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NUMERICALLY CONTROLLED VINYL ARMREST PRODUCTION: ENHANCING PRODUCTIVITY AND REDUCING COSTS

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ABSTRACT

The production of armrests involves creating a substrate and shaping vinyl before assembling the final product. As a key component of the car door, the armrest is one of the most profitable products for XYZ Sdn. Bhd. Previously, the company relied on manual vinyl slab cutting and die-cutting of sheet and rolled materials. These labour-intensive methods are inefficient for mass production due to the numerous processes and significant manpower required. To address these limitations, an automatic knife cutting system using a numerically controlled (NC) cutting machine has been introduced to replace manual cutting. However, no established standards or guidelines currently exist for using the NC cutter specifically for vinyl armrest production. Given the critical nature of this machine in ensuring smooth, safe, and efficient operations, a comprehensive standard operating procedure (SOP) is urgently needed. This project aims to develop a standard document for technical staff to operate the NC cutter for armrest vinyl cutting and evaluate its impact on production and economic performance. Key tasks include software optimization, identification of the maximum cutting layer, and the development of a tailored SOP. The implementation of the NC cutter has demonstrated significant benefits, including reduced raw material waste, improved production rates, and lower overall production costs.

1. Introduction

The automotive parts manufacturing industry places great emphasis on quality and production capability in meeting customer demand and maintaining a seamless automotive supply chain environment. These parts are divided into interior and exterior components such as headliner, instrument panel, door, floor, pillars, package shelf, seats, side mirrors, lamp etc. (Rosa et al., 2018). Most of automotive components are outsourced to suppliers, caused an increasing competition and pressure on international suppliers to cut prices while maintaining a high perception of the value of the products (Powell, 2008). Among the

elements focused by companies for cost-saving strategies are improvements in terms of manufacturing methods, materials used, product design or man power (Müllerklein et al., 2022).

Improvements in manufacturing methods usually involve the utilization of a new machine or modifications to the techniques or procedures of existing machines (Papulová et al., 2022). For vehicle parts that involve textiles, the process of preparing the material before joining is very important as it will affect the entire working process as well as the quality of the final products. Among the things that affect the prepared textile quality, are the problems of the cutting process, lack of adequate fabric quality control operations, or poor-quality textile materials (Vilumsone-Nemes, 2018b). The production of vehicle armrest door panels involves the preparation of the substrate and softcover for the outer wrap. Vinyl materials such as polyvinylchloride (PVC) are commonly used as the softcover of the armrest. However, joining faulty might occurred if the poor-quality cover being used for the armrest wrapping, therefore, good vinyl preparation should be taken into account during the armrest manufacturing process (Ma et al., 2021).

In this study, the improvement of the vinyl cutting method was carried out in XYZ Sdn. Bhd., which runs the armrest door panel manufacturing industry. The vinyl cutting activity is the most important process in the production of the armrest door panels and without it, the armrest production will stop and no output gained. Previously, XYZ used manual cut of the vinyl slab and die cut to achieve the desired shape of the material. This cutting method is unsuitable especially for producing large-scale vinyl cuts for mass production of armrests. The die-cut vinyl slab measurement is excessive and the raw material is not fully utilized compared to its size. The waste of material majorly came from the design measurement and the arrangement of patterns. For measurement the size slab and die-cut template are big. The size is not optimized between it. The space between the patterns is wide which is 4.5 mm. The root cause of the waste came from the space between the pattern is too wide. Therefore, the utilization of the material will be high. Moreover, the number of labor workforce is high due to the unnecessary processes and movement performed during the manual cutting process. Using the fully automated machine may reduce the number of workers and labor workforce.

Therefore, to overcome the issue related to the vinyl cutting method, a numerically controlled knife cutting system or NC cutter is implemented in XYZ. However, there is no working standard and standard operating procedure available specifically for the cutting process of armrest vinyl. Moreover, the maximum output of the production using this new machine is still unknown and needs to be tested to its maximum performance and yield. Other than that, the NC cutter needs to be evaluated on their performance towards production and economics for improvement.

