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THE IMPACT OF CUTTING CONDITIONS ON CUTTING FORCES ANDCHATTER LENGTH FOR STEELS AND ALUMINIUM

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ABSTRACT

In the present study, an attempt has been made to investigate the effect of cutting parameters (cutting speed, feed rate and depth of cut) on cutting forces and chatter starting point length in finish turning of EN8 steel, EN24 Steel, Mild steel and Aluminium. Machining test cuts were conducted using sharp tool and the effects of cutting conditions (depth of cut, cutting speed and feed rate), tool overhanging length and work piece over hanging length studied. Here experiments were conducted on EN8 steel, EN24 Steel, Mild steel and Aluminium at different cutting parameters and different overhanging lengths. Here chatter starting point length is measured from the free edge of the work piece and graphs were plotted between over hanging length verses cutting forces and chatter starting point length.

Keywords: Chatter Length, Tool Overhanging Length, Cutting Parameters

1. Introduction

In metal cutting, a cutting tool is used to remove excess material from a work piece in order to convert the remaining material into the desired part shape. Proper selection of tool materials, cutting parameters, tool geometry ,work piece and tool over hanging length and machine tools is essential to produce high-quality products at low cost. Therefore, many attempts have been made to reduce cost and improve quality through the understanding of the cutting process. A considerable amount of these investigations has been directed towards the measurement and prediction of the cutting forces during machining. That is because, knowledge of the cutting forces is important as they have a direct influence on the generation of heat, and thus on tool wear, quality of machined surface and accuracy of workpiece. Due to the complex tool configurations/cutting conditions of metal cutting operations and some unknown factors/stresses, theoretical cutting force calculations failed to produce accurate results and therefore experimental measurement of the cutting forces became unavoidable. In the literature, there are many studies concerning the cutting force measurement. Successful machining operations depend upon the dynamic relationshipbetween the work piece and cutting tool.

Under certain piece can produce a self-exciting system, resulting in large amplitude of vibrations. This vibration, or chatter, adversely affects the life of the tool, the quality of the cut, and the speed at which operations may be performed. Understanding and properly controlling the interaction of tool/work piece dynamics to control chatter can yield reduced costs and higher overall productivity. This requires the ability to predict chatter behavior, allowing guidelines to be formed to simplify the process of selecting appropriate machining parameters. A lot of research efforts towards the understanding and the controlling of chatter have been done for the past Fifty years. Early on, chatter was thought as a result of a negative damping effect. This proposition was later challenged by Gurney and Tobias , Tlusty and Tobias who showed that chatter, occurred due to the regenerative effects and mode coupling.

2. Experimental Procedure

A schematic diagram of the Experimental setup is presented in Figure.1. This consisted of a centre lathe onto which was attached a kistler tool post strain gauge dynamometer platform to gives measurements in the x-and y- direction forces. A hand held digital tachometer was used to adjust the cutting speed (Vm/min) on the surface of the work piece.

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The required feed rate (s, mm/rev) was chosen from the lathe pre-set values and the cutting tool wound to the uncut diameter until it just touched the work piece producing very fine chips at the tool point. This point was taken as the datum from which the desired depth of cut was to be applied. The flank and crater wear on the tool faces were measured before and after the experiments. Crater wear was measured with the aid of a dial test indicator, whilst flank wear length was measured using a toolmaker's microscope. In this Experimental work chatter is recognized by the sudden increase in force which is indicated by the strain gauge dynamometer and these cutting forces shown in tables are the maximum values. Here tool is changed for each cutting condition and tool wear is measured after the experiment. The measured chatter starting point lengths are taken from the free end and tail stock support is taken in every experiment.

