Investigation of the Effects of Cutting Parameters on Surface Roughness in Turning Operations

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Abstract: ***In this study, the effect of cutting parameters used in turning operations on surface roughness has been experimentally investigated. AISI 304 stainless steel material was used as the workpiece material in the experimental studies. Cutting operations were conducted with WNMG O80408 EA cutting tool according to the experimental plan determined by the Taguchi method, involving different cutting speeds, depths of cut, and feed rates. The influence of cutting parameters on cutting forces and surface roughness has been determined.***

Keywords: Cutting parameters, surface roughness, AISI 304 stainless steel, turning operations, machinability

1. Introduction

Stainless steels constitute a significant material group due to their preferred characteristics in many industrial applications. (1) Compared to most other metals and alloys, stainless steels possess much higher resistance to corrosion, making them ideal for constructing durable structures under various conditions. They are resistant to chemical and atmospheric exposures, which explains their preference in equipment for maritime, chemical, food production, and pharmaceutical industries.

Despite these superior qualities and advantages in various fields, stainless steels have low machinability, leading to challenges during production stages. The presence of materials such as chromium, nickel, carbon, sulfur, and molybdenum in their chemical compositions adversely affects their machinability. (2) These issues manifest during machining as reduced tool life, continuous chip formation, deterioration of surface quality, high cutting forces, risk of vibrations, and increased production costs.

Stainless steels produce long chips during machining, which is economically disadvantageous in terms of chip handling. Long chips imply that the machining process cannot be left unattended and can wrap around the workpiece, compromising surface roughness and leading to aesthetic issues. Handling these long chips can also pose risks to operators and necessitate additional steps for their removal, thereby increasing costs. These reasons contribute to the poor machinability of stainless steels. (3, 4)
To overcome these challenges, this study aims to experimentally investigate the effects of cutting forces and surface roughness during chip removal using turning methods on AISI 304 stainless steel material. The experimental data on chip removal forces and surface roughness values will be analytically modelled, and the interactions of parameters influencing cutting forces and surface roughness will be examined.

2. Materials and Methods

Material Characteristics Used in the Experimental Study In the experiments, AISI 304 austenitic stainless steel material was used as the workpiece material. The quality certificate of the AISI 304 material used in the tests was obtained from Valbruna S. P. A. The chemical composition of AISI 304 stainless steel material is provided in Table 1.

Table 1: Chemical composition of material

AISI	C %	Si %	Mn %	Cr %	Mo %	Cu %	Ni %	Co %	P %	S %	N %
304	0, 017	0, 54	1, 78	18, 40	0, 48	0, 46	8, 14	0, 100	0, 029	0, 029	0, 086

2.1 Cutting Tools Used in the Experiments

In the experiments, cutting tools with the code WNMG 080408 and tool holder with the code MWLNL 2525 M08 were used. (5, 6) The cutting insert used is CVD - coated and possesses high wear resistance. This tool is suitable for high - speed machining of stainless steels and exhibits excellent wear resistance.

2.2 Lathe and Measurement Instruments Used

The machining experiments were conducted on a HYUNDAI - WIA L210LA brand and model turret lathe. Coolant was not used during the experiments. A Kistler model 9257B dynamometer was used for measuring cutting forces, and a Mitutoyo surface roughness measurement device was used for measuring surface roughness.

2.3 Experimental Design

The experiment is based on a full factorial design. In a full factorial design, 8 experiments were conducted for each cutting tool with different chip breaker forms, resulting in a total of 24 experiments. The cutting parameters used in the experiments were determined to include two different cutting speeds, two different feed rates, and two different depths of cut (see Table 2).

During the process, three cutting forces—main cutting force (F_c), feed force (F_f), and radial force (F_r) —were measured using a dynamometer. This dynamometer was

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connected to a signal amplifier (Kistler Type 9257B), and the cutting force signals were sent to a computer via an RS - 232C patch cable for acquisition in the Dynoware program. Main cutting force (F_c), feed force (F_f), and radial force (F_r) were determined based on the obtained force graphs.

Surface roughness was measured using a Mitutoyo surface roughness measurement device after the machining experiments, and the values were recorded.

Table 2: Cutting Parameters Used in the Experiments

Cutting Speed v (m/dak)	Feed f (mm/dev)	Cutting depth a (mm)
100	0, 1	1
200	0, 3	2

3. Experimental Results

The surface roughness values obtained from the experiments for different cutting parameters (cutting speed, feed rate, depth of cut) are presented in Table 3.

Table 3: Surface Roughness Values

Exp. no	Ra	V (m/dk)	F (mm/dv)	a (mm)
1	0, 73	100	0, 1	1
2	0, 72	200	0, 1	1
3	3, 2	100	0, 3	1
4	3, 21	200	0, 3	1
5	3, 41	100	0, 3	2
6	3, 32	200	0, 3	2
7	0, 81	100	0, 1	1
8	0, 86	200	0, 1	1

4. Regression and Analysis of Variance

Regression analysis method was employed to represent the surface roughness values obtained from the experiments with cutting parameters (cutting speed, feed rate, and depth of cut). The Minitab software was used for implementing regression analysis, and the effects of cutting speed, feed rate, and depth of cut parameters on experimental measurement values were analyzed.

