PERFORMANCE EVALUATION AND DEAR BASED OPTIMIZATION ON MACHINING LEATHER SPECIMENS TO REDUCE CARBONIZATION

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ABSTRACT

Due to the variety of benefits over traditional cutting techniques, the usage of laser cutting technology has risen substantially in recent years. The hot wire machining can cut the leather in the required shape by controlling through the wire by generating thermal energy. In the present study, an attempt has been made to investigate the effects of performance measures in hot wire machining process on cutting leather specimens. Carbonization and material removal rate were considered as quality indicators. Burning leather during machining might cause carbon particles, reducing product quality. Minimizing the effect of carbon particles is crucial for assuring operator and environmental safety, health, and product quality. The hot wire machining can efficiently cut the specimens by controlling current through it. Taguchi- DEAR based optimization was also performed in the process which results in a required Carbonization and material removal rate. Using the DEAR approach, the optimal parameters of the present study were found with 3.7% of prediction error accuracy.

Keywords: *Leather; Current; Wire; MRR.*

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1. INTRODUCTION

There are several uses for leather in the aviation, automobile, and marine sectors. Seat coverings and gaskets are two of the most common roles that leather plays in these industries. Depending on the maker and the skin, buffalo leather may have a thickness that ranges anywhere from 1.2 millimeters to 2.0 millimeters [1]. The strength and longevity of this particular sort of leather have earned it a high market value. In addition to being time-consuming and labor-intensive, traditional methods of cutting leather may be rather expensive. On top of that, it was discovered that contemporary industrial cutting processes lacked the precision and accuracy that was expected of them [2, 3]. In addition, traditional leather cutting tools need to be sharpened and maintained on a regular basis, which may be a time-consuming and expensive process. The use of contemporary machining methods, like as water jet, laser, and electron beam machining, is gaining popularity for the purpose of cutting leather. These techniques are characterized by their precision and effectiveness [4, 5]. Due to the fact that these methods are capable of accurately cutting complicated shapes and patterns, they are particularly useful for cutting leather. As a result, the possibility of using hot wire machining to cut leather specimens has been suggested. Hot-wire cutting is a common material removal process used to shape and sculpt plastic foam materials, such as expanded polystyrene (EPS). Due to the low cost and sculpt- ability of plastic foams they are popular materials for large sized (> 1m^3) prototypes and bespoke visual artefacts. Recent development in robotic foam sculpting machines has greatly increased the ability of hot-tools to sculpt complex geometrical surfaces bringing the subject into the realm of subtractive rapid prototyping/manufacturing[6]. evertheless foam / letter cut objects are not being exploited to their full potential due to the common perception that hot-wires are a low accuracy cutting tool. If greater accuracy for hot-wires can be obtained, it could provide a low-cost method of producing high value functional engineering parts.

Polystyrene patterns for lost foam casting are one such possibility. However the current through the wire has to be controlled for achieving better performance measures. Hence it has to be incorporated with proper controller loop during the cutting process. The objective of this study is to investigate thermal effects of the hotwire cutting on the sheets and to find relationships between process parameters in order to obtain optimal conditions for hotwire cutting and improve dimensional accuracy of the process [7]. Several experiments were performed to find the relationships between maximum cutting speed and heat input, and between cutting offset and heat input. Numerical analyses were carried out to investigate the influence of the cutting parameters on temperature distribution around the hotwire and to estimate the amount of the sheet melted away. Moreover, the size of the thermal front as the hotwire is about to lose its stiffness was predicted to propose the optimal cutting conditions.

Multi-criteria decision-making (MCDM) is a method that may be applied in this kind of study because of the multiple aspects that are associated with the cutting process. The Taguchi-Grey relational analysis (TGRA)-based multi-criteria decision making (MCDM) technique [8] presents a challenge when it comes to selecting the Grey coefficient. Despite the fact that Taguchi-Data Envelopment Analysis-Based based Ranking (DEAR) is the most straightforward method, it is not applicable to all lower-level performance measurements [9, 10]. Hence, an attempt has been made to investigate the effects of performance measures in hot wire machining process on cutting leather specimens.

