Indian Journal of Fibre& Textile Research
Vol.48, June 2023, pp. 124-131
DOI: 10.56042/ijftr.v48i2.65514

Development of two novel methods using sensors to operate the industrial over-lock machine for loco-motor disabled person

S S Suresh & D Raja[a]

Department of Fashion Technology, Sona College of Technology, Salem 636 005, India

Received 12 August 2022; revised received and accepted 13 October 2022

In this research, two sensor-based methods have been developed to operate industrial over-lock sewing machine,especially for loco-motor disabled person. Generally, the over-lock sewing machine is operated using foot pedal and this sensor based method eliminates the foot pedal and use alternative ways to sew garment. The method-1 uses a flex-touch sensor and method-2 uses a textile sensor integrated wearable hand glove to operate the over-lock sewing machine.The seam efficiency of over-lock stitches performed using both the methods (1 & 2) has been assessed and compared with that of normal foot pedal method. Avariety of woven and knitted garments are sewed by implementing both the methods, and results are evaluated to calibrate and standardize the sensors/methods toencourage loco-motor disabled persons as self-employed sewing operators.

Keywords: Conductive fabric, Loco-motor disabled persons, Over-locksewing machine, Textile sensor, Touch sensor, Wearable hand gloves

1 Introduction

The over-lock machine is a versatile machine used in more than 3000 garment manufacturing (knitted and woven) industries in India. The foot lever method (pedal) iscommonly used to operate industrial sewing machine. In this, foot and hand are used during sewing operation, i.e foot to control motor on/off and hand to hold/fold the garment. This method is only suitable for normal persons and is not ideal for a person with lower limb impairment (loco-motor disabled persons). In India, 2.68 billion people are ‘disabled,' accounting for 2.21% of the entire population. The loco-motor disabled persons (lower limb-foot disability alone) have ability to speak, listen, learn, think and also work using their hands. They are in desperate need of an assistive technology for their mobility and also to stabilize themselves in terms of food, shelter and survival. A suitable job work would generate income that would fulfill all the above needs.

Sewing garment is one of the suitable jobs for loco-motor disabled persons. Garment industries provide wide scope for sewing operators. We devised unique stitching methods using two types of sensors, viz(i) flex-touch sensor based hand operated sewing method and (ii) textile sensor integrated wearable hand glove, that can control/operate the over-lock sewing machine through their hands and would eliminate the foot pedal operation in sewing machine. Both the methods are suitable for right/left handed operators to perform over-lock stitches for side seam, arm hole, sleeve and inseam etc. By this way the loco-motor disabled persons deliver the same level of work efficiency in par with other healthy operators (normal persons) and can earn revenues to progress their financial status.

Suresh *et al.*[1] designed and developed a new technology to assist disabled persons for operating an industrial single needle lock stitch sewing machine. A novel hand operated sewing methodology was developed for locomotor disabled persons who are devoid of their lower limbs (leg/foot). This hand operated sewing method was successful but had a constraint with reverse stitch operation. The differently abled persons cannot use the reverse lever function during sewing because both the hands are in use for sewing and cannot press and hold the reverse stitch lever downwards.

Mysios*et al.*[2] developed and implemented a dynamic PID (proportional-integral-derivative) force feedback controller for robot online sewing to enhance the real-time and stability of the sewing process control. The PID parameters are adjusted in time according to the change in the distance from the

[a]Corresponding author.
E-mail: rajaslm@gmail.com

sewing point to the gripper and the change in the sewing speed to ensure the optimal control parameters, to achieve a high-quality sewing effect.

Book *et al*.[3] developed an automated system for producing clothing that uses new sensor and actuation techniques. Also, machine vision is used to determine the location of the cloth during precision movement, and feature matching is used to align the stitching position of the cloth with the needle. This will increase the overall stitching process speed and effectiveness.

Zhou *et al*.[4] investigated a method for measurement of rail profile according to line-structured light vision. A system made up of a line laser and camera is used by structured light vision technology, an active three-dimensional measurement technique, to find and follow the edges of objects.

