Development of assistive technology to operate industrial grade sewing machines for differently-abled persons

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An assistive technology to operate the sewing machine by hand has been developed and made suitable for differently-abled persons. This assistive device has been developed using two variant techniques, viz Technique-A and Technique-B. Technique-A involves electromechanical potentiometer control and Technique -B involves electrical servo motor control. The sewing machine is developed individually for each technique and tested in terms of machine handling factor, energy consumption, maintenance and productivity. Based on comparative test results, the assistive device of Technique -B is highly suitable and suggested for differently- abled persons. The operator performance in terms of single cycle time (SCT), efficiency, earning and skill level between normal persons and differently-abled persons has also been studied. With this new development, differently-abled persons can work and earn in garment industry like a normal sewing operator.

Keywords: Differently-abled person, Garment industry, Hand-operated mechanism, Potentiometer control, Sewing machine, Servo motor control

1 Introduction

The Industrial sewing machine is normally operated by using foot pedal. The foot pedal design and operating mechanism is well suited for a physical healthy operator. Other than normal human beings, there are more than twenty million differently-abled persons in our country who are either completely deprived of the lower limbs or possess incapacitated ones. Considering the economical need to benefit differently- abled persons a new technique to operate an industrial sewing machine need to be developed.

Fujikawa[1] developed a sewing machine control device with an operating switch which acts as a commanding medium to start and stop the sewing machine by turning it on and off . Along with the switch, an electronic counter is added to monitor the duration of a running machine. By this, the status of sewing can be collected. Yoneji and Yoshiharu Higuchi[2] designed an electrical drive system for a sewing machine to improve the speed controlling performance for an electric motor. This system controls the starting operation, speed and braking operation of sewing machine.

Newbold[3] attempted to design an adjustable semi-stationary foot switch for operating the sewing machine. This device accommodates various sizes of foot switch mechanism with two threaded rods. The foot switch treadle panel of various sizes can be changed according to foot size of operator. Yamauchi[4] analysed a new method named 'Sewing machine controller inhibiting sewing medium' to perform uninterrupted sewing operation with safety by detecting operator's hand using sensors.

Sawato *et al.*[5] analysed the pedal assembly of the sewing machine with potentiometer control. When the pedal is depressed to actuate the machine, a signal is transmitted that changes the speed. The extent of change is proportional to the extent to which the pedal has been depressed. The pedal is depressed slightly for slow speed and fully for high speed. According to Lewis[6] in alternative sewing machine control, the rotary potentiometer controlling the electronic circuit require 320^0 movement to give complete control of the sewing machine. They developed three prototypes. The first prototype was designed and constructed using a pulley system to convert the 80 mm of linear movement into the 320^0 of rotary movement. The second prototype incorporated a friction device and third prototype is designed with a rack and pinion arrangement. However, these designs were found over-complicated.

Curry and Leamon[7] developed an alternative speed control for industrial sewing machine.

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A suitable speed-control mechanism is developed for paraplegics, which controls the sewing operation using chest movement with help of a lever. Li *et al.*[8] analysed the factors affecting posture for machine sewing tasks and the need for change in sewing machine design. They studied the musculoskeletal problems arising during the sewing process and they suggested two design parameters to improve table inclination angle and needle view of sewing machine.

Many researchers worked on sewing machine automation, machine speed control and computer assisted sewing technology. Their research outcomes exposed some improvements in sewing machine performance. However, the focus to provide alternative sewing method for benefit of differently-abled persons was not fulfilled. Therefore, in this research an assistive device has been designed and developed with user-friendly features to benefit the differently -abled persons.

2 Materials and Methods

2.1 Designing of Assistive Devices

In an industrial sewing machine, the electric motor is connected to a drive wheel by using a drive belt. The motor is controlled by a foot pedal, which lets the sewing operator to vary the speed. Differently-abled persons with deficit of lower limbs cannot operate a foot pedal in the sewing machine. To overcome this, an alternative solution was developed to perform sewing using specialized instrument which facilitates differently-abled persons to control sewing operation using their hand. A hand plate was designed, fabricated using steel and mounted adjacent to the throat plate on the sewing machine. The plate profile, dimension and fixing position were determined from detailed research and observations collected from highly skilled sewing operators.

