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A Review on Mechanical Fuzzy Logic Control Cutters for Latex Glove

Qi Xuen Pang, Kai Jie Low, Kai Liang Lew*, Yit Hong Choo, Suleiman Aliyu Babale, Andi Prademon Yunus and Chia Shyan Lee

***Abstract* – Latex gloves are widely used in various industries, such as healthcare, laboratories, and manufacturing. Especially in the healthcare industry, it provides protection for doctors and nurses so that they will not get infected by viruses. The latex gloves contain some types of proteins that will trigger the allergic reactions of people with latex allergies. Therefore, before the latex gloves are sold on the market, protein concentration tests need to be done. In order to do the protein concentration tests, 2 cm by 2 cm samples of the latex gloves are needed. A cutter machine is needed in order to increase efficiency, save time, and also precisely cut. The samples can be obtained by cutting or stamping the latex gloves. In this paper, research in the literature that attempted to identify the mechanical cutters for latex gloves is reviewed. Furthermore, considering the ambiguity and variability in glove materials and cutting requirements, this paper explores the integration of fuzzy logic into cutter selection processes to accommodate uncertain criteria and optimize cutter performance in diverse operating conditions.**

Keywords—Mechanical Cutter, Fuzzy Logic, Protein Concentration Test, Efficient Cutting, Precise Cutting.

I. Introduction

Nowadays, there are many types of modern mechanical cutters that are developed for industrial usage. They are able to cut materials way faster, as some of them are using rotary cutters and some of them are using stamping blades that allow users to cut whatever shape they want. These modern cutters increase production, reduce material waste for manufacturers, and perform precise cutting. They play an important role in increasing the efficiency of the manufacturing process. Abrasive saws, bandsaws, diamond saws, tungsten carbide steel, drill press machines, lathes, milling machines, and Computerized Numerical Control (CNC) router cutting machines are a few examples. They are used for cutting and removing extraneous components or elements from wood, metal, plastic, stone, and bricks.

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The lever shear with a movable jaw, sometimes referred to as an alligator shear. To accomplish its responsibilities, it is propelled by either a flywheel or a hydraulic cylinder. Many manufacturers always use it to cut scraps for remanufacturing waste purposes. For example, they can be remanufactured into angle mesh steel [1]. The alligator shear can only be used when precision cutting is not required.

The abrasive saw is also known as a cut-off saw and is usually used for cutting hard materials such as metal, heavy steel cable, granite, and marble, which means that it is a strong cutting machine. Nowadays, the abrasive saw is not just for workshop use; it is now a favorite cutting machine in construction sites that used to cut concrete, metals, asphalt, and pipes. Steel or hard metals are being cut off by abrasive saws using composite friction disc blades.

The band saw machine has a long, sharp blade consisting of a continuous band of toothed metal. Basically, it cuts materials by stretching between two wheels. It is able to perform uniform cutting because it has an evenly distributed tooth load. The band saw machine is one of the most popular cutting machines used by manufacturers to cut raw materials such as metal, plastic, and even semiconductors [2].

The diamond saw is called a diamond because it has diamonds fixed to the blade edge [3]. Diamonds are one of the hardest substances on earth. With a blade that contains diamonds, it is able to cut hard or abrasive materials such as coal balls, ceramics, and stones [4]. Moreover, it is able to be used on construction sites to cut concrete, bricks, and asphalt. Currently, there are 3 types of diamond blades: circular diamond saw blades, diamond gang saw blades, and diamond band saw blades.

The tungsten carbide steel consists of tungsten and carbon and is well known for its high temperature resistance, hardness, and wear resistance [5], [6]. It is usually used to cut metal, wood, plastic, and composite materials. Because of its high temperature resistance, hardness, and wear resistance, it is even being used as a ripper for tunnelling machines.

