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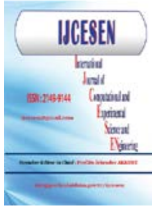

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Research Article

Investigation of the Effect of Cutting Parameters on the Cutting Force and Energy in the Bar Cutting Process[#]

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Abstract: In this paper, cutting forces and expended energy which generated in the process of cutting the scrap bars are investigated an experimental study. Parameters affecting the cutting force is defined as cutting speed, the clearance, the cutting tool the radius, the cutting edge length and the bar diameters. In contrast to the preexisting studies is aimed to reduce the cutting forces and expended energy rather than the improvement of the cutting surface in this study. Three different levels of all five parameters are identified as variables. The number of experiments increases proportionally with the number of parameters. In order to use more parameters and perform fewer the number of experiments, this study is designed based on Taguchi L_{27} orthogonal array. The effect of these parameters which influence the cutting force on result is identified through variance analysis (ANOVA). As a result, the appropriate the cutting parameters are found by implementing verification tests.

1. Introduction

Bar cutting is a widely used metal forming processing for many years. The quality and cost of manufactured components has a direct influence on the quality of bar cutting [1]. Conventional bar cutting method has many drawback such as high cutting force, worse surface quality, lower productivity, high cost and waste of energy. To overcome these problems, optimization is emerging as a need during the bar cutting process [1-6-7]. Because bar cutting process very complicated, and energy productivity and cutting force are affected by many factors such as cutting speed [2-7], clearance [4], cutting tool of the radius [5], cutting edge length [6] and bar diameters.

Recently, researchers have shown an increased interest for the bar cutting method and its devices[1], but there is still no study optimization of cutting parameters on scrap shearing machine with the Taguchi method.

In this study, a novel advanced precision bar cutting technology, high-speed and lower energy, is proposed. The cutting force and energy productivity has been analyzed and a new kind of high-speed precision bar cutting machine has been created. The effects of process parameters on the cutting force and productivity energy of the cutting surface has been studied using both methods of Taguchi and ANOVA numerical simulation and experimental study.

2. Experimental

2.1. Materials and Equipment

The aim of this study is to design and construct a compact prototype a scrap bar cutting press which uses electric motor and mechanical re-cocking mechanism. This C type eccentric press has 50 tons capacity.

Firstly it's desired for the press to be able to work in three different speeds and to make it possible three different pulleys had been used and the velocities 120 mm/s, 270 mm/s and 325 mm/s has been obtained. Secondly the press has been designed in a way that the tables of the press can move on the three axes. Thanks to this, it is possible to set the distance between the upper and the lower cutters, modify the sensors in the body of the press and calibrate them precisely as well as fix the parallel alignment problem that occurs between the upper and the lower tables after a while on the C type presses. It's also intended to measure loads and distances in the press so a loadcell has been placed beneath the fixed cutter and a linear rule has been added to the running cutter. A pedal is used to obtain the stored energy in the flywheel when necessary. Additionally by using the pedal, the cutters are put into motion only when the cutting zone is feeded so it can act as a safety measurement as well. For every experiment conducted, a different blade profile was necessary so 27 paired, each pair got different heat treatment, blades had been manufactured.

Load stroke graphs of the each studied materials were obtained in the cutting process. Load versus strokes were measured by using a linear potentiometer and loadcell in this process, *respectively. Area under the load-strokes curve gives* energy that is needed to the cut the materials. The loadcell placed under the lower die provides the value of the load transferred to workpiece. A data logger (2000 data/second) is used so as to transfer the data from linear potentiometer and the loadcell to a computer. A schematic view of this equipment are given in Figure 1.

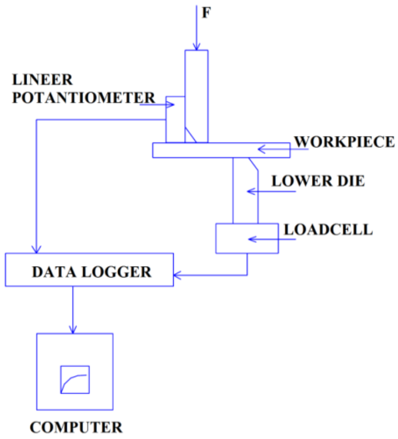

Figure 1. *A schematic view of the data logger, the loadcell and the linear potentiometer*

2.2. Taguchi Method

The Taguchi method is an extremely useful technique for the design of high quality systems, although this method is generally understood as experimental design technique. Furthermore, the Taguchi method is a systematic and efficient approach to determining optimal in terms of performance, quality, and cost during experimental configuration of design parameters [8-9].