Fig .1 Experimental Set-up

3.Theory on Chatter

A single degree of freedom (DOF) model based on the turning operation is considered. Turning a material removal process performed on a lathe machine, is focused upon because the operation is industrially ubiquitous, and is perhaps the most basic material removal operation. This is because the cutting parameters, the chip thickness, feed rate and spindle speed, and moreover, the equations examined in lathe operations are both generic in nature and can be easily extended to other machining operations like drilling, milling and grinding .A rigidly held tool is made to traverse along the axis of rotation of the work piece. Material is removed from the surface of the work piece to reduce its diameter. The main parameters of the turning operation are (i) cutting speed the tangential velocity of the surface of the work piece, (ii) the feed-the axial distance moved by the tool for every complete rotation of the work piece, and (iii) the depth of cut-the thickness of the metal removed from the work piece. The central idea of the model is the study of regenerative chatter effect, which qualitatively explains the effect of various parameters like speed, feed, Depth of cut (DOC), overhanging length of tool and overhanging length of work piece on chatter.

4.Summary of Servation and Discussion

4.1 Effect of cutting parameters and overhanging length on cutting Forces

4.1.1 Effects of cutting speed

Since the feed rate and depth of cut were fixed for each cut, the area of cut (a function of these entities) remained constant. However, as the cutting speed increased the material removal rate increased resulting in an increase in temperature. Increased cutting temperature caused the work piece material to deform and flow easily, hence less cutting force was required to shear and swarf. From the figures observed that when cutting speed increases from 45 rpm to 90 rpm forces both in X direction and Y Directions.At low speeds cutting forces increases gradually with over hanging lengths and at high speeds initially forces increases slowly at low over hanging lengths and at high over hanging length forces increase very rapidly. Figures 2 and 3 shows how cutting forces increases in EN8 and EN24 steels with increasing speed and depth of cut when feed remains constant.

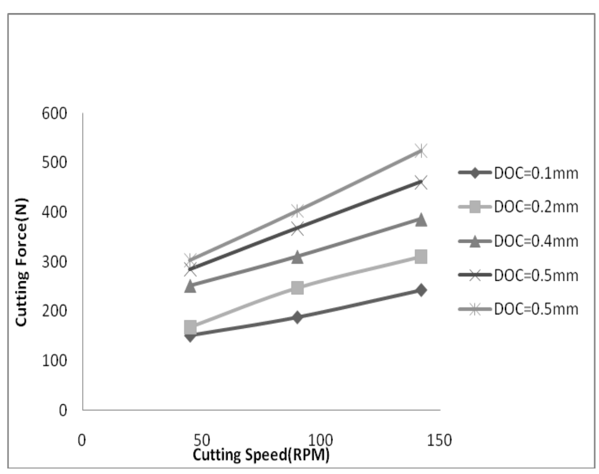

Fig. 2Cutting Speed(RPM)-Cutting Force(N) (EN8 steel,feed=0.1mm/rev,WOL=510mm, OL=56mm)

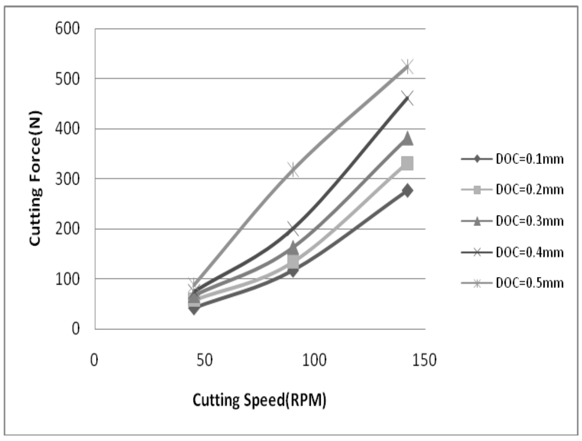

Fig.3 Cutting Speed(RPM)-Cutting Force(N) (EN24 Steel, Feed=0.1mm/rev, WOL=520mm, TOL=52mm)

4.1.2 Effects of feed rate

The static forces generally increased as the feed rate was increased. This was attributed to the fact that the area of cut substantially increased per cycle of cut, hence more shearing had to be done which required more force. In this paper feed rate is increased for Mild steel and Aluminium and from the Tables 1,2,3 and 4 observed that when the feed rate increases cutting forces also increases slowly. Figures 4 and 5 shows how cutting forces increases in in aluminium and Mild Steel with feed rate when depth of cut remains constant.