A milling machine is also called a multitasking machine because it has the ability to mill and turn materials as well. The rotary cutter tool on the milling machine often has several cutting points. In contrast to drilling, the milling machine is often moved perpendicular to its axis so that the cutter's perimeter can be cut. The tool is advanced along its revolving axis [7]. The milling process contains three important steps: milling, cutting, surface, and gang milling, in order to complete the operation. The milling machine that uses composite machine tool structures, which have a lower weight, has better performance, which will increase productivity. Suh et al. [8] have mentioned that the composite structure has reduced the weight of the machine from 34% to 26%, and the damping has increased from 1.5 to 5.7 times. Moreover, there are a lot of types of milling cutters, such as concave milling cutters, convex milling cutters, and corner rounding milling cutters. The drill press machine is a middle-size machine. The function of a drill press machine is to dig holes in hard materials. Manufacturers usually use it to drill holes for screws on metal plates, brackets, wood, and plastic. Since the materials are secured in a vice on a resting table, the drill press machine enables us to drill holes in any sort of material accurately. The drill is being fixed in the rotating spindle and is being used to drill into material that is clamped in a vice on a resting table. A tapered shank that slides into a tapered hole in the spindle allows workers to operate the drill.

The lathe machine is a machine that can perform cutting, sanding, knurling, drilling, deformation, facing, and turning operations on materials. It has the ability to rotate a material in a direction and perform cutting, sanding, and so on with the material. Normally, manufacturers use lathes for woodturning, metalworking, metal spinning, and glass working. Moreover, it is a favorite machine of pottery manufacturers due to all the abilities mentioned above that are suitable for making pottery.

In Table 1 presents nine different types of cutting machinery along with their characteristics. Alligator shear is a hydraulic shear designed primarily for cutting scrap metal. Its primary material is steel, and it is generally used in the scrap metal recycling industry. Abrasive saw is a machine that uses a rotating abrasive disc for cutting, suitable for processing various materials such as metals, concrete, etc. It is widely used in metal products and woodworking industries. Bandsaw uses a continuous band of saw teeth for metal cutting, suitable for cutting wood and metal. It is commonly used in woodworking and metalworking fields. Diamond blade uses diamond particles for cutting hard materials. It can be used to process hard stone materials, concrete, etc., mainly used for stone cutting and concrete cutting. Carbide blades can be used to cut a variety of materials, such as metals, wood, etc. They are commonly used in the metal products and woodworking industries. Milling and drilling machines use rotating milling cutters and rotating drill bits respectively for material removal and hole processing. They can handle a variety of materials such as metals, plastics, wood, etc., and are widely used in metalworking, woodworking, and construction industries.

Before the products of natural rubber latex gloves are sold to the market, the manufacturers need to detect or determine the protein concentration of the latex gloves. During the formers (hand molds) dipping process of the production, usually the fingertips of the latex gloves will have the highest concentration of protein [9]. Figure 1 shows the flow chart of manufacturing process of latex gloves

Concerning latex gloves, one of the biggest problems is that latex that has a high concentration of protein will possibly trigger latex allergy, and sometimes the case can be even worse and lead to a life-threatening condition. According to the majority of cases in which people trigger allergic reactions due to exposure to latex, the symptoms can be hives, itching, stuffiness, or a runny nose. Moreover, it may also result in difficulty breathing, chest tightness, and wheezing. Normally, the symptoms that have been mentioned will begin within minutes after being exposed to latex products.

Nowadays, several methods, such as the Lowry method [10], and the Maximum Minimal Variation (MMV) test [11]v are used to determine or evaluate the potential of allergy in latex gloves by estimating the level of protein concentration for quality control. The methods that have been mentioned above have a disadvantage, which is that they often take a lot of time due to the fact that they involve many chemical processes and glove sample preparation.

TABLE 1. Nine types of cutter machine.