A pressure recognition sensor which acts as an electronic transducer is mechanically connected beneath the hand plate. It converts the pressure given by hand into an electrical signal (voltage). This hand plate is supported by a spiral spring arrangement to provide elasticity during pressing and release. The pressure given to the hand plate is transferred to pressure recognition sensor. All the input and output electrical signals are processed and controlled by a microcontroller. The sewing motor start-up speed, regulated speed and brake mechanism are controlled

by using two different techniques (Technique-A and Technique-B) as given below.

2.1.1 Technique - A

The assistive device of Technique-A (Fig. 1) is designed with electronic mechanical devices. The setup includes metal hand plate with pressure sensor, AC clutch motor with clutch lever, lever pulling arm, lever control motor, magnetic brake, amplifier, microcontroller unit, control circuit and electronic potentiometer. All the functionalities are programmed and stored in microcontroller chip. The clutch lever is mechanically interlinked with lever control motor. When the operator applies gentle pressure on hand plate the pressure sensor is triggered
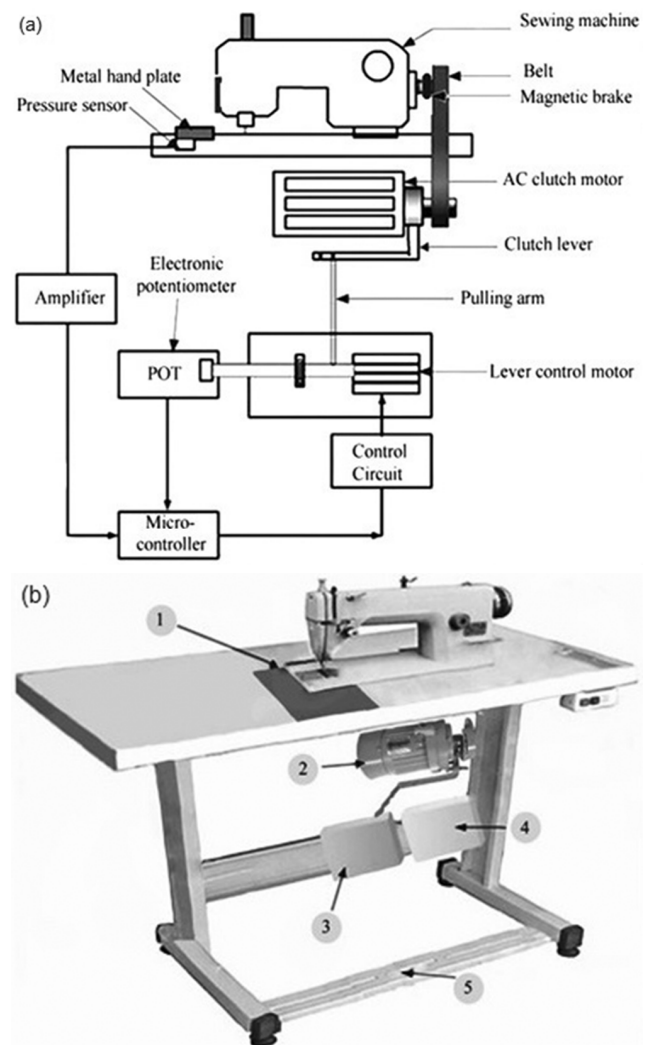

Fig. 1 — (a) Model and (b) block diagram of sewing machine in Technique -A [1–Hand plate and pressure sensor, 2–Clutch motor and lever, 3–Lever control and potentiometer, 4–Microcontroller unit, and 5–Absence of foot pedal]

and it develops electrical signal. The signal is transmitted to the microcontroller and processed internally to control the potentiometer device.

The potentiometer directs the lever control motor rotary motion in clockwise or counter-clockwise direction. In clockwise motion, the clutch lever is pulled downward and engages the belt drive wheel with motor drive wheel. The counter-clockwise motion pushes the clutch upwards and disengages the belt drive wheel. After disengagement the sewing machine drive wheel is stopped instantaneously using a magnetic braking device.