1.1 Polyvinylchloride (PVC) vinyl cutting process

Polyvinylchloride is thermoplastic that is flexible, unbend, clear, and can be fully colored. It has been heavily utilized mostly for clothing, wall covering, medical devices, piping, and automotive textiles. Rigid PVC which zero percent of plastic contains is used in furniture, automotive, and other industrial application (Carroll et al., 2011). The shape, surface, and

color of PVC can be custom according to the specification, demand, and quantity. However, industry faced high challenge to supply such textiles successfully due to the high cost of entry, stemming from the need to be able to deliver the same product with detail specifications and quality standards worldwide (Hardcastle, 2019).

The vinyl cutting process involves the separation of vinyl material into two parts through the application of force. The simple situation of cutting is scissoring a piece of paper into two parts. This method requires physical and equipment to complete the task. If high volume of mass production, it will require a high scale of man force level and need to produce precise the cut (Mitsomwang & Nagasawa, 2015). The simple square straight cut for the material to be placed on a shape of a die and pressed into the actual or required shape(Bari et al., 2020). The consumption of material will be high if we just cut a piece of the actual shape. So, a slab of vinyl material is needed to fully optimize or use the space of material before being pressed to require the shape(Zhang et al., 2016).

1.2 Automatic knife cutting system

The knife cutting system is widely used for the current production of cutting sheet and rolled material due to its wide application and low production costs. The most efficient way to cut fabrics or vinyl is using a fully automated knife-cutting machine(Sun et al., 2022). Nowadays, computer numerically controlled machines replacing the traditional die-cut since it is no longer efficient (Sun et al., 2022; Vilumsone-Nemes, 2018a).

The NC cutter comprises several components essential for its smooth operation and optimal performance. These are the main parts of the NC cutter machine:

i. The cutting device
ii. The cutting device drive system
iii. The cutting tables
iv. Horizontal cutting tables are used in the cutting process. They are classified as follows based on their shape and mechanism of operation:
    - Static tables
    - Conveyor tables
    - The control panel

A lot of advantages can be obtained when die cutting compared to NC cutting process (Adeleye et al., 2020; Kaneko & Horio, 2012). The advantages and the parameters been showed in Table 1.

Table 1. Advantages of automated knife cutting system

Parameters	Automated cutting
Cutting equipment	Automated knife cutting system
Cutting principles	All components are cut with a straight knife. Creating holes using a drill or a puncher.
Cutting method	Cutting process is realized in cutting zones
Elimination of ply displacement	During the cutting process, use a vacuum system to compress the plies together.
Advantages of the method	Very high productivity High cutting precision

2. Methodology

The implementation of the NC cutter system started with the nesting design, generating of material consumption, and execution of the drawing. The evaluation of the vinyl cut is based on the measurement, quantity, and adherence to the product standards. In order to fulfil the objectives of this work, all the cutting process procedures need to be analyzed and optimized. This section will explain based on the vinyl cutting process for the armrest production of JL Sahara vehicle model as shown in Figure 1.

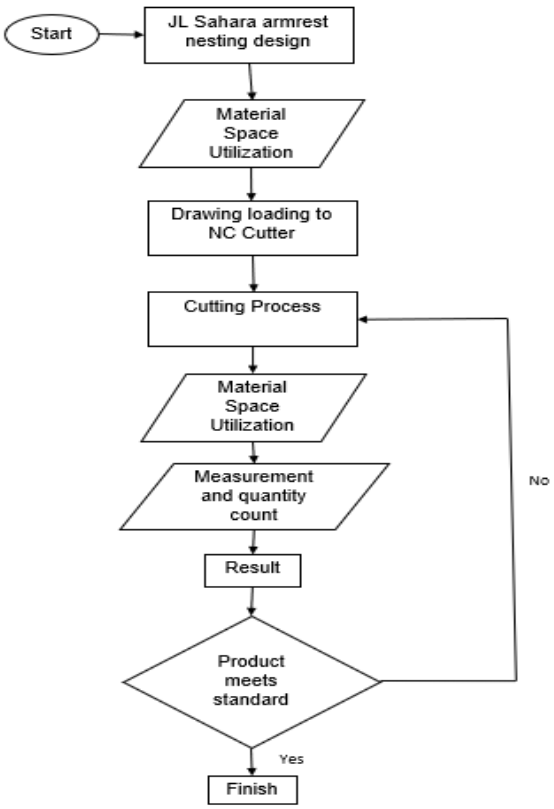

Figure 1. Process flow of JL Sahara armrest cut

The detail of the processes involve will be explained in details in the next subtopics.