Machine	Description	Cutting Mechanism	Main Material Used	Typical Applications
Alligator Shear	Hydraulic shear designed for cutting scrap metal	Hydraulic shear	Steel	Scrap metal recycling
Abrasive Saw	Uses a rotating abrasive disc for cutting	Abrasive disc	Various materials (metal, etc.)	Metal fabrication, woodworking
Bandsaw Machine	Utilizes a continuous band of toothed metal for cutting	Continuous toothed metal band	Wood, metal	Woodworking, metalworking
Diamond Saw	Employs diamond particles for cutting hard materials	Diamond particles	Hard materials (stone, etc.)	Stone cutting, concrete cutting
Tungsten Carbide Steel Blade	Utilizes a blade made of tungsten carbide steel	Tungsten carbide steel blade	Various materials (metal, etc.)	Metal fabrication, woodworking
Milling Machines	Removes material using rotary cutters	Rotating cutter	Metal, plastic, wood	Metalworking, woodworking
Drill Press Machine	Used for drilling holes in various materials	Rotating drill bit	Metal, wood, plastic	Metalworking, woodworking
Lathe Machine	Rotates the workpiece against a cutting tool	Rotating cutting tool	Metal, wood	Metalworking, woodworking

In order to shorten the time spent preparing the samples of gloves for further estimation of protein concentration, a computerized latex glove cutting machine was developed. The latex glove cutting machine focus on cutting the fingertip areas since the fingertip areas have the highest protein concentration during the dipping process. This method is also used by the Glove Surface-Based Protein Binding (GSPB) method [12], which is designed to determine the protein concentration level of the fingertip areas. Moreover, the palm area will also be cut by the latex glove cutting machine as a sample for further estimation of protein concentration since it is the most touching area of the user. As a conclusion, this system

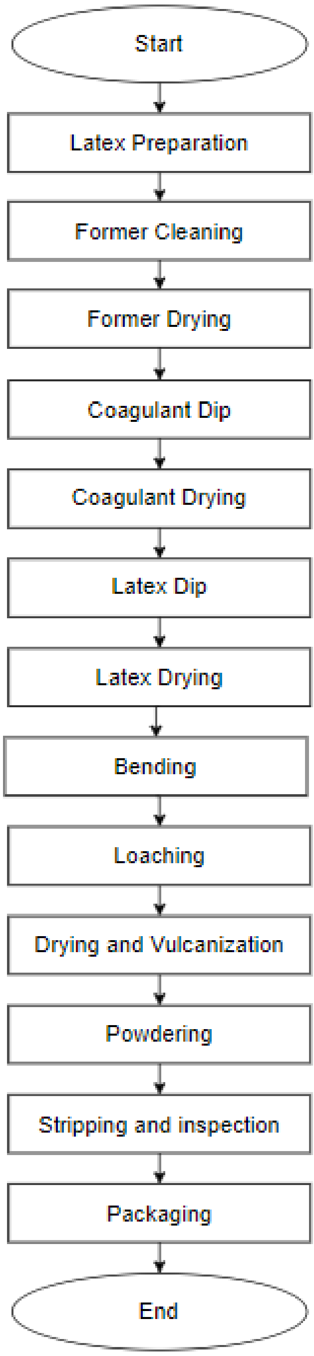

FIGURE 1. The manufacturing process of latex gloves.

is designed to shorten the time in the aspect of glove sample preparation so that the time of the overall protein concentration estimation process can be shortened as well.

The objectives of this paper are to review a mechanical fuzzy logic latex glove cutter that is able to help the workers prepare latex glove samples and to implement the fuzzy logic technique for the cutter machine in order to complete the cutting task.

II. Literature Review

A. Latex Glove Samples Cutting System with Fuzzy Controller.

A research paper on Latex glove sample cutting system with fuzzy controller [13] has invented a latex glove sample cutting machine that implements the fuzzy technique. The machine contains a double-cutter actuator and three stepper motors. The reason that the double cutter actuator is used is because it saves a lot of time in the cutting process compared to a single actuator. Moreover, the step motors on the machine allow it to be more flexible during the cutting process. Figure 2 shows the structure of the latex glove samples cutting machine

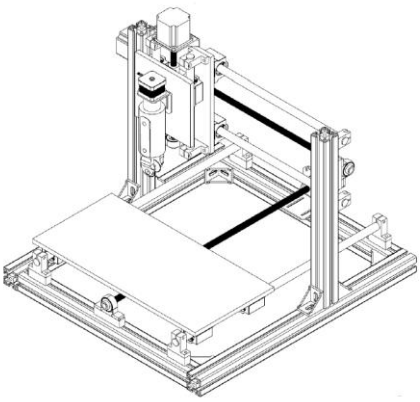

FIGURE 2. Structure of the latex glove samples cutting machine.