Figure 1(b) shows the actual picture of model sewing machine in Technique-A. The hand plate with pressure sensor is designed ergonomically using L- shaped metal plate, fabricated and assembled on sewing machine. Clutch motor with clutch lever arrangement is the main drive unit of sewing machine. Lever control unit with potentiometer arrangement operates the clutch lever. Microcontroller unit controls the entire logical operations of all devices during sewing process and electromagnetic brake setup is installed to stop the drive instantaneously.

2.1.2 Technique - B

The device in Technique-B (Fig. 2) is designed with AC servo motor and servo drive unit.The setup includes metal hand plate with pressure sensor, AC servo motor, servo driver unit, amplifier, user interface unit and microcontroller unit. The electrical speed control techniques are used in Technique-B to perform soft start, dynamic braking and speed regulation operations. All the functionalities are programmed and stored in a microcontroller unit. Power saving AC servo motor is used which provides higher accuracy for the entire sewing process. The microcontroller is programmed to control the servo motor based on user requirements. This system operates with variable speed ranging from 100 to 3000 revolutions per minute.

A hand plate with pressure sensor is designed ergonomically using L- shaped metal plate, fabricated and assembled on sewing machine. A power saving servo motor is the main unit to operate sewing machine. Servo drive unit controls the speed of the sewing machine. Microcontroller unit controls the entire logical operations of all devices during sewing process and the user interface unit allows for setting the desired speed/sensitivity as required by the user.
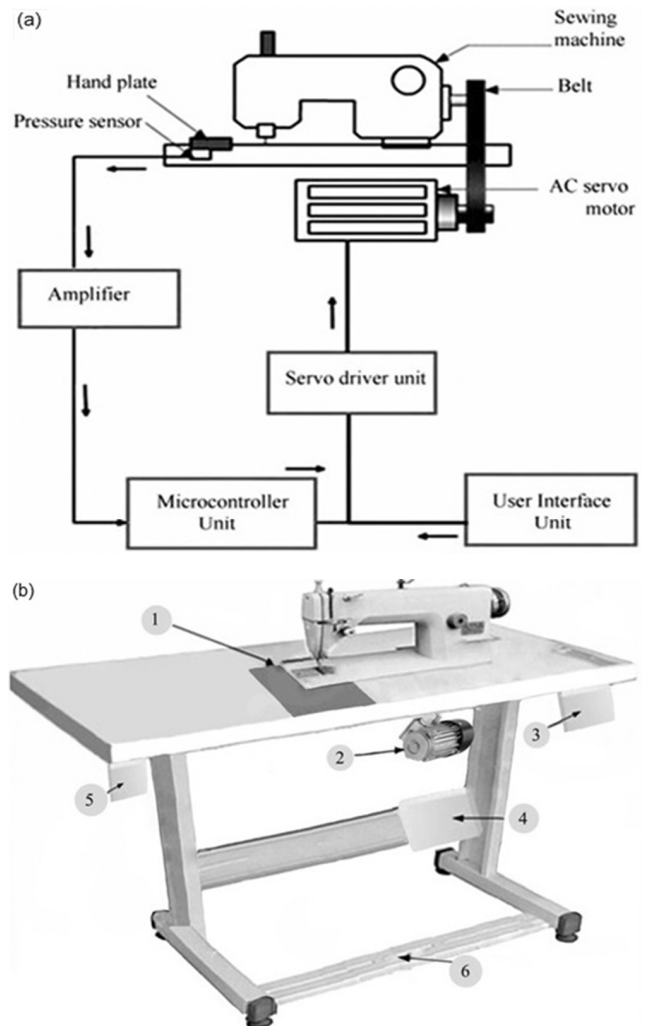

Fig. 2 — (a) Model and (b) block diagram of sewing machine in Technique –B [1–Hand plate and pressure sensor, 2–Servo motor unit, 3–Servo motor driver unit, 4–Microcontroller unit, 5–User interface unit, and 6–Absence of foot pedal]

When the operator applies gentle pressure over the sensor it gets activated to start the sewing motor. When the operator removes the hand away from the hand plate the pressure on the sensor is reduced and the servo drive stops the motor. The above- said entire sewing operation is executed by hand and it helps the differently-abled persons to operate the sewing machine easily.

