DESIGN AND DEVELOPMENT OF A MECHANISM TO IMPROVE PRODUCTIVITY IN BUGLE BEAD ATTACHING IN APPAREL INDUSTRY

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Thesis Submitted in Partial Fulfillment of the Requirements for the Degree Master of Science in Manufacturing Systems Engineering

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Declaration

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Abstract

It is quite an obvious fact that as with progress of time various types of sophisticated innovative machines are developed in the world from time to time in order to mechanize and improve the enhancement of the productivity of manufacturing processes. Weaving machine and the sewing machine are very typical examples. With the evolution of advancement in technology in the textile technology in the west have moved extensively to more developing extents, as the labor cost is relatively cheaper in these regions, mechanization was not essentially a commercially viable option. Therefore the cause for the pace of development of the industry has dropped drastically.

In this particular instance Sri Lanka has arrived at a rising labor cost and therefore it's not viable to execute all the manual operations which were previously made profitable for the business. As a result of this we were forced to be pushed towards 2 options where it was to let go these operations to cheaper destinations or invent novel innovative productive processes for these operations.

This study done was with the main objective of proposing a novel productive method for bugle bead attaching mechanism, it involves a novel method of stitching, a novel needle type. This analyses the needle head influence over the final quality, selection of thread types and possible bead releasing angles.

Acknowledgement

First and foremost, I would like to express my sincere gratitude to my main research guide, Dr.V.P.C Dassanayake. I was privileged to experience a sustained enthusiastic and involved interest from his side.

Last but not least, I would like to thank for the tremendous support given from the staff of world renowned swim wear manufacturer Linea Aqua (Pvt) Ltd for giving me the opportunity to study the drawback of current bead attaching operation and allowing me to research on novel methods of bead attaching. Further I would like to express my gratitude to MAS Linea Aqua management for giving the financial support to complete the project successfully.

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1 INTRODUCTION

1.1. Current State

Sri Lanka is a renowned destination known in the world for possessing very high quality apparel industries. Sri Lanka adapted a positive approach of expanding the apparel industry as a very fast developing industry as far back from the late seventies parallel with the open economic policies of the then government. With the blessed educated and literate dedicated work force, the nation became as the preferred destination for high quality complex apparel manufacturing factories for world's leading brands.

With the current economic trends and the higher wages, the industry was facing a severe threat of moving the industry out from the country. Countries like Bangladesh and Vietnam were becoming more popular as they possessed more competencies in technology and experience; hence this threat has exponentially increased.

Therefore the implementation of automation has become an utmost important and priority factor for the mere survival of the industry.

1.2. Background and Motivation

Attaching beads and other embellishment to an apparel is done mainly by manual means. This causes great deal of difficulties in the present Sri Lankan context due to the unavailability of sufficient trained and skilled labor force.

Sequin attaching and some other appliqué attaching techniques are automated today due to the lesser complex nature of the attaching methods. For example we can make use of pattern sewers and embroidery machines.

In particularly to Linea Aqua scenario, where the most of the high-end customers are requesting hand embellished garments, which have a great demand in the western markets. With the available capacity for hand embellishment within the Companies of the country cannot accept on all the orders coming on their way. As a temporary solution, out sourcing the embellishment operation to India could be taken as an

option, still this is not a viable precise solution as it involves a great deal of proper logistics.

In the field of apparel embellishment the embroidery techniques and machines were developed but the attaching of different shaped beads which were not properly studied and has not given sufficient interest by major machine development Companies of based under apparel manufacturing. This may be due to two main reasons.

1. Automation of the hand attaching system is extremely difficult due to the complex motion patterns involved in the attaching process.
2. World has got enough and more cheap labor sources to get a this type of jobs done without much hassle and burden

In this scenario the studying and development of a mechanism to replace the hand embellishment has a greater potential of saving the future of the countries greatly involved with the apparel industry, and it would help to achieve a truly outstanding position to be amongst the forefront in this very particular field.

Automation of the complex motion patterns of hand attaching would be difficult or impossible with the present available technologies since it needs a very high degree of dexterity. Therefore to support the operator through mechanization we need to invent a simplified motion technique process version.

When attaching the beads to a fabric hand, it involves a huge number of complex motions which are very difficult to duplicate by using a simple mechanism. Therefore finding a simplified motion pattern for the hand attaching is an important and impressive proportion of this project.

1.3. Objective

Scope of this project is to identify a cost effective, speedy innovative solution for the existing bead attaching operation whilst maintaining the same visual appearance and it is not to improve the wearer experience or any other improvement to the garment.

1.4. Methodology

This research work has a slightly different objective compared to a standard research work carried out with the intention of filling the gaps of the body of knowledge. In order to set a methodology for deriving an innovative solution for en existing consumer pain points the steps followed are novel. The effort on deriving a methodology for this research is described in chapter 2. Once the methodology is set in the following chapters the below are analyzed according to the mentioned sequence.

1. Deriving a methodology
2. Study on sub systems and their relationships / identification
3. Intellectual property landscaping
4. Solution generation (Diverge)
5. Solution selection (Converge)
6. Proving the selected solution

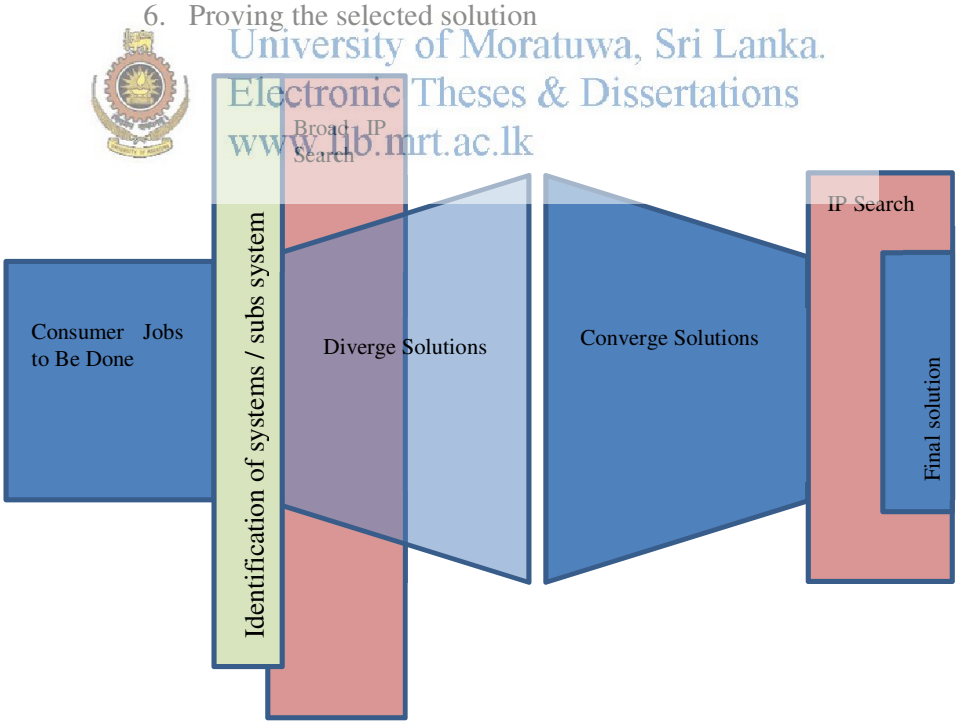


Figure 1.1 Research Methodology

1.5. Contribution

The contribution of this thesis is essentially in an attempt for the innovation of a novel mechanism for the manual beading operation in the apparel industry and thereby giving the industry a competitive clear cut edge amongst the other rival countries possessing cheap labor resources. Since there is a greater possibility of lodging a successful patent for this particular innovation the chance of securing the mechanism for the betterment of industry is much high.

As a secondary benefit this study defines a method for execution of innovation projects. Future researchers could use this as it is for their studies or as a base for the development of a standard enhanced methodology. Presenting an innovation systematically is one of the challenges most innovators faced. This approach could be used as a tool to minimize the cost of failure of a project even before developing prototypes.

1.6. Chapter Summary

A high level overview to each chapter is given below with the references.

Chapter 2

This whole section is dedicated for the identification of the real problems faced by each stake holder and a priority is set based on the importance and impact towards the final outcome. In order to execute the task; a set of tools are derived from prior work done by few scholars in different research streams. [1] [2] [3] [4]

Chapter 3

Objectives of having this section are to scientifically define the relationships between components and the contribution towards the final product, defining the design tree. The findings of this section are used in next sections to converge the wider solution spectrum into a more realistic assessable number of combinations.

Chapter 4

This section is dedicated mainly on patent search results from various online patent search engines. This is more related towards a new innovation where the possibility

of patenting is high. Even though this chapter is dedicated for prior art the research on prior art is done in every chapter to validate the assumptions made therein.

Chapter 5

This chapter is mainly focused towards the convergent of broadly defined solution spectrum into a viable set of limited solutions. Few tools are used in this chapter in order to carry out the selection process effectively. Financial viability, ease of manufacturing process smoothly and technology readiness level are taken as the main criteria for solution selection. [3] [7]

Chapter 6

This chapter is dedicated for critically analyzing the selected solutions and identifying the most suitable solution. In order to prove the concept the components or / and sub-systems selected for solutions were taken from the commercially available items, but not designing those components or systems from the scratch.

Chapter 7

This chapter describes the results and finding from the laboratory level apparatus which was built to prove the simplified bead attaching mechanism selected in the previous chapter.

Chapter 8

This chapter is dedicated for discussions, conclusions and future work.

2 PROBLEM ANALYSIS

This whole section is dedicated for the identification of the real problems faced by each stake holder and a priority is set based on the importance and impact towards the final outcome. A methodology was developed in order to execute this task in a more scientific manner rather than going with a trial and error method.

It is noted that, by thoroughly mapping the job a customer is trying to get done; a company can discover opportunities for breakthrough products services. The goal of creating a job map is not to find out how the customer is executing a job that only generates maps of existing activities and solutions. Instead the aim is to discover what the customer is trying to get done at different points in executing a job and what must happen at each juncture in order for the job to be carried out successfully [6].

This study is conducted as a two stage survey.

1. A qualitative research carried out with the involvement of expertise in respective areas. The sampling is done on the basis of judgmental sampling technique. It is important to carry out qualitative studies where improved understanding of complex human issues is more important than generalizability of results [7].

2. Quantitative analysis is used for prioritizing the gathered insights from the qualitative research and this is conducted for a larger population. The most important insight that has dominated the field of innovation studies in recent decades is the fact that innovation is a collective activity [3].

As a basic principle during the study researcher critically observed the practices at the needle point by visiting to the respective places. The lean tool “go and see it yourself” (Genchi Genbutsu) played a pivotal role on identifying the real problems confronted by the user. Observation plays an interesting and central role in the acquisition of knowledge. Observation promotes organizational learning and facilitates both employee involvement and the culture of continuous improvement. [4]

2.1. Stake Holder Survey

The initial and most vital step on the need analysis was conducting the alpha expert qualitative research. This was conducted for an audience of 6 individuals covering all angles and different hierarchical levels.

