Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 12 Issue 9, September - 2025

Design and Development of an Automated System for Cutting the Protruding Length of the Sewing Thread Cone

D.M.M.P. Lawrence
Department of Textile and Apparel Engineering
University of Moratuwa
Sri Lanka
181025m@uom.lk

P.M.N. Dilshan
Department of Textile and Apparel Engineering
University of Moratuwa
Sri Lanka
181012v@uom.lk

K.P.M.C.K.B. Karunaratne
Department of Textile and Apparel Engineering
University of Moratuwa
Sri Lanka
charukak@uom.lk

P.L. Liyanage
Department of Textile and Apparel Engineering
University of Moratuwa
Sri Lanka
pasindul@uom.lk

Prof. E.A.S.K. Fernando
Department of Textile and Apparel Engineering
University of Moratuwa
Sri Lanka
sandunf@uom.lk

Prof. T.S.S. Jayawardena
Department of Textile and Apparel Engineering
University of Moratuwa
Sri Lanka
jaya@uom.lk

W.V.P.R. Fernando
Department of Textile and Apparel Engineering
University of Moratuwa
Sri Lanka
philipf@uom.lk

***Abstract* — The sewing thread cone packing process in textile factories often encounters challenges of protruding thread ends on the thread cones, leading to cone damage and reduced productivity. To overcome this, an automated system has been designed and developed, focusing on the precise cutting of protruding thread ends of the sewing thread cones. Through a careful examination of the current packing process and a comprehensive literature review, suitable techniques were identified. Authors attempt to resolve the said problem by utilizing compressed air and heat cutter. Subsequently, a prototype of the system was designed based on the collected data, and the experiments were conducted to determine a suitable cutting temperature for different thread types. The implementation of the automated system enhances productivity, minimizes sewing thread cone damage, and reduces labor in the sewing thread cone packaging. This research significantly contributes to improve and betterment of the overall operations within the apparel industry.**

Keywords—Protruding length, sewing thread cone, heat cutter, automated cutting system

I. INTRODUCTION

Sewing threads are produced using natural fibers, synthetic filaments, or blends of both, which are converted into yarn through the spinning process. The yarn cones obtained from spinning are subjected to the plying and twisting process to convert as the sewing thread. Subsequently plied and twisted undergoes dyeing process with HPHT (High Pressure High Temperature) dyeing machines. Once the dyeing process is complete, the yarn packages are delivered to the winding section where they are waxed and wound into sewing thread cones based on customer requirements. These sewing thread cones are then transferred to the packing section for further processing to make them suitable for shipment to customers.

In the packing process, the first step involves feeding, sewing thread cones into a labelling machine to attach labels containing the specifications of the sewing thread. The labelled sewing thread cones collected in plastic bins are manually transported to the packing machine, where the cones are placed on a table prior to being fed into the packing machine. At this stage, two operators are responsible for cutting the unfolded thread ends protruding out from the cones. The cones are then fed into the packing machine, where a polythene cover is added and sealed at both ends with a heated sharp plate. Ultimately, the packed sewing thread cones are placed in boxes and shipped to the customer. In the packing section, a common issue is the presence of protruding ends on the sewing thread cones received from the winding section. This results in the entanglement of sewing thread with the machine parts of the packing machine, causing the position of the thread cone on the conveyor belt to shift. This, in turn, can lead to the crushing of the sewing thread cones when they come into contact with the heated sharp plate. The issue of damaged sewing thread cones also leads to the need for removing crushed cones as waste, further impacting the overall productivity of the factory. According to the observations made in the industrial process, damage to the sewing thread cone during packing is a major problem in the factory. Therefore, addressing this issue is crucial for improving the packing process and ensuring optimal productivity.

As an alternative to the current manual method of cutting the protruding sewing thread ends, an automated system has been developed that utilizes airflow to direct the unfolded sewing thread ends to the cutting mechanism[1]– [3]. This newly developed system incorporates a heat-based thread cutter that cuts the thread and ends with precision. By utilizing this automated system, the risk of manual error is minimized, while the efficiency and accuracy of the cutting process are improved. This development is expected to have significant positive implications for the packing process, leading to reduced manual work and increased productivity.

II. Literature review

The literature review will investigate existing sewing thread handling (gathering) methods, thread sensing methods, thread gripping methods, thread cutting methods and waste thread removal methods to cut the protruding sewing thread ends that come out from the cones in order to overcome the sewing thread cone damage during the packing process. When cutting the unfolded sewing thread ends from cones on a conveyor belt, there are several steps that should be followed to ensure a safe, efficient, and precise cutting process. They can be stated as Gathering, Sensing, Griping, Cutting, Removing the waste.

A. Gathering

Unfolded thread ends can freely move, and they can be at any place on the cone. Therefore, it is difficult to cut the unfolded thread ends without gathering it into one place. Therefore, gathering is important to cut the unfolded thread ends accurately.