3 Results and Discussion

The sewing machine for disabled persons is developed with Technique-A and Technique-B. They are compared to analyse the factors, such as motor performance, sewing speed, motor control and multilevel skill analysis.

3.1 Sewing Speed Analysis

The variation in pressure applied on sensor produces voltage variation in the sensor output voltage. The sensor output voltage range is 4-20 mV, where 4mV corresponds to the lowest pressure on sensor and 20mV corresponds to the maximum pressure applied on sensor.

In Technique-A, the clutch motor speed is lagging than in Techinque-B cluth motor speed. The Technique-B has a steady state speed response due to servor motor attachment and will be suggested as suitable for assistive device for disabled persons (Fig. 3).

3.2 Motor Performance Analysis

The start, sew and stop are the main operations in sewing machine. The disabled persons should perform all these tasks using hand operation. In Technique-A, clutch motor is used. The hardness of clutch lever results in some time delay of one second and continuous run of clutch motor draws high current of 2.5 Amp. The Technique-B uses servo driver with quick start at 0.5s and energy saving servo motor consuming 1.5 Amp current. Hence, Technique-B has an improved performance (Fig. 4).

3.3 Motor Control Analysis

The responses from assistive devices of Technique-A and Technique B are analysed for stopping sewing motor. As soon as the the disabled person moves the hand away from pressure sensor, the sewing motor gets deactivated (stoped) instantly. Figure 5 shows

the deceleration comparision plot of Technique A and Technique B. Technique-A shows a gradual braking time of 1.5s, while Technique-B shows an instantaneous braking time of 0.9s. The brake performance of assisitive device in Technique-B is efficient than in Technique-A.

3.4 Productivity Analysis

Productivity factor is analysed based on Single cycle time (SCT) to sew a complete garment using both techniques (Table 1). Technique-A has low productivity value than Technique-B. Higher responsive electronic circuit, accurate servo operation, soft start, dynamic braking, energy saving and low maintenance proves that technique-B has a better productivity.
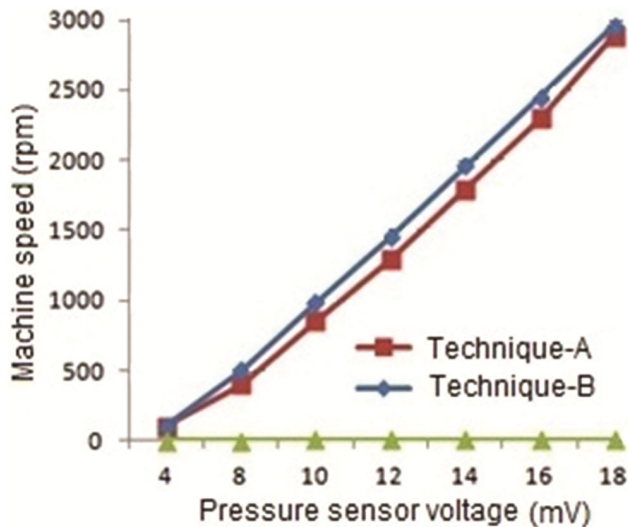

