommended to pass the binary filter process. Binary image of this material can clearly show the flaw since the void defect is easy to detect here (Table 9-F2).

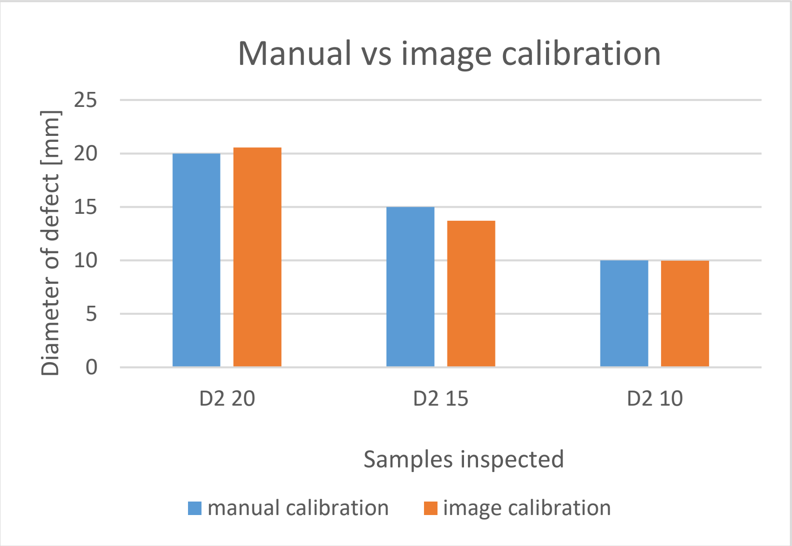


Fig. 48. Comparison between defect length diameter measured in real fabric sample and image analysis

To show the comparison of the manual inspection and calibration from the software, a graph is plotted here Fig.48, which shows that the difference between defect diameter measured in sample and image is small. For comparison, the image analysed diameter is converted from inches to [mm].

3.3.3. Analysis of the defect of sample F3

a) Coloured defect analysis

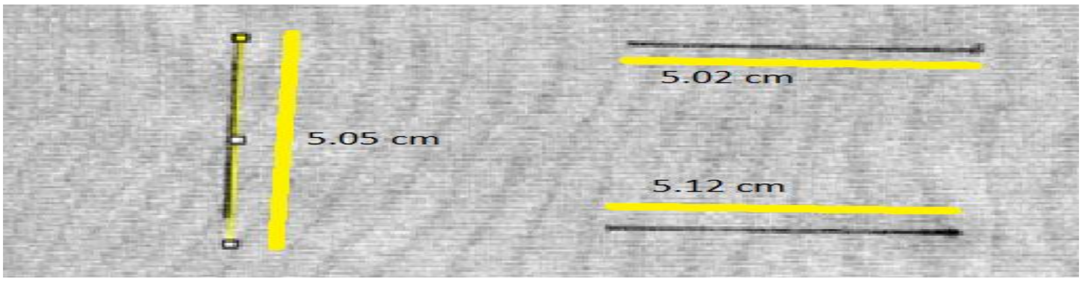


Fig. 49. Coloured defects under the scanner

The coloured defects here are made using the dark markers since the fabric is bright in colour and the same is analysed under the software and results are obtained as seen in the table here with the calculations of the coloured markings made, the graph made here is the Analysis of the defect length compared (Fig.49). In Fig .49, there are two horizontal and one vertical coloured defects, which is measured using the tool as discussed under section 3.2.2. Also, the fabric is graded with 1 according to standard ASTM D 5430-04.

Table. 15. Results obtained from the coloured analysis

Label	Sample defect length (mm)	Image defect length in pixels				Length in [mm](image analysis)				Grade
		1	2	3	Average	1	2	3	Average	
D1 H	50.2	186	188	189	187.6	49.2	49.7	50.0	49.6	1
D1 V	50.5	192	189	191	190.6	50.8	50.0	50.5	50.4	1
D1 H	51.2	194	201	195	196.6	51.3	53.1	51.5	51.9	1

As we can see from Fig.49, the background of the material is white, and the defect is clearly visible in black colour, adjusting colour threshold is not required for this material. However, to make sure that other kinds of hidden flaws do not erupt out of the material its recommended to pass the binary filter process (Table 9-F3).