A pneumatic suction unit can be used to gather unfolded thread ends. A pneumatic suction unit is a device that uses compressed air to create a vacuum, which can be used to suck up one or more running threads and other waste. The suction unit can be mounted on the conveyor belt or other moving surface, and as the thread cones pass over it, the vacuum sucks up the thread ends, and waste thread ends are collected in a container or bag[5]. There are a few potential advantages of using a pneumatic suction unit over a robotic arm and a mechanical brush or roller to gather unfolded thread ends.

They enhance efficiency by swiftly and effortlessly gathering thread ends from various locations. Pneumatic suction units boast versatility as they can be adjusted to accommodate different types of threads with variable thicknesses. Another noteworthy benefit is the minimal physical contact between the pneumatic suction units and the thread. This characteristic reduces the risk of damaging the sewing thread and thread cone.

Pneumatic suction units are commonly used in the textile industry to handle yarns during the winding, twisting, and other processing operations. These units use a combination of compressed air, suction to hold and manipulate the threads, allowing for more precise control and increased efficiency in the manufacturing process. The suction units can also be used to remove any dust or waste that may have accumulated on the threads during production[6]. In air jet loom, pneumatic suction unit is used in main nozzle that is used to weft insertion[1]. In the rapier loom, Pneumatic suction device is used for the removal of the weft yarn waste[7]. The yarn suction gun, which is an essential component of spinning machines, is responsible for picking up a running yarn either at the start of the spinning process or in the event of thread breakage and then taking it to a bobbin. Additionally, during the bobbin exchange step, it is used to transfer the thread from a full bobbin to an empty one[2].

B. Sensing

It is important to identify whether thread is sucked by the suction unit before griping and cut the yarn. Sensors can be used to do that. There are several types of sensors that can be used to detect whether yarn has been successfully sucked by a suction unit.

An optical sensor typically consists of two main components: a light source and a detector. The light source, such as an LED or laser, emits light that is directed towards the target (in this case, the thread). The detector, such as a photodiode or a photosensitive transistor, is positioned to receive the light that is reflected or transmitted by the target. Thread vibration can significantly affect detection in sensors[8]. Optical sensors use light scattering, interference, diffraction, or other optical phenomena to detect the position, movement, and shape of an object.

In a two-component optical sensor, when a thread passes through, it interrupts the light beam, causing a change in the amount of light received by the detector. This change in light intensity is then converted into an electrical signal, which can be used to detect the presence of the thread. Photoelectric sensors are primarily used to detect the presence or absence of a thread [9].

A line-laser-based thread break sensor is a sensor that uses a line laser to detect breaks in threads. The sensor illuminates the thread with a laser line, and the light spots created by the laser light on the threads are counted and compared to a previously recorded number. Changes in the number of light spots can indicate a break in the thread [8], [10]. Therefore, line-laser-based thread break sensors can be used to sense the presence of thread. But light spot detection may be difficult when the thread is too thin.

C. Gripping

After gathering the unfolded thread ends using a suitable method, the thread should be gripped to cut as per the requirement. The sewing thread should be gripped in a way that is secure and stable, and that allows for precise cutting. It is not possible to maintain the tension required to cut the thread after gathering using the pneumatic suction unit. The cutting frequency can be reduced by providing a required pre-tension to the sewing thread [11]. Therefore, the use of a thread gripping mechanism is required. The gripping method involves securely holding the thread in place so that it can be cut to the desired length.

A pneumatic clamp or gripper is a device that uses compressed air to generate mechanical force that can be used to grip or hold materials. Pneumatic clamps or grippers are typically designed with a mechanical linkage that converts air pressure into a gripping force. The mechanical linkage may consist of a piston, a cylinder, and a set of jaws or other gripping elements that can be used to hold the material securely. This method is commonly used in automated textile manufacturing processes and is known for its fast and precise grasping capabilities[12].

A mechanical clamp or gripper typically consists of a set of jaws or other gripping elements that can be moved or adjusted to hold the material securely. These devices use mechanical means, such as gears, levers, and cams, to generate a force that can be used to grip or hold materials. The mechanical clamp or gripper can be designed to hold a wide range of materials, including threads, fabrics, and other materials used in the textile industry. Mechanical gripping is commonly used in manual textile production processes because of its durability and reliability. The mechanical clamp or gripper is a simple and straightforward device that requires minimal maintenance and can be used for a wide range of applications[13].

D. Cutting

After the unfolded thread length is correctly gathered and gripped, the thread is cut using a cutting mechanism. It is important to note that the choice of cutting method depends on the type of thread and application of cutter. Currently, various types of yarn cutting methods are used in the machines that are used in textile industry such as air jet weaving machine, water jet weaving machine, yarn winding machines, knitting machines[3], [14], [15].