Table 2.1 Expert Survey Findings

CATEGORY	NAME	DEMERITS
Operator	Amila	Eye ache and headache if work continuously Cannot work properly during days we are stressed Always difficult to follow the plan Rejects due to dirt marks
	Sampath	Cut damages could happen Achieving the target is tough
Front end	Kapila	Loads of orders move out due to lack of capacity India has capacity and the quality is also good, still lead times are high At the moment we coordinate with sub-contractors whom are at a distance of 120km away Operator retention low in these places due to operation difficulties
	Iresha	Do not like permanent employees, these operators are not properly trained. Therefore, different operators have different skills. It affects to the quality of the product as well as the efficiency.
Industrial Engineer	Kasun	At the moment we cannot use embroidery machines for these operations due to complexity As an example, a separate mechanism is needed to hold the sequins. Also the holes of each sequin are different to one another. Therefore separate mechanisms are needed per one separate art work. Still there are no machines or mechanisms for hand attaching operations. Therefore, if we need to produce a machine/mechanism

Table 2-A 1 Expert Survey Findings Cntd.

CATEGORY	NAME	DEMERITS
Industrial Engineer	Senani	Some less complicated styles such as making ties will be better to automate. No proper machines are available for these operations since no one can meet the prices that the India is offering for manual operations. Therefore I think no one is bothered developing a new system, in our case we need this to sustain our other business The mechanisms are completely different from style to style. (stitching, braiding, pasting, making ties etc)In some styles, combinations of above mechanisms are used.

This survey covered the 360^0 of stake holder's involvement in the process of hand attaching beads to swim wear. With the help of the survey the main pain points faced by the users of the system were identified.

2.2. The Consumer Jobs to Be Done

After analyzing the results of the alpha expert survey, the followings given in Table 2-2 were identified as the consumer jobs to be done and the main pain points of the current system.

Table 2.2 Expert Survey Summary

CONSUMER JOBS
Difficulty to pass beads through the needle
Cannot work at a stretch
Difficult to take needle out piercing the back side
Painful on the eyes and headaches
Lower efficiency
Cannot predict an efficiency
Damages due to soiling
Damages due to mistakes
Damages due to unraveling

The findings of the qualitative results were validated with the help of a quantitative survey. Here the number of participants was 10. With the values given for each problem by the interviewees the final score for each problem was calculated. The final score for each problem is taken as the consumer value proposition for each of the problem.

Table 2.3 Consumer Job Priority

CONSUMER JOBS	LEVEL
Pain full on the eyes and headaches	96
Difficult to work at a stretch	94
Appearance similar to hand attaching	92
Lower efficiency	90
Damages due to soiling	88
Difficult to pass beads through the needle	86
Damages due to mistakes	80
Difficult to take needle out piercing the back side	78
Cannot predict an efficiency	78
Damages due to unraveling	64

3 DETAILED ANALYSIS

This could be taken as a continuation of the ground work on finding out the real pain points a user faces during the obligatory interaction with the current process. The key differentiator between the chapter 2 and chapter 3 is that here we use more tools to find the details of the system rather than taking them from the users.

The tools used are as below

1. Functional analysis that is to identify the relationships between each element and the actions involved in the process. The success of innovations to a large extent is determined by how the innovation system is built up and how it functions. [5]
2. Method studies and work studies are carried out at this stage for easier analysis of productivity levels and the related costs that are associated with.
3. Design tree is used to visualize the available solution for each and every problem statement

3.1. Functional analysis

The functional analysis is carried out in order to identify the relationships between each element in the current system (Competing system). There are eight sub work elements that require precision movement of hand for the final operation and execution of the task of attaching a bugle bead. Therefore for those work elements need synchronized movement between hand, and eye, and thereby the level of fatigue involved for those movements are higher. Out of eleven operations carried out by the operator eight of them require hand eye coordination. Therefore we can come to a conclusion that the level of fatigue during the execution is extremely high

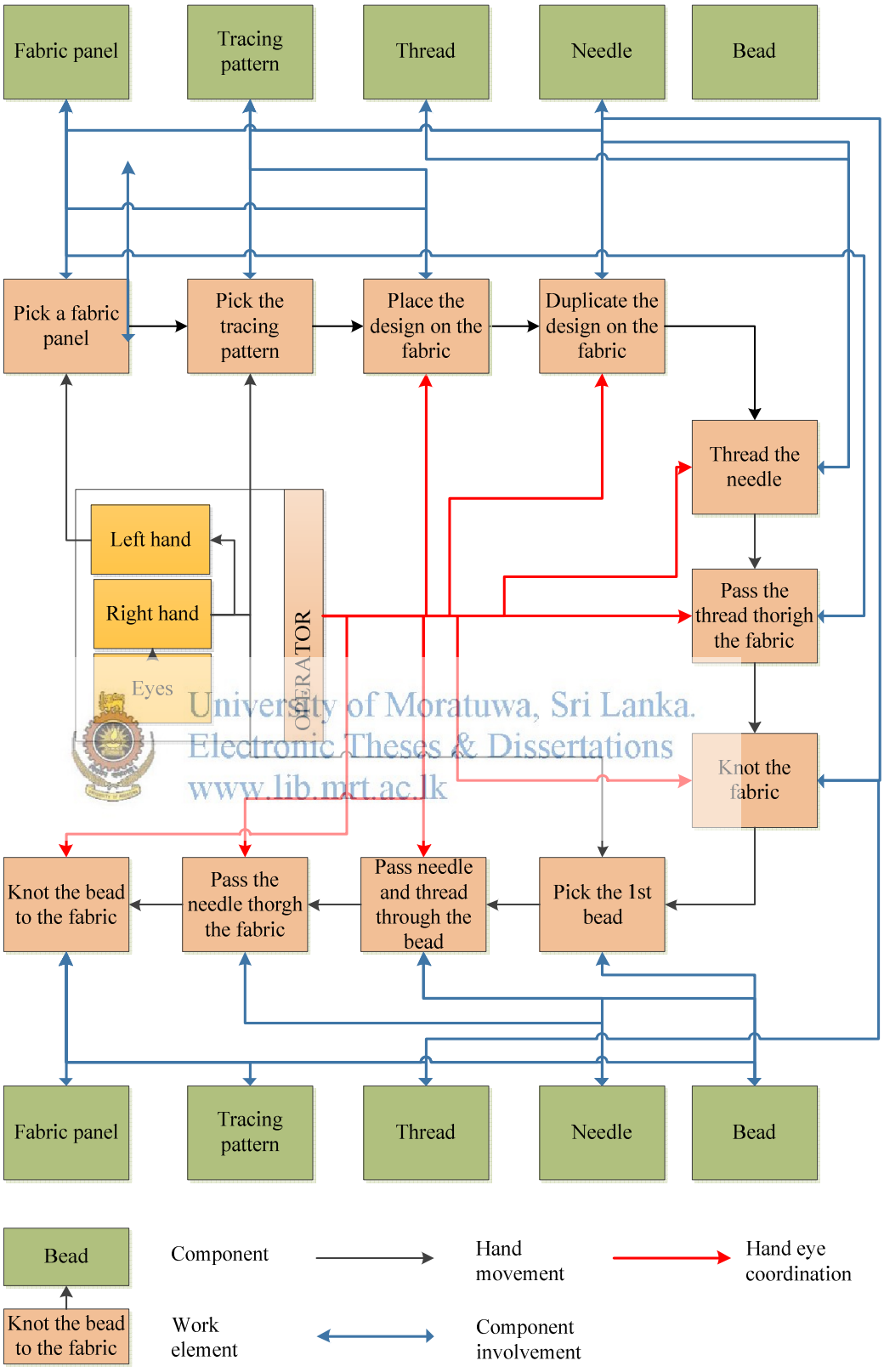


Figure 3.1 - Functional Analysis of the System

3.2. Elements and Component Analysis

In order to identify the optimal solution for this existing unresolved problem we have analyzed the components and each component's contribution and the relationship towards the final outcome.

1. Bugle bead – Bead is a decorative component that is attached to a garment by means of hand sewing with below mentioned physical properties. Bugle bead is a sub class of beads and the shape of a bugle bead is universally similar.

   Physical properties

Length	5-25mm
Diameter	1.8 – 2.1mm
Hole diameter	6.5-7.5mm

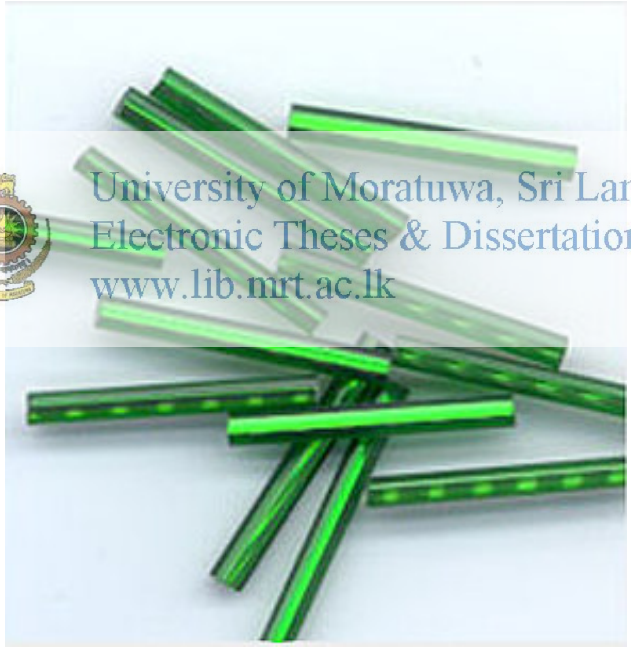


Figure 3.2 Bugle Beads

2. Hand needle is the device used to pass the sewing thread through the beads and consequently through the attaching of a bead to a fabric panel, semi-finished or a finished garment is carried out using a hand needle.

3. Fabric panel – all the beads are attached on the fabric. We can hypothetically take the fabric as a warp knit fabric, therefore we can say the fabric is anti-fray and anti-curling.
4. Design – the design to which the beads are attached on the garment. This could be the print design on the fabric or a temporary marking on the fabric for the operator to follow through and during the attaching operation.
5. Thread – this is used to fasten the beads to the fabric and uses standard industrial sewing threads of 120tkt.

3.3. Method Study

Table 3.1 Method Study

NO	MOTION		TIME(S)
	RIGHT HAND	**LEFT HAND**	
01	Pick-up a bead by needle	Hold the fabric panel	2.47
02	Take the needle to the panel	Hold the fabric panel in place	2.06
03	Pierce the 1st point on fabric with the needle	Hold the fabric panel in place	0.89
04	Pierce the 2nd point on fabric with the needle	Push the needle by index finger to the front	0.67
05	Release the needle	Hold the needle and the bead by thumb finger	0.45
06	Re-hold the needle from front	Hold the panel and the bead in place	0.52
07	Pull the needle through the hole	Hold the panel and the bead in place with the thumb finger	2.49
Total time for 1 bead			**9.55**

3.4. Productive and Non-Productive Motions Involved

Table 3.2 Productive vs Non Productive Timing

NON-PRODUCTIVE MOTIONS	
Pick-up a bead by needle	2.47
Take the needle to the panel	2.06
Release the needle	0.89
Re-hold the needle from front	0.67
Time	6.09
Non-productive Percentage	**64.0%**
PRODUCTIVE MOTIONS	
Pierce the 1st point on fabric with the needle	0.45
Pierce the 2nd point on fabric with the needle	0.52
Pull the needle through the hole	2.49
Time	3.46
Productive Percentage	**36.0%**

Here we could see that it involves a significant amount of non-productive elements. It is more than 1/3rd of the total number of elements an operator carried out during the operation of attaching beads. This means that with the effective reduction or through complete elimination of these non-productive elements we can significantly improve the overall productivity.