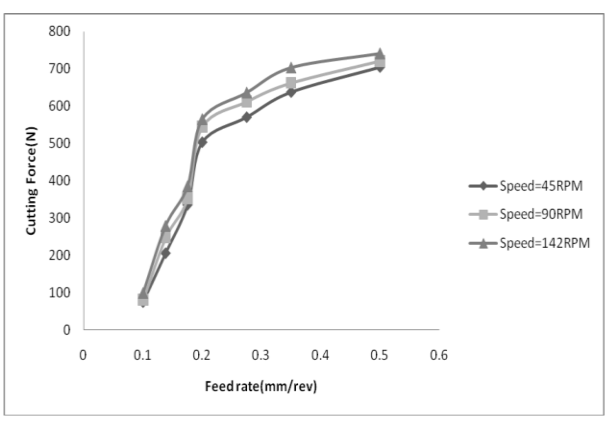

Fig.4 Feed rate-cutting force (Mild steel, WOL=560mm, DOC=0.2mm, TOL=54mm)

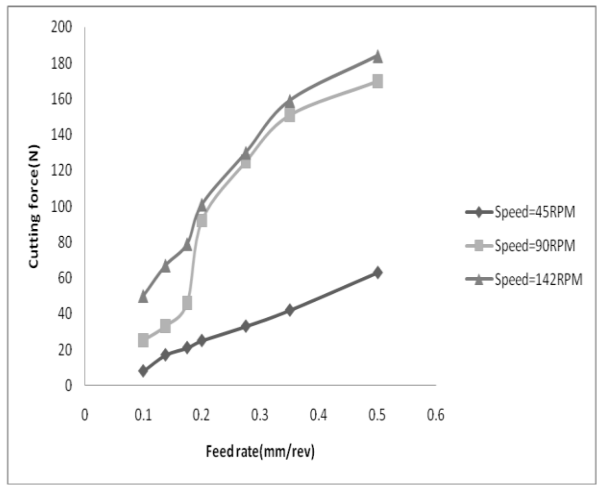

Fig.5 Feed rate-cutting force(Aluminium, WOL=560mm, DOC=0.3mm,TOL=52mm)

4.1.3 Effects of depth of cut (DOC)

Increasing the DOC generally resulted in a proportional increase in the static cutting forces. In this paper Depth of cut is increased for EN8 steel and EN24 steel and from the Tables 1,2,3 and 4 observed that when the depth of cut increases cutting forces also increases moderately. Figures 6 and 7 shows how cutting forces increases in in EN8 and EN24 steels with depth of cut when feed rate remains constant.

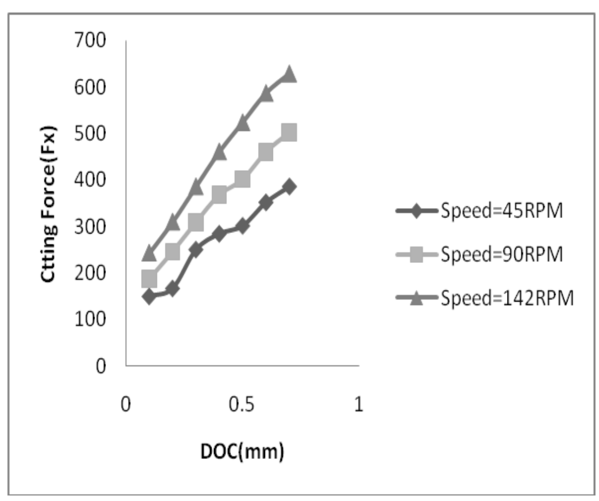

Fig.6 DOC-Cutting force (EN8 steel, Feed=0.1mm/rev, WOL=510mm,TOL=53mm)