2.1 JL Sahara armrest nesting design

i. Sequence and nesting

The sequence of the cutting will be automated and generated by the computer, but the nesting is manually designed and controlled by the technical staff. In this situation, the CAD drawing of the JL Sahara is produced in CAD format and needs to be imported and converted into .CUT file.

The steps of sequence and nesting given as follows:

- The marking order size (cutting length size) is set as follows (also shown in Figure 2):
  Width of JL armrest vinyl: 1500 mm
  Length of 1 roll JL armrest: 30 meter (it is suggested to use 2 meters when installing the machine).

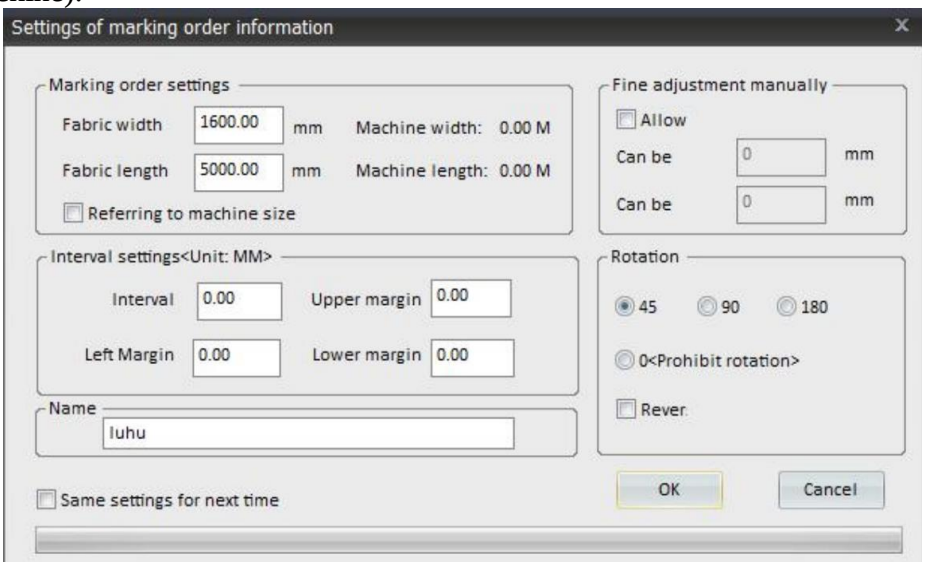

Figure 2. Marking setup

- In the pattern set marking menu, the quantity number of patterns is inserted (as shown in Figure 3).