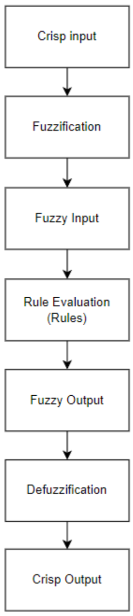

FIGURE 3. Fuzzy logic inference system (FIS) operation.

As compared to the conventional logic-based approach, the fuzzy logical model provides a closer look at the human mindset when it comes to problem-solving. Through a set of rules, the model represents the behaviour of the system. Each of the rules consists of an antecedent and a consequence. The primary benefit and purpose of fuzzy logic is to use detailed knowledge to convert linguistically specified procedures into automatic control procedures. The fuzzy logic set is going to increase the performance of complex tasks as compared to conventional control. This is because the input data is too complicated and has many ambiguities for the conventional logic set to handle. Figure 3 shows fuzzy logic inference system operation.

A fuzzy inference system (FIS) is used to compute the fuzzy output before defuzzification, based on fuzzy input variables and a predetermined set of rules. The relationships between the input variables and the output are defined by the rules.

Lotfi [14] published a fuzzy sets mathematical theory in 1965, it has been extended frequently by researcher over the years. The common subset of A in the set X is determined by set A conditions. Set A is defined in Equation 1.

$$\boldsymbol{A} = \begin{cases} \boldsymbol{1} \;\; \boldsymbol{if}\; \boldsymbol{x} \in \boldsymbol{A} \\ \boldsymbol{0} \;\; \boldsymbol{if}\; \boldsymbol{x} \notin \boldsymbol{A} \end{cases} \qquad (1)$$

The set of components with x ∉ X is represented by a ⊆ X. Every x has the option to be a part of the fuzzy logic set A or not. The fuzzy logic's membership function uses interval-valued membership variables to map the elements of X. Either x ∊ A or x ∊ A are the variables. The concept of degree on the components of a fuzzy set is made possible by fuzzy logic. Values can be defined between Boolean values 1 and 0, or true and false, due to the fuzzy set. This provides the notion of a degree for membership functions. A(x) is the membership function of x in set A. If X is the condition for component x, then the fuzzy set A in x is defined in Equation 2 [15].

$$\boldsymbol{A} = \{(\boldsymbol{x}, \boldsymbol{\mu_A}(\boldsymbol{x}) | \boldsymbol{x} \in \boldsymbol{X} \qquad (2)$$

It is necessary to define the suitable universe discourse and the membership function for the construction of a fuzzy logic set. The universe of discourse X is a continuous value that must be split into different fuzzy sets based on the situation. In the fuzzy logic sets, these sections are named in order to confirm the adjectives that appear in real-life linguistic usage. The linguistic values, labels, or variables are examples such as "high," "medium," "low," "hot," "cold". Table 2 shows the comparison of Boolean logic and fuzzy logic.

TABLE 2. Comparison of Boolean logic and fuzzy logic.

Value	Boolean Variable	Fuzzy Variable
Speed	Fast, Slow	Very Fast, Slight Slow…
Temperature	High, Low	Extreme High, Too Low…
Pressure	Hard, Soft	Bit Hard, Soft…
Distance	Far, Near	Far, Average, Near, Reach…
Error	Large, Small	Very large, Very small…

Fuzzification establishes the foundational principles of the fuzzy system for the first major component. This part recognizes the inputs, establishes appropriate IF-THEN rules, and applies the membership function using the crisp values that are received. In the subsequent component, the fuzzy output is determined by evaluating each rule derived from the IF-THEN rules. The input data will use partial matching to interpolate an output if any of the IF-THEN criteria do not accurately correspond to the input. The defuzzification module of the third main component transforms the incoming fuzzy value into a crisp output [15].