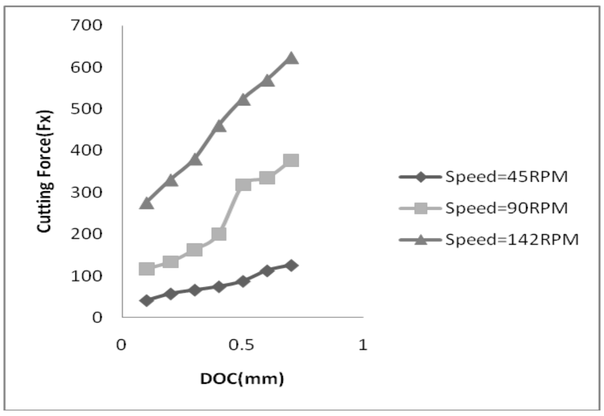

Fig.7 DOC-Cutting force (EN24 steel, Feed=0.1mm/rev, WOL=520mm,TOL=55mm)

4.1.4 Effect of over hanging length

When Over hanging length increases Forces both in X direction and Y Direction increases as shown in Figure 8 also observed that from all the tables at low over hanging length forces increases slowly and at high over hanging length forces increases very rapidly.

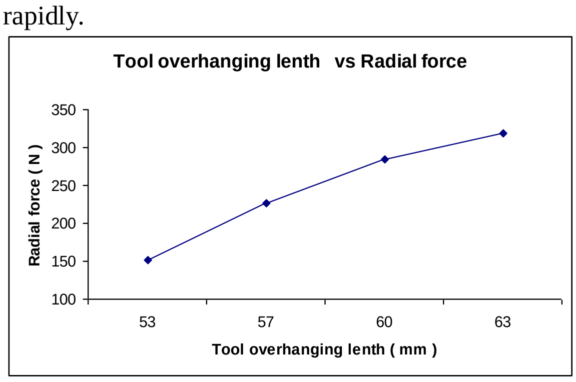

Fig. 8 Tool Overhanging length-- Forces for EN8 steel at 45 rpm (Tool = NDS S-200 HSS Feed =0.1mm/rev ; WOL =510mm)

4.2 Effect of cutting parameters and overhanging length on chatter starting point length

4.2.1 Effects of cutting speed

From the figure 9 observed that at high tool overhanging length chatter commences immediately than at low over hanging lengths. But from this experimental work also observed that chatter depends on the material properties also since chatter length of theEN24 steel is less compared to remaining three materials because the hardness of the EN24 is more compared to EN8,Mild steel and Aluminium. From the tables we observed that when cutting speed increases chatter starting point length also decreases .

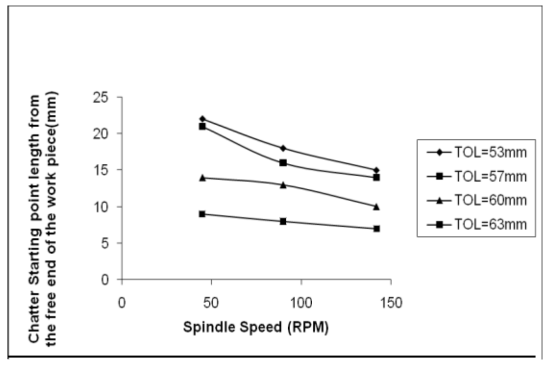

Fig. 9 Cutting Speed(RPM)-Chatter starting point length (EN8 steel, feed=0.1mm/rev,WOL=510mm, OL=56mm)

4.2.2 Effects of feed rate

The chatter starting point length decreases when increased the feed rate was increased. This was attributed to the fact that the area of cut substantially increased per cycle of cut, hence more shearing had to be done which required more force and there by decreases the chatter starting point length. In this work feed rate is increased for Aluminium and steels and from the Tables 1,2,3 and 4 observed that when the feed rate increases chatter starting point decreases from the free end of the work piece.

