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The Effect of Different Chip Breaker Forms on Cutting Force and Surface Roughness in the Machining of AISI 304 Stainless Steel

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Abstract: ***In this study, the effect of different chip breaker forms on cutting forces and surface roughness during chip removal process has been investigated experimentally. AISI 304 grade austenitic stainless-steel material was machined by the cutting tools with an ISO notation of WNMG O80408 EA, WNMG 080408 EM, WNMG 080408 MP and the effects of these factors on cutting forces and surface roughness values were determined.In the experimental studies, the highest cutting forces were obtained by the cutting tools with the EM coded chipbreaker form and the best surface quality was obtained by the MP coded cutting tool.***

Keywords: AISI 304, Cutting forces, Surface roughness, Chip breaker form

1. Introduction

Since high mechanical properties affect the machinability of materials adversely, they cause big problems in the manufacturing phase (1). Corrosion resistance, ductility and high tensile strength are the main properties of stainless steels.Materials such as chromium, nickel, carbon, sulfur and molybdenum affect the machinability of stainless steels adversely. These problems can be listed as decreaseof tool life during machining, continuous chip formation, surface quality deterioration, high cutting force, risk of vibration, and increased manufacturing costs (2). In order to overcome these problems, in this study, it is aimed to experimentally investigate the effects ofdifferent chip breaker forms and breaker forms made of AISI 304 stainless steel materialson cutting forces and surface roughness during machining process. Cutting force sand surface roughness values of the machined piecesto be obtained through this study will be modelled analytically and the interactions of the parameters affecting cutting forces and surface roughness will be revealed. Many products we encounter in our daily life are formed by machining or shaping stainless steel materials. Many different quality stainless steel materials exist, and there are different usage areas for all of them. AISI 304 grade stainless steels are widely used as engineering materials due to their high chromium content (3). AISI 304 austenitic stainless steels are among the most difficult to machine materials due to the high temperatures that arise on tool interfaces during machining.Austenitic stainless steels' high work hardening, their low heat conductivity and their tendency to form built up edge (BUE) cause high tool wear and low surface quality in the machining of these steels (4). A number ofmachining difficulties are encountered in machining austenitic stainless steels due to wear. In addition, continual chip formation is seen during machining and it is very difficult to break them. Unbreakablechip is wrapped around the workpiece surface and it affects the cutting process and surface roughness adversely (5). It is seen that high cutting force is needed during the machining of stainless steels; as a result excessive tool wear is seen, and the fact that these steels have high fracture toughness increases the tendency of burr formation in contrast to normal steels (6). In this study, by selecting AISI 304 austenitic stainless steel as a test sample it is aimed to determine the most suitable machining parameters and chip breaker forms, and to shorten the machining process of the manufacturers and to reduce the production costs.

2. Material and Method

In experiments, AISI 304 austenitic stainless-steel material was used as the workpiece material. Quality certificate of AISI 304 material used as a test material was taken from Valbruna S.P.A. Company. The chemical content of AISI 304 stainless steel is given in Table 1. For machining experiments, the surfaces of AISI 304 austenitic stainless - steel materials with a diameter of 110 mm and a height of 350 mm were grinded and centre holes were made on one side. Prior to the experiments, the surface of the material was cylinder grinded at a cutting depth of 0,5 mm against potential external surface hardening and obliquity of the workpiece, and the potential obliquity and irregularities on the outer surface of the material were eliminated. In machiningexperiments, cutting tools in the form of WNMG 080408 and cutting tool holder in the form of MWLNL 2525 M08 which are suitable for these cutting tools were used (7).

Table 1: AISI 304 Stainless SteelChemicalCompositionTable

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

In experiments, WNMG 080408 MP TT9225, WNMG 080408 EM TT9215 and WNMG 080408 EA TT9225 cutting tools with different cutting tool forms of TaeguTeccompany have been used (7). The tool holder used with these cutting tools is MWLNL 2525 M08. TT9215 and TT9225 tools are CVD coating and they have high wear resistance. These tools are suitable for machinability of stainless steels at high speed and they have quite well wear resistance.With CVD coating method, such problems as fracture at the shear edge, formation of built up edge and friction between the chip and the contact surface have been reduced.