The heat cutting method uses heat to melt the thread, which allows the thread to be cut cleanly and without fraying. This can be done with a heated knife, wire or laser cutting machine. This method is commonly used in the cutting of synthetic fibers such as nylon and polyester. However, this method can result in the formation of bead-like residue on the cut edge, also known as "beading". This is caused by the melted fibers being forced out of the cut edge and then solidifying into small beads. Thus, making a bead at the cutting edge of the yarn is a hindrance for the next process and it may be a disadvantage of this method. Also, this method has disadvantages such as safety hazards, risk of injury to operators, risk of discoloration or distortion.[4]

A heat cutter can be used to cut thread without the need for a gripping element that is used to produce stability and pre-tension on thread, as the thread can be cut simply by touching it with the heated elements. Since the heated element is always hot, it is not necessary to use sensing to detect the thread, as the element will cut the thread whenever it comes into contact with the thread. But, if the heated blade comes into contact with the airflow generated by the suction gun, it can cause the blade to cool down.

Mechanical cutting method uses a mechanical cutting blade or scissors to physically cut the thread. This can be done manually or with an automated cutting machine. Mechanical cutting blades are used in the air jet weaving machine and water jet weaving machine to cut the weft yarns. The cutting blade that is used in air jet weaving machines is typically made of a hard and durable material, such as steel, and is sharpened to ensure a clean cut. The cutting mechanism is designed to be fast and efficient, so as not to slow down the overall production process. Also, mechanical cutting systems used in the automatic yarn winding machines to cut the yarn after wound required length of yarns on the cones[16].

Ultrasonic cutters are another method of cutting used in the textile industry. They use high frequency ultrasonic vibrations to cut fabrics, threads/yarns, and other textile materials.

This cutting method is known for its precision and clean cuts, as well as its ability to cut through multiple layers of fabric at once. The principle of ultrasonic cutting is based on the use of high-frequency vibrations to create a cutting action. An ultrasonic transducer generates vibrations, which are then transmitted to a cutting blade. When the blade comes into contact with the material, the high-frequency vibrations cause the material to weaken and break, resulting in a clean and precise cut[17].

Laser cutters use a focused beam of light to cut through materials, including yarns and threads. The yarn is placed on a cutting bed, and a high-powered laser beam is directed at the yarn. The laser beam heats the yarn to a high temperature, causing it to melt or vaporize along the cut line. The laser beam is guided by a computer-controlled system, which allows for the precise cutting of complex patterns and shapes[18]. The laser cutting process is fast, accurate, and efficient, and it produces minimal fraying or unravelling of the yarn. Laser cutting is also useful for cutting delicate or intricate patterns, as the laser beam can be easily guided to cut even the smallest details. Overall, the use of laser cutters in cutting threads can bring a lot of benefits such as high precision, speed, flexibility, and minimal waste, for that reason it is widely used in the textile industry. Safety issues are the main drawback of the laser cutting method[19].

E. Removing the waste

The weft yarn wastage of the rapier loom is removed by using a pneumatic suction system[7]. But it is an extra cost to install a waste thread removal unit on this machine. Because a pneumatic gun is used to suck the unfolded. The thread that was sucked by the suction gun is drawn into the thread inhalation tube and is propelled by the air from the compressed-air inflow tubes and then blown out of the air suction gun together with the compressed air[5], [20]. Therefore, guiding for waste (cut) sewing threads to the waste-collecting container or bag from the outlet of the suction gun is enough.

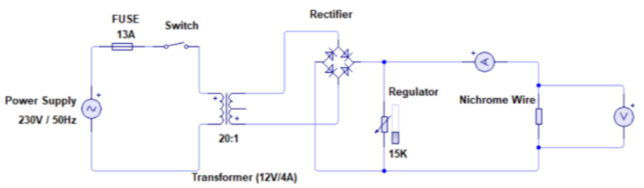

Fig. 1. *Design of the Heat Cutter*

III. METHODOLOGY

The labelling machine is used to apply a label containing product information on the top of each thread cone. The main purpose of the labelling machine is to ensure that each cone of thread carries the necessary product information such as composition, color, thread count, ticket number, batch/lot number, brand name, or customer details. These labelling machines are semi-automatic machines, which require manual labor to place the sewing thread cones on a conveyor belt at the feeding side. The protruding free thread ends could entangle with various parts of the machine during the labelling process. The labelled thread cones are then collected into plastic bins and protruding thread ends could have a further possibility of entanglement within the bins. These bins are manually transported to the packing machine, where the cones are placed on a table prior to being fed into the packing machine. The protruding length of the sewing thread cones disturbs the packing process as well due to probable entanglements.

Fig. 2. *Labelling Machine*

A. Design a heat cutter to cut the protruding sewing thread ends

In the heat-cutting method, sewing thread is cut by applying heat to the thread through a wire, and thereby melting it. A wire made of a high resistance material, such as Nichrome, is used in the cutter. When an electric current is passed through the wire, the resistance causes the wire to heat up due to the Joule heating effect. The heat

energy dissipated by the wire depends on several factors, such as the electrical resistance of the wire, the amount of electrical current passing through it supported by the length and thickness of the wire. The power requirement to achieve the required temperature with various gauges were experimented in order to identify the most suitable nichrome wire type, gauge, and power supply for designing the heat cutter [4].