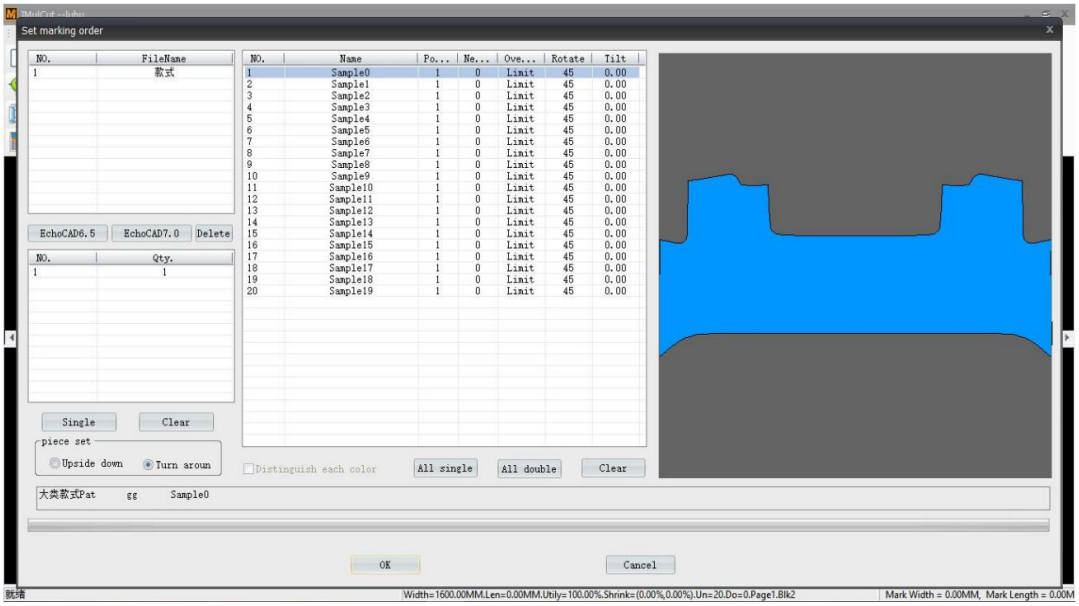

Figure 3. Pattern set marking menu

- The set marking order tab menu (X mark on top right) need to be close and the automatic layout icon is clicked.
- IMulCut will then automatically arrange the nesting in sequence and optimized the space used for JL armrest vinyl, as shown in Figure 4. The process took several minutes depending on the number of patterns to be optimized.
- The drawing is then verified and the .CUT file is saved on the desktop.

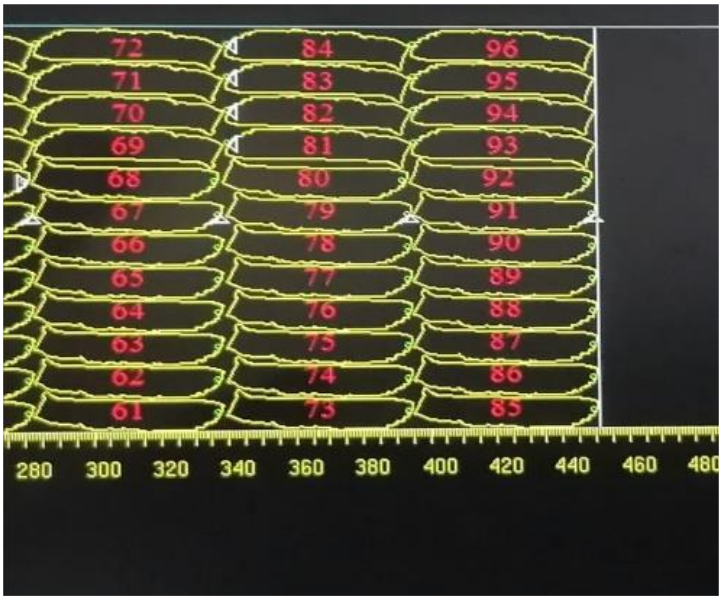

Figure 4. Nested Drawing in ImulCUT

ii. Material space utilization (percent of yield)

The percent of yield referring to the space of consumption of material generated by the ImulCut software can be seen at the bottom of the nested drawing interface (as shown in Figure 5). The highest number indicated the best arrangement because the space of utilization is high and bigger. However, the quality of the cutting process must be observed to confirm.

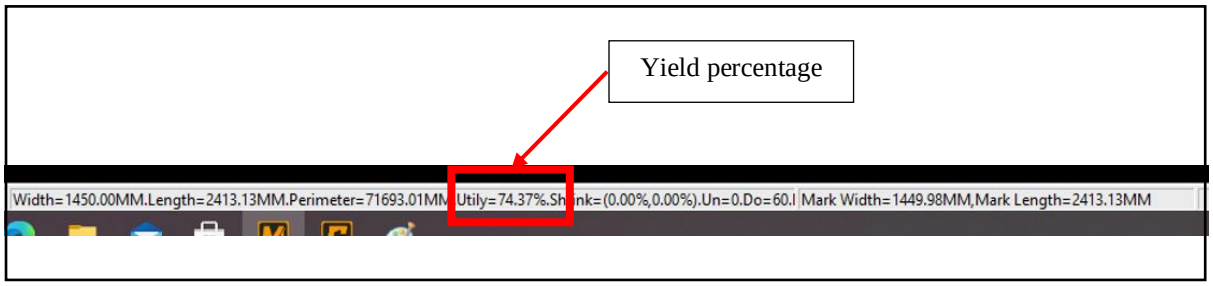

Figure 5. Material space utilization

2.2 Cutting Process

The cutting process of vinyl is the most important step for armrest JL Sahara production, either using an NC cutter machine or die cut. The NC cutting process begins with the loading of .CUT design into the machine, loading the material onto the cutting table, and the execution of .CUT file., as shown in Figure 6.