At the same time by altering the productive high skilled elements to fairly deskilled operations the overall fatigue and the skill requirements for the operation could be minimized.

3.5. Design tree

The problem statement created is converted to a visual format during this step. The design tree is done in a way that it represents the consumer value propositions, functional analysis finding, method study findings, standalone solutions and the possible patented, published and known process solutions.

During the first phase of designing only the basic elements were considered. An in-depth analysis of the dependent and secondary problems will be done in the next phase.

1. Need of simplifying the bead attaching operation
2. Need of simplifying the bead insertion mechanism
3. Finding a simplified bead feeding mechanism
    a. Bead releasing mechanism
4. Needle placement mechanism
5. Stand-alone solutions
6. Patented and published processes

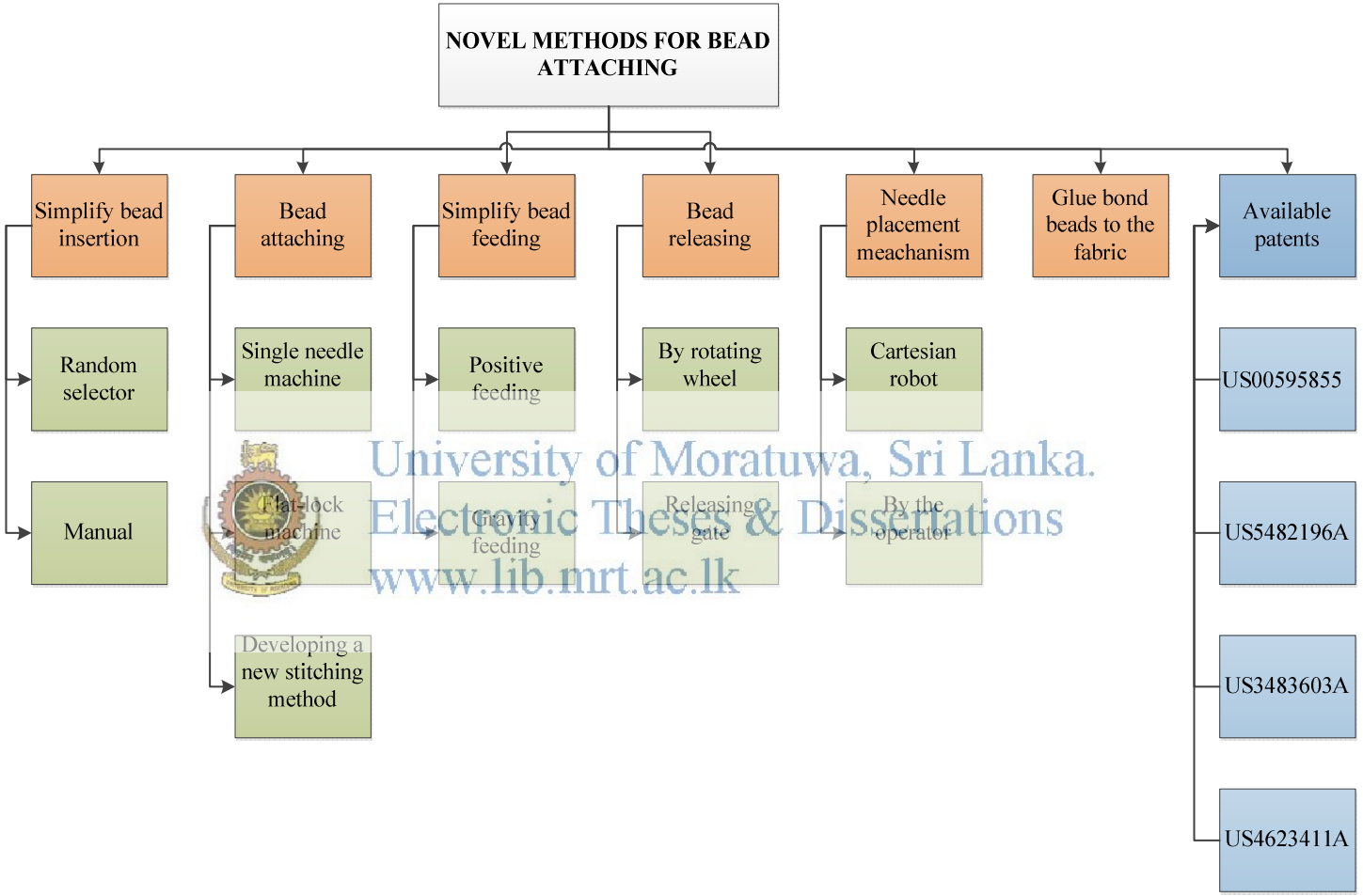


Figure 3.3 Design Tree

4 LITERATURE SURVEY

4.1. Prior Art Search and IP Landscaping

The core requirement of this project is coming up with an innovative solution that could give Sri Lankan apparel industry an edge over the other rival countries. Therefore patenting is an utmost importance to protect the intellectual property.

The chapter has a discussion on patents in the same domain and that are having closer relationship for the final solution. The objective is to identify whether there are possibilities of using these findings as a solution or it could have possible infringements towards the project findings and recommendations.

The research methodology is done referring to many scholarly articles and concepts developed by many researches around the world. This has guaranteed the innovation of a novel process for the said requirement of bugle bead attaching.

In order to carry out the search of prior art, researcher conducted an online search on existing patents. This is a norm in the industry to carry out the initial landscaping by the individuals involved in the project and then pass it on to IP attorneys who are professionals in the field to carry out a thorough search, this reduces the risk of costing legal fees on obvious non grantable patents as well as this expedite and help the attorneys to start the project with the basement of a technical persons insights.

Below mentioned are the basic sets of inputs used for the online patent search.

Table 4.1 IP Search Guidelines

INPUT	**DATA**
Methodology used	online patent search
Tools used	Google patents, AuLive patent inspirations, Free online patent
Domain	Textiles, Apparel, machinery related to apparel,
Key words	apparel, bugle beads, automate, semi automate, beading mechanism, sequins, embroidery, sewing, attaching ,

4.2. Survey Results

4.2.1. Patent 1

Description	Decorative element
Pat No	US 005,958,535
Date	28th September 1999
Inventor	Norbert Desmet (Meiningen, Austria)

The invention makes it possible for a traditional decorative element for expensive embroidered luxury materials namely the bugle beads, i.e. very small tubes of glass or glass-like other materials, which are conventionally either sewn on directly using complicated hand work or in the form of pre-formed fine bugle beads strung on a thread which is stitched in time-consuming manner, for example using single-head Lorraine sewing machines, to the supporting material, to be manufactured with virtually the same quality but in a simple manner without involving manual work. This method uses a narrow film formed from a multiple layered laminate of different synthetic or natural materials in such a way that during a subsequent treatment, eg a heat treatment, the material starts to curve in a pre-determined direction bends up and finally curls and assumes the shape of a bugle bead. The narrow film is applied to the substrate by conventional sequin embroidery techniques [8].

This patent takes a completely different root towards solving the same problem. In terms of patentability, this patent is does not become a hurdle.

1. Patent no US 005,958,535 describes a method making a tubular shaped embellishment which is similar to a bugle bead but not a bugle bead
2. Method of applying this new material is done with a conventional sequin embroidery techniques
3. Shaping of the embellishment achieved by heating the multi substrate material which bends duet differential thermal expansion properties.
4. In the novel method described in the thesis uses the same bugle bead and does not use a conventional sequin embroidery techniques for attaching the piece to the fabric panel

Therefore this patent does not affect the patentability of novel process described by the researcher on this thesis. Apart from above this technique is not commonly used in the commercial manufacturing of apparel.

4.2.2. Patent 2

Description	Attaching articles to sheet material with flexible ties
Pat No	US5482196A
Date	March 1993
Inventors	Doyel John S, (United States)

A hand operated implement for attaching articles such as buttons or tags to sheet material such as fabric with flexible ties by loading a grooved needle with the bar of a tie having a stem to which the article is attached, pushing the needle through the material and pushing the bar out of the needle such that the bar is at one side of the material while the article and at least some of the stem are at the other side. A needle cover attached to the implement pivots between a storage position in which it covers the sharp end of the needle and an operative position in which it serves as a thumb rest for operating the mechanism pushing the flexible tie's bar out of the needle. A storage compartment is provided within the implement. [9]

The US patent 5482196A describes a method of attaching embellishment to apparel or sheet like material using a flexible pin, similar to the tag pins used to attach tags on to the apparel. There is a significant amount of difference between these 2 patents,

1. Described how this technique could be used for 2 dimensional elements, eg buttons and tags. Bugle bead is a 3 dimensional element with the groove lying parallel to the attaching surface.
2. In the novel method described in the thesis uses bugle bead and uses standard sewing threads to attach the bugle on to the apparel

Though there are similarities between the patent and the novel method there is enough distinctions between 2 methods.

4.2.3. Patent 3

Description	Device for attaching ornaments to fabrics
Pat No	US 3483603 A
Date	October 1969
Inventors	Briskin Samuel

This invention relates to a device for attaching ornaments to fabrics, plastics, leather and garments, and more particularly, to hand-operated device for attaching various sized nail heads and artificial stones, such as rhinestones, positively to the fabric or garment for the purpose of ornamentation.

It is well-known in the ornamentation of clothing and fabric to attach nail heads, sequins and artificial stones, such as rhinestones, or inexpensive jewels to clothing and fabrics by means of machines or by hand. Where the same size stones or rhinestones are used, a machine or implement can securely fasten the rhinestone to the fabric. If, in the course or ornamentation, a different size of stone or ornamentation was to be attached to the fabric, an entirely new unit had to be used, or the die and plunger had to be replaced. Further, in order to attach a nail

Head to the fabric requires a different machine. Hence, for persons desiring to ornament their clothing themselves, or as a hobby, required the purchase of several different devices in order to attach a variety of artificial stones or nail heads to the fabric or clothing. [10]

This patent is in the same domain of ornamentation on apparel. The main difference between these 2 innovations is the method of application. In the patent US3483603A describes a method of attaching the ornament using a die that positively engage the fabric and the ornament and there by securing the bond.

4.2.4. Patent 4

Description	Method and apparatus for producing and attaching sequins
Pat no	US4623411A
Publication date	18 Nov 1986

Inventors Pollak Axel [US] ; Stein Sondra [US]

This is a method of stamping sequins from a sheet of material and substantially simultaneously attaching the stamped sequins to backing material. Apparatus for carrying out the method includes a punch and die assembly for stamping the sequins and needle and cooperating looper means for receiving and attaching the stamped sequin to backing material by an interlocking chain stitch. [11]

This patent has the highest number of similarities with a significant amount of dissimilarities.

1. In both methods uses a chain stitch as the mode of attaching the embellishment to the fabric panel. in the patent US4623411A the sewing thread is passed through the needle whereas the novel method the thread is passed through the bugle beads instead
2. In the novel method needle with a latch similar to a knitting needle is used, on the US4623411A needle is a standard sewing needle with an eye at the needle point, but both produces the same chain stitch appearance.
3. In the patent no US4623411A there is no evident of proven to be used for bugle beads particularly. This technique is not suitable for an embellishment with the thread groove parallel to the panel or the surface of the apparel.

Therefore this patent does not affect the patentability of novel process described by the researcher on this thesis.

4.3. Sorting Technologies

During the literature survey few sorting technologies were found which are directly linked to apparel industry and outside the industry.

4.3.1. Button sorting machines

Button attaching is one of the highly automated attaching methods in the apparel industry. There are two conceptually different methods of sorting buttons.