Yoshimi *et al*.[5] created a robot system for stitching fabric in three dimensions. Three-dimensional curved surface sewing is possible on the basis of low-speed feeding. The tracking accuracy of the trajectory, however, degrades with increase in the feeding speed.

Sawato *et al.*[6] designed a pedal arrangement for the sewing machine and it was controlled using a potentiometer device.When the operator presses the pedal mechanism, an electrical signal is produced that causes the pedal to move, in turn, activating the sewing machine. The resulting signal is sent to the motor, which changes its speed. The speed is proportional to the depressed movement distance of the lever. In proportion to how deeply the pedal has been pressed, the speed changes. Hence, the pedal can be depressed gently for slow speed and fully for fast speed, giving the rider a range of control from low to high.

Fujikawa[7]investigated and developed a mechanism to operate sewing machine. It contains a control device which works based on switch mechanism to start, control and stop the machine. The electronic based counter unit is also included to monitor the machine run time collecting all the status of machine.

Lewis[8] used a rotatory potentiometer control mechanism along with electronic circuit which rotates from 0^0 to 320^0 in circular motion. This rotation controls the speed of sewing machine electrically. Three types of prototype devices were developed using mechanical pulley, friction control device and rack/pinion arrangement device. All these prototypes cannot control the motor operation accurately, because the pulley based rotatory motion has operational delay, which was not suitable in real-time usage.

Curry and Leamon[9] designed a different speed control system for a sewing machine suitable for industry type sewing machines. This speed control system helps the handicapped people to operate the sewing machine using chest movement. A lever is used as channel to push/release the motor clutch and adjust sewing speed of machine.

Li *et al.*[10]examined the influence on sewing posture and the necessity for changes required in sewing machine design. The research focused and investigated the musculoskeletal issues that arise because of sewing and also they recommended two new design elements to enhance the sewing machine's table inclination angle and needle view.

Yamauchi[11]examined a novel technique for uninterrupted sewing using the sewing machine controller device. The invention uses sensors to detect the operators hand and operated the sewing machine ensuring safety for the operator.

Many of the researchers had worked to develop assistive technology devices for the benefit of differently abled persons. Every research had resulted in development of these beneficial assistive devices, such as electronic walking stick, automated voice controlled wheel chair, google guidance glass, etc. All these devices provide support / guide to overcome their physical disability and not in regard to their financial/livelihood developments. Therefore, in the present study, two novel operating methods have been developed for loco-motor disable person to operate industrial overlock sewing machines. This would provide an opportunity to sew garments and earn revenue for their financial and livelihood developments. The developed device has been taken up for testing with loco-motor disabled persons. The assistive device functionality and usability are tested and found suitable for them successively.

2 Materials and Methods

2.1 Materials

In this study, two novel methods using sensors to operate the over-lock sewing machine were developed. The method-1 is based on a flex-touch sensor fabricated using transparent insulating glass material coated with electrically conductive indium tin oxide. The fabricated sensor is bondedto a rigid fibre glass layer and this composite formed was fixed on the work area of over-lock sewing machine. The method-2 is based on textile sensor fabricated using silver coated knitted conductive fabric and silicone elastomer. The fabricated sensor was integrated inside awearable hand glove made using nylon fabric. The ergonomically designed hand glove holds the textile sensor internally at palm area and wireless enabled mini PCB (printed circuit board) over the wrist area. Along with this a removable/rechargeable slim power source (battery) was integrated to wrist area. A motor control unit (MCU) common for both the sensor methods was fabricated and fixed under the table of over-lock sewing machine.The MCU used for method-1 (flex-touch sensor) is connected through wire with socket and for method-2 the MCU communicates wireless with textile sensor integrated wearable hand glove.An infrared optical sensor is used at the bottom of work area of over-lock sewing machine to provide safety to the operator. Thissensor detects the presence of garment over the work area and prevents unintended machine operation accidentally.

