Mech. Engg. Res. Bull.
Vol. 10, (1987), p p. 11—18

Investigation of the Influence of chatter on Tool Wear

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Experimental investigations have been carried out to determine the influence of chatter on cemented carbide tool wear in turning medium carbon steel. Conditions of stable cutting and those conducive to intensive chatter in the investigated range of cutting speed and other cutting conditions were established. Tool wear test performed under these two different conditons have facilitated to establish the typical nature of tool wear during chatter. Chatter leads to intensive wear of the flank surface due to additional rubbing of the same along the wavy cutting surface, formed during chatter. Besides chatter leads to lowering down of the values of chip-tool contact lengths due to a lower value of the coefficient of chip shrinkage. Consequently tool wear along the rake surface is less during chatter.

INTRODUCTION :

Chatter is a type of vibration of machine tool element with extremely high amplitude that appears during metal cutting process. It is undesirable because of many adverse consequences which it leads to. Chatter is responsible for high noise level, lower life of machinine tool elements, lower machining accuracy and surface finish and higher rate of tool wear. As regards the cause of chatter formation there are many theories proposed. In the opinion of one of the leading groups of scientists chatter is caused due to mutual interaction of different vibrations with natural frequencies of the various elements of the Machie-Tool-Fixture-Work (MTFW) system (1). Another group is of the opinion that chatter is the result of resonance caused when the natural frequency of any element of machine coincides with or is close to the frequency of instability of chip formation (2, 3, 4, 5). It has been established by the later group that there are mainly two ranges of cutting speed where chatter may appear. The first range refer to a relatively lower cutting speed, where the spindle-work system loses stability and enters into resonance. The second range is offset with respect to the first towards higher cutting speed. In this range the tool bit holder enters into resonance. Amplitude of vibration in these two ranges is high and is a function of the rigidity and damping characteristics of the closed dynamic MTFW system and

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cutting parameters. Depending on them amplitude may be either so high that metal cutting process is bound to be interrupted or it may be so low that there is no significant influence of it on metal cutting process. Frequency of chatter in each of the above mentioned range remains practically constant during resonance.

Chatter resulting from resonance of the spindle-work system and that of the tool bit holder is harmful for the operators, machine and its accessories as well as the tool, There is no doubt that chatter adversely affects tool life but the exact inature of its influence on the characteristics of metal cutting process and mechanism and magnitude of tool wear is still not very clear. The present investigations were carried out in this particular direction.

EPERIMENTAL SETUP AND PROCEDURE

Experiments were carried out on lathe machine model (USSR) 1M63. As work and tool materials medium carbon steel (with 0.45% C) and cemented Carbide tip BK-8 (with 8% Co and 92%WC) were used respectively. Feed (s) and depth of cut (t) were respectively 0 467 mm/rev. and 2mm. Tool geometry was as follows : rake angle, $\gamma=0^\circ$, side and end clearance angles α and, $\alpha_1=10^\circ$, inclination angle, $\lambda=0^\circ$ side and end cutting edge angles, $\varphi=45^\circ$ and $\varphi_1=25^\circ$ respectively. Two cutting speeds for the investigations were so selected that for the given MTFW system and conditions of cut the first speed was well inside the first range and the second speed well inside the second range of cutting speed, where intenstive chatter is encountered. The cutting speeds were as follows : the first speed, $V_1=0.67$ m/sec and the second speed, $V_2=1.67$ m/sec. Two different tool holders, T_1 and T_2 were used. Their frequency characteristics are shown in Fig. 1. As shown in the figure, use of the tool holder T_1 is conducive to the formation of low frequency, chatter (horizontal line of the corresponding