1. Reciprocate movement of a sieving bed with groove similar to the size and the shape of the button. These movements randomly sort the buttons into the grooves and then use for the subsequent automated operations. Fundamental

difference between the bugle bead and the button is that the thread passing directions of both components are complete opposite. Therefore using beads sorting in this manner could not be used in existing subsequent operations. This could be one of the reasons for the under development of bead attaching operation.

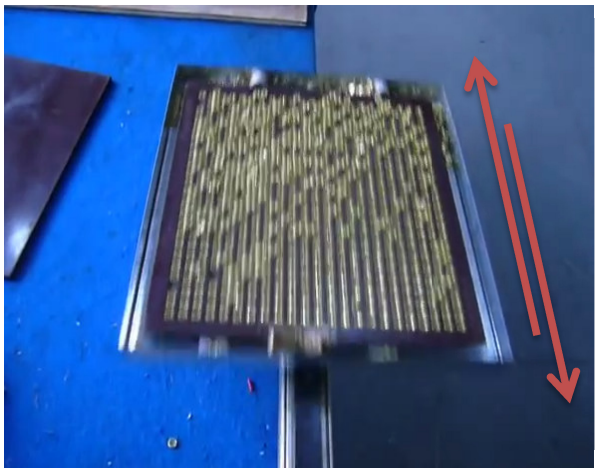


Figure 4.1 Button Sorting Mechanism 1

2. Rotating drum is a very common method used for sorting buttons and this technology is used by Brother, PFAF, and many other leading machine manufacturers. In this method buttons are placed in a rotating drum and sorts and move to a groove due to the random movement. Then these aligned buttons are guided out of the drum using the same groove and used for subsequent operations.

Figure 4.2 Button Sorting Mechanism 2

4.3.2. Bullet sorting machine

This uses a technology of the rotating drum very much similar to the button sorter. The difference of this machine is the ability to sort bullets according to their height. By placing height pickers the bullets are dropped to different buckets. On this machine there is no organized lining up mechanism for subsequent processing.

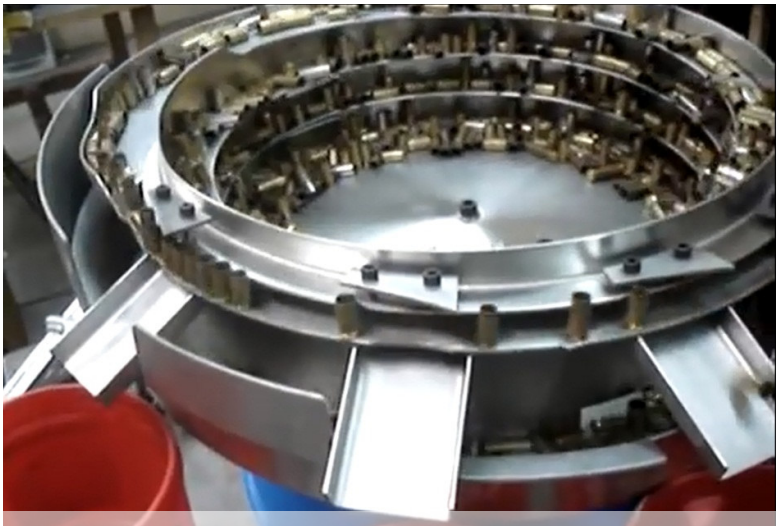


Figure 4.3 Bullet Sorting Machine

Pencil Making)

This process uses cylindrical shaped graphite rods and place sandwiches them in-between tow layers of wood. Though the product is similar in shape, it can not be taken as a similar process since the requirements of the subsequent processing are completely different to bead attaching.

Figure 4.4 Graphite Rod Sorting (Pencil Making)

4.3.3. Diodes and Capacitors

For assembly purposes these components are attached to tapes. The pick and place robots uses these components since they are places in a more organized manner. Major difference between these processes and the bead attaching is that beads are attached individually and not by soldering or pinning. There is a patent on this aspect and it is also not popular in the industry due to its lower easthetic appeal.

Figure 4.5 Capacitor Sorting

4.4. Surface Mounting Robots

This is the preferred assembly method for electronic components on to printed circuit boards. There are many similarities between the bugle attaching and electronic component assembly process. Both fixes a component to a surface or a two dimensional plain using a third material. Main dissimilarity is the fixing method and the technical requirements of both operations. Aesthetic appearance of the finished product is highly important in the bugle bead attaching and therefore it is evident that needs to be attached loosely to the fabric using a thread. Where the gluing the beads to the fabric is considered a low cost option.

Therefore the pick and place robot in this particular application is inappropriate.

With the above findings it is evident that there is a great need in the apparel industry for a mechanism to attach bugle beads to fabric surfaces without compromising the aesthetic appeal of the product.

5 SOLUTION GENERATION

This chapter is dedicated for arriving at a solution for each identified problem through scientific means. Since this is an application for the industry, the cost and time are key contributors for the decisions, in all scenarios. Hence, the time to commercialization and financial impact are considered. In most cases the Technology Readiness Level (TRL) is used as a tool for assessing the maturity of the technology here the assessment is done based on the Integration Readiness Levels (IRL). This problem needs an integration of many technologies to solve single consumer need, therefore the IRL found to be a better system to follow than the TRL. [13] [14]

5.1. Need of Simplifying the Bead Attaching Operation

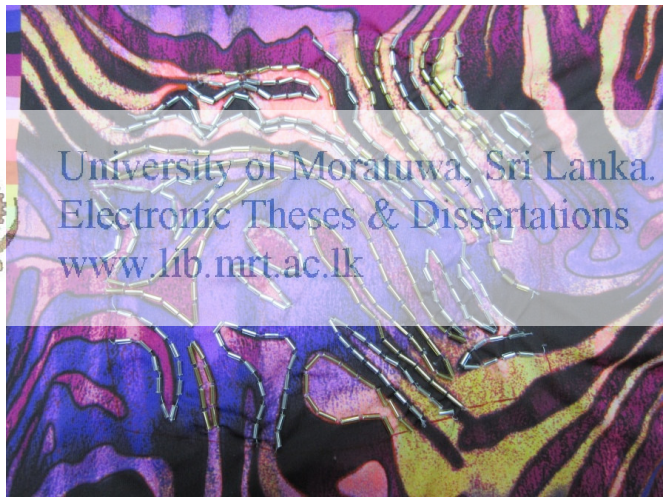


Figure 5.1 A Finished Panel

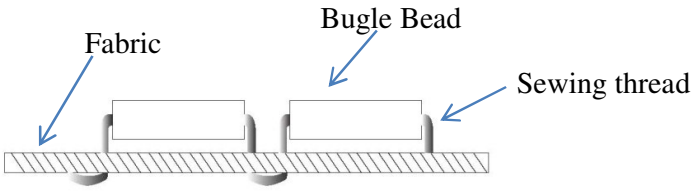


Figure 5.2 Cross-sectional View of the Beading

5.1.1. Solution 1

Single needle lock stitch / Zig-Zag sewing machine,

Figure 5.3 Attaching Beads with Zig-Zag Sewing Machine

Table 5.1 Zig Zag Summary

ADVANTAGES	DISADVANTAGES
Can use an existing machine – lower development cost	Appearance slightly different and the aesthetic appeal lower
IRL – 7	Need to develop a system that could be incorporated next to the sewing machine needle area for ejecting bead by bead
Can use the existing needle system	No of needle breakages higher
Operation speed 3000-4000rpm (stitches per minute.	

As shown in the Figure 5.2 the thread and the needle are sent through the bead hole. Therefore the needle has to be disengaged from the fingers at one point and needs to hold back and pull from there onwards. If we compare the lock stitch formation the needle is permanently fixed by one side and therefore we cannot easily duplicate the same motion pattern. If we are to use the lock stitch machine as it is the threaded beads has to be fed thorough the needle hole. This is impossible with the present machine as the needle hole has a size limitation.

Next option was to attach threaded beads to the panel using a lock stitch machine as code stitching operation. This is possible to do but it does not give the exact appearance of the hand attached bead on Figure 6.

This mismatches the scope statement where no changes to the visual appearance of the current methodology. Therefore the solution is disregarded and dropped

5.1.2. Solution 2

Flat lock sewing machine,

Table 5.2 Flat Lock Summary

ADVANTAGES	DISADVANTAGES
Can use an existing machine – lower development cost	Limited to stitching rows only, no of possible designs is a constrain
IRL – 7	Difficult handle the machine on fine work, constrain of the existing machine
Can use the existing needle system	Need to develop a system that could be incorporated next to the sewing machine needle area for ejecting bead by bead
Has a very good stretch	No of needle breakages higher
Appearance slightly better than the solution 1	Pivoting is difficult
Operation speed 3000-4000rpm (stitches per minute.	

Two needle flat lock machine attaching is faster and easier to control. Still the final appearance of this method does not look similar to a hand attach and it cannot stitch every single design we stitch with the manual method. Therefore this method also finds difficult to be implemented. Figure 8

This solution is with a higher IRL and a better visual appearance, still due to the cumbersome machine foot and the complicated needle point area this machine found to be not suitable for intricate handling. This mismatches the scope statement where

making the operation deskilling is impossible. Therefore the solution is disregarded and totally dropped.

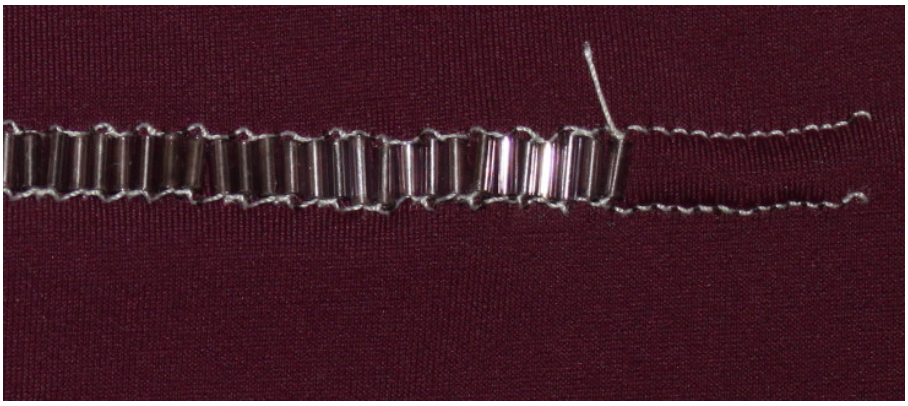


Figure 5.4 Attaching Beads with Flat Lock Sewing Machine

5.1.3. Solution 3

Developing a new stitching method

Here describes a hybrid sewing technique using principles of knitting and reciprocate movement of a single needle sewing machine.

Table 5.3 Novel Technique Summary

ADVANTAGES	DISADVANTAGES
Can stitch very much similar to the hand operation	Need to develop a mechanism
IRL – 6-7	Need to develop a new needle
Has a good stretch	Need to develop a system that could be incorporated next to the sewing machine needle area for ejecting bead by bead

The other possible method is formation of a chain stitch in the same thread. Disadvantage is there is no machine to duplicate this stitch and we have to develop a mechanism to carry out the motion. As in the Figure 5 the beads can be attached to

the panel and need to use a needle as shown in Figure 6 to carry out the operation. This is similar to the shoe maker's needle and needle has to be designed as fine as possible and has to consider the stresses involved during the stitching and panel piercing operation

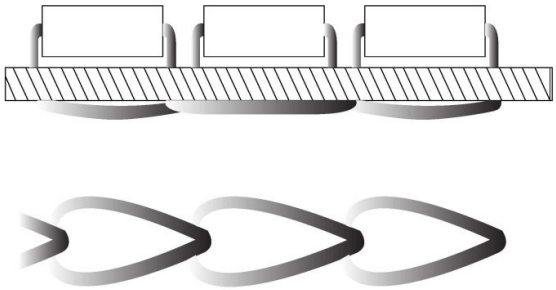


Figure 5.5 Schematic Illustration Novel Technique

.