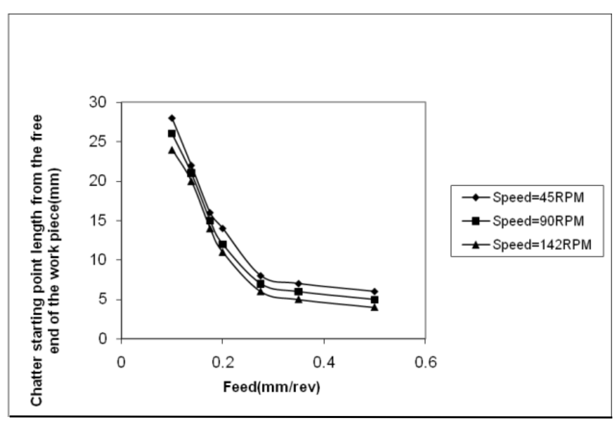

Fig. 10 Feed rate(mm/min)-Chatter starting point length (EN8 steel, feed=0.1mm/rev,WOL=510mm, OL=56mm)

4.2.3 Effects of depth of cut (DOC)

Increasing the DOC generally resulted in a proportional decrease in chatter starting point length decreases. In this paper Depth of cut is increased for EN8 steel and EN24 steel and from the Tables 1,2,3 and 4 observed that when the depth of cut increases chatter starting point length decreases from the free end of the work piece.

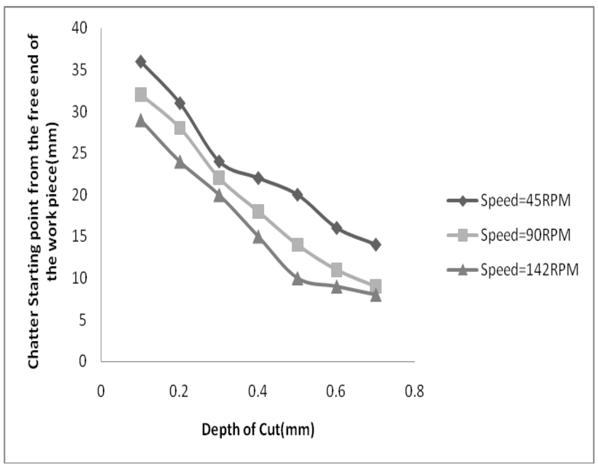

Fig .11 Depth of cut-Chatter starting point length (EN8 steel, feed=0.1mm/rev,WOL=510mm, OL=56mm)

4.2.4 Effect of over hanging length

When over hanging length increases chatter starting point length decreases as shown in Figures 11 and also observed that from all the tables at low over hanging length chatter length is more and at high over hanging length chatter length is less from the free end of the work piece.

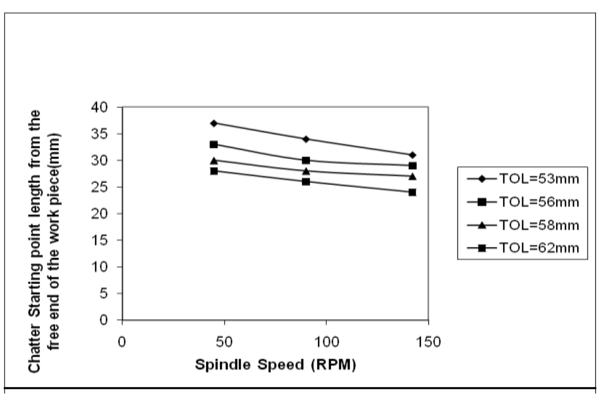

Fig. 12 Tool overhanging effect on Chatter starting pointlength (EN8 steel, feed=0.1mm/rev, WOL=510mm, OL=56mm)