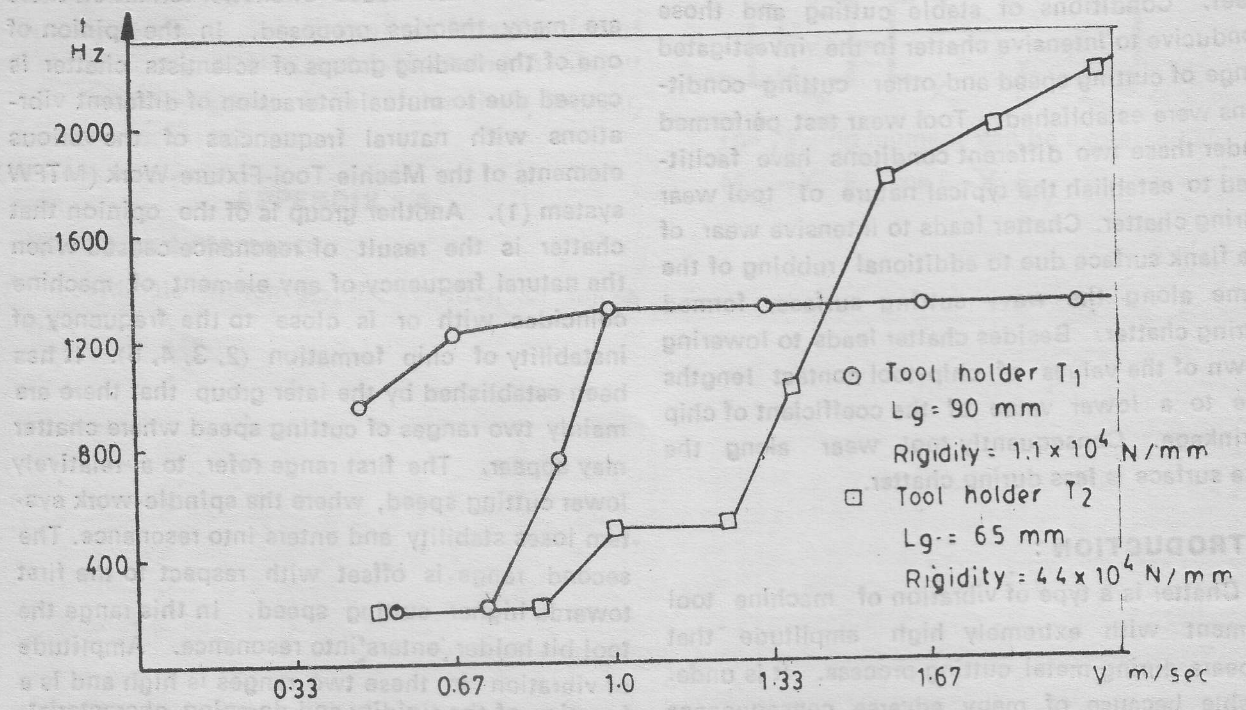


Fig. 1. Influence of tool bit holder on the orientation of the second horizontal portion of the chatter frequency versus cutting speed curve, $f=\varphi$ (V),