2.1.1 Fabrication of Flex Touch Sensor(Method 1)

The sensor is developed by using two partially conductive layers which are separated by an empty air space. These layer arrangements make the top layer flexible and when gentle hand pressure is applied over the layer, it bends down and makes contact with the bottom layer.

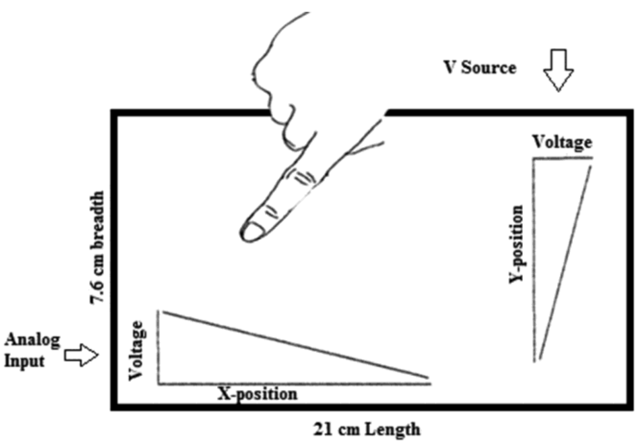

Fig. 1 — Calibration of flex touch sensor along X and Y axes

Table 1 — Pin configuration and status of flex touch sensor device

Sensor layer	Pin type	Pin config	Pin status
Top layer	Input	Analog	High
Bottom layer	Output	Digital	Low
Top layer	Input	Analog	Low
Bottom layer	Output	Digital	High

To sense the electrical change / feedback, a metal strip is drawn along two edges of both layers. The strips on one layer will run along the top and bottom, while the strips on the other will run along the right and left. By applying voltage gradient the sensor performance was electrically tested and calibrated as per the hand pressure applied on its flex-touch top layer(Table 1). The calibration test confirms equal sensitivity at all areas and corners of its surface (Fig. 1).The MCU unit has microcontroller chip which was programmed to select the modes (normal or wireless) and sensors parameters. The touch sensitivity and motor speedwas adjusted(incremented or decremented) and set by the operator using keypad unit available in MCU.This helps in sewing different types of garments which have different surface smoothness, weave pattern, thickness, roughness etc.

2.1.2 Fabrication of Textile Sensor Integrated Glove (Method 2)

Based on the study conducted on various conductive materials as listed in Table 2, the stretchable conductive fabric[Fig. 2(a)]has the excellent electrical conductivity and stretch property. This stretchable conductive fabricand silicone elastomer are used for the fabrication of composite textile, where the conductive textile acts as the electrical conductive component and elastomer is used to increase the durability of the developed composite textile sensor.The composite textile sensor is electrically conductive, stretchable and scalable onto different sizes/shapes as per requirement. The textile sensor is charged with electrical voltage (5 VDC),and stretched along its length,providingan electrical output based on the change in area of sensor. The change in area is inversely proportional to the electrical resistance.

The fabric used to develop the stretchable textile sensor (Table 3) is high ionic silver plated nylon elastic knitted fabric. The fabric has stretchable property in double direction.The glove is fabricated using blend of

Table 2 — Study of conductive materials for fabricating textile sensor

Material	Base material & coating	Electrical conductivity	Durability & stretch
Conductive felt	Non-woven polyester fabric with nickel coating	Good	Non stretchable
Conductive foams	Polyurethane foam coated with copper and nickel	Good	Good
Conductive rubber	Rubber filled with silver, nickel & Aluminium particles	Good	Excellent
Conductive fabric	Nylon and elastic fibre blend fabric coated with medical-grade silver	Excellent	Excellent