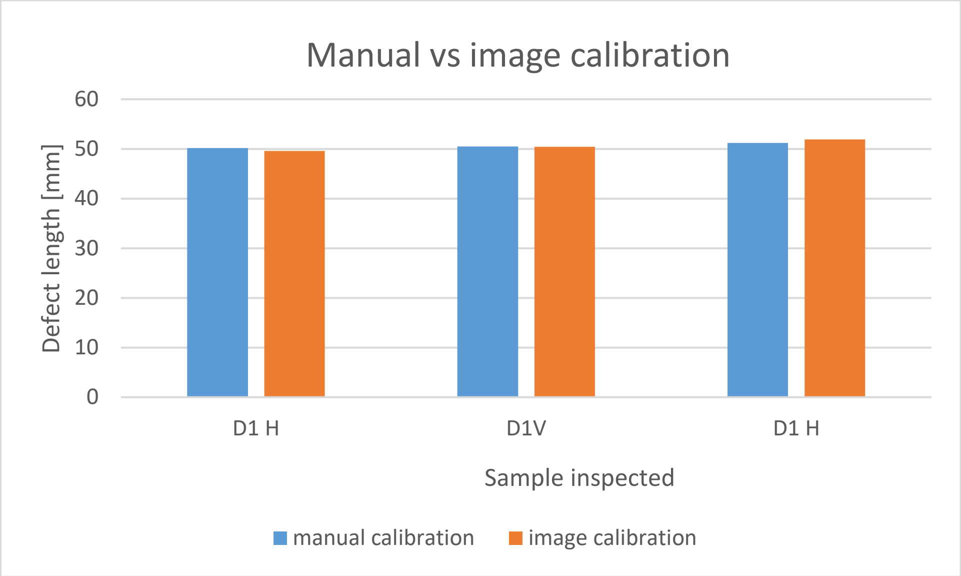


Fig. 50. Comparison between defect length measured in real fabric sample and image analysis

From the graph, it is evident that there is only negligible difference obtained and image analysis gives more precise measurement compared with human calibration method, and relatively here both have only a little variation.

b) Defected holes analysis

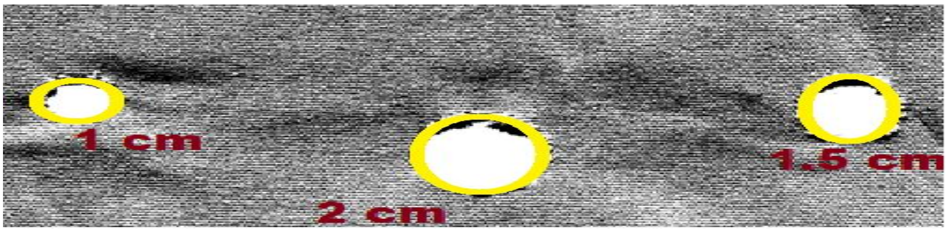


Fig. 51. Holes in fabric analysed adjusting the threshold level

With the help of the background colour change the deformed structure shows very clear results of being different thus resulting in the void or holes in the tested sample, the fabric is changed to 8-bit type from RGB for better image analysis and a better image result.
For manual calibration of the hole here, we need to calculate the void space as shown below:

Area of circle = πr^2...(where π=3.14 and r is the radius in [mm]) [19]

1. Area of D2 10 : 3.14 × 5 × 5 = 78.5 [mm] (radius r is 5 [mm])
2. Area of D2 15 : 3.14 × 7.5 ×7.5 = 176.62 [mm] (radius r is 7.5 [mm])
3. Area of D2 20 : 3.14 × 10 × 10 = 314 [mm] (radius r is 10 [mm])

Table. 16. Results obtained from the void analysis

Label	Diameter [mm]	The area manual calibration [mm]	The area by image analysis		Length of holes under image analysis(pixels)				Length in inches	Grade
			pixels	[mm]	1	2	3	Average		
D2 20	20	314	1135	300.3	77	80	79	78.6	0.81	2
D2 15	15	176.62	696	188.1	52.8	51	53	52.2	0.56	2
D2 10	10	78.5	339	89.6	39.6	38.9	39	39.1	0.40	2

Here, there are three holes, which is measured using the tool, as discussed under section 3.2.2. Also, the fabric is graded with 1 according to standard ASTM D 5430-04 Four-point fabric. As we can see from Fig.51, the background of the material is white, and the defect is clearly visible in black colour, adjusting colour threshold is not required for this material. However, to make sure that other kinds of flaws erupt out of the material, it's very much recommended to pass the colour threshold filter process. Binary image of this material can clearly show the flaw since the hole is very clear to observe (Table 9-F3).