Fig. 4 — Motor current and time comparison graph

Fig. 3 — Pressure sensor voltage and machine speed comparison graph
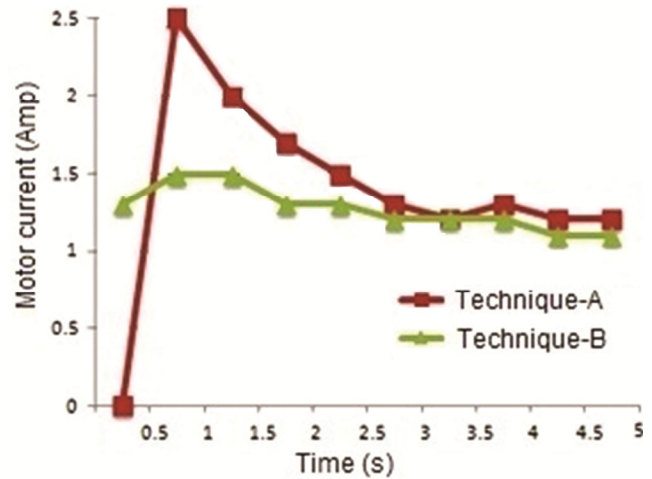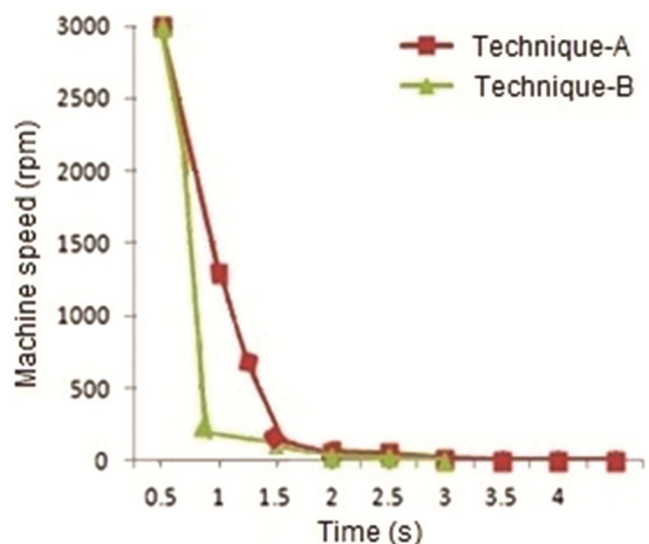

Fig. 5 — Machine speed and time comparison graph at braking

Table 1 — Single cycle time value recorded for SNLS machine for full sleeve shirt in Technique-A and Technique-B

Single cycle time, min

Technique –A				Technique –B			
Collar	Front panel	Sleeve	Assembly	Collar	Front panel	Sleeve	Assembly
2.85	1.70	2.05	6.06	2.65	1.58	1.97	5.78
2.86	1.73	2.10	6.08	2.53	1.56	1.88	5.70
2.83	1.70	2.08	6.11	2.62	1.60	1.97	5.65
2.86	1.72	2.11	6.10	2.66	1.58	1.95	5.78
2.92	1.75	2.06	6.06	2.68	1.55	1.97	5.73
2.95	1.78	2.05	6.12	2.58	1.56	1.95	5.70
2.88	1.70	2.12	6.06	2.52	1.56	1.94	5.73
2.85	1.73	2.10	6.13	2.63	1.58	1.95	5.75
2.88	1.77	2.11	6.08	2.66	1.60	1.96	5.80
2.86	1.80	2.08	6.07	2.65	1.63	1.97	5.82
2.87	**1.73**	**2.08**	**6.08**	**2.61**	**1.58**	**1.95**	**5.74**

Values in bold are average values.

Table 2 — Disabled and non-disabled operator performance analysis
[Sewing operation – Shirt bottom fold, Standard minute value – 0.55 min (target 872 pcs /day)]

Non-disabled operator (leg operated method)					Disabled operator (hand operated method)				
Operator	SCT min	Hourly production	Production/ 8 h	Efficiency %	Operator Name	SCT min	Hourly production	Production/ 8 h	Efficiency %
N1	0.686	87.5	700	80	D1	0.79	75.9	608	70
N2	0.62	96.8	774	89	D2	0.75	80.0	640	73
N3	0.71	84.5	676	78	D3	0.74	81.1	649	74
N4	0.692	86.7	694	80	D4	0.77	77.9	623	71
N5	0.61	98.4	787	90	D5	0.76	78.9	632	72
	0.6636	**90.4**	**723**	**83**		**0.762**	**78.7**	**630**	**72**

Values in bold are average values.

3.5 Disabled and Non-disabled Operators Performance Analysis

To compare operator performance analysis (single cycle time, production, efficiency and earnings) of both disabled and non-disabled, we selected a group of five operators in each category. Before taking this analysis, we gave training for disabled and non-disabled persons. Disabled persons were trained in the assistive device sewing machine,where non-disabled trained in normal sewing machine. After proper training, we measured SCT for a specific operation (shirt bottom fold). Using SCT, we calculated hourly production, production per day and his/her efficieny (Table 2).