TABLE I. POWER REQUIREMENT CALCULATION FOR TYPE A NICHROME WIRE WITH VARIOUS GAUGES

Gauge(A)	Ohms/Feet	Total Ohms (15 cm)	Current (Amps) for				Power Required (Watts) for			
			250C	300C	400C	500C	250C	300C	400C	500C
24	1.61	0.79	2.49	2.80	3.28	3.93	3.01	4.26	6.42	9.52
25	2.03	1.02	2.17	2.44	2.93	3.52	3.39	4.86	7.01	10.64
26	2.57	1.27	1.86	2.09	2.50	3.01	3.53	5.17	7.53	11.45
27	3.24	1.59	1.49	1.68	2.01	2.42	3.53	4.93	8.29	13.23
28	4.09	2.01	1.25	1.40	1.68	2.01	3.72	5.25	8.72	13.79
29	5.01	2.50	1.09	1.22	1.45	1.74	4.00	5.75	9.58	14.98
30	6.50	3.20	0.94	1.06	1.25	1.50	4.34	6.23	10.40	16.00
31	8.20	4.00	0.83	0.93	1.08	1.29	4.76	6.90	11.11	17.21
32	10.39	5.00	0.67	0.80	0.95	1.13	4.83	7.27	11.67	18.18
33	12.59	6.40	0.67	0.71	0.83	1.00	6.00	7.70	12.47	19.09
34	16.20	8.10	0.52	0.63	0.74	0.88	5.91	8.10	12.79	20.00
35	20.30	10.20	0.49	0.56	0.66	0.78	7.29	9.36	13.92	21.26
36	26.00	13.00	0.42	0.48	0.57	0.67	7.98	10.30	15.08	22.60
37	33.00	16.50	0.36	0.42	0.50	0.58	8.59	11.09	16.04	24.12
38	41.00	20.50	0.31	0.36	0.44	0.50	8.99	11.62	17.05	25.00
39	52.00	26.00	0.27	0.31	0.38	0.44	9.49	12.57	18.09	26.67
40	67.64	33.20	0.24	0.27	0.33	0.38	9.94	13.42	18.90	27.88
Max			2.49	2.80	3.28	3.93	6.22	8.52	9.52	12.22

TABLE II. POWER REQUIREMENT CALCULATION FOR TYPE C NICHROME WIRE WITH VARIOUS GAUGES

Gauge(C)	Ohms/Feet	Total Ohms (15 cm)	Current (Amps) for				Power Required (Watts) for			
			250C	300C	400C	500C	250C	300C	400C	500C
24	1.67	0.82	2.40	2.80	3.28	3.93	4.93	7.09	10.98	19.65
25	2.11	1.04	2.10	2.45	2.95	3.53	4.65	6.85	10.82	19.19
26	2.65	1.27	1.82	2.10	2.53	3.02	4.65	6.85	10.82	19.19
27	3.35	1.59	1.48	1.71	2.06	2.46	4.63	6.84	10.82	19.19
28	4.15	2.10	1.19	1.38	1.67	2.00	4.70	6.95	10.95	19.35
29	5.19	2.59	1.01	1.17	1.42	1.70	4.75	7.05	11.05	19.46
30	6.53	3.20	0.87	1.01	1.22	1.46	4.88	7.25	11.35	19.73
31	8.21	4.10	0.77	0.89	1.07	1.28	5.00	7.44	11.59	20.00
32	10.38	5.20	0.67	0.77	0.93	1.11	5.12	7.64	11.98	20.28
33	12.90	6.60	0.60	0.70	0.83	1.00	5.36	8.00	12.40	20.55
34	16.39	8.30	0.52	0.63	0.72	0.88	5.59	8.26	12.85	21.00
35	20.90	10.50	0.48	0.56	0.64	0.78	5.87	8.50	13.26	21.50
36	26.30	13.00	0.42	0.48	0.55	0.67	5.98	8.69	13.63	22.00
37	33.20	16.50	0.36	0.42	0.48	0.59	6.01	8.82	13.89	22.55
38	42.10	21.00	0.31	0.37	0.43	0.51	6.16	8.99	14.20	23.10
39	53.10	27.00	0.28	0.32	0.37	0.45	6.36	9.15	14.46	23.75
40	71.70	34.57	0.24	0.28	0.32	0.38	6.54	9.34	14.76	24.20
Max			2.40	2.80	3.28	3.93	6.46	8.58	8.55	12.69

Type A and Type C Nichrome wires are available as options. Type A wire comprised 80% Nickel and 20% Chromium and could be heated up to 1150°C. Type C wire contained 60% Nickel, 16% Chromium, and 24% Iron and could be heated up to 1000°C. Both types of wire were available in gauges ranging from 0 to 46. As the maximum required temperature of the heat cutter does not exceed300°C, calculations were performed from 250°C to 500°C to determine the required current to heat the wire to a specific temperature. The results indicated that the current requirement does not vary much based on the type of wire utilized. So, it was decided that either Type A or Type C wire could be employed for the heat cutter.