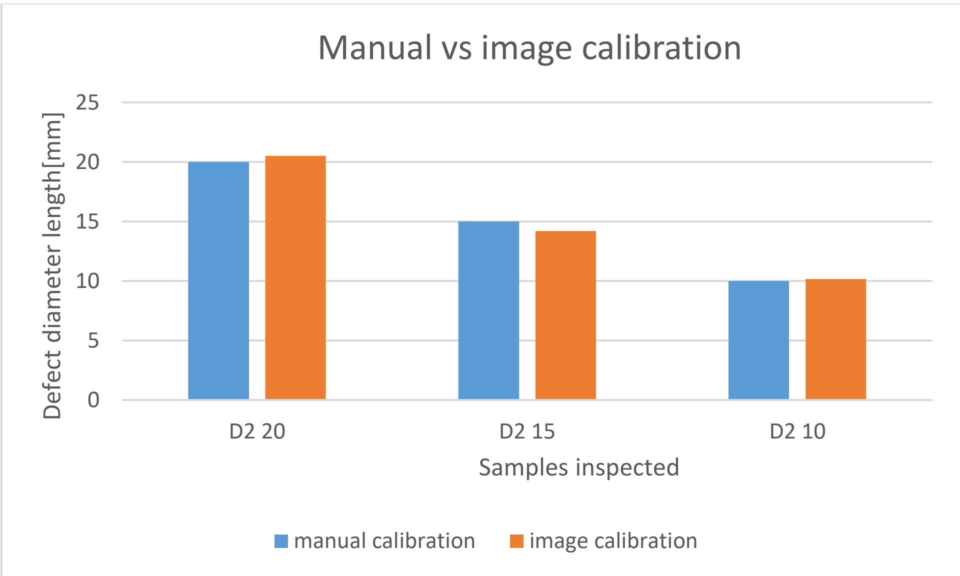


Fig. 52. Comparison between defect length diameter in real fabric sample and image analysis

A graph is plotted here Fig.52, which shows that the difference between defect diameter measured in sample and image is small. For the purpose of comparison, the image analysed diameter is converted from inches to [mm].

c) Oil stain analysis

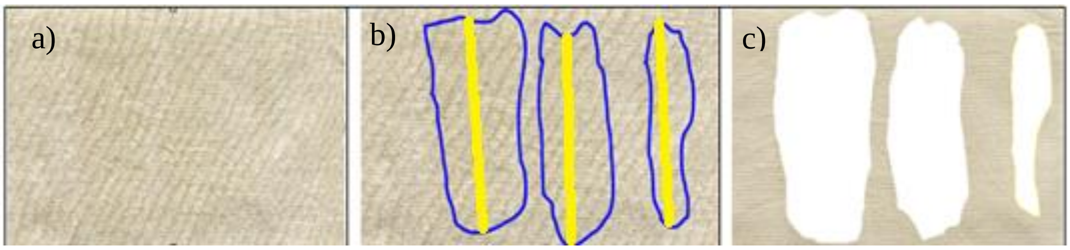


Fig. 53. Oil stained a) sample under scanner; b) measuring the bordered stains; c) oiled structure eroded in the software

The scanned fabric sample is taken for Analysis under software, and the oiled area has put a boundary with the clear boundary line, the fabric is changed to 8-bit type from RGB for better image analysis, and the boundary of the oiled area is calculated for area stained. The oil stains are measured using the length tool; the measurements are made horizontally and vertically over the stains. Multiple measurements are taken, and then the biggest length of the defect is considered for the analysis (Fig.53). Some fabrics have the natural way of repelling oil stains, as discussed in section 3.1.4. once the material is scanned marked the boundary of the stain, as shown in Fig .53 (b). The graph here shows the variation of the manually inspected dimension and length analysed by *Image J* software. According to the ASTM D 5430-04, four-point grading the lengthy defect till 3 inches and up to 75 [mm] is awarded a point of 1

Table. 17. Results obtained from oil stain analysis

Label	Stain length (mm)	Pixel length after image calibration				Length in mm(image analysis)				Grade
		1	2	3	Average	1	2	3	Average	
D3O	52	190	194	188	190.6	50.2	51.3	49.7	50.4	1
D3O	48	177	180	183	180	46.8	47.6	48.4	47.6	1
D3O	46	170	175	173	172.6	44.9	46.3	46	45.7	1

After dripping the oil on the fabric, it tends to spread due to its viscous nature, and this leads to the irregular shape of stain and also the stain is deep in the centre region than at the boundary area. When the material was observed after some time, let is room temperature, the stains slowly started to disappear and lightened due to absorption [21]. In some cases, the stains were totally disappeared, leaving no traces of flaws. It's recommended scanning the material only after it gets dried sufficiently without fresh oil stains. Some fabrics have the natural way of repelling oil stains, as discussed in section 3.1.4. once the material is scanned mark the boundary of stain and measure the lengthy defect as shown in Fig.53 later erode the area with the use of software for a clearer vision of oil stain.