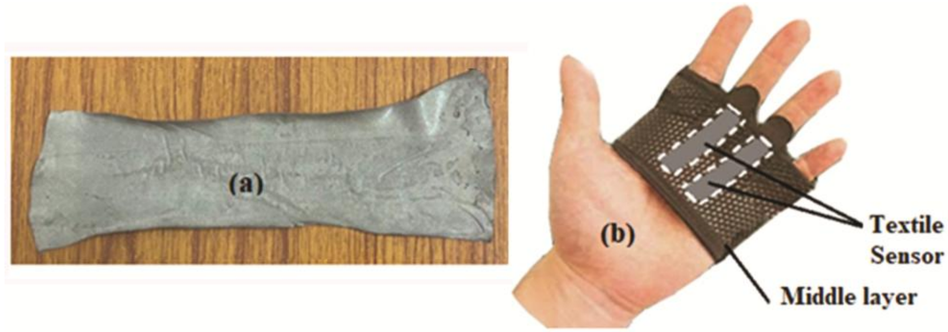

Fig. 2 — (a) Conductive stretchable knitted fabric coated with silicone elastomer, and (b) wearable glove integrated with textile sensor

98 % nylon and 2 % spandex fibre. Nylon fibre is chosen for its excellent durability and its light-weight property. Also nylon has good elasticity and provides good comfort for the wearer. The durability of nylon fibres provides cut resistant for gloves and can be easily wrapped with the third layer materials. A mini electronic PCB was specifically fabricated for this purpose and it contains embedded electronic components of microcontroller, bluetooth transceiver and replaceable/ rechargeable battery. The PCB unit of size (3.5breadth × 2 length in cm) is fixed on the wrist area of glove and covered by a textile layer. The developed textile sensor is scaled into small proportions of size (1 cm breadth x 3.5 cm in length) and tested electrically. After calibration the sensor is embedded into the glove and electrical connections were sewn using conductive yarn.

2.1.3 Fabric Detection Sensor

The Infrared proximity sensor switch (Fig. 3) is used as the fabric detection sensor. This sensor is a safety component which permits the sewing operation only if there is a garment placed on the work area of over-lock sewing machine. The sensor has an IR light transmitted and IR light receiver photo detector, having detection range 3-80 cm (Table 4). The Infrared light is sent by the sensor and the light is reflected back by the cloth. The photo detector reads the reflected light and ensures the fabric specimen placed over the work area and allows user to operate the over-lock sewing machine.

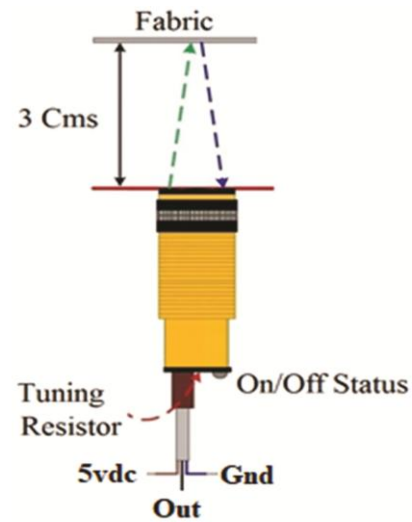

Fig. 3 — Calibration of fabric detection proximity sensors

Table 3 — Specification of stretchable conductive fabric

Property	Specification
Fabric blend	Nylon 76 % and 24 % elastic fibre
Coated material	Ionic higher grade silver
Electrical conductivity	Excellent conductivity
Fabric color	Grayish silver
Surface resistance	0.5 ohm (Normal state)
Fabric thickness	0.40mm
Stretch allowance	100% in Course and 60% in Wales

Table 4 — Pin configuration and status of fabric detection proximity sensor

Sensor pin	Pin type	Pin config	Pin status
Brown pin	5 V DC	Input power	High
Blue pin	0 V DC	Ground	Low
Black pin	Variable DC	Output	High at detection

2.2 Methods

2.2.1 Sewing Machine Operating Method-1

The over-lock sewing machine is operated using two novel methods containing two different sensors. The method-1 uses flex-touch sensor that recognises the human hand pressure applied on its surface. Also the sensor surface is smooth and allows the free movement of fabric over its surface and do not harm the quality of fabric. The sensor is rigid and withstands human hand pressure during sewing of over-lock seams.