The diameter of a wire decreases as its gauge increases. Consequently, it is not advisable to employ higher gauge nichrome wire in heat cutters as it can be easily damaged. Additionally, using lower gauge wires requires a high current to heat the wire to the desired temperature. Hence, it was determined that medium gauge wire, specifically 24-34 gauges, would be suitable for use as the heat cutter.

In order to cut the sewing thread, maximum temperature of 300°Cis adequate and hence a nichrome wire with a gauge between 24 and 34 was deemed to be suitable for the heat cutter. Consequently, a 12V power supply was adequate for the device, with a minimum current output of 4 amps as per the calculations.

When designing the power supply for the heat cutter, a regulator was used to control the voltage and the current through the wire to control the temperature and a rectifier was used to convert AC voltage to DC voltage. The decision to choose a 15cm length of nichrome wire for the heat cutter was made based on the height of the sewing thread cone, which was 13.1cm in height. When experimenting with a heat cutter, the surface temperature measuring device is required to measure the temperature of the nichrome wire and multimeter is required to measure the DC voltage and current through the nichrome wire.

B. Develop a prototype heat cutter to cut the protruding thread ends

Careful consideration of the design phase calculations and equipment availability, a prototype was developed using the following components,

- 25-gauge type "A" nichrome wire was used as the initial wire.
- Step down 12V transformer.
- KBPC3510(35A, 1000V) bridge rectifier
- SZBK07 300W 20A Buck converter to adjust the voltage and the current through the nichrome wire.

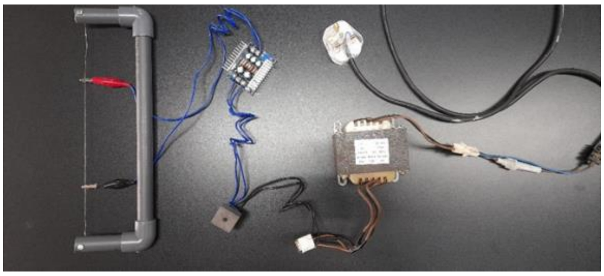

Fig. 3. *Prorotype Heat Cutter*

C. Design a suitable suction unit and blower to gather the protruding sewing thread ends

It was observed that protruding sewing thread ends were scattered on both sides of the labelling machine, with more thread ends scattered at the front of the machine. In order to consolidate the thread ends to one side of the machine, a pneumatic system was designed. Specifically, a blower unit was decided to position at the back of the machine, while a suction unit and heat cutter were placed at the front. The intention of this design was to utilize the blower to gather the thread ends and direct them toward the suction unit, where they could then be cut and disposed.

It was determined that the maximum height of the thread cone should serve as the height of the nozzle of the suction unit. Consequently, the nozzle face was designed to have a height of 14.5cm and a width of 3cm. The reason for these dimensions of the design was to ensure that the nozzle could effectively capture the protruding thread ends regardless of their location on the cone.

An experiment was conducted to find a suitable place on the labeling machine to install the suction nozzle and the blower unit. The minimum velocity required to pull a thread to the suction unit was experimentally determined. For the experiment, a vacuum unit with 1500W power and 53 liters per cubic meter flow rate was used. A 30mm diameter hose was used to direct the suction airflow from the vacuum unit to the relevant thread. In this test, hood/nozzle was not installed on the horse. From that, an average value for the minimum distance that should be maintained between the thread and the nozzle to be able to suck the thread from the airflow of the suction unit was obtained. The minimum distance between the thread and the nozzle was 2.25 inches.

Thus, Q is the airflow required to establish any given velocity "V_X" at a distance "X". For the case where no duct is used, the relationship between "V_X", "X" and "Q" can be shown as follows. A is area of the face opening.[21],

$$\boldsymbol{Q = V_X[10X^2 + A]}; \qquad (1)$$

$Q = 53\ ls^{-1} = 0.053\ m^3s^{-1}$
$X = 2.25\ inch = 0.0571m$
$D = 30mm = 0.03m$
$A = \ 0.000706m^2$

$$\boldsymbol{V_X = \frac{Q}{10X^2 + A}} \qquad (2)$$

$$\boldsymbol{V_X = 1.5883\ ms^{-1}}$$

By substituting above parameters to the equation (1) minimum velocity required to pull a thread to the suction unit was determined. Minimum velocity was calculated as $1.5883\ ms^{-1}$.

Then calculations were done to find the airflow required to suck the thread at the relevant distance. The relationship between "V_X", "X" and "Q" is shown as follows for Slot type hood[21]. By substituting the below values to the equation (3), airflow was determined as $0.05011\ m^3s^{-1}$.

$$\boldsymbol{Q = 3.7LV_XX} \qquad (3)$$

$X = 2.25\ inch = 0.05715m$
$L = 14.5cm = 0.145m$
$V = 1.58\ ms^{-1}$

$$\boldsymbol{Q = 0.05011\ m^3s^{-1}}$$

D. Experiment

Subsequent to the development of the prototype heat cutter, an analysis was conducted to investigate the behavior of the nichrome wire temperature by altering the current passing through nichrome wire. Temperature measurements were obtained using a thermal camera. Threads being processed in the packing section were cut while varying the temperature of the wire. The objective was to observe the cutting behavior of the different types of thread at various temperatures. Additionally, threads were cut under varying levels of tension to ascertain the impact of tension on thread cutting behavior. Based on these observations, the most appropriate temperature for precise thread cutting was identified for each thread type.