The technique of determining the system's overall output from the fuzzy rules and the input values is known as fuzzy inference. Fuzzy logic performs inference using techniques such as Mamdani or Sugeno to combine fuzzy sets and rules to provide a fuzzy output. The first stage in the inference process is the input data, which is frequently expressed as linguistic variables associated with the fuzzy sets. Fuzzy input values represent the lack of clarity or uncertainty inherent in the data by reflecting the degree of membership of each linguistic variable in its associated fuzzy set. The next stage will be ruling activation. The fuzzy input values are used to evaluate the antecedent (condition) part of each rule in the rule base. The level of activation of a rule is determined by how well its requirements are met. Fuzzy logic operators like "and" "or" and "not" are used to combine the input fuzzy values. The consequent (conclusion) part of each rule is applied after it has been activated to produce a fuzzy output for that particular rule. Often represented as an additional language variable associated with the fuzzy set, the fuzzy output represents the system's reaction to the input conditions provided. Next, a combined fuzzy output is created by adding together the fuzzy outputs from each activated rule. Several collection techniques, like the maximum or weighted average, can be used to combine the individual rule outputs and obtain a comprehensive picture of the system's overall reaction. Lastly, A fuzzy output which captures the ambiguity and imprecision in the input data, is the final result of the inference process [13]. The system's confidence in the inferred conclusion is shown by the fuzzy output's degree of membership in the fuzzy set, which is a linguistic variable.

In fuzzy logic systems, defuzzification is the process of converting fuzzy sets or fuzzy values into a crisp or non-fuzzy output. Variables in fuzzy logic can have values in the range of 0 to 1, which indicate different degrees of membership in a fuzzy set. When the final decision or action must be made based on the fuzzy inputs and rules of the system, defuzzification will be the best choice. The common defuzzification methods include Centroid Method, Mean of Maximum Method, Weighted Average Method, and Bisector Method [16].

The implementation of the fuzzy logic in cutting machine is designed to enhance the precision of the cutting. The flow of the fuzzy logic is input variables, fuzzification, rule base, inference engine, and lastly defuzzification. The input variables are the variable include the thickness of the glove material, the cutting speed, and the pressure applied by the cutting blade. Fuzzification is to convert the input variable into fuzzy set. For example, the thickness of the glove can be categorized as "thin," "medium," or "thick," each with corresponding membership functions. The equation is shown in (3)

$$\mu_{thin}(T) = \begin{cases} 1, \ if \ T < T_2 \\ \frac{T_2 - T}{T_2 - T_1}, \ if \ T_1 < T < T_2 \\ x, \ if \ T \geq T_2 \end{cases} \tag{3}$$

Rule base is using a set of IF-THEN rules to determine the relationship between input variables and the output variables. For example, IF the glove is "thick" AND the desired cutting speed i s "high," THEN increase the cutting pressure. The inference engine processes the input variable based on the rule base to generate fuzzy output. This step is crucial as it combines all the rules to determine the overall fuzzy output. The defuzzification is the final step to convert the fuzzy output into a value to control the cutting machine. The common defuzzification method is the centroid method which calculates the center of area under the fuzzy set curve. The equation of the calculation is shown in (4)

$$P_{crisp} = \frac{\sum \mu_i(x) \cdot x_i}{\sum \mu_i(x)} \tag{4}$$

where $\mu_i(x)$ is the membership value of output x_i.