The IRL is slightly lower than the previous solution route; this is mainly due to the requirement of developing a new mechanism and a needle system. Solution has better visual appearance compared to all the competing solutions. Operation is simpler and the developer gets the ability to custom design the machine to the requirements of the operation this is found to be the best possible alternate to the problem at the moment.

5.2. Need of Simplifying the Bead Insertion Mechanism

5.2.1. Solution 1 (Manual insertion)

This is the existing method of inserting beads into the needle. There the cost involved is as below

Time for a single bead pick up (seconds)	=	2.47
Average no of beads per design	=	200
Total time (seconds)	=	494
Total in minutes	=	8.233333
At 40% efficiency	=	20.58333
Minute cost of manufacturing in Sri Lanka $	=	0.09
Cost USD	=	1.852

5.2.2. Solution 2 (Random selector)

The concepts used here are the random movement of objects and the centrifugal force due to the angular velocity.

During the research and lab trials it is evident that the material gets pushed to the wall of the circular chamber due to the rotational velocity of the object. In this method an artificial twister is formed inside of a cylindrical chamber. Due to this air turbulence beads got moved inside the chamber in a path similar to the air flow pattern. It was observed that the beads were moving keeping the thread passage parallel to the path of movement. Due to this moving pattern and the orientation of the beads it was observed that the beads could be picked by a stationery rigid metal wire place against the direction of movement.

5.3. Finding a simplified bead feeding mechanism

Maximum speed of a single needle machine	=	4000rpm
Average distance a needle should move during the operation	=	25mm
Time interval between 2 needle punches	=	60/4000
Gap between the needle point and the bead releasing point	=	350mm
Minimum time available for a bead to reach the needle	=	23m/s

If the time taken is > time interval we need to go for a positive feeding mechanism for beads. A proper mathematical model needs to be developed the evaluate scenarios considering possible frictions involved in the system. If the time needed for a bead to travel from the releasing point to the needle point is greater than the time gap between two needle punches we need to use and ejecting mechanism.

This could be a simple Venturi air flow ejector fixed parallel to the thread. This is a simple modification where much engineering is not necessary; therefore for the

concept evaluation optimal condition calculations were not studied. This finding and the basis of the calculation is entered for the future work on development of a working model where the exact ejection time is essential to calculate the optimum air floor rates to run the machine at the highest productivity level.

5.4. Bead Releasing Mechanism

5.4.1. Solution 1

Using an open / close gate, this will have a reciprocate movement by means of magnetic or a pneumatic force.

Table 5.4 Solution 1 Summary

ADVANTAGES	DISADVANTAGES
IRL – 7	Noisy
Smaller in size	Could damage beads due to movements and impact
No additional motors are required	Does not have a smooth ejection
Can synchronize with the needle reciprocate mechanism	

This mechanism is used to prove the concept and this works fine for the conceptual work.

5.4.2. Solution 2

Here used a roller that could hold beads at predefined gaps and a stepper motor controlled motion system to release the beads at given intervals.

With the evaluation results this mechanism finds to be the best possible method for the releasing mechanism. For study purpose on the design section the control system and the detailed designs are attached. Similar release mechanisms could be found in the literature survey for the graphite rod dispensing in pencil industry. The significant similarity is the cylindrical shape of the element. By changing the direction of movement the grove on the wheel can be placed opposite direction to that of the graphite rod dispenser.

Table 5.5 Solution 2 Summary

ADVANTAGES	DISADVANTAGES
IRL – 7	Additional motors are required
No or less noise	Comparably larger and disturb the visibility
Smooth ejection	
Can synchronize with the needle reciprocate mechanism	

5.5. Needle Placement Mechanism

5.5.1. Solution 1

This will not have any mechanization, where the cost of the manual operation is studied for the purpose of comparison for cost benefits of the novel method.

Time for a single bead pick up (seconds)	=	2.06
Average no of beads per design	=	200
Total time (seconds)	=	412
Total in minutes	=	6.87
Minute cost of manufacturing in Sri Lanka $	=	0.09
Cost USD	=	0.62

Any option that has a lower operational cost with a capital investment that could be paid off in 2 years period could be taken as a financially viable option. For the return of investment calculations we need the order quantities and lots of other variables. Therefore it is not proved on this research work.

5.5.2. Solution 2

Cartesian robot could do the movement of the panel according to the pattern. This will fully automate the operation. Output quality of this operation will be as same as or better than the manual operator, therefore the main criterion for the decision is the cost and the time to recover the investment.

Cost of developing a Cartesian robot for the operation is mentioned in the Appendix B quotation 1.

This needs to be validated properly after developing a prototype.

These two solutions are not discussed in the design section of this thesis since those are not the core objectives of the research work and do not involve any innovative steps or new knowledge in the development of the units.

6 DESIGN OF THE MODEL

The selected solutions from the previous section are critically analyzed in this section. In order to finalize the acceptance or the dismissal of the ideas the possible financial models are discussed. The intellectual property landscaping is studied to eliminate possible infringement of patents.

The discussion here is only on the main part of innovation where identification of the novel method of attaching beads which has higher potential of deskilling than the current method of attaching with the hand needles. The construction and the design of the complete unit is also explained in this section with the design illustration and the actual cost of manufacturing a working g model.

6.1. Bead Attaching Operation – Solution 3

The loop transfer technique used in the knitting industry and uses a needle type named latch needles. [15]. These needles are used to transfer stitches between new and the previously formed stitches.

Knitting stitch formation is presented as below diagram. The same principle is used in forming the knot using only one thread. This is described as single thread chain stitch, that is making the both loop and the knot using the same thread. [16]

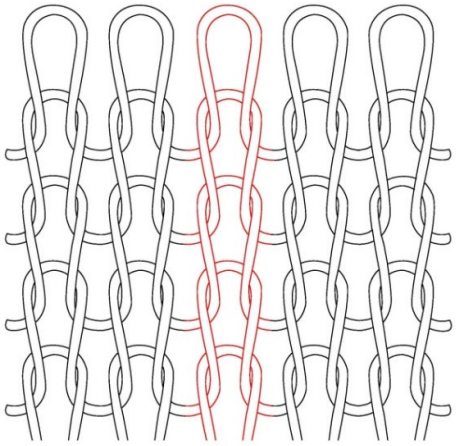


Figure 6.1 Schematic Diagram Single Jersey Knitting

The chain stitch sewing machines were patented in 1933 and the product patent for chain stitch sewing machine is no longer active. Therefore we can use the United States patent US 1929321 as knowledge for this thesis and research work. [17]

Below images give a clear illustration of the novel method of bead attaching, using the chain stitch and the stitch formation methodology.

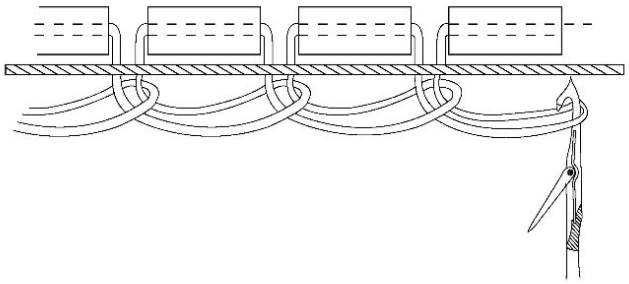


Figure 6.2 Loop Making operation

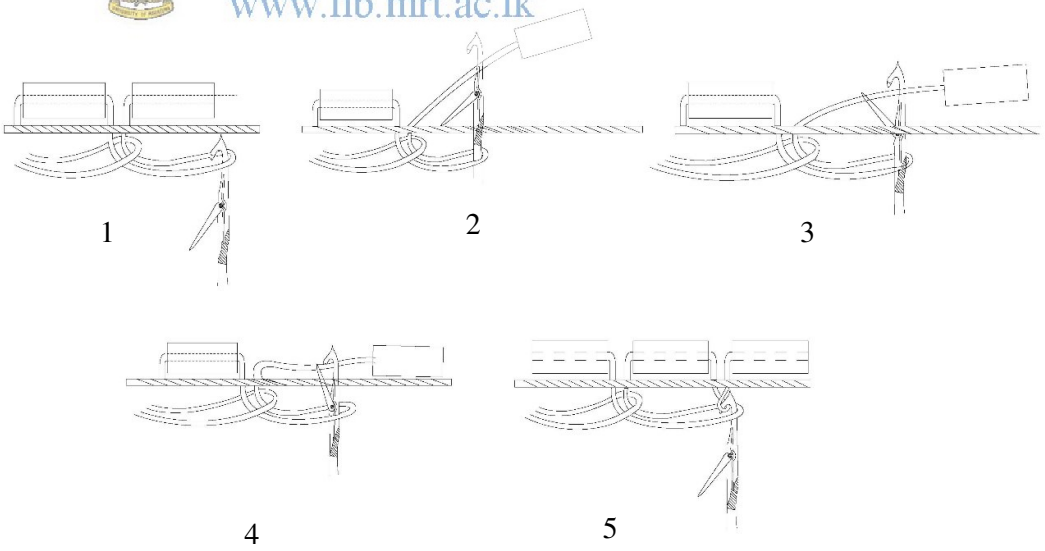


Figure 6.3 Steps of Loop Formation

6.2. IP Landscaping Needle Construction

During the IP search for the needle design and assembly researcher found few relevant patents. Manufacturing of needles is not a specialty of the company and it will be an expert's job. As Groz Beckert is a supplier who has both distribution and custom development channels in Sri Lanka, researcher found its best to work with this particular supplier. Apart from above Groz Beckert holds the patent rights for manufacturing particular latch needle which can be used for the novel process with slight modifications [12].

Description	Latch needle with a fixed spring
Pat number	US6510714 B2
Inventors	Lothar Dehner
Publication date	18 Nov 1986
Original Assignee	Groz-Beckert Kg

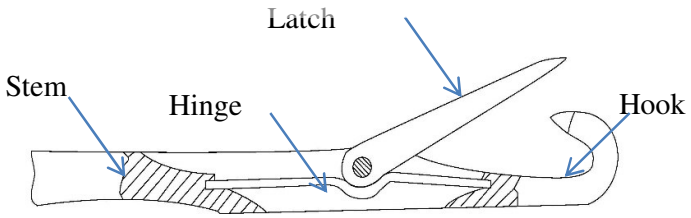


Figure 6.4 Kitting Needle with Latch

6.2.1. Needle point design

After the set of laboratory trials it was evident that the existing needle head is not supportive due to two main reasons.

1. The needle point is too large to penetrate through the stitches of the knitted fabric

2. Needle point was not blunt enough to support the penetration without cutting the yarns, which ultimately creates a cut hole on the fabric. .

As a solution for this the existing sewing needles were studied and found that the sewing needle has a special mechanism to support penetration without damaging the yarns. In most cases sewing machines operates at 3000 revolutions per minute and they are capable off speeding up to 4500 revolutions per minute. Therefore logically we could say the solutions used in the sewing industry could be applied to the new development.