The block diagram of MCU (Fig. 4) consists of capacitive touch sensor, textile sensor glove with wireless Bluetooth transceiver, fabric detection optical sensor, power supply unit, and main control unit withwireless Bluetooth transceiver, servo motor

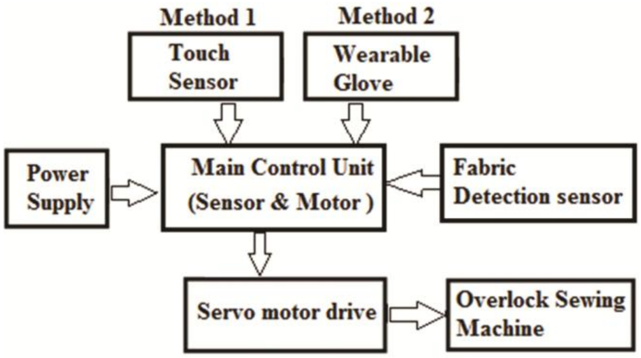

Fig. 4 — Block diagram of devices used in operating two methods for over-lock sewing machine

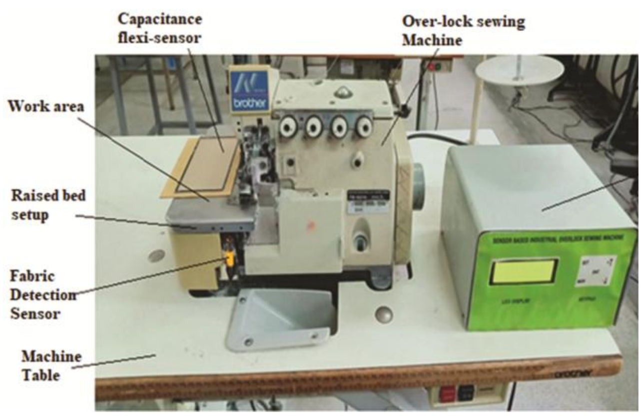

Fig. 5 — Flex touch sensor based operating method for over-lock sewing machine

drive and over-lock sewing machine. The MCU has two modes such as normal and wireless modes.The normal mode is selected for method-1, flex-touch sensor operated sewing method and wireless mode is selected for method-2 textile sensor integrated wearable hand glove operated sewing method. This MCU is a common unit which is compatible for both flexi-touch sensor and wearable handglove based sewing methods.

The over-lock sewing machine is setup as shown in Fig.5. The flex touch sensor is fixed firmly on the work area. The garment is placed over the sensor and the gentle pressure is applied over the sensor (Fig. 6). The change in electrical parameter and signal is transmitted to MCU unit. The microcontroller chip present in MCU reads the received serial data from sensor. The electrical drive is activated by the output signal of microcontroller chip and over-lock sewing machine is operated.

2.2.2 Sewing Machine Operating Method -2

To operate the over-lock sewing machine using method-2, the hand gloves is switched on and connected wirelessly with MCU. The MCU is set to

Fig. 6 — (a) Over-lock stitch formation and (b) sewing garment using flex touch sensor method

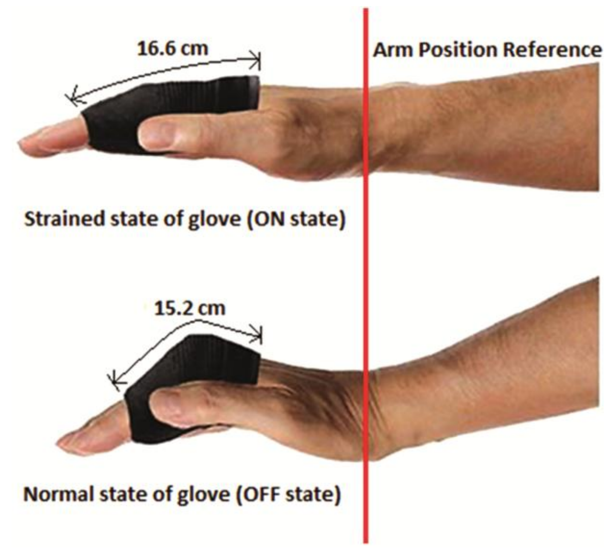

Fig. 7 — Textile sensor integrated wearable hand glove ON & OFF states

wireless mode and bluetooth wireless transceiver communicates with textile sensor integrated hand wearable glove.