Table 4: Equation model and analysis results for arithmetic mean surface roughness (Ra)

Regression Analysis: Ra versus v; f; a

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	29,2528	9,7509	208,08	0,000
v	1	0,0376	0,0376	0,80	0,381
f	1	29,1501	29,1501	622,03	0,000
a	1	0,0651	0,0651	1,39	0,252
Error	20	0,9372	0,0469		
Lack-of-Fit	4	0,0180	0,0045	0,08	0,988
Pure Error	16	0,9192	0,0575		
Total	23	30,1901			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,216477	96,90%	96,43%	95,53%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-0,363	0,212	-1,71	0,102	
v	-0,000792	0,000884	-0,90	0,381	1,00
f	11,021	0,442	24,94	0,000	1,00
a	0,1042	0,0884	1,18	0,252	1,00

Regression Equation

Ra = -0,363 - 0,000792 v + 11,021 f + 0,1042 a

Table 5: Analysis of variance for Ra surface roughness values

General Linear Model: Ra versus takım; v; f; a

Method

Factor coding (-1; 0; +1)

Factor Information

Factor	Type	Levels	Values
takım	Fixed	3	EA; EM; MP
v	Fixed	2	100; 200
f	Fixed	2	0,1; 0,3
a	Fixed	2	1; 2

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
takım	2	0,5463	0,2732	12,58	0,000
v	1	0,0376	0,0376	1,73	0,205
f	1	29,1501	29,1501	1342,21	0,000
a	1	0,0651	0,0651	3,00	0,100
Error	18	0,3909	0,0217		
Total	23	30,1901			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,147370	98,71%	98,35%	97,70%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1,8787	0,0301	62,45	0,000	
takım					
EA	0,1538	0,0425	3,61	0,002	1,33
EM	0,0512	0,0425	1,20	0,244	1,33
v					
100	0,0396	0,0301	1,32	0,205	1,00
f					
0,1	-1,1021	0,0301	-36,64	0,000	1,00
a					
1	-0,0521	0,0301	-1,73	0,100	1,00

Ra = 1,8787 + 0,1538 takım_EA + 0,0512 takım_EM - 0,2050 takım_MP + 0,0396 v_100 - 0,0396 v_200 - 1,1021 f_0,1 + 1,1021 f_0,3 - 0,0521 a_1 + 0,0521 a_2

Regression Equation

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4. Conclusion and Evaluation

In the experiments, surface roughness values were measured, revealing that increasing cutting speed decreases surface roughness values, while increasing feed rate and depth of cut adversely affect surface roughness values. This observation holds true across all cutting tools with different chip breaker forms. Increasing cutting speed to reduce surface roughness is a commonly applied method in machining processes. According to the measurements from the experiments and studies in the literature, working at low feed rates and shallow depths of cut appears to be an effective method for achieving better surface quality. (7, 8)

The analysis of variance was conducted at a significance level of 5% and a confidence level of 95%. Upon reviewing the results in Table 3 and Table 4, it is concluded that the most influential factors for average surface roughness (Ra) values are feed rate and cutting tool type. For both factors (feed rate and cutting tool type), the P - Value was found to be 0.000, which is less than 0.05, confirming this observation.

References

[1] Özçatalbaş Y., 2002. Kesici takım aşınması ve iş malzemesi mekanik özelliklerinin yüzey pürüzlülüğü ve kesme kuvvetlerine etkisi. Politeknik Dergisi, 4 (1), 47 - 52.
[2] Çakır M. C., 1997. Zor malzemelerin işlenebilirliği, Denizli Malzeme Sempozyumu, 162 - 169, Denizli.
[3] Bhattacharya, D., 1987. "Machinability of Steel", Journal of Metals, March.
[4] Sasahara H., 2005. The effect on fatigue life of residual stress and surface hardness resulting from different cutting conditions of 0, 45 % C steel, İnternational Journal of Machine Tools & Manufacture, 45, 131 - 136
[5] TaeguTec, 2018. Kesici Takımlar Kataloğu, http: //www.taegutec. com. tr/
[6] Sandvik Coromant, 2005. Talaşlı İmalat Teknik Kılavuzu, SE - 81181 AB Sandvik coromant, İsveç.
[7] V. Sivaraman, S. Sankaran, L. Vijayaraghavan, 2012. The Effect of Cutting Parameters on Cutting Force During Turning Multiphase Microalloyed Steel. Procedia CIRP, 4, 157 - 160.
[8] Arslan B., 2019. "AISI 304 Paslanmaz Çeliğin İşlenmesinde Farklı Talaş Kırıcı Formlarının Kesme Kuvvetleri ve Yüzey Pürüzlülüğüne Etkisinin Deneysel Olarak İncelenmesi", YL Tezi, Konya