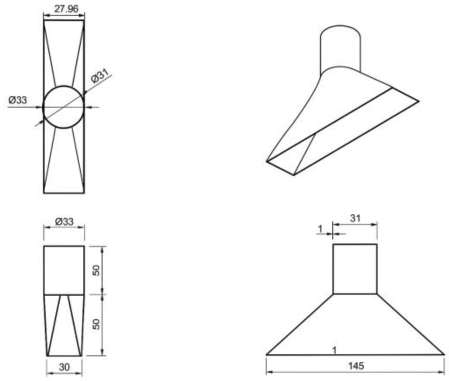

Fig. 4. *Drawing of the Nozzle*

TABLE III. CURRENT THROUGH NICHROME WIRE AND THE CORRESPONDING TEMPERATURE ACHIEVED

Current (Amps)	Temperature (Celsius)
6.58	326
5.81	272
5.47	260
5.00	250
4.43	230
4.33	205
4.00	214
3.50	196
3.47	190
3.00	168
2.50	144
2.00	120

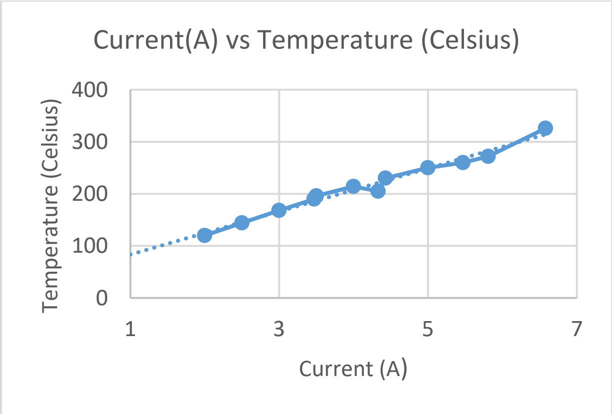

Fig. 5. *Temparature vs Current Graph*

IV. RESULTS AND DISCUSSION

A. Temperature control of nichrome wire

The development of a prototype heat cutter involved the use of type A nichrome wire with 25-gauge thickness and 15cm in length, corresponding to a resistance of 1.8 Ohms/feet. Temperature regulation was achieved through the manipulation of the current passing through the wire, which was accomplished using a buck type converter. The temperature of the wire was subsequently monitored using a thermal camera, while varying the current passing through the wire. The results of this experiment are presented as follows:

Upon analysis of the experimental data, it was observed that there exists a direct correlation between the current passing through the nichrome wire and its corresponding temperature. Specifically, higher levels of current passing through the wire resulted in higher temperatures, while lower levels of current corresponding to lower temperatures. Therefore, the current and temperature of the wire were found to be mutually directly proportional. These findings indicate that precise control of the temperature of the wire can be achieved by controlling the current passing through it.

In the determination of the relationship between the current passing through the nichrome wire and the corresponding temperature, it was noted that there were discrepancies between the theoretical values and the values obtained experimentally. Specifically, it was observed that to achieve the desired temperature, a higher current was required than what was theoretically predicted. This observation led to the identification of two potential contributing factors to the observed differences. The first factor is related to the resistance of the nichrome wire used in the experiment.

The linear resistance of the 15cm length of 25-gauge nichrome wire used in the experiment was found to be

1.8 ohms/ feet, which is lower than the resistance value of 2.5 ohms/ feet as reported in relevant literature sources. The second factor that could have influence the experimental results is the heat loss. When the nichrome wire is exposed to the surrounding atmosphere, thermal energy can be dissipated through radiation and convection, which can decrease its temperature and affect the accuracy of the experimental outcomes. Given these differences between the theoretical values and actual experimental results, the practical values obtained were more appropriate for subsequent operations.

B. Cutting behaviour of the ewing thread

The protruding sewing thread ends in the packing section were cut using the prototype heat cutter at various temperatures of wire and observed the cutting behavior of each sewing thread at different

temperatures. The sewing thread ends were cut with and without sewing thread tension and the cutting behavior of the sewing thread on each occasion were monitored. According to the observations the following results were recorded.

TABLE IV. CUTTING RESULTS OF POLYESTER YARNS

Thread Type	Temperature/ Cutting Behaviors															
	145 Celsius		137 Celsius		128 Celsius				120 Celsius				116 Celsius			
	Without Tension		Without Tension		1 cN Tension		Without Tension		1 cN Tension		Without Tension		1 cN Tension		Without Tension	
	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)
S 120	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s
T 160	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s
160 S	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s
C 36	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	1.3 s	Yes	< 1s	Yes	2 s	Yes	1 s	Yes	2.6 s
C 120	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s	Yes	< 1s

(S120, T160, 160S, C36, C120 – Types of polyester threads packed in packing section.)