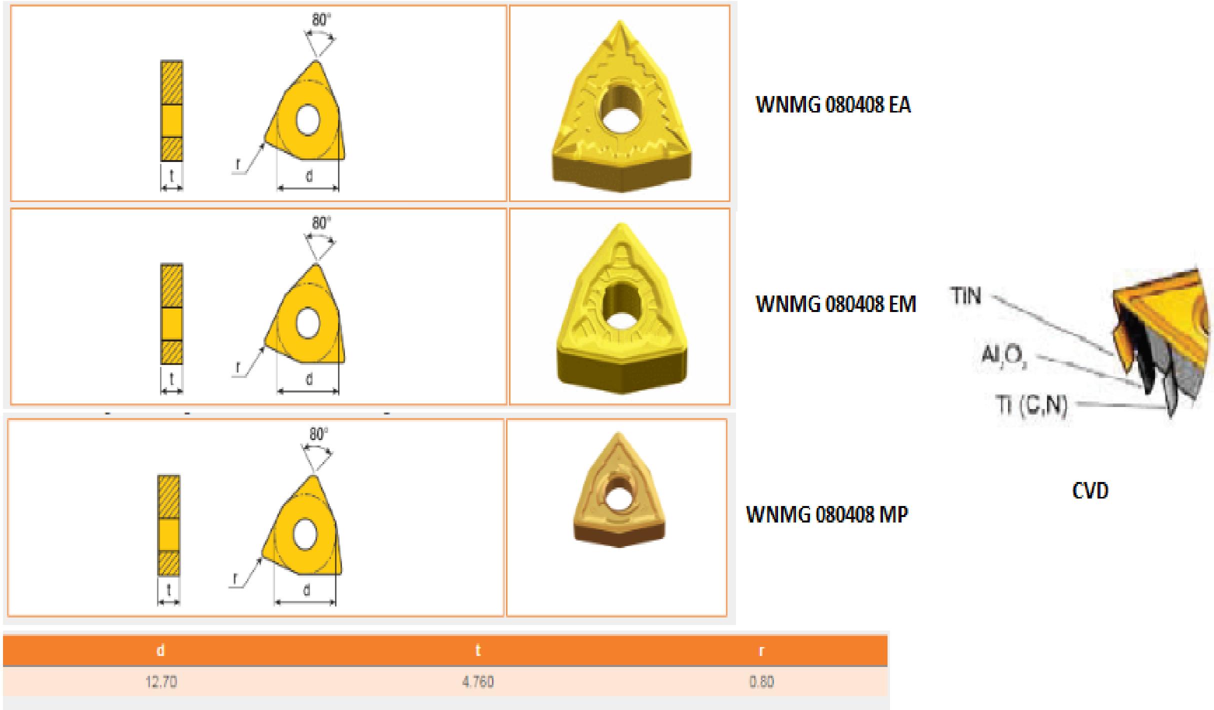


Figure 1: Properties of cutting tools and coating used in experiments (8-9)

Machining experiments were carried out on a turning lathe (HYUNDAI-WIA L210LA). No coolant was used in experiments. The design of the experiment was based on the full factorial design. In full factorial design, 8 experiments were conducted for each cutting tool with different chip breaker form; in total 24 experiments were conducted. The cutting parameters used in experiments were determined in a way that they have two different cutting speeds, two different feed rates and two different depth of cut. (Table 2). Three shear forces:main cutting force F_z (F_s), feed force F_x (F_f) and radial force F_y (F_r), which come into being in the machining process were measured by dynamometer.

This dynamometer was connected to a signal amplifier (Kistler Type 9257B) and cutting force signals were sent to the computer via RS-232C patch cord to obtain graphics in the Dynoware program. The main cutting force F_z (F_s), feed force F_x (F_f) and radial force F_y (F_r),were determined by the obtained graphics of forces. Surface roughness was measured by Mitutuyo brand surface roughness measuring device after machining experiments and the values were recorded.

Table 2: Cutting parameters used in experiments

Cutting Speed v (m/min.)	Feed rate f (mm/rev)	Depth of cut a (mm)
100	0,1	1
200	0,3	2

3. Experimental Findings

Cutting tools with different chip breaker forms were subjected to machining in different cutting speeds, feed rates and depth of cut on CNC turning lathe.During the machining, cutting force and the surface roughness on the machined pieces were measured and the effectsof these variables on cutting forces and surface roughness values were interpreted.