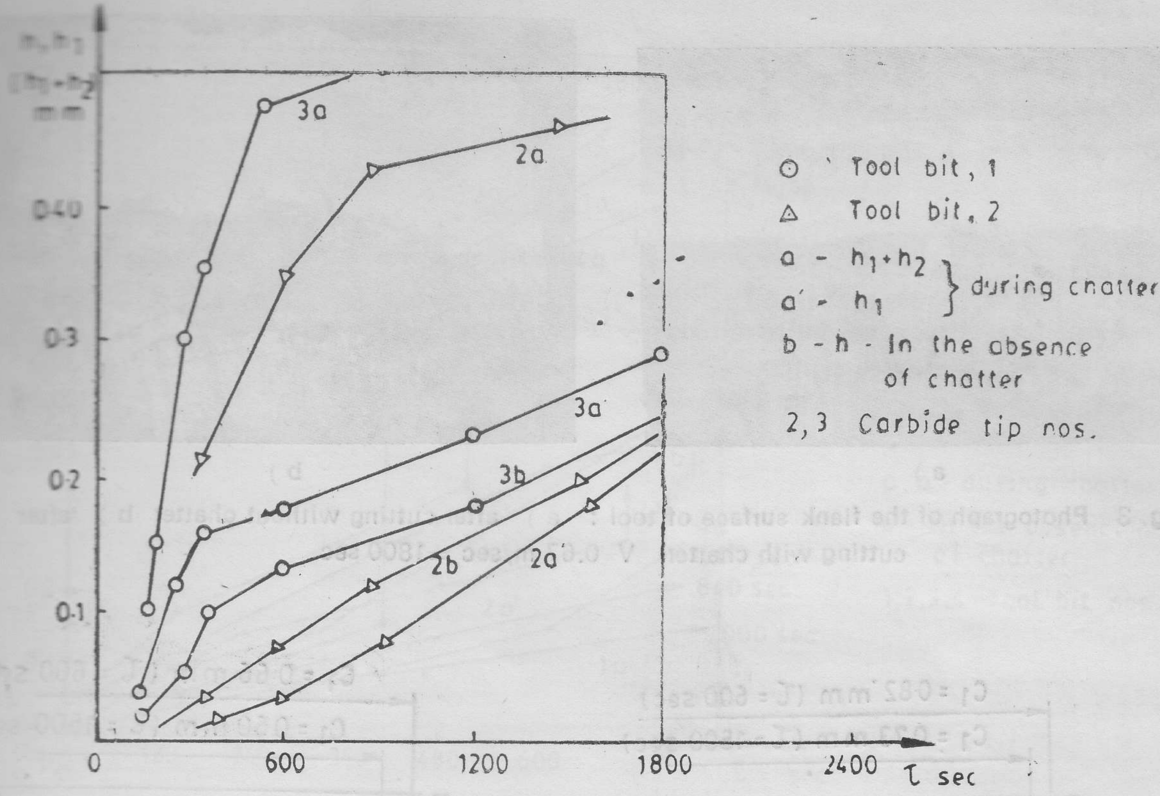
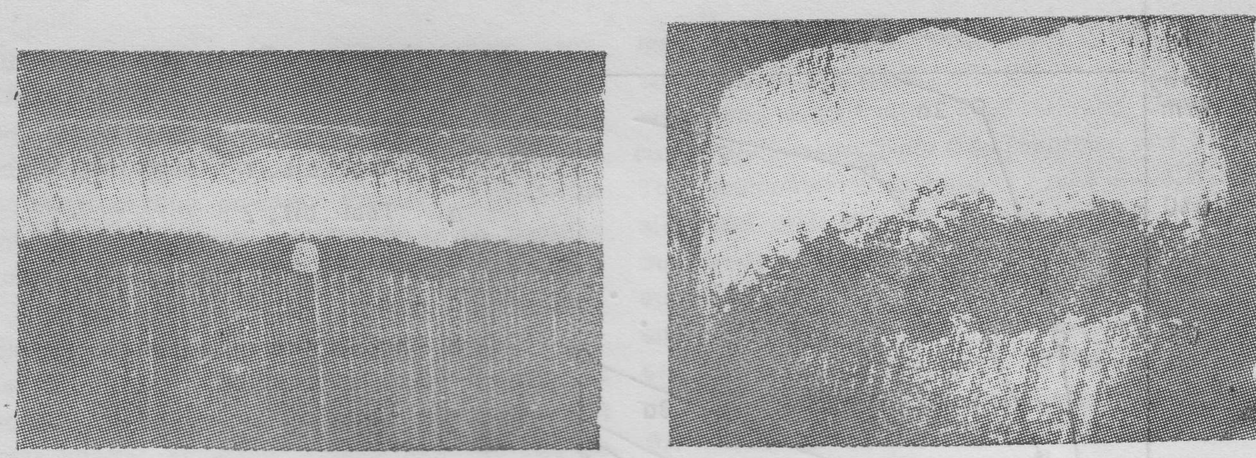


Fig. 2 Influence of chatter on tool flank wear. Cutting speed V=0 67 m/see.

curve in the range from 0.5 to 0 85 m/sec), with a constant frequency of approximately 200 H_z, whereas, the second tool holder T_2 does not give any significant chatter in this range (small extent of the horizontal portion in this range). On the other hand tool holder T_2 is very sensitive to high frequency chatter with a frequency of approximately 1300 H_z in the range from 1.0 to 2.0 m/sec and above. In this range of cutting speed the other tool holder, T_1 is quite stable.