TABLE V. CUTTING RESULTS OF D – CORE YARNS

Thread Type	Temperature/ Cutting Behavior											
	182 Celsius				165 Celsius				153 Celsius			
	1 cN Tension		Without Tension		1 cN Tension		Without Tension		1 cN Tension		Without Tension	
	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)	Cut	Time (s)
D 120	Yes	< 1s	Yes	< 1s	Yes	3.4 s	Yes	< 1s	Yes	3.8 s	No	> 5 s
D 50	Yes	0 s	Yes	1.3 s	Yes	1.7 s	No	> 5 s	*	*	No	> 5 s
D 26	Yes	2.5 s	No	> 5 s	Yes	1.6 s	No	> 5 s	*	*	No	> 5 s

(D-core – Cotton and polyester blended thread/ D120, D50, D26 – Types of D-core threads)

All polyester threads tested at the temperatures of 137°C and 145°C could be cut in less than one second, in both with cases. The results show that the sewing thread can be easily cut at temperatures of 137°C and above, with and without tension [Table 4.3.1]. However, it is advisable to keep the temperature as low as possible for cutting all thread types. During the experimentation, it was observed that the time to cut the sewing thread increases as the temperature reduces. The cutting system developed was incorporated with a suction unit to gather the sewing thread ends and also to provide with required tension. The application of tension enhances cutting process as compared to cutting without tension.

As per the results, cutting the thread under tension at a temperature of 116°C is possible, but it takes longer cutting time. Therefore, it is recommended that the heat cutter maintains a minimum temperature of 120°C for better cutting performance. This finding highlights the importance of maintaining an appropriate temperature for efficient thread cutting. The study also identified the appropriate temperatures to be sustained for the heat cutter for D-core thread, which is a blend of polyester and cotton. The best temperature for heat cutting of D120 and D50 was found to be 196°C and for D26, it was 214°C.

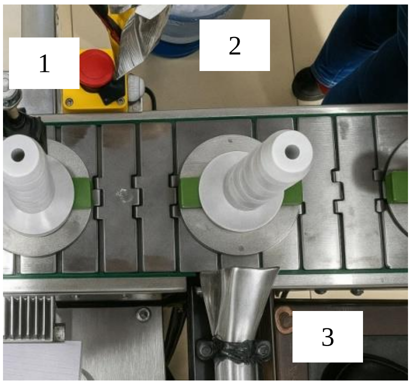

Fig. 6. *Yarn Cutting Mechanism*

Fig. 7. *(1 – Yarn Cutting device, 2 – Suction device. 3 – Blower)*

The heat cutting of polyester thread was performed without tension, resulting in a varying cutting time and an uneven cutting edge. However, uneven cutting-edge does not have a detrimental effect on either the quality of the product or the satisfaction of the customer. However, the residue accumulated from melting thread on the wire, causes to reduce its temperature. This experiment also confirms that the necessity of maintaining a tension on the thread is required for precise cutting using heat.

V. Conclusion

In addressing the above issue, a thermal cutter and a suction unit were designed and developed as an integral part of an automated cutting system. The relationship between the current and the temperature of the Nichrome wire for thermal cutting was subsequently investigated. However, it was noted that experimentally obtained linear resistance of a 25-gauge nichrome wire was deviated from its specified value. Therefore, the derived relationship was used to determine the current passing through the nichrome wire to maintain the required temperature. Furthermore, an experiment was conducted to determine the minimum temperature required for cutting the thread passing through the packing part. As a result of this experiment, maintaining a temperature of 120°C is sufficient for cutting all polyester threads and that could be achieved with 2A current through the nichrome wire. For D-core threads with blended nature, a relatively high cutting temperature was required. It was determined that a cutting temperature of 196°C was required for D120 and D50 threads, and this could be achieved with a current of 3.4A through the nichrome wire. A current of 4 amps through the Nichrome wire can achieve a temperature of 214°C which is required for cutting D26 threads.

In addition, the impact of thread tension on the cutting process and the quality of the thread edge was assessed. It was revealed that the thread tension is essential for precise cutting. Additionally, the thread was cut without tension or with insufficient heat, the temperature of the wire decreases due to the accumulation of residue on the wire due to melting of sewing thread. This phenomenon warrants further investigation. The blower was designed to enable the gathering of all unfolded thread ends and guide them to cutter. Nozzle for the suction unit serves to provide necessary tension to the protruding sewing thread ends to facilitate effective cutting and reduction of residue accumulation on the wire of the heat cutter.

References

[1] A. Shandilya and S. Gangopadhyay, “New Designed Main Nozzle of Air-Jet Weaving Machine for Optimizing Air Consumption Using CFD Simulation,” *CFD Letters*, vol. 14, no. 9, pp. 108–117, Sep. 2022, doi: 10.37934/cfdl.14.9.108117.