Figure 7 shows the textile sensor integrated hand wearable glove sensor. In normal state of glove, the length of glove measures 15.2 cm and at stretched state it is 16.6 cm. Here, the change in length of glove is proportional to the change in textile sensor length. There is an electrical change in sensor which is manipulated by the mini PCB and wireless signal is transmitted from the bluetooth transceiver of hand glove to bluetooth transceiver of MCU which, in turn, actuate the sewing motor of over-lock sewing machine.

As shown in Fig. 8(b), the user narrows the inner wrist area by placing the hand on table of sewing machine the strain is applied to the glove and sewing machine is operated. The sewn garment and user hand is moved in forward direction over the sewing table surface. The over-lock stitch formation is shown in Fig. 8(a).The textile sensor integrated wearable glove is used to operate the over-lock sewing machine by strain principle. The user hand in normal state does not strain the glove.At the time of sewing, the strained glove remains in ON state for the strain length (16.3 - 16.6 cm) and automatically gets turned OFF as strain value is less than 16.2 cm elongation. This strain value control is executed by the programmable microcontroller chip of mini PCB. For user requirements, these strain length value can be adjusted (increment/decrement) by changing the software program and can make them to remain in ON state for a particular time period.

3 Results and Discussion

3.1 Comparison of Operators Stitch Performance using all Methods

The over-lock sewing machine is operated in three methods and the sewing performance is analysed based on the stitches performed for a particular time period(in seconds). The sudden start, sew (motor speed in revolutions per minute or rpm) and stop operations for a particular time period (s) are used to test the ability of the operator to perform stitches in all the three methods. The comparison results of over-lock seams performed in all three methods are tabulated in Table 5. The seamed length is measured in centimetres (cm).

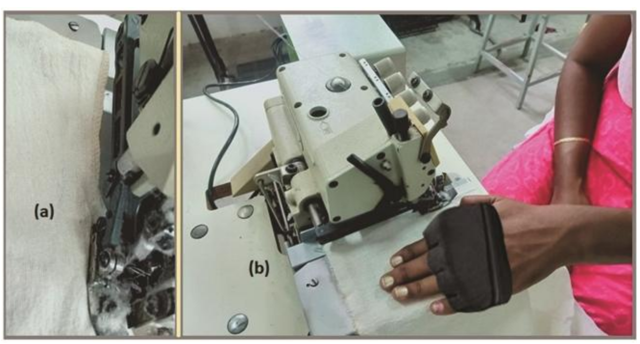

Fig. 8 — (a) Over-lock stitch formation and (b) Operating over-lock sewing machine using textile sensor integrated wearable hand glove

For a practical analysis, different types of garments, fabrics (knitted/woven) and stitch variant (4 thread & 5 thread) over-lock stitches arestudied. Table 5 shows the over-lock stitch performed by normal operator using foot pedal method and trained locomotor disabled operator using novel sensor based methods (flex touch and textile sensor hand glove). Both the woven and knitted garments are used, which are made of different variety of fabric materials. The results showthat the novel sensor based methods deliver the equivalent level of stitch performance like normal foot pedal sewing method.Generally, an over-lock sewing operation is used to perform edge covering stitch. This operation is easiest than any other operations, so loco-motor disabled operators can do without any discomfort, and moreover there will be break time in-between the working hours. Hence, the loco-motor disable operator can perform sewing in a garment industry effectively and make efforts to deliverproductivity equivalent to normal operators.