3.1 Evaluation of cutting forces

In the experiments; the effect of the changes in cutting speed, feed rate and depth of cut on the maincutting force (Fc) is shown the graphs in Figure 2 for each cutting tool (EA, MP, EM) with different chip breaker forms. When the graphics are analysed, it is observed that the increase in cutting speedreduces the cutting force, and the increase in feed rate increasesthe cutting force and the increase in depth of cut increases the cutting force. This is the same for all cutting tools (EA, MP, EM) with different chip breaker forms and it shows parallelismwith literature. The decrease in cutting force as a result of increase in cutting speed is explained by the decrease in the contact area of cutting tool's chip surface due to the increase in temperature and the partial decreasein shear strength in the zone of flow. The increase in cutting forces as a result of increase in feed rate and increase in depth of cut is explained with Kienzle equality. In this equality;

$$Fc = A \times ks$$

The main cutting force (Fc), the chip cross-sectional area (A), specific cutting strength (ks), feed rate -chip cross section 'feed rate x depth of cut', and the chip cross section area (A) that increases with the raise of cutting depth cause cutting forces to increases as well (10).

When the cutting force graphs of the cutting tools with EA, MP and EM chip breaker forms are examined, it is seen that the main cutting force is the highest in the form of EM chip breaker form and then EA chip breaker form and MP chip breaker form respectively.

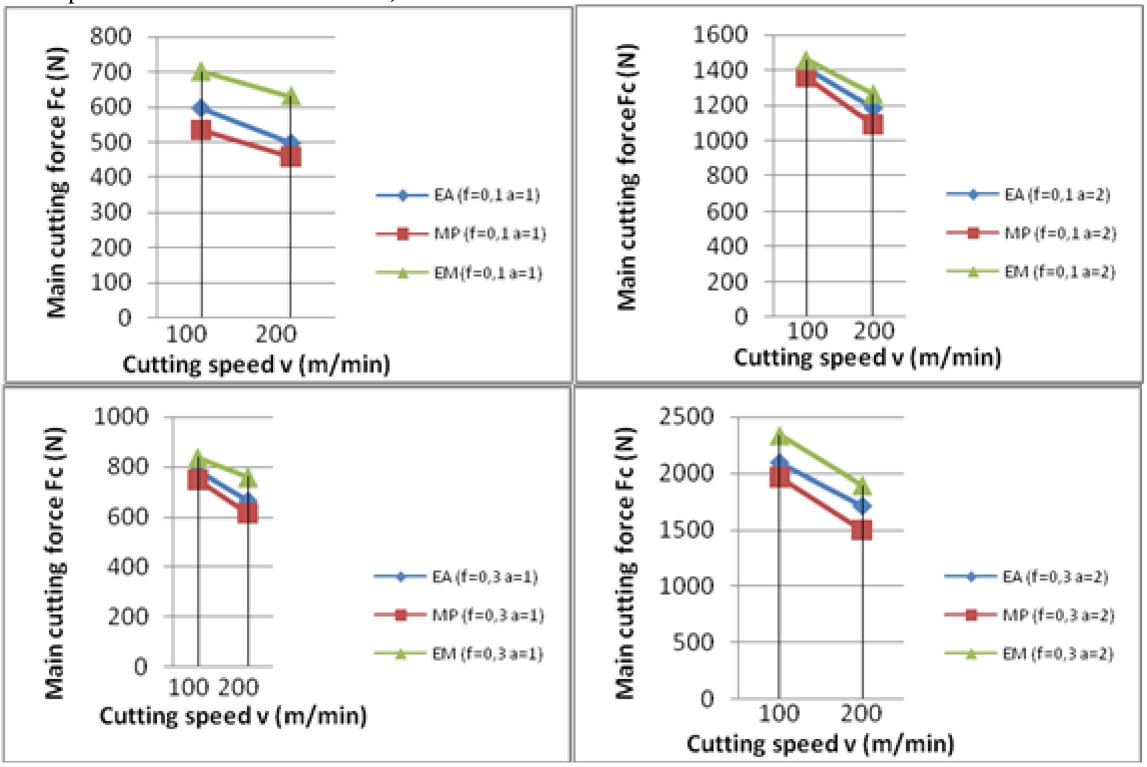
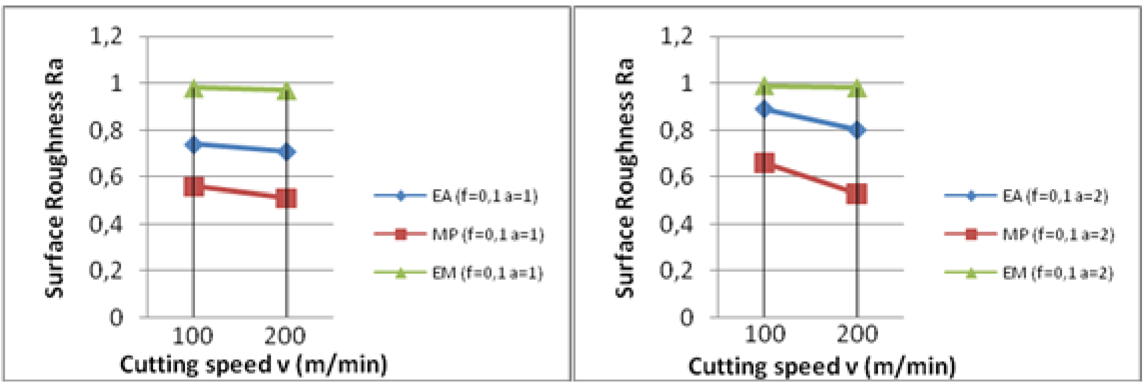