2. EXPERIMENTAL SETUP OF THE SEMI AUTONOMOUS WHEELCHAIR

The cutting is done by a hot wire which is fixed in the shafts. The foam will be placed at the middle. The hot wire moves along the x and they axis cutting the foam in any desired shape. The hot wire melts down the foam and the cut is obtained. The complete working of the machine is described below. The basic structure of the machine is made using SS rods both on the X and Y axis. SS rods are used because they provide high stability and also flexibility to the machine. Linear bearings are used in specific places, these bearings are used to hold L clamps at both ends of the machine as shown in Fig. 1. The L clamps hold the machine together, they are used to keep the machine intact and make the machine stiff. There is a big U clamp in the middle of each of the poles, this is where the clamp for the wire will be placed and there is a similar clamp on the other side to make sure the wire is stiff throughout the entire cutting process. There are lead screws going through the middle of each of the halves of the machine, these help facilitate the movement of the wire through both X and Y axis. The lead screws rotate and this circular motion is then converted into linear motion and this causes the device to move in the X axis and the Y axis. The wire is held in place using clamps that are present on the bent U clamp placed on the Y axis on either side of the machine. Hotwire cutters work by heating a thin wire, with a low voltage power supply.

Most hotwire foam cutters use nichrome or Inconel wire for their strength and ability to resist oxidation under high temperature and nichrome is cheaper. Too low of a current and the wire will not be hot enough, resulting in wavy cut. Too high of current and the wire may melt in two. So, in-order to solve this we have to see that the rate of heat produced by the wire should be equal to rate of heat absorbed by foam. So this is maintained by temperature of wire, resistance, tension, material etc., If the wire is too hot, it breaks more frequently. If the wire is not hot enough, it takes forever to push it through. There are lots of ways to adjust the heat, many of them involving controlling voltage. Pulling back so the wire length between is longer cools it down. Fig. 2 shows the basic working principle of the hot wire foam cutting machine.

There are 4 stepper motors used in total, 2 for each of the axes. These help move the wire up and down along the Y axis and right to left along the X axis. To provide the required voltage to the microcontroller a base board is used. The stepper motors are controlled by using the TB6560 driver circuit. The coding is done by using MAC 3 software and then is inputted into the machine. Once this code is received by the machine it the uses the code to cut the give foam to the shaped designated by the codes. The wire is heated through a stable dc power source, this enables the wire to heat up, but we also have to control the heating of the wire to stop the wire from heating up too much, this is achieved by using a thermistor. A thermistor gives out resistance in relation to either an increase or decrease in temperature. To maintain at a particular temperature the thermistor sends signals to the Arduino board so that it can vary the current coming to the wire so that the temperature is maintained at the required level.

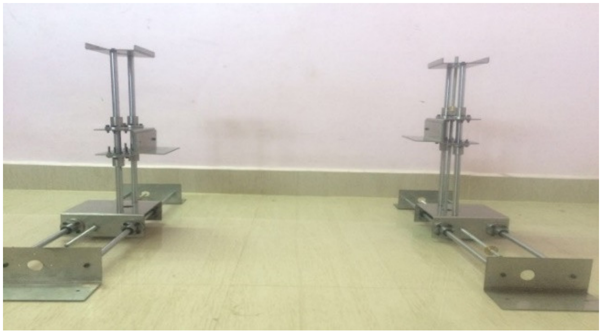

Fig. 1. Hot wire Setup

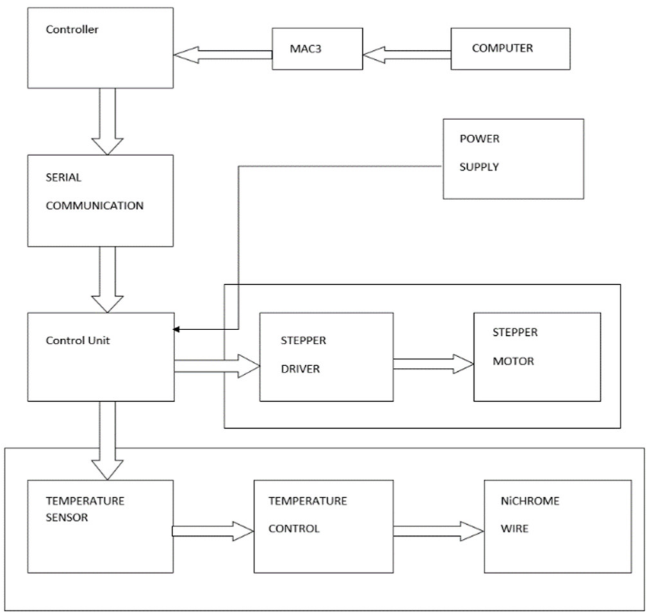

Fig. 2. Block diagram representation of Hot wire machining Setup

3. RESULTS AND DISCUSSION

The current through wire (IW), feed rate (FR), and duty cycle (DC) were chosen as the process input parameters to assess the quality of hot wire machining (HWM) process. An L_9 orthogonal array (OA) was chosen for conducting experimental trials as per the Taguchi design, since the present study dealt with three input factors with no interactions among them. The input and output parameters were preferred after considering inputs from various leather suppliers and laser machining specialists. The output variable percentage of carbonization and material removal rate were considered as the output process parameters because of their influence on productivity. The percentage carbonization (CW) was determined by calculating the number of black and white pixels in the image obtained after the cut. The material removal rate (MRR) was considered an output parameter to determine the leather material removed per unit time.