3.2 Comparison of Seam Quality using all Methods

In the clothing sector, denim trousers are the most popular item.The structural properties of the fabric, such as weave, thickness in millimetre (mm), weight in g/m^2, yarndensity (threads/cm), yarn count in New English count (Ne) and stitch type, mostly determine how well a seam performs in a garment. To evaluate the seam quality two essential elements, such as seam strength and seam efficiency, are required. The test is performed by sewing over-lock stitches in trousers made from two different denim fabrics. The denim fabric normally has good strength and over-lock stitch performed in fabric would be clearly providing the inputs to evaluate the seam quality and

Table 5 — Comparison of over-lock seams performed in all three methods using woven and knitted garments

Fabric type of woven garment (Trouser)	In seamed length starting from crotch, cm	Time taken (s) to perform over-lock seam (Motor speed set at 1000 rpm)		
		Foot pedal method, s	Flex sensor method, s	Textile sensor glove method, s
		Woven		
Denim	31.5	14.5	15.8	17.0
Cotton	31.0	14.0	15.0	16.5
Polyester	30.5	13.5	14.5	16.0
		Knitted		
Cotton	28.0	13.5	15.0	17.2
Polyester	27.5	13.0	14.5	16.5
Blended	27.0	12.5	14.0	16.5

seam strength values. The cotton denim, woven with elastane fabric (CE) and pure cotton fabric (C) are used in order to evaluate the seam performance.

Table 6 provides the information about the denim fabric used in trousers. The two different garment trousers made of denim fabrics are sewn in outer leg area using “over-lock with lockstitch”.The lock stitches are selected as 3 and 5 stitches/cm.The warp and weft densities of the sample fabrics are measured as per the ASTM D 3776-09a standard, and the seam strength& fabric strength are measured as per the ASTM D 1683-11a standard.Three fabric specimens selected for testing are cut in dimensions (450mm × 150mm) along weft direction and allowance is taken as (+/- 3mm) in length and width directions. The over-lock sewing machine is setup in raised and submerged bed positions accordingly and fabric test samples are sewn. The over-lock with chain stitch formation is done for three fabric samples and tested using computerised fabric vital tensoflow-1(fabric seam slippage tester).

The strength of fabric and strength of seam are measured for the weft portionof sample fabric and to evaluate the seam efficiency (Table 7) of over-lock chain stitch, the following formulais used.

Efficiency of seam =[Strength of seam (N) / Strength of fabric (N)]× 100

The value of strengths of seam and fabric are measured in Newtons (N) and the efficiency of seam is obtained in percentage value (pct). Before start of sample test, the test samples are inspected and kept for 24 h in room temperature(32° C) and60% humidity of environment.To evaluate arithmetic mean and results statistically, IBM - statistical analysis software has been used where the multi-variance analysis is kept as a fixed model and Newman-keuls test is used to compare the mean values obtained for three samples in three methods, foot pedal, flexi-touch sensor and wearable gloves method.

Table 8 shows the NK statistical analysis test results. The results prove that fabric used, stitch density and stitch variant measured for all three methods (foot pedal, flexi-touch sensor and wearable gloves method) are significantly equal. While comparison of fabrics, the seam efficiency of cotton with elastane fabric sample is found higher than that

Table 6 — Fabric types selected for testing seam ability

Weave	Denim fabric	Thread density threads/cm		Thread count of fabric, N		Warp thread type	Weft thread type	Thickness mm	Weight g/m^2
		Warp	Weft	Warp	Weft				
Twill	Cotton with elastane	28	22	12	8	Cotton	Cotton &elastanecore spun yarn	0.88	203.5
Twill	Cotton	22	20	10	9	Cotton	Cotton	0.92	285.8

Table 7 — Seam efficiency of over-lock chain stitch using normal foot pedal method, flex touch sensor method and wireless glove method