The classic design methods are complex structure and difficult to use. In addition, increasing the number of parameters leads to an increased number of experiments. The Taguchi method has become an important method because of presenting solution the aforementioned drawbacks of the other design methods.

The parameters which influence the cutting force called control parameters such as the diameter of cut steel bars, cutting speed, clearance, the radius of the cutting tool and the cutting edge length. In this work, four controllable parameters are considered and each parameter is set at three levels. The parameters and their levels are shown in Table 1.

Table 1*.Control Parameters And Their Levels*

Levels	Speed (mm/s)	Diameter (mm)	Clearance (%)	Radius (mm)	Edge Lenght (mm)
1	120	10	5	0	4
2	270	12	10	0,5	6
3	325	14	15	1	8

3. Results and Discussion

3.1. Cutting Force

The experimental results for cutting force are shown in Table 2. In addition to, the signal-noise ratios (S/N) obtained using Eq.1 are shown in the last column.

$$S/N = -10.log(\frac{1}{n}\sum_{k=1}^{n} y_i^2) \quad (1)$$

Fig 2. and Table 3. show the S/N ratio graphs in which the horizontal line presents the value of the total mean of the S/N ratio. Basically, if the S/N ratio is bigger, the quality characteristics for the blank is getting better. As per the S/N ratio analysis from graph the levels of parameters to be set for getting optimum value of cutting force.

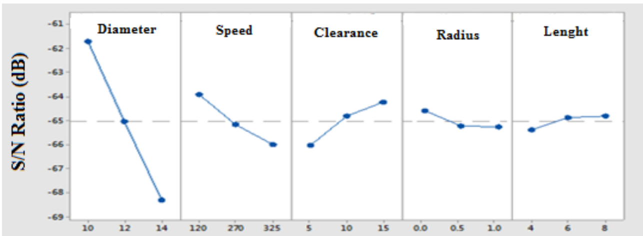

Figure 2. *S-N Ratio for force*

Table 4 shows the results of ANOVA analysis. The results in this table indicate that diameter is the most effective parameter. To reduce variation, the relative power of a factor is demonstrated percent contribution. If a factor has a high percent contribution, it effects significantly performance. The percent contributions of the cutting parameters on cutting force are shown in Table.4. After the diameter, according to this, speed was found to be the major factor affecting the cutting force (6,4%). A percent contribution of clearance is lower than speed, being (4,6%). The other parameters effect too low cutting force.

3.2 Cutting Energy

Fig 3. and Table 5. show the S/N ratio graphs where the horizontal line is the value of the total mean of the S/N ratio. As per the S/N ratio analysis from graph the levels of parameters to be set for getting optimum value of cutting force.

Table 2. *Experimental results and S/N ratio*

EXPERIMENT NO	SPEED (mm/s)	DIAMETER (mm)	CLEARANCE (%)	RADIUS (mm)	LENGHT (mm)	CUTTİN G FORCE (kg)	S/N RATIO (dB)	CUTTING ENERGY (j)	S/N RATIO (dB)
1	325	10	5	0	4	1628	-64,2331	1628	-64,2331
2	325	10	5	0	6	1535	-63,7222	1535	-63,7222
3	325	10	5	0	8	1546	-63,7842	1546	-63,7842
4	270	10	10	0,5	4	1274	-62,1034	1274	-62,1034
5	270	10	10	0,5	6	1199	-61,5764	1199	-61,5764
6	270	10	10	0,5	8	1245	-61,9034	1245	-61,9034
7	120	10	15	1	4	954	-59,5910	954	-59,5910
8	120	10	15	1	6	913	-59,2094	913	-59,2094
9	120	10	15	1	8	933	-59,3976	933	-59,3976
10	325	12	10	1	4	1982	-65,9421	1982	-65,9421
11	325	12	10	1	6	1751	-64,8657	1751	-64,8657
12	325	12	10	1	8	1840	-65,2964	1840	-65,2964
13	270	12	15	0	4	1793	-65,0716	1793	-65,0716
14	270	12	15	0	6	1699	-64,6039	1699	-64,6039
15	270	12	15	0	8	1619	-64,1849	1619	-64,1849
16	120	12	5	0,5	4	1985	-65,9552	1985	-65,9552
17	120	12	5	0,5	6	1763	-64,9250	1763	-64,9250
18	120	12	5	0,5	8	1675	-64,4803	1675	-64,4803
19	325	14	15	0,5	4	2808	-68,9679	2808	-68,9679
20	325	14	15	0,5	6	2610	-68,3328	2610	-68,3328
21	325	14	15	0,5	8	2735	-68,7391	2735	-68,7391
22	270	14	5	1	4	2757	-68,8087	2757	-68,8087
23	270	14	5	1	6	2850	-69,0969	2850	-69,0969
24	270	14	5	1	8	2887	-69,2089	2887	-69,2089
25	120	14	10	0	4	2423	-67,6871	2423	-67,6871
26	120	14	10	0	6	2401	-67,6078	2401	-67,6078
27	120	14	10	0	8	2073	-66,3320	2073	-66,3320