Figure 6 NC Cutter Cutting process

2.3 Cut Stock Checking

The cut stock needs to be verified by using a master cut. Trained operators need to verify that the cut stock of the vinyl must follow the size and pattern of the master cut. The procedure starts with overlapped the cut stock with the master cut that has been verified by the QA officer. The operator will check the dimension and interface quality for the newly cut of JL Sahara cut stock (refer Figure 7).

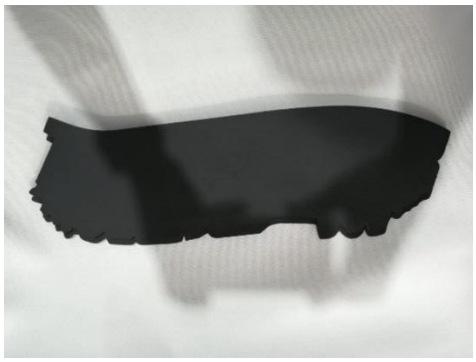

Figure 7 JL Sahara cut stock

2.4 Maximum cutting layer identification

After the optimization of the drawing using ImulCUT software, a cutting monitoring simulation is performed with the NC cutting machine. This is to identify the maximum layers of JL Sahara vinyl production that can be obtained in a period of time. The simulation needs to start with some initial layers. After each vinyl cutting execution, the defect rates need to be analyzed to ensure the smoothness of the cutting process. Next, layer after layer is added before starting the new cut to evaluate the rejection of vinyl due to not meeting the set quality values (Figure 8).

Figure 8 The Simulation of 10 and 15 layer of vinyl cut

2.5 Standard operating procedure of machine and working standard development

The development of standard operating procedures for NC cutters needs to be very specific and complete for the reference of others. Good standard operating procedures will make it easier for people to understand the machine and carry out the desired process efficiently. NC cutter operating procedure consists of several steps according to the guideline below:

a. The procedures for the construction of SOPs is listed properly.
b. The SOP development and management procedure is planned according to the company decision.
c. Important information for the content is gathered based on the simulation and testing of NC cutter.
d. The SOPs developed then finalized and verified with engineers.

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3. Result and Discussion

3.1 The rejection rates

The value of the rejection rate is important when running the NC cutter simulation. It is used to decide the number of appropriate cutting layers. Table 2 shows a rejection rate for 12 and 15 layers of vinyl during the cutting process.

Table 2: Rejection rate for 12 and 15 cutting layer

12 layer	
Date	Reject
1/3/2022	7
2/3/2022	0
3/3/2022	8
4/3/2022	2
9/3/2022	14
10/3/2022	2
15/3/2022	13

15 layer	
Date	Reject
23/2/2022	9
24/2/2022	15
25/2/2022	14

The decision of rejection is based on the defect that occurred such as scratch, line marks, press mark, marking, and overcut as shown in Table 3. These defects must be recorded and shown to the operator for their acknowledgment.

Table 3: List of defects

Type	Example	Type	Example
Scratch		Press Mark	
Line mark		Torn	
Joint mark		Overcut	

3.2 Maximum cutting layer

The trial processes need to be recorded to determine the best number of cutting layers. The trial must be verified using a master sample or limit sample. Summary of the result is shown in Table 4.

Table 4: Summary of cutting simulation result

Number of vinyl layer	Total Produce	Total Rejects	Rate
8	3360	25	0.744%
10	4200	34	0.809%
12	5040	37	0.734%
15	6300	60	0.953 %

Then, an approved number of cutting layers will be used for mass production. The layer must be verified by the top management, studied, and approved by all the people in charge of production based on acceptance of rejection before it can be implemented (as shown in Table 5).