Denim fabric type	No of stitches stitches/cm	Strength of fabric Newton	Extension of fabric, %	Strength of seam Newton	Extension of seam, %	Efficiency of seam, %
Foot pedal method						
Cotton with elastane	3	870.50	86.50	470.56	81.90	54.05
	5	870.50	86.50	540.58	80.50	62.09
Cotton	3	1690.45	23.56	845.54	25.41	50.01
	5	1690.45	23.56	985.63	30.25	58.30
Flex touch sensor method						
Cotton with elastane	3	870.50	86.50	469.80	81.65	53.96
	5	870.50	86.50	539.75	80.10	62.00
Cotton	3	1690.45	23.56	844.10	25.35	49.93
	5	1690.45	23.56	984.20	30.10	58.22
Wireless glove method						
Cotton with elastane	3	870.50	86.50	469.80	81.80	53.96
	5	870.50	86.50	539.75	80.20	62.00
Cotton	3	1690.45	23.56	844.90	25.40	49.98
	5	1690.45	23.56	985.10	30.15	58.27

Table 8 — NK statistical analysis for seam efficiency comparison among three methods

Denim fabric type	No of stitches cm	Strength of seam Newton	Extension of seam %	Efficiency of seam %
Cotton with elastane	3 5	505.04	81.02	58.04
Cotton	3 5	914.91	27.77	54.12

of cotton fabric sample. Hence, the two novel methods deliver the same level of seam efficiency with that of normal foot pedal method. This study shows over-lock sewing machine operation using the two novel methods, whichare suitable for loco-motor disabled persons. The disabled can deliver the same level of work efficiency equal to a normal machine operator.

4 Conclusion

Two different novel methods using sensor to operate industrial over-lock sewing machine has been developed and tested. The developed methods are found more suitable for loco-motor disabled people.Operating methods is tested practically by sewing various garments and the findings are tabulated. The seam efficiency is calculated by using two different denim fabric samples employed for sewing over-lock stitches in all the three methods. The seam efficiency is determined and results prove that the two sensor-based sewing methods for over-lock sewing machine provide the same seam efficiency as equal to the normal foot pedal operated method. All the three methods provide good seam efficiency and seam quality. For loco-motor disabled persons, the foot pedal operationis a constraintand hence is eliminated using thesenovel sensor-based hands operated sewing methods. Here, we conclude that the utilisation of this invention in over-lock sewing machines of garment industry would create employment opportunities for differently abledto work comfortably, sew garment and shall earn revenues for their economy development.

Acknowledgement

The authors are thankful to the Institute of Engineers India Limited (IEI) for providing financial research grant under R & D grant-in-aid scheme.

References

1 SureshSS, Raja D& Mani K, *Indian J Fibre Text Res*, 44 (3) (2019) 314

2 Misios I H, Koustoumpardis P N & Aspragathos N A, *AdvIntelligent Systems Computing*, 980 (2020)104

3 Book Wayne J, Winck Ryder C, Killpack Marc D, Huggins James D, Dickerson Stephen L, Jayaraman Sundaresan, Collins Thomas R&Prado Ronald J,. *Proceedings, International Symposium on Flexible Automation (ISFA)*, 12-14 July 2010.

4 Zhou P, Xu K& Wang D,*IEEE Access*, 6(2018) 16423

5 Yoshimi T, Takezawa K & Hirayama M, *IFAC Papers On Line*, 51(22)(2018) 1.

6 Sawato T,Yamada H &Takikoshi K, *U S Pat* 5,208,520, 4May1993.

7 Katsuhiro Fujikawa, *U S Pat* 4,915,045, 10 April1990.

8 Tim Lewis, *Studies Design Education J*, 13(2)(1981) 201.

9 Curry Z D &Leamon T B, *National Center for Biotechnol Information J*, 24(4)(1993)284.

10 Li G, Haslegrave C M & Corlett E N, *Appl Ergonomics J*, 26(1)(1995)35

11 Satomi Yamauchi, *U S Pat* 4,840,135, 20 June1989.