The proposed solution for the needle is a hybrid of the sewing needle and the knitting needle.

Figure 6.5 illustrates the common shapes of needle points in the sewing needles in order to minimize the impact of needle damages.

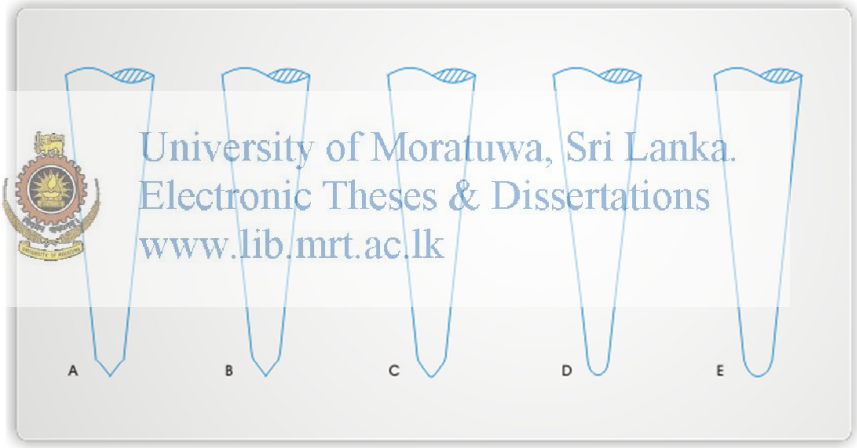


Figure 6.5 Needle Points

A. Standard Point

B. Polished Point

C. Slightly Rounded Point

D. Medium Rounded Point

E. Rounded Point

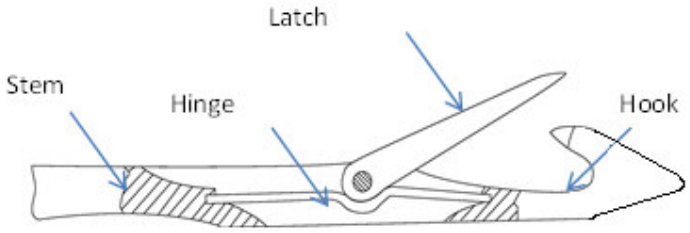


Figure 6.6 Proposed Hybrid Needle

6.3. Bead Guide Wheel

Figure 6.6is the detailed drawing of the bead guiding system. The identified requirements of this part of the system are the release of beads at predetermined time and space intervals. Considering the shape and the size of the bead the wheel is designed. A detailed drawing of the wheel is attached in the annexure.

Figure 6.7 Bead Guide Wheel

6.4. Complete Mechanical System

In the “Appendix A” section a complete set of drawing are illustrated for a possible mechanical system. It would consist of the below parts and for the design purpose the material is not specifically selected.

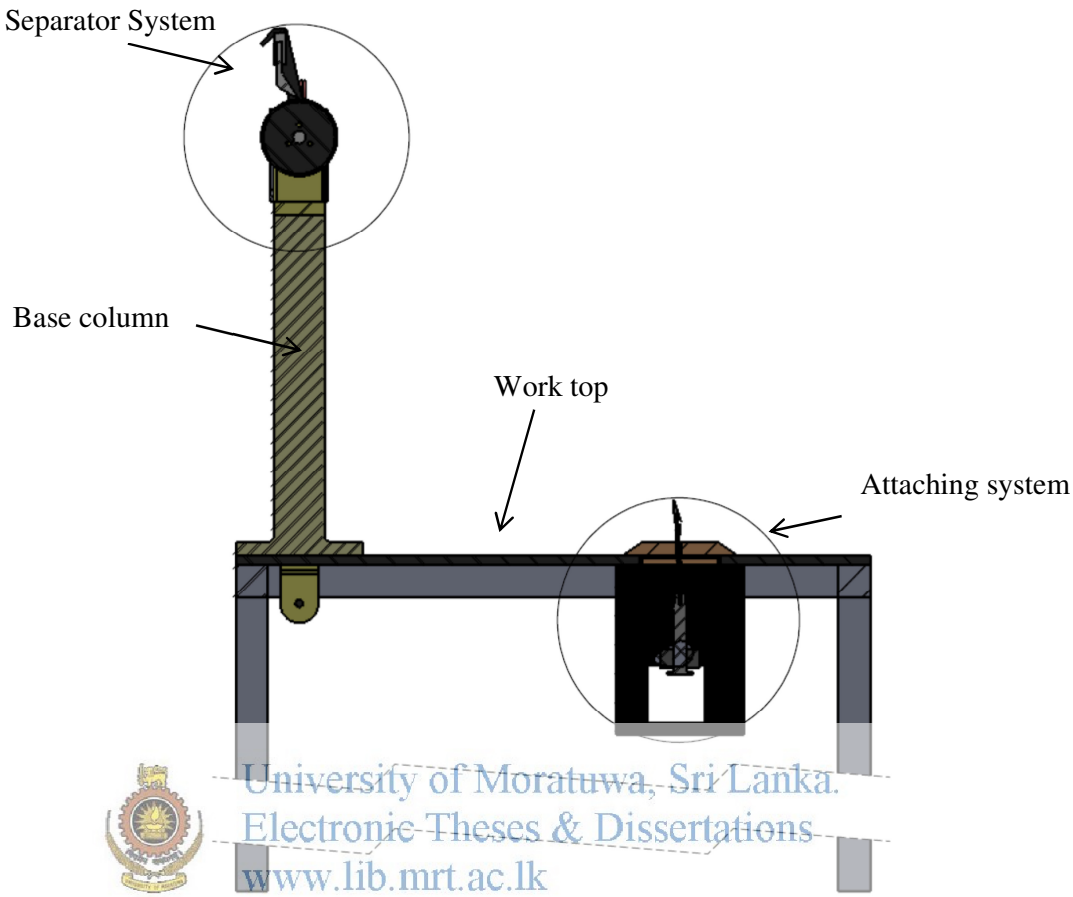


Figure 6.8 Complete Mechanical System

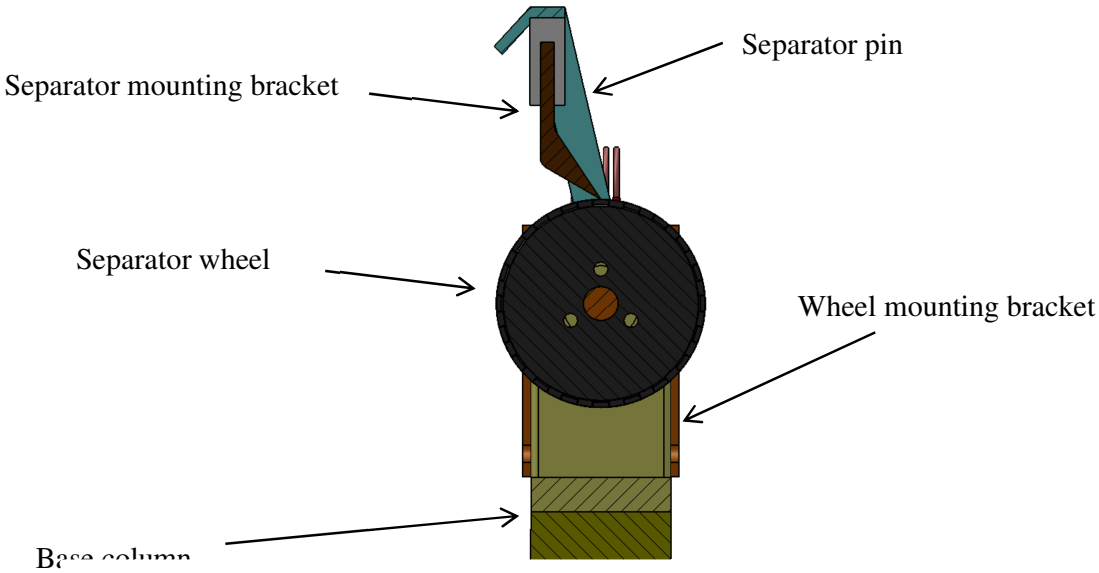


Figure 6.9 Separator System

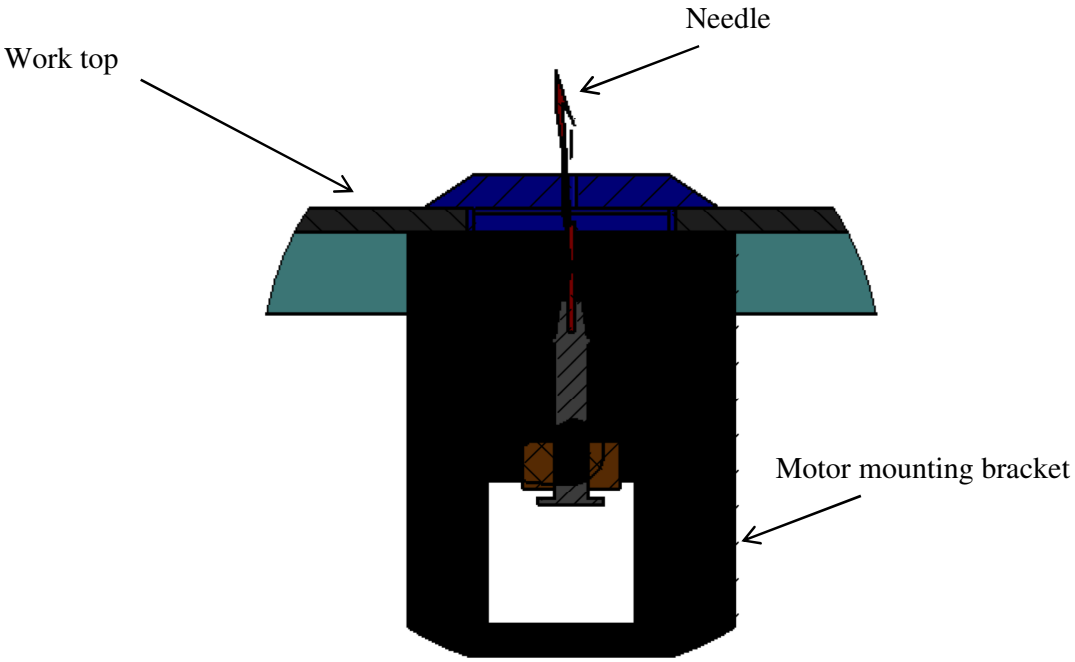


Figure 6.10 Attaching System

Figure 6.11 CAD Design of the Complete System

Cost for manufacturing a similar system is attached in the “Appendix C” under quotation 2 considering the job is out sourcing to a third party workshop.

7 BUILDING THE PROTOTYPE

Out of five need areas identified in Chapter 5, need of simplifying the bead attaching mechanism is the most important and critical step for this innovation. From both the user point of view and from the research point of view this found to be the most crucial area. Therefore the proof of concept plays a pivotal role on the success of the project.

Figure 7.1 Proto System Used to Prove the Concept

7.1. Used methodology

Used basic pneumatic cylinders, actuators and custom made parts to support the operation. This was manually operated using a foot controller. The unit built to prove the concept was capable of duplicating the reciprocating movement of the needle and the releasing of the beads synchronizing with the needle movement. An existing weft knitting needle was used for as the needle in the trial machine, instead of custom developing a needle as per the findings in the solution profile.

Observations

Knot formation as described in the diagram 6-3 could be observed during the trial. Therefore the main objective of the trial was achieved by the proto type machine. Therefore by the project concept was proven.