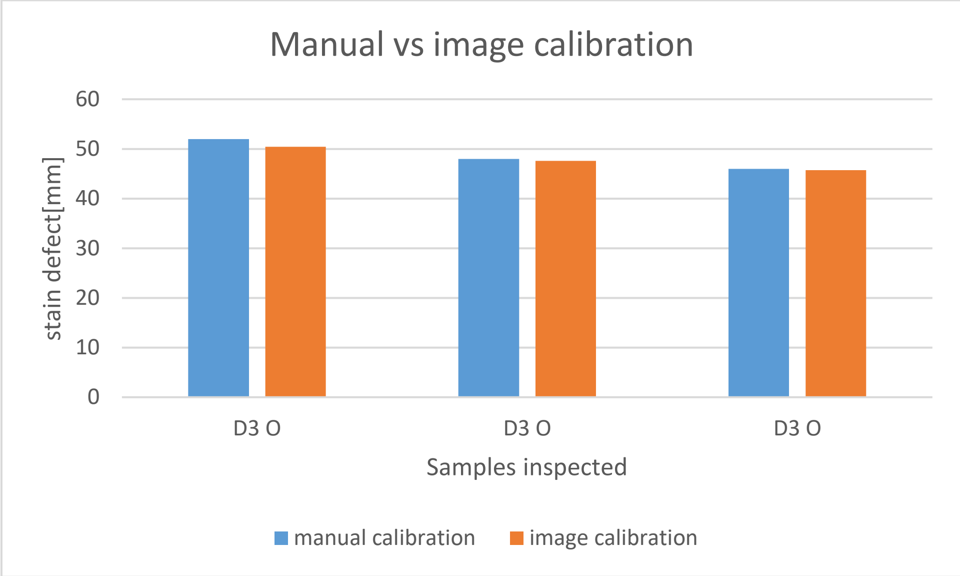


Fig. 54. Comparison between stain defect length measured in real fabric sample and image analysis

3.3.4. Analysis of the defects of sample F4

a) Coloured defect analysis

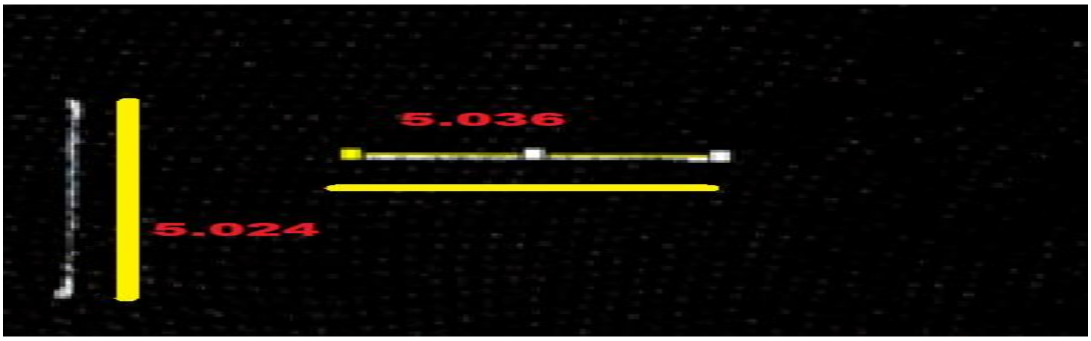


Fig. 55. Coloured defects

The fabric here is in black in which we used whitener for making coloured defects, and then we analysed it under the scanner.

Table. 18. Results obtained from a coloured analysis

Label	Sample defect length (mm)	Image defect length in pixels				Length in mm(image analysis)				Grade
		1	2	3	Average	1	2	3	Average	
D1 H	50.36	193	190	192	198	51	50.2	50.8	52.3	1
D1 V	50.24	189	191	188	201	50	50.5	49.7	53	1

In Fig .55, there is one horizontal and one vertical coloured defects measured using the tool as discussed under section 3.2.2. Also, the fabric is graded with 1 according to standard ASTM D 5430-04 four-point fabric analysis. As we can see from Fig.55, the background of the material is black, and the defect is clearly visible in white colour, adjusting colour threshold is not required for this material.