Table 1: Forces and chatter starting point lengths for EN8 steel at 45 rpm (Tool = NDS S-200 HSS Feed =0.1mm/rev ; WOL =510mm)

S.No	TOL (mm)	DOC (mm)	F_X (N)	F_Y (N)	CSPL (mm)
1	53	0.1	151	290	36
2	53	0.2	168	329	31
3	53	0.3	251	357	24
4	57	0.1	226	396	34
5	57	0.2	264	454	28
6	57	0.3	327	483	26
7	60	0.1	285	415	24
8	60	0.2	302	478	22
9	60	0.3	352	580	18
10	63	0.1	319	464	18
11	63	0.2	369	580	16
12	63	0.3	411	676	12

Table 2: Forces and chatter starting point lengths for EN8 steel at 90 rpm(Tool = NDS S-200 HSS Feed =0.1mm/rev ; WOL =510mm)

S.No	TOL (mm)	DOC (mm)	F_X (N)	F_Y (N)	CSPL (mm)
1	53	0.4	369	580	18
2	53	0.5	402	652	14
3	53	0.6	461	725	11
4	57	0.4	411	652	16
5	57	0.5	503	701	12
6	57	0.6	545	773	10
7	60	0.4	461	701	13
8	60	0.5	545	773	9
9	60	0.6	608	870	8
10	63	0.4	562	894	8
11	63	0.5	608	957	7
12	63	0.6	712	1063	5

Table 3: Forces and chatter starting point lengths for Aluminium at 45 rpm (Tool = NDS S-200 HSS DOC =0.1mm ; WOL=454mm)

S.No	TOL (mm)	Feed (mm/rev)	F_X (N)	F_Y (N)	CSPL (mm)
1	53	0.1	8	48	37
2	53	0.138	17	68	26
3	53	0.175	21	87	20
4	56	0.1	12	72	33
5	56	0.138	21	125	24
6	56	0.175	25	175	20
7	58	0.1	21	92	30
8	58	0.138	29	121	23
9	58	0.175	35	174	18
10	62	0.1	38	116	28
11	62	0.138	63	179	22
12	62	0.175	84	232	16

Table 4: Forces and chatter starting point lengths for Aluminium at 90 rpm (Tool = NDS S-200 HSS DOC =0.1mm ; WOL =454mm)

S.No	TOL (mm)	Feed (mm/rev)	F_X (N)	F_Y (N)	CSPL (mm)
1	53	0.2	92	328	16
2	53	0.275	125	387	11
3	53	0.35	151	464	9
4	56	0.2	159	386	14
5	56	0.275	184	444	9
6	56	0.35	205	512	8
7	58	0.2	163	357	14
8	58	0.275	201	201	9
9	58	0.35	247	473	7
10	62	0.2	247	425	12
11	62	0.275	302	454	7
12	62	0.35	356	512	6

5. Conclusions

At low speeds cutting forces increases gradually with over hanging lengths and at high speeds initially forces increases slowly at low over hanging lengths and at high over hanging length forces increase very rapidly. The static forces generally increased as the feed rate was increased. This was attributed to the fact that the area of cut substantially increased per cycle of cut, hence more shearing had to be done which required more force. Increasing the DOC generally resulted in a proportional increase in the static cutting forces. The fresh (sharp) tool static cutting forces increased linearly. When Over hanging length increases Forces both in X direction and Y Direction increases .At low over hanging length forces increases slowly and at high over hanging length forces increases very rapidly. Above all parameters effects on chatter starting point length from the free end of the work piece, i.e. by increasing above all parameters chatter length decreases.

6.References

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Abbreviations

Abbreviations	Meaning	Unit
TOL	Tool over hanging length	Mm
WOL	Work-piece over hanging length	Mm
DOC	Depth of cut	Mm
CSPL	Chatter Starting point Length	Mm