B. Fuzzy Logic in CNC cutting machine

A fuzzy logic controller can improve the control system of a CNC cutter machine. Fuzzy logic is a mathematical framework that addresses imprecision and uncertainty, making it appropriate for systems where creating precise mathematical models is difficult. Fuzzy logic controllers can adjust the different cutting situations, including variations in the properties of the material, wear on the tools, and external influences. The CNC cutter can keep performing at its peak because of its ability to adapt over time. Next, the fuzzy logic can be used to develop the rule-based systems that are capable of managing complex decision-making procedures. Fuzzy controllers are also helpful in reducing mistakes and uncertainty in the CNC cutting process. Fuzzy logic can also be used to control the vibration of the cutting machine during cutting process by monitoring and adjusting parameters in real-time. This function is able to improve the cutting precision and also increase the life of the tools. Furthermore, tool path planning can be improved by the fuzzy logic by considering factors such as material hardness, tool wear, and cutting forces. It can also minimize the wear and tear on the cutting tool. Fuzzy logic can be used to create a defect diagnostic and detection system for the CNC cutter. Through the analysis of sensor data and machine parameters, it can identify potential issues early on, reducing downtime and facilitating timely repair. Lastly, to have a more intuitive and user-friendly experience, fuzzy logic can enhance the CNC cutter's user interface. Machine operation becomes easier by the controller's ability to understand operator inputs more naturally.

A mathematical system called Boolean logic is named by the mathematician and logician George Boole It is a mathematical framework that uses variables that have binary values (true or false), and it is controlled by operators like AND, OR, and NOT, and follows laws and theorems such as identity, null, dominance, complement, idempotent, associative, distributive, and De Morgan's laws. It is important for manipulating logical expressions and is frequently used in computer science, digital circuit design, and other fields for methodical analysis and optimization [17]. Moreover, there are some key concepts in Boolean logic which are Boolean Operators, Boolean Expressions, Truth Tables, De Morgan's, and Boolean Algebra.

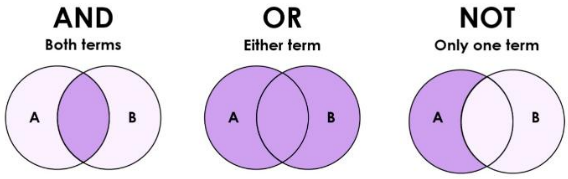

FIGURE 4. Example of Boolean operators.

Figure 4 shows the Boolean operators, including AND, OR, and NOT are useful tools that used to combine and manipulate binary values, they are usually represented as true or false. AND(Conjunction) will only return true if both of the operands are true. For example, (A && B) is true only when both A and B are true. The OR(Disjunction) will return true if one of the operands is true. For example, (A || B) is true if either A or B (or both) is true. The NOT(Negation) will return the opposite Boolean value of the operand. For example, (A && B) is true if either A or B is false. The Boolean Expressions is a combination of variables, constants, and operators that produces a Boolean result. It can be used to do many kinds of tasks such as Combining Conditions, Comparisons and Membership Test. For example, (isSunny && temperature > 25) is true only if it's sunny and the temperature is above 25 degrees (Combining Conditions), (userScore >= passingScore) is true if the user's score is greater than or equal to the passing score (task of Comparisons), (age >= 18 && age <= 25) is true if the age is between 18 and 25 (task of Membership test) [17].

A	B	A AND B
T	T	T
T	F	F
F	T	F
F	F	F

FIGURE 5. Example of truth table (A AND B).

Figure 5 shows a truth table is a tabular representation of a set of logical expressions or propositions that shows every possible combination of truth values (usually "true" or "false"). It demonstrates how the various combinations of truth values of the variables that make up a logical expression affect the expression's result.