From Fig.56, the graph shows the comparison between defected length measured in the fabric sample and image analysis performed by *Image J* software analysis. The graph clearly shows that the analysed length by image analysis and manual measurement is approximately the same with little difference. For the results to be the accurate and precise manual measurement from the Table.18 is taken as reference and compared with distances which are calculated three times as seen in the table and then taken average, then these pixel distance are converted into [mm] dimensions since the reference; manually inspected length is taken in [mm].

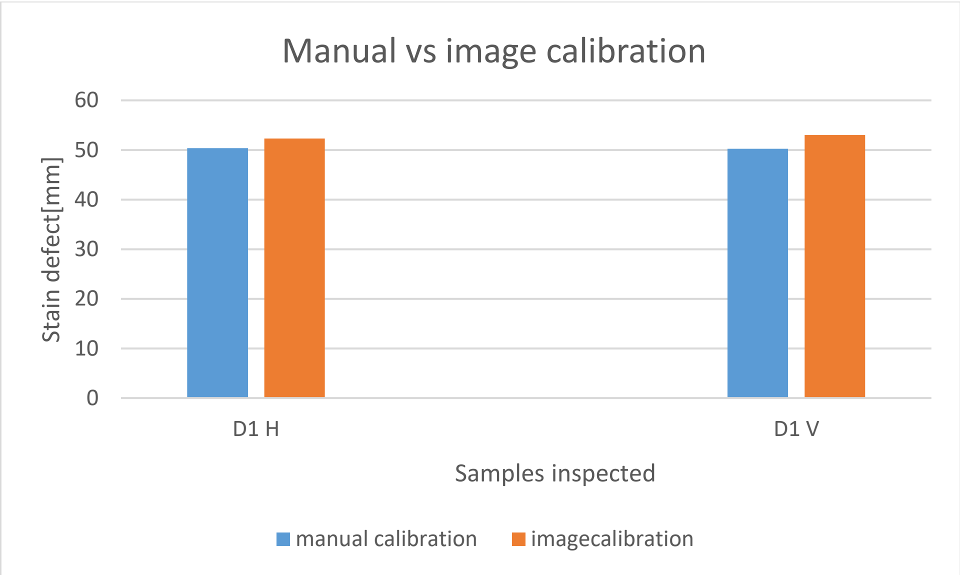


Fig. 56. Comparison between defect length measured in real fabric and sample under image analysis

b) Defected holes analysis

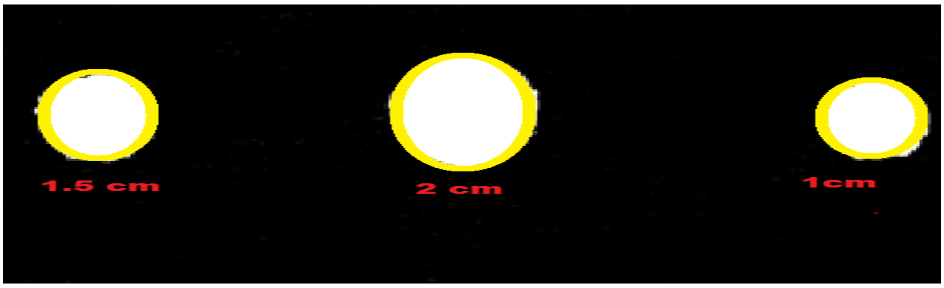


Fig. 57. Defected holes under the scanner

In the same way that we saw in all the previous section here also we calculate the area obtained due to holes and analyse using the software.

For manual calibration of the hole here, we need to calculate the void space as shown below:
Area of circle = πr^2...(where π=3.14 and r is the radius in [mm]) [19]

1. Area of D2 10 : 3.14 × 5 × 5 = 78.5 [mm] (radius r is 5 [mm])
2. Area of D2 15 : 3.14 × 7.5 ×7.5 = 176.62 [mm] (radius r is 7.5 [mm])
3. Area of D2 20 : 3.14 × 10 × 10 = 314 [mm] (radius r is 10 [mm])

Here, there are three holes, which is measured using the tool, as discussed under section 3.2.2. Also, the fabric is graded with 2 according to standard ASTM D 5430-04 four-point fabric analysis. As we can see from Fig.57, the background of the material is white, and the defect is clearly visible in black colour, adjusting colour threshold is not required for this material. The comparison graph for the defect diameter measured manually, and through the image, Analysis is presented here(Fig.58).