While the traditional Taguchi design is only capable of solving problems involving single-response optimization, it is absolutely necessary to implement multi-response optimization, also known as MRO. Considering how straightforward it is, the Taguchi data envelopment analysis-based ranking (DEAR)-based MRO technique was chosen to be used in this particular research endeavor. A combination of experimental data that have been recorded and plotted into a ratio is employed in the process of optimization. The following stages are used in order to optimize the parameters.

- Calculating the weights of each answer involves finding the proportion between replies over the total number of experimental measurements. This is done in order to produce the weights.
- For the purpose of obtaining the weighted data, these values are then multiplied by their respective weights.
- Calculating the MRPI, which is the ratio between "the larger the better" and "the smaller the better," was done in accordance with the stages.
- For the purpose of the DEAR analysis, the average values of carbonization, kerf width, and MRR for the LBM process were collected. The experimental trials have been performed and tabulated as shown in Table 1.

Table 1. Experimental trials

Trial	Input factors			Output factors	
	I_W (A)	FR (mm/min)	DC (%)	CW (%)	MRR (g/min)
1	2	100	50	80.890	0.063
2	2	150	60	79.893	0.079
3	2	200	70	77.364	0.099
4	3	100	60	72.430	0.075
5	3	150	70	70.548	0.134
6	3	200	50	79.483	0.102
7	4	100	70	81.232	0.145
8	4	150	50	77.647	0.134
9	4	200	60	82.354	0.174

Table 2. Calculated values for weight and MRPI

Trial number	Carbonization (%)	MRR (g/min)	MRPI
1	0.106849331	0.062686567	0.000457
2	0.108182724	0.078606965	0.000718
3	0.111719176	0.098507463	0.001128
4	0.119329592	0.074626866	0.000648
5	0.122512932	0.133333333	0.002067
6	0.108740767	0.101492537	0.001198
7	0.106399477	0.144278607	0.002420
8	0.111311993	0.133333333	0.002067
9	0.10495	0.173134	0.003486

Though the combined control can provide better quality measures than existing approached, it was attempted to introduce Taguchi-DEAR based MRO to compute optimal process parameters combination to further improve the cutting measures. The values of the weight and MRPI for each experimental result were computed based proposed approach and tabulated as explained in Table 2. The values were computed by including values of MRPI for corresponding level of each technological parameters. Due to larger value of MRPI of each technological parameters indicates the value of the optimal technology parameter, Iw (Level 3), FR (Level 3) and DC (Level 3) can create better quality measures as shown in Table 3, and the combination is formed by the optimal combination of the process parameters in this optimization problem (Table 4).

Based on the DEAR method, it was concluded that the optimal parameters for cutting chrome vegetable tanned cow leather are a current of 2 A, feed rate of 200 mm/min and duty cycle of 70%. To confirm the optimization approach, a confirmation experiment was also performed. The material removal and carbonization have been found as The experimental results at the optimal conditions show that the deviation of the MRPI of the quality indicators at the optimal conditions is 3.7% compared with the maximum mean value. This value is lower than the acceptable tolerance value which is 5%. Hence, the prediction accuracy of the present approach was observed as acceptable limit. The highest Max–Min value has shown that the more significant influence on the determination of the quality parameters in the machining processes. The current through the wire was observed as high influential factor in the process due to its importance on determining thermal energy.

Table 3. Computation of optimal parameter combination

Factors	Levels			Max - Min
	1	2	3	
I_W	0.000768	0.001304	0.002658	0.001890
FR	0.001175	0.001618	0.001937	0.000762
DC	0.001241	0.001617	0.001872	0.000631

Table 4. Optimized process parameters

Factors	Level	Parameters
I_W	3	4 A
FR	3	200 mm/min
DC	3	70%

4. CONCLUSIONS

In the present investigation, performance measures such as carbonization and material removal rate were taken into consideration. The hot wire machining process was utilized with current control to cut vegetable chrome tanned leather. The following conclusions were drawn from the experimental analysis.

- The hot wire machining approach can cut the leather material in an efficient way with current control approach.
- The optimal parameters for cutting chrome vegetable tanned cow leather were found as current of 2A, feed rate of 200mm/min and duty cycle of 70%.
- The current through the wire was observed as high influential factor in the process due to its importance on determining thermal energy.

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