Figure 2: Main cutting force - cutting speed graphics for the cutting tools with different chip breaker forms

3.2 Evaluation of Surface Roughness

In the experiments, the surface roughness values were also measured, and it has been observed that the increase in the cutting speed decreases the surface roughness values, and the increase in the feed rate and depth of cut affects surface roughness values adversely. It is the same for all cutting tools with different chip breaker forms. Increasing cutting speed in order to decrease surface roughness is one of the common methods applied in machining processes. According to the measurements as a result of the experiments and studies in the literature, it will be a correct method to work at low feed rates and low depth of cut to achieve better surface quality (11).

When the graphs in Figure 3 are examined, it is seen that the best surface quality is obtained by the cutting tool with MP chip breaker form. While better surface quality is achieved by the cutting tool with EA chipbreaker form at lower feed rates and lower depth of cut, when feed rates and depth of cut increase, the cutting tool with EMchipbreaker form gives better results compared to the cutting tool with EA chip breaker form. The manufacturer has stated that EA chipbreaker form will give better results for low feed rates and depth of cut (7). Figure 4 shows the images of chips formed during machining for the cutting tools with different chip breaker forms. The faster the chip breaker removes the pattern, the more the heating will decrease, as a result wearing will delay, the tool life will increase, and this will affect the surface quality positively (12).



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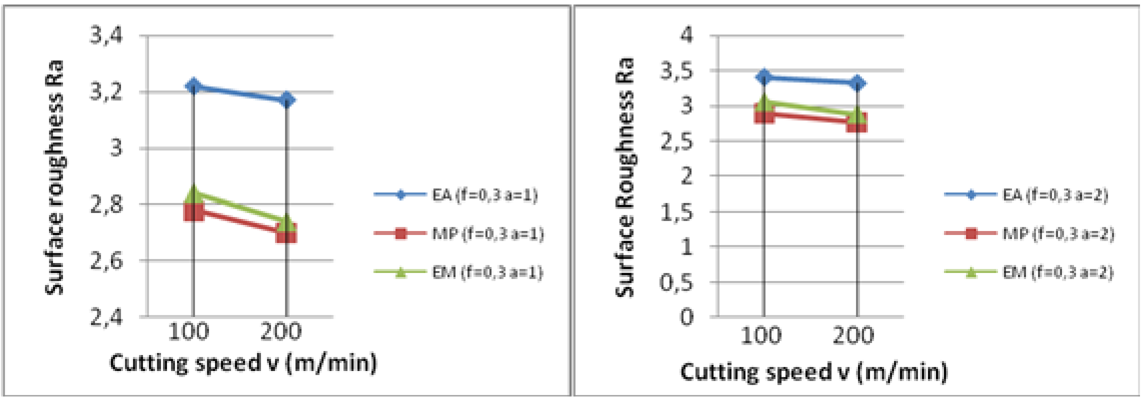

Figure 3: Surface roughness for cutting tools with different chipbreaker forms– cutting speed graphs