Table 3. *S/N response table for force*

LEVEL	SPEED	DIAMETER	CLEARANCE	RADIUS	LENGHT
1	-63,91	-61,72	-66,02	-64,25	-65,37
2	-65,17	-65,04	-64,81	-65,22	-64,88
3	-65,99	-68,31	-64,23	-64,60	-64,81
Delta	2,08	6,58	1,79	0,65	0,56
	1	1	3	1	3

Table 4. *Results of the ANOVA*

	DOF	ADJ SS	ADJ MS	F	P	PCR %
Speed	2	632555	316277	36,86	0,0	6,4
Diameter	2	8549328	4274664	498,23	0,0	86,5
Clearance	2	463817	231909	27,03	0,0	4,6
Radius	2	19917	9958	1,16	0,338	0,2
Edge L.	2	70834	35417	4,13	0,036	0,7
Error	16	137275	8580			1,3
Total	26	9873726				100

Table 6 shows the results of ANOVA analysis. The results in this table indicate that diameter is the most effective parameter. The percent contributions of the blanking parameters on cutting force are shown in Table 6. After the diameter, according to this, speed was found to be the major factor affecting the cutting force (3%). A percent contribution of clearance is lower than speed, being (1,32%). The other parameters effect too low cutting force.

Table 5. *S/N response table for energy*

LEVEL	SPEED	DIAMETER	CLEARANCE	RADIUS	LENGHT
1	-30,64	-27,86	-31,96	-31,45	-32
2	-32,83	-31,22	-31,52	-32,09	-31,79
3	-31,64	-36,03	-31,63	-31,58	-31,32
Delta	2,19	8,16	0,44	0,64	0,68
	1	1	2	1	3

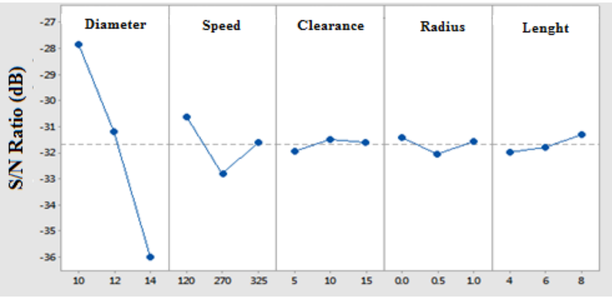

Figure 3. *.S-N Ratio for energy*

Table 6. *Results of the ANOVA*

	DOF	ADJ SS	ADJ MS	F	P	PCR %
Speed	2	512,41	256,2	8,39	0,003	3
Diameter	2	7261,29	3630,65	118,92	0,0	85
Clearance	2	113,54	56,77	1,86	0,188	1,32
Radius	2	96,07	48,03	1,57	0,238	1,11
Edge L.	2	51,93	25,97	0,85	0,446	0,6
Error	16	488,49	30,53			5,7
Total	26	8523,74				100

4. CONCLUSION

In this paper, experimental studies are performed to investigate the effects of some factors on the bar cutting process. These factors are the cutting speed, the clearance, the cutting tool the radius, the cutting edge length and the bar diameters, especially the cutting force and energy. The Taguchi method which benefits from the time and resources is used to achieve better results during the bar cutting process. The minimum cutting force values cutting speed of 120 mm/s, 10 mm diameter material being cut, the cut-off value of 15 % clearance, no edge radius and cutting edge length of 8 mm was observed in options. The minimum force for these parameters were found to be 871.5 kg by Minitab -17 program. Minimum cutting energy values cutting speed of 120 mm /s, 10 mm diameter material being cut, the cut-off value of 10 % clearance, no edge radius and cutting edge length of 8 mm was observed in options. The minimum energy for these parameters were found to be 12.48 j by Minitab -17 program. When the blanking speed increased, cutting force and energy increased but when the clearance decreased, cutting force and energy increased.

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