Boolean logic is essential to CNC (Computer Numerical Control) cutting machines, which are used in a variety of industries for precise machining due to it can contribute CNC cutter machines in several ways [16], [17]. Boolean logic is fundamental in the control systems of CNC machines. The control systems of CNC machines are based on Boolean logic. It supports the design of the logic circuits that control the machine's components such as actuators, sensors, and motors. Logical conditions are used to determine when a tool should be activated, when the machine should move in a particular direction, and also when to stop or change tools. Programmable Logic Controllers (PLCs) that are programmed with Boolean logic, are frequently used by CNC machines to control the sequence of operations. The ladder logic diagrams that show the control sequences for various machining processes are also made easier by the use of Boolean logic. Tool Path Planning is a tool path for CNC machining created by Boolean operations in CAD/CAM software. It maximized tool movement, avoided collisions, and specified cutting regions using logic. Boolean operation is able to create complex tool paths for complex machining processes can be achieved by combining or subtracting. In error handling and diagnostic systems, Boolean logic is used to find malfunctions or irregularities in the machine's operation. Logical conditions are a helpful diagnostic tool that helps diagnose issues, show error messages, and assist operators in troubleshooting. In the user interface of CNC machines, Boolean logic is used to evaluate the input signals, such as sensor feedback or operator commands. The user interface can utilize logical conditions to confirm inputs and guarantee that the machine operates within predetermined operational and safety parameters. Boolean logic is used for conditional operations to allow the CNC machine to adapt its behaviour based on different input conditions. Conditional statements can be programmed to control variations in material quality, such as tool wear, or other elements that impact the machining process.

C. Comparison of CNC cutter machines with Fuzzy Logic Control and without Fuzzy Logic Control.

CNC cutters with Fuzzy Logic Control are able to handle uncertainty better, adapt easily to change situations and make better decisions. They are good at applying complicated control logic designed for certain machining operations. However, because of their advanced nature, their setup and maintenance may call for a greater level of skill [18], [19]. CNC cutters without fuzzy logic control are simple to set up and maintain. They provide consistent performance within predetermined bounds and might have cheaper initial costs. However, when compare to the one with Fuzzy Logic Control, they might be less flexible in changing conditions, show less advanced decision-making, and have problems when dealing with uncertainty [20], [21] Table 3 shows the summary of the comparative results

TABLE 3. Summary of comparative studies.

Study	Methodology	Key Findings	Improvements Over Traditional Methods
[13]	Fuzzy logic with double-cutter actuators	Improved cutting precision and reduced cutting time	Significant time savings and enhanced flexibility
[9]	Optimized cutting parameters for rubber	Reduced extractable latex protein levels	Maintained material integrity while achieving precise cuts
[2]	Deep learning optimization for bandsaw machines	Enhanced cutting efficiency and precision	Framework adaptable for rubber cutting techniques
[22]	Automated system using a rotary cutter mechanism	Efficiently produce multiple samples, reducing processing time for protein determination	Enhanced overall efficiency of latex glove manufacturing processes

III. Gap, Trends and Future Direction

Based on the review studies, there are a few gaps in the work. There is limited real-world validation, which the machine does not have real-world testing to validate the effectiveness of the machine. While some studies start to implement advanced technology, some of the works do not have the implementation and remain underdeveloped.

There are several trends, and potential future directions can be identified. The increased precision and efficiency can be found in the review studies. Future research should focus on developing cutting techniques that improve precision and efficiency. The implementation of the fuzzy logic can show great improvement in cutting machines. Moreover, the implementation of advanced technology such as machine learning and deep learning can provide optimized cutting parameters so the machines can be more adaptive and efficient during the cutting process.

IV. Conclusion

In conclusion, it is impossible to exaggerate the value of latex gloves, particularly in the healthcare sector. They offer an essential line of defence against infections. However, certain people may experience allergic reactions to latex, thus before these gloves are put on the market, protein concentration testing are required. A cutting machine must be used in order to obtain the precise glove samples needed for these testing. There have been several investigations of mechanical cutters for latex gloves across the literature reviewed in this research. It has been suggested that fuzzy logic be included to the cutter selection process because glove materials and cutting needs vary widely. This approach allows for the accommodation of uncertain criteria, optimizing cutter performance across diverse operating conditions. Future research could further refine this process, ultimately leading to safer and more effective use of latex gloves in various industries.

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Chia Shyan Lee: Writing – Review & Editing

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