Figure 7.2 Needle Before Engaging the Thread

7.2. Speed

Speed of the system was thoroughly observed in order to get an understanding of the possible damages that could happen on the surface of the fabric. The cylinder manufacturer provides the minimum and the maximum travel speeds of the cylinder under different inline pressure levels. With the existing compressor pressure range the maximum possible and minimum pressure range was defined and tested the possible surface damages using stereo microscopic images.

Brand	C&F		
Cylinder Ref.	CDJ2K16-25		
Pressure (Mpa)	0.06	0.7	
Speed (mm/s)	50	750	

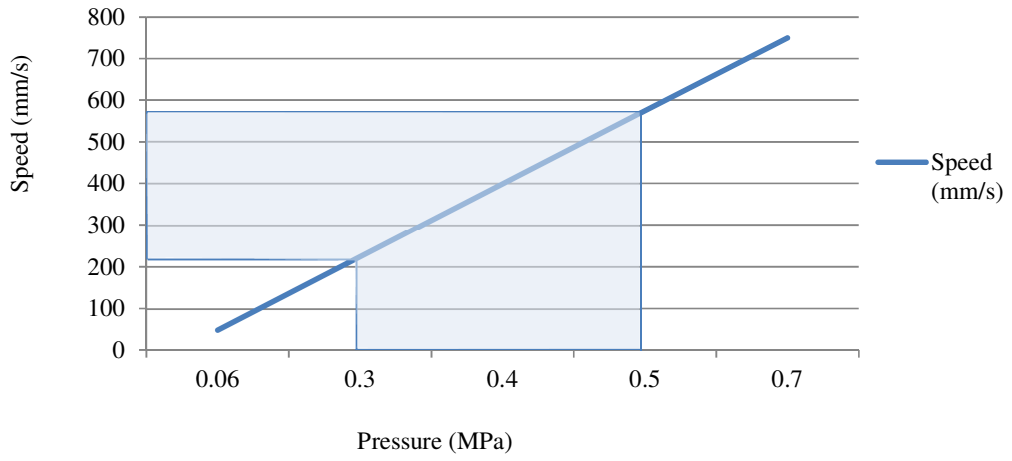


Table 7.1 Cylinder Travel Speed vs. Pressure

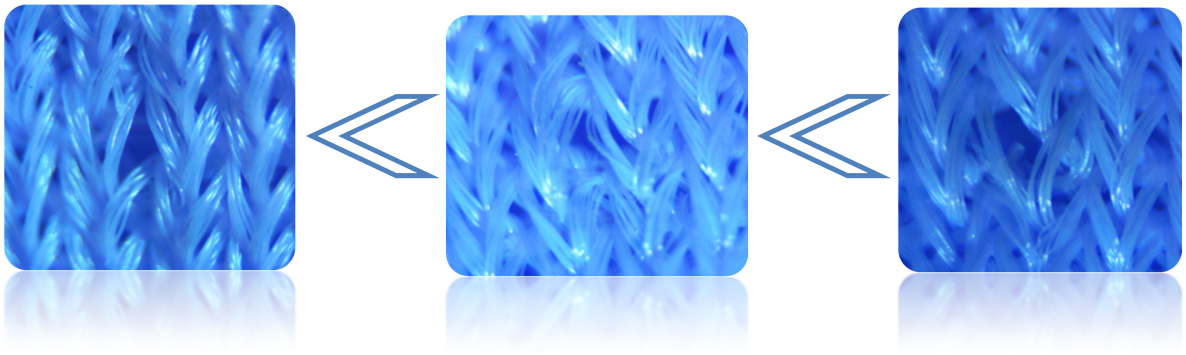


Figure 7.3 Surface Damage with the Change of Speed

By observing the results it was evident that the speed has a direct correlation with the surface damage. More yarns were broken due to the higher speeds and less was broken at lower speed. The yarn breakage of a fabric leads to cut holes and this is

considered as a critical quality failure in apparel industry. Therefore the speedo needs to be controlled or needle needs to be developed further to improve the failure.

7.3. Piercing effect

The force exerted by the needle on the fabric caused a needle cut on the fabric. This is an expected scenario and if we used a needle with a proper head as describe in 6.2.1 this would have been overcome.

A test using needle heads with the similar shapes described in 6.2.1 was conducted. There the same swimwear fabric was used for all testing and all condition was kept constant and the needle head type was changed. The surface damage monitored using a stereo type microscope and the results are as below.

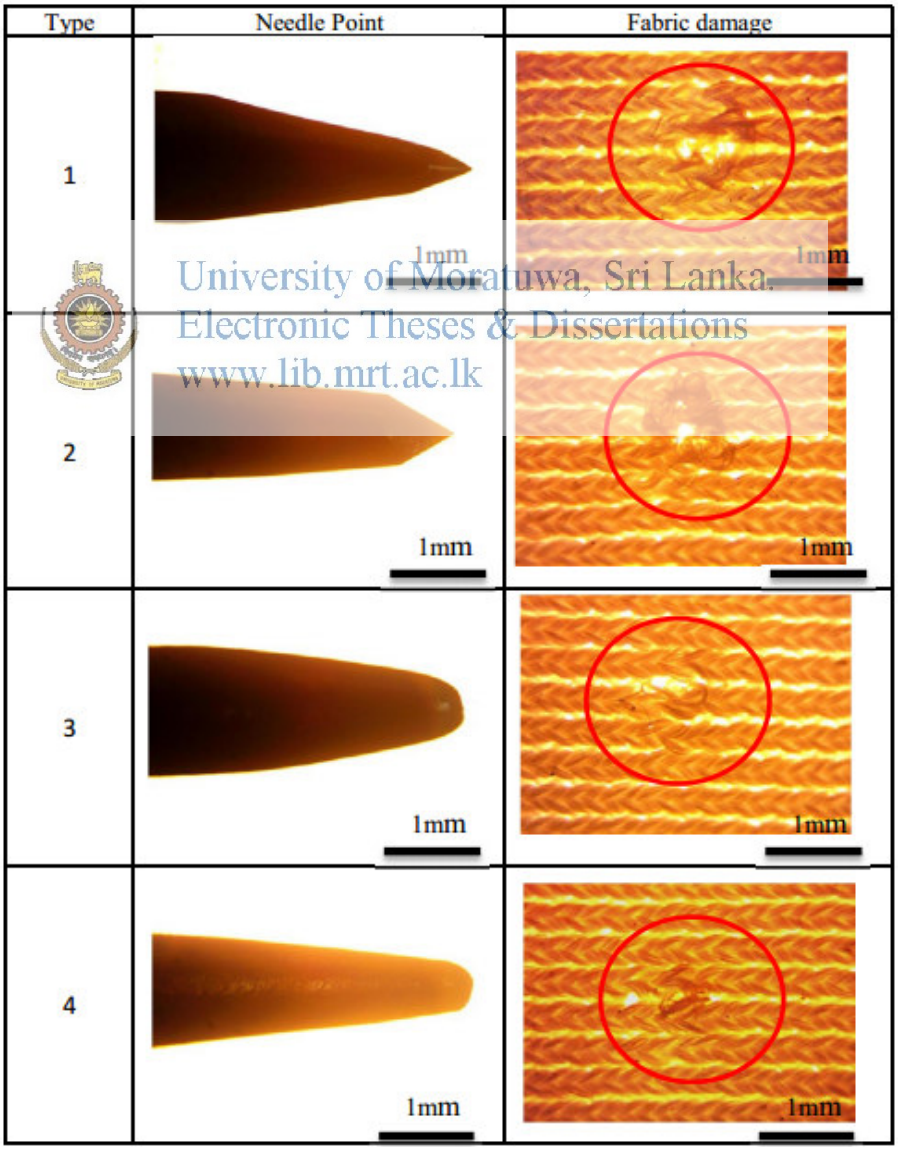


Figure 7.4 Needle Head vs. Fabric Damage

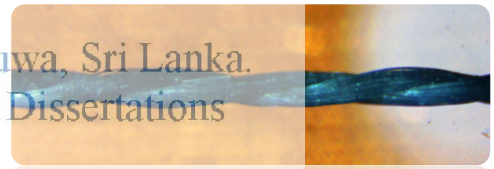
7.4. Bead movement

Bead flow speed is also a factor that was considered during the trial as we used only the gravitational force for the movement of the bead. This information could be used in making decisions of developing positive feeding mechanism for the industrial scale machine.

Test 1

This is carried out to identify the coefficient of friction between the yarn and the bead. With this the best possible thread type that could give the lowest possible friction was identified.

Table 7.2 Minimum Angle Required to Move Beads

YARN	**TRILOBAL POLYESTER**	
Yarn size (TKT)	120	
Length of the yarn (cm)	43.18	
Weight of a bead (g)	0.02105	
Angle at bead start to move	**30.967** °	
YARN	**POLYESTER WRAPPED POLY CORE**	
Yarn size (TKT)	120	
Length of the yarn (cm)	43.18	
Weight of a bead (g)	0.02105	
Angle at bead start to move	**76.795** °	

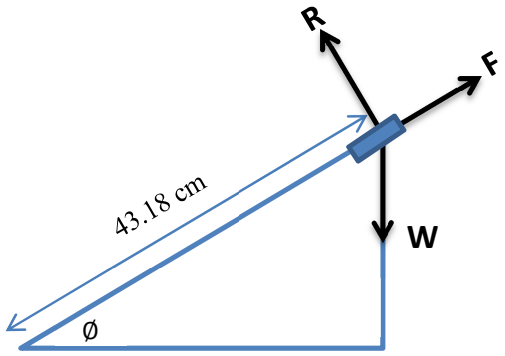


Figure 7.5 Forces Applied on a Bead

$$F = W\sin\emptyset \qquad R = W\cos\emptyset \qquad F = \mu R$$

	ANGLE AT BEAD START TO MOVE(°)		ANGLE AT BEAD START TO MOVE (°)
1	31.46	1	75.63
2	32.26	2	78.20
3	31.46	3	76.46
4	30.65	4	75.65
5	29.81	5	77.56
6	30.65	6	76.46
7	29.81	7	78.69
8	31.46	8	75.29
9	31.46	9	76.32
10	30.65	10	77.69
Avg	30.967	Avg	76.795
	Coefficient of friction (μ) 0.6		

With the results it was evident that the Trilobal Polyester yarn has the lowest coefficient of friction and the angle required to initiate a passive movement of the bead was less. This will provide higher flexibility to the designer in terms of deciding thread feed angle and at the same time passive feeding speedo would be higher.

Test 2

This is carried out to identify the passive feeding speed of beads to the needle point under different feeding angles. Once the needle movement speed is set to the optimum level bead feeding time has to support the efficient attaching of beads by feeding beads to needle point without a lag.

Since the Wrapped Core Polyester yarn failing to provide feeding angle flexibility this test uses only the Trilobal Yarn.