Operation Efficiency

Operation efficiency of both normal and differently-abled persons are shown in Table 2. Ratio between actual output with target output (operation efficiency) is calculated using the following equations:

Non-disabled operators (leg operated)

Operation efficiency = (Actual output/Target output) × 100
= 723/872 × 100 = 83%

Disabled operators (hand operated)

Operation efficiency = [(Actual output/Target output)] × 100
= 630/872 × 100 = 72%

Operator Earnings/Economy

Average production per day of normal operators and disabled operators was studied (Table 2) Earnings per day can be calculated by multiplying production per day with construction (Shirt bottom fold) cost per piece.

Non-disabled operators

Earning/day = Production per day × Construction cost per piece
= 723 × Rs 0.80
= Rs. 579
Earning/day = 579/697 × 100
= 83%

Disabled operators

Earning/day = Production per day × construction cost per piece
= 630 × Rs 0.80
= Rs. 504
Earning/day = 504/697 × 100
= 72%

When compared to non-disabled operator earnings (83%), differently-abled operator earning is comparatively less (72%). But when compare to other disabled people earnings (Rs 300/day working as helper), it increases 66% (Rs. 504/day as semi skilled operator). Therefore, this innovative technique improves the earning and economy of disabled community.

Operators SCT Study

Non-disabled and disabled persons operation (shirt bottom fold operation) element (distinct part of a operation) analysis was done seperatly using time study procedure to calculate SCT. Results shows that the disabled operators take more time than non-disabled operators. The reason is disabled operator needs to use only hands to operate the machine as well as controlling the material feeding (Table 3).

Operator Skills

The required skills to sew shirt bottom fold operation are:

- Folding the bottom twice properly
- Start with a back tack at the starting point
- swing the fabric in the folder and stitch for 5 cm
- Swing out the folder in side seam then fold & stitch the bottom hem
- Swing the fabric in the folder and stitch
- Swing out the folder and End with aback tack at the other side
- Inspect the garment and dispose the piece

For the above skills to sew shirt bottom fold operation, we studied disabled and non- disabled operators skill levels. We found that disabled operators are slightly laging as compared to non-disabled operators. This is because they control both the material as well as the sewing speed only by hands. But in the case of normal operators he/she can use leg to control sewing speed and hand to control material handling.

Operator peformance analysis (SCT, production, efficiency and earnings) of both disabled and non-disabled operators shows that the disabled operators performance is 73%, whereas non-disabled persons performance is 88%. With this developed technology, disabled opertors can perform and produce 80% output of non-disabled operators. Proper trainings and skills development sessions will further improve the disabled operators performance.

4 Conclusion

A new assistive technology has been designed and developed to operate industrial sewing machine suitable for differently-abled persons. Two different techniques and devices, namely Technique-A and Technique-B are developed to operate single needle lock stitch (SNLS) sewing machine. The results show that both the techniques are suitable for differently-abled persons to operate industrial sewing machine and Technique-B is more efficient than Technique-A. The disabled and non-disabled persons operation performance analysis in the developed technique has also been done and the results show that the disabled persons can produce 73% of SCT target and 87% of regular operator production levels. This development helps differently-abled persons to improve their livelihood.

Table 3 — Operators elements and single cycle time (SCT)

Procedure for shirt bottom fold operation	Non- disabled operator elements times	Disabled operator elements times
Picking shirt bottom area	3.2	3.6
Fold bottom twice at front placket side and place it under foot	4.2	4.5
Start with a back tack at the starting point	3.2	5.3
Swing the fabric in folder and stitch for 5 cm	6.2	8.6
Swing out the folder in side seam then fold & stitch bottom hem	6.4	8.7
Swing fabric in folder and stitch	6.5	7.9
End with aback tack at other side	4.2	4.9
Inspect garment and dispose the piece	5.3	5.3
Total elements time	39.2	48.8
Operation SCT	39.2/60 =0.66 min	48.8/60 =0.81 min

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