Table. 19. Results obtained from the void analysis

Label	Diameter [mm]	The area manual calibration [mm]	The area by image analysis		Length of holes under image analysis(pixels)				Length in inches	Grade
			pixels	[mm]	1	2	3	Average		
D2 20	20	314	1152	305	75	81	76	77.3	0.80	2
D2 15	15	176.62	695	184.1	54.5	53	52	53.1	0.55	2
D2 10	10	78.5	321	85	40.1	39.1	39	39.4	0.41	2

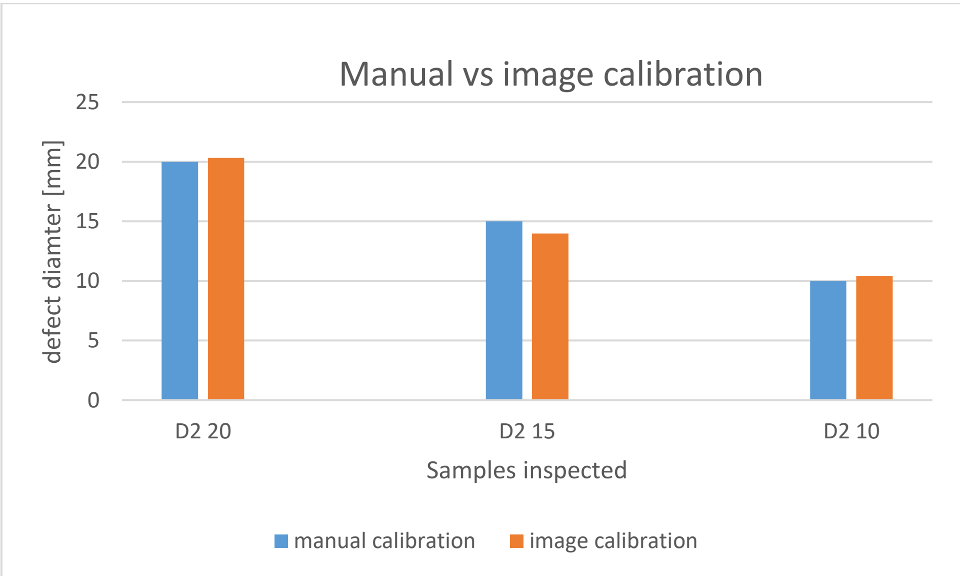


Fig. 58. Comparison between defect length diameter measured in real fabric sample and image analysis

4. Examining the proposed method

Presently the textile industry uses various methods to detect flaws, to have a better understanding of the proposed image analysis technique in this report let us analyse the machine that is used presently in the market. ASTM D 5430-04 standard is being used in the company considered here in our report, so let us analyse the same for a better understanding and comparison with the proposed system. The pros and cons of the machine will give a clear view on how the proposed system can be beneficial to the company using Ramson‘s Checkmate machines.

Benefits of using the *Ramson‘s Checkmate fabric inspection machine*:

1. The machine allows the labour to detect the defects under the light provided overhead to the machine.
2. The speed controller of the fabric rolling speed makes the labour control the speed of the fabric to be examined at speed comfortable to the labour for visual inspection.
3. The wide board to accommodate the fabric to be inspected made it easy to look at all the flaws quickly.
4. The illumination of light provided in this version is comparably brighter, making the detection process easy.

Drawback with the *Ramson‘s Checkmate fabric inspection machine*:

1. The quality inspection is carried through the machine overviewed by a human where the labour‘s visual inspection plays the major role in making the quality inspection dependant totally on human eyes.
2. The fabric inspection sometimes is carried out in a faster way, and at times the process goes slow due to the fatigues of labour.
3. The process, at times, misses some of the major flaws due to optical illusion and stress in the visual power of the labour.
4. The patterned fabric with variable designs and colours at times makes the visual inspection difficult to identify the flaws with bare human eyes.
5. The time of the inspection is not guaranteed at times, making the delivery process delayed due to the status of labour‘s physical conditions.

Efficiency of Ramson‘s Checkmate fabric inspection machine:
This machine stands as a tool to detect fabric defects in an epitaxial layer only and is mostly dependant on the visual inspection of human beings. The quality inspection is carried out using this machine, but the work is time taking and assuring the detection of all flaws can not be guaranteed. To deliver the goods at the final outlet the quality tag is very important since the process takes much time the overall production time in the unit is also debatable.