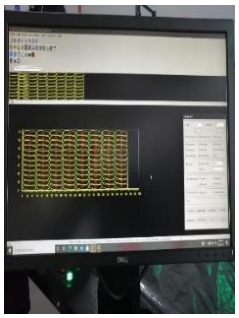
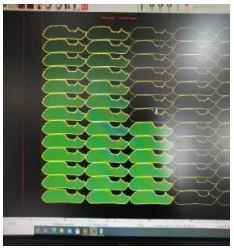
Table 5: Approved maximum number of cutting layer

MODEL	MATERIAL	QUANTITY		
SAHARA	LAMINATED VINYL McKINLEY - PUR + FOAM	Max - 15 layers		
SPORT	LAMINATED VINYL McKINLEY - PVC + FOAM	Max - 15 layers		
TONNEAU	STD VINYL	Max - 5 layers		
SEAT COVER	SUPAPROOF CANVAS	Max - 3 layers		
Remark:		PREPARED	CHECKED	APPROVED
Date : Oct 2021	Rev : 0			

3.3 Approved standard operating procedure

The automatic vinyl cutting process starts by turning on the main power switch of the machine until the execution of .CUT file. Based on the practical execution, the standard operating procedure of NC cutter is simplified as in Table 6.

Table 6 Standard Operating Procedure

Procedure	Illustration	Procedure	Illustration
1. Switch on main power		2. Turn on vacuum function	
3. Turn on the machine		4. Turn on CPU	
5. Select and open ImulCUT software		6. Press enabler key on machine control panel for home finding	
7. Load the raw material that we want to cut		8. Open the part drawing file in ImulCUT software	
9. Set the starting point for cutting by using measure feature at the control panel		10. Execute the cut process and wait for the cutting process to finish	

The standard operating procedure has been approved by the top management and engineers for implementation (shown in Figure 9). This procedure will be used by operators to handle the machine and training module for new operators.

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Figure 9. Approved standard operating procedure

3.4 Economic and production impact of NC cutter implementation

Based on cost analysis, the implementation of NC cutter gives a positive impact on the company in terms of production cost reduction and increases the company's profitability. Table 7 shows the value of the engineering change note issued by the engineering department after the business development department calculation using a confidential formula for the production of the JL armrest. Based on the evaluation, since NC cutter implementation, the company has saved up to 11.56 % cost of producing a piece of Sahara FR cut stock.

Table 7 Engineering change note for JL armrest production

Cost Price (Die cut)	Cost Price (NC Cutter)
SAHARA FR : RM 11.68	SAHARA FR : RM 10.33
SAHARA RR : RM 9.76	SAHARA RR : RM 8.40

The impact on production rate for front armrest is given in Table 8.

Table 8 The new production rate of JL Sahara Front

SAHARA FR Upper	SAHARA RR Lower
12 layers	12 layers
720 set	720 set
30 minutes	34 minutes
Rate= 24 set/minutes	Rate= 21 set/minutes

The impact on production is also calculated and compared to the old method (die cut) in order to identify the best way to produce the cut stock, by using either NC cutter or die cut. The

results are shown in Table 9. From the analysis, it is proof that the space utilization of vinyl slab NC cutter is higher than die cut, the cut stock quantity produced is the same for both methods and the cycle time for die cut is faster than NC cutter cycle time, which is almost 2.5 minute. However, both methods can achieve the desired Takt time set by the company.

Table 9. Comparison NC cutter and Die cut method

Type of cut	**NC cutter**	**Die Cut**
Layer of cut	12 layer of vinyl (2420.78 m x1800 mm)	120 layer (380mm x 1800 mm)
Percent of yield (utilization)	74.13 %	68.53 %
Cut stock produced	720 Pcs	720 Pcs
Cycle time	28.5 mins	26.0 mins

4. Conclusion

In conclusion, the implementation of the NC cutter has facilitated the vinyl armrests cutting process, and in turn, increased the production rate of the components. The development of NC cutter working procedures (SOP) helps to improve the efficiency of the machine application, as well as saving vinyl cutting time and reducing the use of raw materials. Moreover, the cost savings is up to 11.56 % due to the full utilization of the vinyl sheet and the reduction of material waste. The production rate of JL Sahara armrests using this NC cutter is also higher which is 24 set/minutes for SAHARA FR upper and 21 set/minutes for SAHARA RR Lower when compared to production using die cutting machine. For any company that needs to produce vinyl cut stock in large quantities with great quality, the use of NC cutters is highly recommended.

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