Table 7.3 Average Bead Travel Time at Different Angles

ANGLE OF THE THREAD (DEGREES)	31	45	60	75
1	1.6	0.355	0.235	0.14
2	1.35	0.265	0.255	0.12
3	0.85	0.455	0.2	0.16
4	1.29	0.325	0.215	0.19
5	1.23	0.26	0.255	0.14
6	1.54	0.375	0.205	0.15
7	1.18	0.365	0.245	0.15
8	0.77	0.36	0.24	0.16
9	2.29	0.305	0.26	0.14
10	0.89	0.325	0.215	0.16
Average Bead travel time (s)	1.299	0.339	0.233	0.149

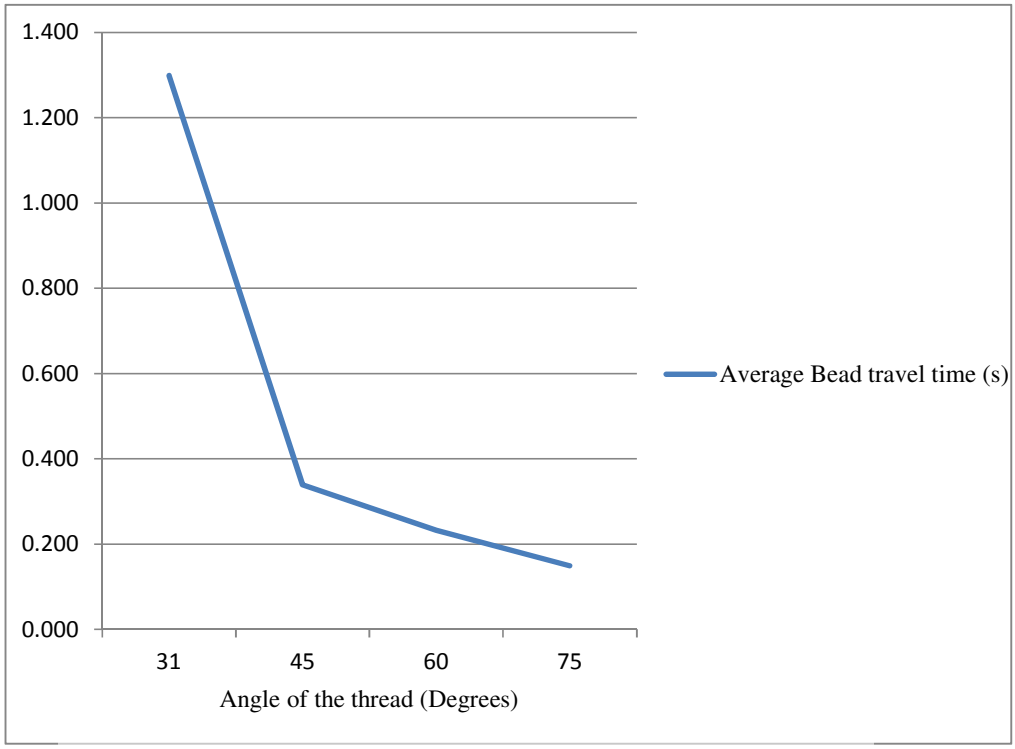


Figure 7.6 - Average Bead Travel Time

8 DISCUSSION AND CONCLUSION

Success of an innovation can be measured by impact that it does in financial and social aspects. Apart from the direct financial and social impact this project has derived two distinct findings to the body of knowledge.

1. A novel method of attaching bugle beads on to the apparel

The core objective of this project is the improvement of productivity of the existing manual bead attaching operation. In other words it is a project to improve profitability of an existing process. Whilst the project is achieving its financial goals indirectly it achieves the social goals by improving the living standards of workers and all stake holders.

The next step of this innovation is the development of a commercial scale machine. It has to be carried out considering economic, ergonomic and engineering constraints that are prevailing in this scenario.

The derived testing figures for the machine operation parameters are valid for both the commercial and prototypes. Needle head type and the possible thread breakages it could do can be used as a base for the development of a needle for the system and the trials proved that the literature used in the sewing needles are valid for the beading as well.

Speed has a direct correlations with the thread breakages and this act as a constrain on the productivity of the machine, therefore this will be a barriers for the commercial scale development. Further developments on this aspect are essential during the next stages of the development.

Tensile strength and the coefficient of friction of the thread place a role in terms of productivity. During this project only one thread type is identified.

Identification of a new stitching concept for the bead attaching operation should not be limited to the bugle beads and this has the potential of rolling out to other apparel as well as non-apparel operations.

2. Proposal of an effective method of carrying out object oriented innovation project.

The process defined with a user centric view point. This is an advantage for any innovation since the user friendliness of the end product or the process is the main reason for success or the failure of the project. Therefore the findings here could be used for the effectiveness and the success rate of any project.

With the findings of the intellectual property landscaping we can conclude that the novel process of bead attaching is patentable. Therefore the financial benefits could be secured for a longer duration of time and it provides the opportunity of opening new income flows through sharing and selling of IP rights. The decision of selling or retaining the IP rights could be taken up at a later stage of the process after properly designing extensive financial models.

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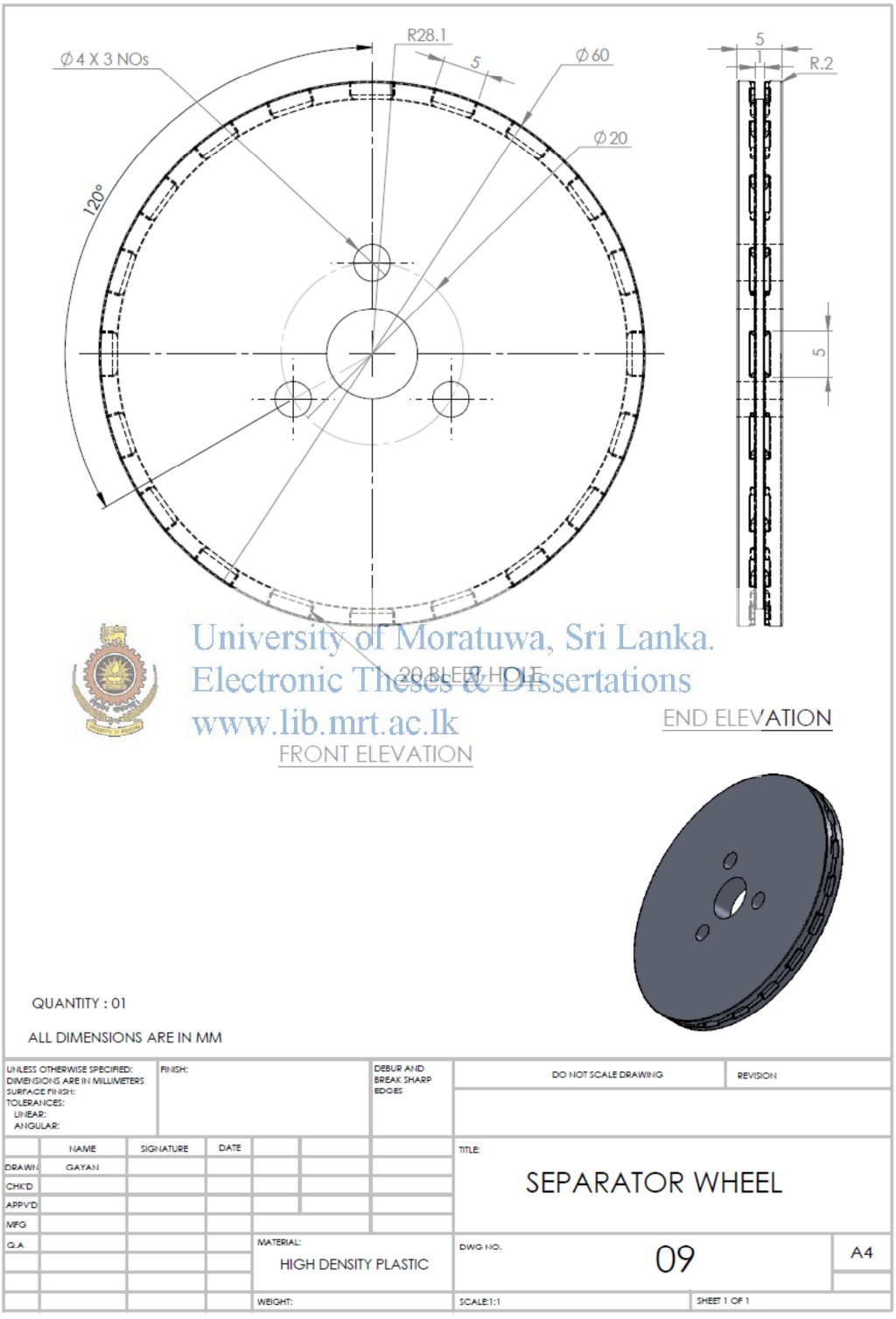
Appendix A:



Appendix B:

Quotation 1

Hitech Solutions Pvt. Ltd.

Engineering Excellence

Quotation for Cartisian Robot with control and mechaanical unit

To : Mr. Gayan
Linea Aqua Pvt Ltd

Quotation No HT11/1044/K
Date 14th Dec 2013
Customer Code 115
Expiration Date 14th Dec 2014

ID	Description	Nos.	Total (LKR)
1	Mechnical parts	1	120,000.00
2	Control system	1	135,000.00
3	User Interface	1	55,000.00

Sub Total	310,000.00
NBT 2%	6,200.00
VAT 12%	37,944.00
Grand Total	354,144.00

VAT No. 114488852-7000

Project Description

The clinet should supply with proper placement locations for the computer. Computer and networking will be done by Hitech Solutions PVT LTD, but any other connection to the LAN and network management tasks are the client's duty.

One year warranty will be supplied to the system excluding the lightening and surges, misusage, physical damages and any failure to the system due to the usage out of the given instructions.
The amounts for item 1 should be supplied by the client at the start of the project and the remaining amount within two weeks of the project completion.

Thank you for giving us the opportunity to bid for your business. We look forward to showing you that it is well deserved.

Quotation Prepared by:
Kosala Jayasundara
Director, Hitech Solutions PVT LTD

This is a computer generated quotation. Signature is note required.

Thank you for your Business...!

Hitech Solutions Pvt. Ltd. No 7/2, Duwahena Watta, Guruwela, Dompe. P: +94713964141, +94714964141, Fax:+94719378329, E:info@hitechsl.com

Quotation 2

C.S.D Steel Engineering

88/A Alawatupitiya,seeduwa
Diamond washer, flat washer, Crank bolt, J bolt an Bolt& Nut
Tel: 011-2233228, 071-4010953
Fax:011-2248540 , E-mail:csdsteeleng@sltnet.lk

PR NO:

QUOTATION

Date :12/12/2013

Linea Aqua (Private) Limited
Thanahenpitiya Estate, Giridara,
Kapugoda, Sri Lanka.

Dear Sir.

We write with reference to the above subject and you inquiry for the same. Please fine given Below our best quotation as per your requirements & specificatifications.

PR NO.	Description	quantity	Unit price	Amount
	1.LEFT SHAFT WITH FLANGE.	1NOs	1200	1200
	2.RIGHT SHAFT WITH FLANGE.	1NOs	1450	1450
	3.SEPARATOR PIN.	1NOs	770	770
	4.BASE COLUMN.	1NOs	5200	5200
	5.MOTOR MOUNTING BRACKET.	1NOs	860	860
	6.SEPARATOR MOUNTING BRACKET.	1NOs	2800	2800
	7.WHEEL MOUNTING BRACKET.	2NOs	1450	2900
	8.WHEEL MOUNTING LEFTBRACKET	1NOs	1750	1750
	9.SEPARATOR WHEEL.	1NOs	13200	13200
		TOTAL		**30130**

If you need any future information or clarification, please contact undersigned at any time. Assuring that our quotation is in line with your requirement and waiting for your favorable Reply.

Thinking you ,
Yours sincerely,
CSD Steel engineering

Appendix C

Video Clip Bead Insertion

Video Clip Laboratory Trial