Ramson‘s Checkmate fabric inspection machine with the proposed image analysis system:
After analysing the machine used here for inspection, the efficiency or the capacity of the Ramson‘s fabric inspection machine seems to be much dependant on the human visual inspecting skills entirely. This process is supplemented with the image analysis system proposed in this report could accelerate the process by increasing the fabric amount inspected. The system proposed here was performed in

laboratory setup, for implementing the same in industries requires setup of large scanners and big screens. The *Image-J* software plays the main role in the analysis of the flaws here, with better methods of scanning suitable for large industrial purposes it could serve as an efficient tool. This method can be performed with more ease if the image scanning is done using scanners which can scan the materials in large quantity for industrial production. The scanned material if viewed on big screens can be more efficient in finding the flaws since the defects, even if minor, is enlarged on the screen. The experiment we performed here was under laboratory setup which if done with big scanners and viewed under big screens for example high resolution 4K HD projectors with best quality in the market can make the process, even easier and time-efficient. The incorporation of the *Image J* software method to analyse the flaws expels the error obtained due to dimensional differences, optical error and error due to human flaws. Large screen can show even minor flaws easily after the application of the filters. The scanning of the fabric material can also be tried using high-quality cameras specially designed for a quality inspection system, as shown in Fig.59.

Fig.59. QEYE cameras designed for quality inspection

QEYE cameras can be used for our proposed method for capturing the image with more precision; these cameras were designed especially for quality inspection in the textile industry which comes with smart dertection of coloured variation flaws, holes and cuts.

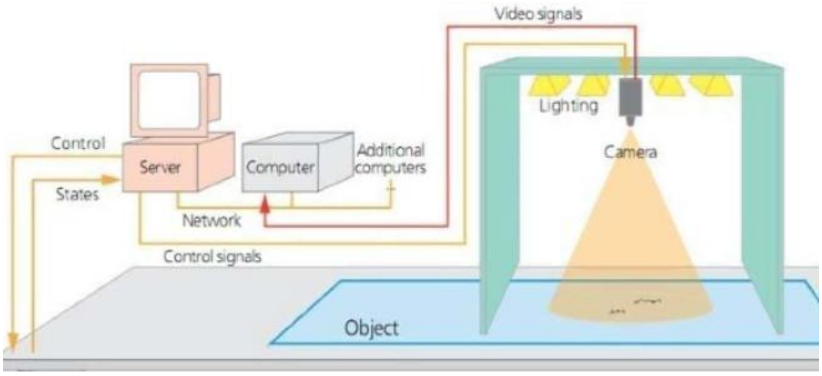


Fig.60. Systematic set up to capture the image of the fabric

Fig.60 shows the schematic version of capturing the images with the QEYE cameras; this setup can be used for the proposed method of image analysis for image acquisition process. Image clarity and large screens are the important factors for inspection. Also good lighting is key factor for image clarity, these kind of setup can boost the proposed method efficiently.

Current scenario in the automated industry:

In today‘s automated industrial environment, the company can update its quality inspection by introducing automated system like Fabriscan which can inspect fabric at a speed of 120 m/min which can identify defect to a range of 0.3 [mm], further the defects are marked using paper tag labels and ink, but it can not measure colour variation flaws and other different defects. However, some fully-automated fabric inspection machine-like IQ-TEX system can measure defects less than 0.1 [mm] and identifies defects at a speed of 1000 m/min. IQ-TEX uses real-time operator alert at each stage of manufacturing then and there itself and the algorithmic software to detect the flaws makes the process efficient [22].

Efficiency of the proposed system in comparison with the present system in the industry:

Let us consider the Ramson‘s checkmate, fabric inspection machine as the present system in the industry; the proposed system can be supplemented with this system since it requires very less investment and almost no cost for the software used. The Ramson‘s checker from the company fails to detect the defects in an efficient way due to paradoxical error in labour‘s visual inspection and other physical fatigues as reasons. The proposed system can eliminate this drawback and accelerate the process in a more efficient way and also in a cost-efficient way.