[2] Y. li, M. Wei, L. Zhang, and D. Chen, “Design of the nozzle of a yarn suction gun for fully drawn yarn,” *Textile Research Journal*, vol. 84, no. 3, pp. 225–230, 2014, doi: 10.1177/0040517513495950.

[3] L. Vangheluwe, “Air-Jet Weft Insertion,” *Textile Progress*, vol. 29, no. 4, pp. 1–63, Dec. 1999, doi: 10.1080/00405169908688878.

[4] A. Abeysinghe, S. Abeysiriwardena, R. Nanayakkarawasam, W. Wimalsiri, T. D. Lalitharatne, and S. Tennakoon, “Development of a numerically controlled hot wire foam cutting machine for wing mould construction,” in *2nd International Moratuwa Engineering Research Conference, MERCon 2016*, Institute of Electrical and Electronics Engineers Inc., May 2016, pp. 60–65. doi: 10.1109/MERCon.2016.7480116.

[5] I. Yoshiyuki, T. Shuichi, H. Jun-ichi, L. Yonggui, M. Atsuji, and M. Tetsuhiko, “Geometry Effect of

Air Suction Gun on the Yarn Suction Characteristics," 2008.

[6] Y. Li, I. Yoshiyuki, T. Shuichi, and T. Satoshi, "Numerical Simulation of Airflow Characteristics in Air Suction Gun," 2010.

[7] . E. A.S. K Fernando, R. Chandra Gopura, and M. Pamuditha Gunasekara, "Design of Weft Gripper System for Required Weft Tension on Rapier Loom Vision Aided Task Planning and Control of Trans-humeral Robotic Prosthetic Arm View project eBorder Solution View project COST EFFECTIVE SYSTEM FOR WEFT TENSION CONTROL AND WASTAGE DISPOSAL IN RAPIER LOOM. EASK FERNANDO RARC GOPURA JMP GUNASEKARA," 2007. [Online]. Available: https://www.researchgate.net/publication/260426216

[8] E. Musa, "Line-laser-based yarn shadow sensing break sensor," *Opt Lasers Eng*, vol. 49, no. 3, pp. 313–317, Mar. 2011, doi: 10.1016/j.optlaseng.2010.10.003.

[9] L. De Jun, "The Research of Broken Filaments Detection Device on Viscose Filament yarn," 2007, doi: 10.1109/CIS.Workshops.2007.223.

[10] Q. Wang, R. Huang, C. Lu, and W. Pan, "Yarn break detection using an optical method in real time," *Journal of Optical Technology*, vol. 84, no. 5, p. 342, May 2017, doi: 10.1364/jot.84.000342.

[11] H. S. Shin, D. C. Erlich, J. W. Simons, and D. A. Shockey, "Cut Resistance of High-strength Yarns," *Textile Research Journal*, vol. 76, no. 8, pp. 607–613, 2006, doi: 10.1177/0040517506067335.

[12] M. Khadeeruddin, T. V. S. R. K. Prasad, and R. Mohammed, "Design & Analysis of a Two-jaw parallel Pneumatic Gripper."

[13] R. Unger, P. Schegner, A. Nocke, and C. Cherif, "Technological Development of a Yarn Grip System for High-Speed Tensile Testing of High-Performance Fibers," *Autex Research Journal*, 2019, doi: 10.2478/aut-2019-0014.

[14] R. M. Dawson, "78—analysis of the weft motion in water-jet weaving," *Journal of the Textile Institute*, vol. 65, no. 12, pp. 654–658, 1974, doi: 10.1080/00405007408630049.

[15] Prof. Dr. H. A. Begum, T. Siddiqua, A. K. M. Mazed, and Prof. Dr. Eng. A. B. Siddique, "Modification of Adapter in Auto Cone Winding Machine for Better Performance," *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no. 6, pp. 2761–2768, Mar. 2020, doi: 10.35940/ijrte.F8381.038620.

[16] H.-S. Shin, D. C. Erlich, and D. A. Shockey, "Test for measuring cut resistance of yarns."

[17] K.-R. Deibel, J. Boos, S. Weikert, and K. Wegener, "Correlation Of Cutting Force And Power Consumption For Ultrasonic-Vibration-Assisted Cutting Of Label Paper Stacks." [Online]. Available: http://www.asme.org/about-asme/terms-of-use

[18] D. Herzog, M. Schmidt-Lehr, M. Oberlander, M. Canisius, M. Radek, and C. Emmelmann, "Laser cutting of carbon fibre reinforced plastics of high thickness," *Mater Des*, vol. 92, pp. 742–749, Feb. 2016, doi: 10.1016/j.matdes.2015.12.056.

[19] A. Wetzig *et al.*, "Latest developments of laser cutting," Laser Institute of America, Sep. 2019, p. 103. doi: 10.2351/1.5119063.

[20] L. Yonggui, I. Yoshiyuki, and T. Shuichi, "Yarn Motion in an Air Suction Gun," 2011.

[21] *Industrial Ventilation, A Manual Of Recommended Practice Of Design*, 27th ed. United States of America: signature publications, 2007.