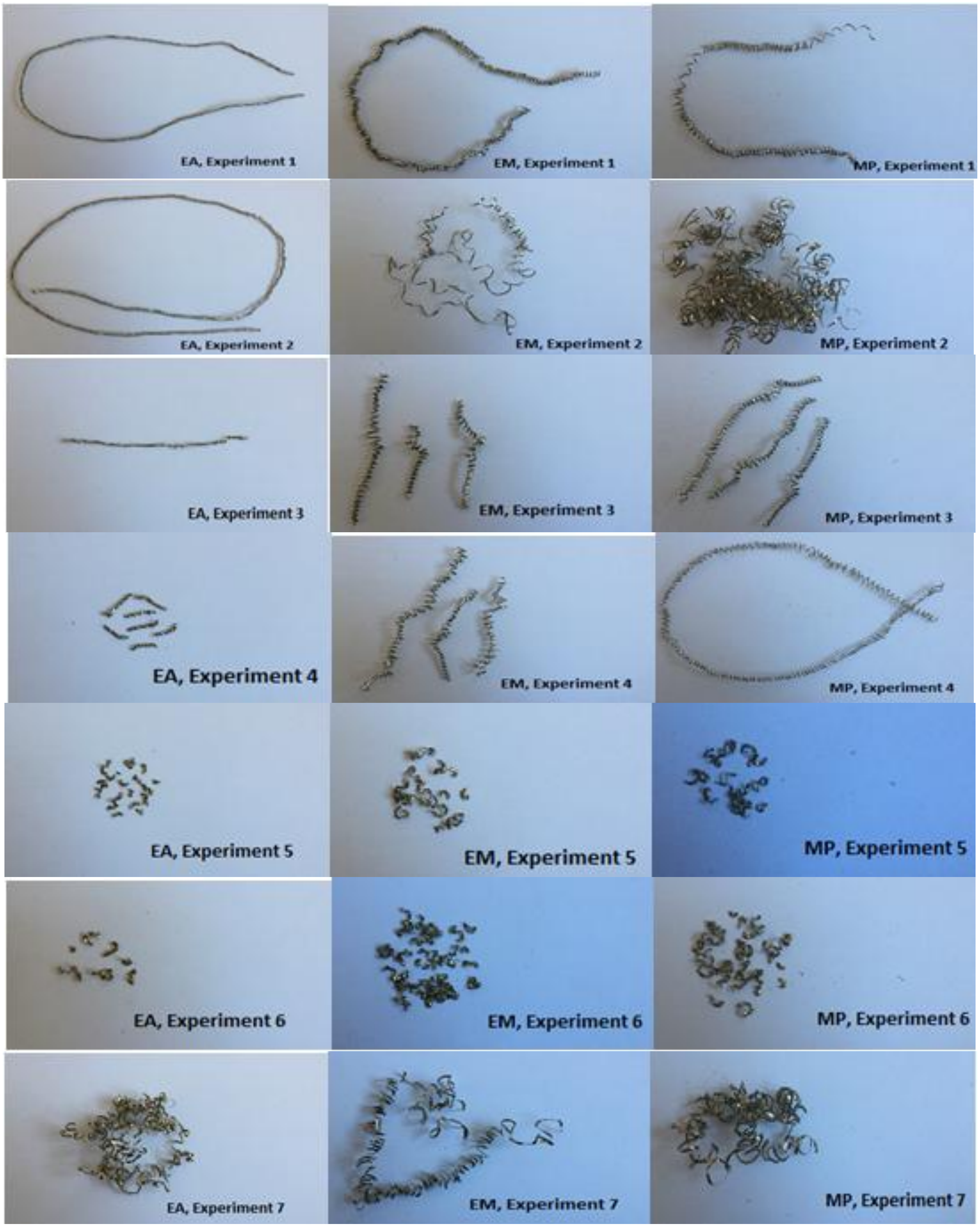

Figure 4: Images of chips formed by cutting tools with different chipbreaker forms when machining

4. Results

The results obtained through this study are summarized below.

- The highest cutting forces obtained depending on different chip breaker forms (EA, EM, MP) were observed in the EM coded cutting tool and the lowest cutting forces were observed in the MP coded cutting tool.
- Among three cutting tools with different chipbreaker forms, it has been observed that the higher depth of cut and feed is, the more cutting forces get; and that cutting forces decree with the increase in cutting speed.
- It has been observed that increase in cutting speed (EA, EM, MP) affects surface roughness values positively for all cutting tools.
- It has been observed that surface roughness values increase for (EA, EM, MP) coded cutting tools depending on the increase in feed and depth of cut and that it affects surface quality adversely.
- As a result of experiments, the best surface quality has been obtained in the cutting tool with MP chipbreaker form.While the EA-coded cutting tool achieves better surface quality at lower feed and depth of cut, EM-coded cuttinggave better results when feed anddepth of cut increased compared to the EA coded cutting tool.

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