Efficiency of the proposed system in comparison with the automated industry:

Automated machines like IQ-TEX, cyclops and many other machines can make the process of defect detection very easily, and much labour is not required for the operation. With IOT, the whole process can be monitored from any corner of the world. The deal here is cost, the automated machines though quite efficient may not be affordable by all the upcoming industries in the globe, the image inspection system proposed in this report is comparably very less and understandable by labours with basic computer skills. Automated machines require advanced skills like cloud computing, IOT and artificial intelligence knowledge but the proposed system is a basic software and does not need labour mastered in computer skills and is quite user friendly which can be taught to labours with basic skills.

Managerial aspect of introducing the proposed system in the company:

The system is cost-efficient and does not need many skilled operators. The system serves as the supplement tool efficiently without affecting the company‘s finance. A company‘s standard and position in the business is determined by its quality in products. If the company discussed in chapter 2 uses this method, it can be more efficient in its production unit and deliver quality goods in less time. Also, it can focus on manufacturing new designs and not fear of losing its market position due to low quality. This is the only fear that the company fails to invest in women’s garment. As analysed about the company, it is an upcoming company, and huge investments on fully automated inspection machines can be a big challenge. To these companies with existing automated inspecting machines like Ramson‘s checker, the image analysis system can be a supplement option with which amenities like big scanners and monitors can be proved to be more efficient. If this proposed method of quality inspection is introduced, it could make the company earn significant profits and concentrate on improving their design ideas without the fear of quality issues. Also, it can reduce the labour cost for the quality sector by promoting this software analysis.

Conclusions

This study is done to analyse a method for inspecting quality of fabric, based on the four-point grading system and to research possibilities to use the proposed image analysis system for automated quality control management. The defects of fabric is analysed using the *Image-J* software, and the quality of the material is estimated with respect to the standard ASTM D 5430-04 four-point system. The identification of limitations is found out with the help of a real-time experience in an industrial visit to a company. If the idea is adopted, it could make the quality inspection process more efficient in the company.

1. The basic common defects (colour, hole, stain) that occur in the fabric were measured using the *Image*-J software tool; the defects were callibrated using image analysis method. The measurement standards of these defects were scaled according to the method followed in the industrial visit made to a textile company where the standards of measurement were according to Four point grading, ASTM D 5430-04 standards which is widely used in most of the textile industries presently. The company used manual visual inspection for the measurement of the defects which if automated could make the process more efficient and less time-consuming.

2. The defects were made in the colour knitted fabrics manually in the laboratory conditions. These are some of the common defects like coloured, holes and oil stains. The image acquisition process is attained here using V370 Epson scanner, which results in high resolution of the captured image. Proposed method to acquire digital image of a fabric makes the defects to be identified easily. The traditional way of analysing the material using the CCD cameras has been altered, proposing a scanner. With the tool of *Image J* software, the defects of fabric were measured and analysed in digital image. Using image analysis method, the length of different kind of fabric defects (colour, hole, stain) was estimated.

3. As seen in the experimental parts the 4 different kinds of knitted fabric were analysed for flaws using the *Image-J* software tool, the defects were measured manually by visual inspection and also with image analysis method, however, image analysis results showed more precision in calculating the defects and also the process was easy to analyse with the application of filters and other tools in the software, a human inspection can only measure the flaws visible to eyes and also the precision and accuracy of the defects analysed varied due to parallax error.

4. Detections of flaws are a top priority for quality management in the textile industry, once this process is automated the production of the industry can aim in better quality goods. The image analysis tool is proven to be more accurate, less time taking and more efficient as compared with manual inspection. Overall the production process can be shown efficient only when the produced goods reach its customers on time, with this image analysis system discussed in the report the process becomes less time taking and comparably easy; this makes the product quality better which supports in boosting the competitive strategy of the industry in the existing market. All machines that are used by industry need human to detect the defects. Only some experimental machines are proposed in the industry today for fully automated inspection. Machines are still handled by people, and this proposed concept can be proven to be an efficient method in quality management of the manufactured goods.

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Appendices

Interview with Penguin Apparels Pvt Ltd

[All the questions were discussed with Mr Jagdish Sethuraman, Assistant Managing Director, of the company]

1. What are the products you want to design in future, do you have such ideas?

2. Does the order from your customer change or remain the same?

3. Will you make your company completely automated in future?

4. Is exporting beneficial for your company?

5. Why does your company not manufacture women‘s wear and other special design?

6. How many customers you are having and who are they?

7. Will the price of the product remain the same?

8. How much waste is generated due to quality defects and what do you do with them?

9. Do you think fabric inspection a delaying factor for not delivering your goods at promised time?

10. What is the working hour in your company? Will it change based on any circumstances?