Two series of experiments were carried out: one in the presence of intensive chatter (using tool holder T_1 for V_1 and T_2 for V_2) and the other during stable cutting conditions (using tool holder holder T_2 for V_1 and T_1 for V_2). In both the cases tool flank wear was mesured at definite intervals using instrumental microscope Tool flank wear versus cutting time curves were plotted as shown in Fig. (2, 5). At the same time the tool side flank and rake suraces were photographed (Fig. 3, 6). On the basis of the recorded profilographs diagrams of the tool wedge at various moments of cut are drawn for both stable and unstable cutting



a)   b)

Fig. 3 Photograph of the flank surface of tool : a) after cutting without chatter b) after cutting with chatter. V=0.67 m/sec, =1800 sec

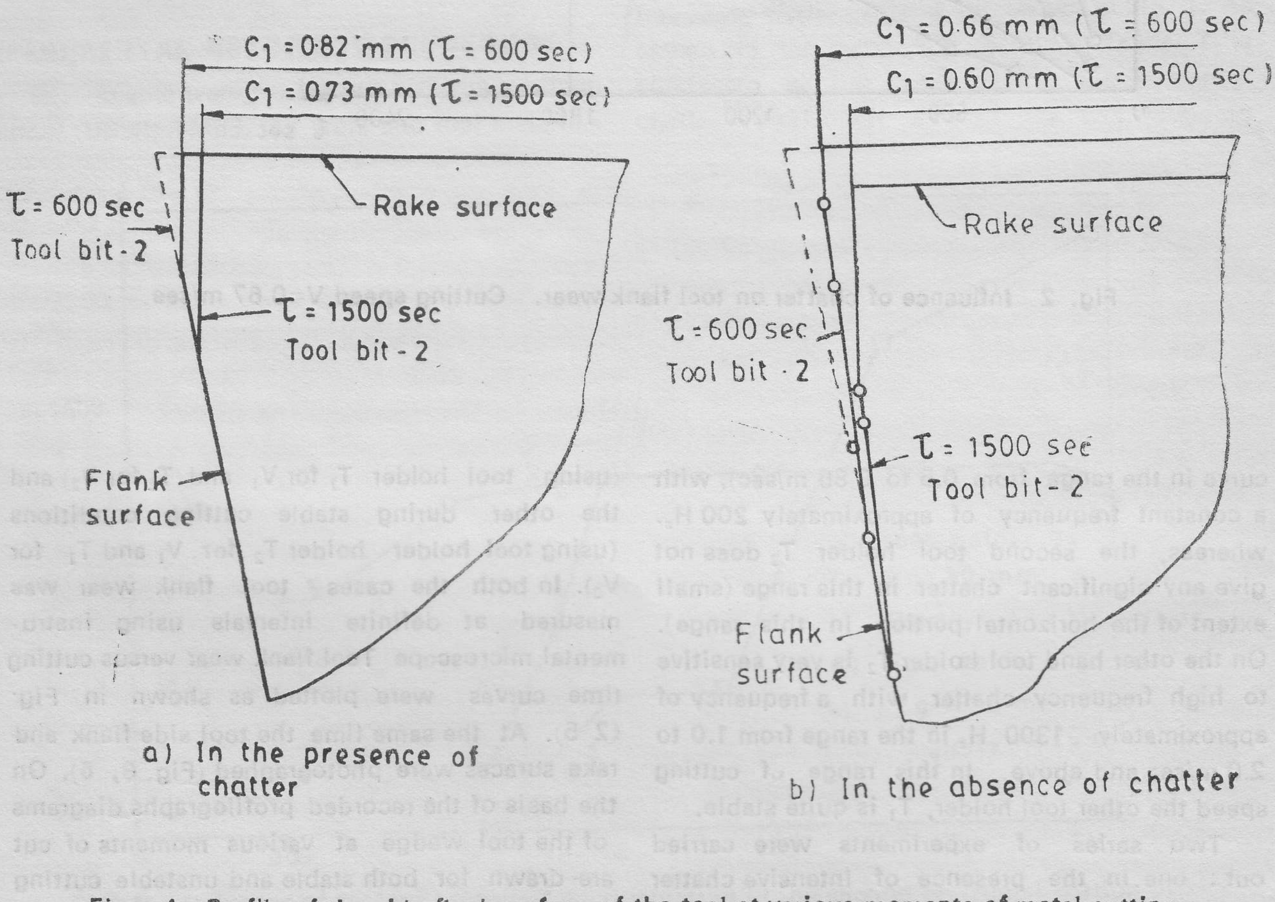


Fig. 4 Profile of the side flank surface of the tool at various moments of metal cutting with and without chatter.

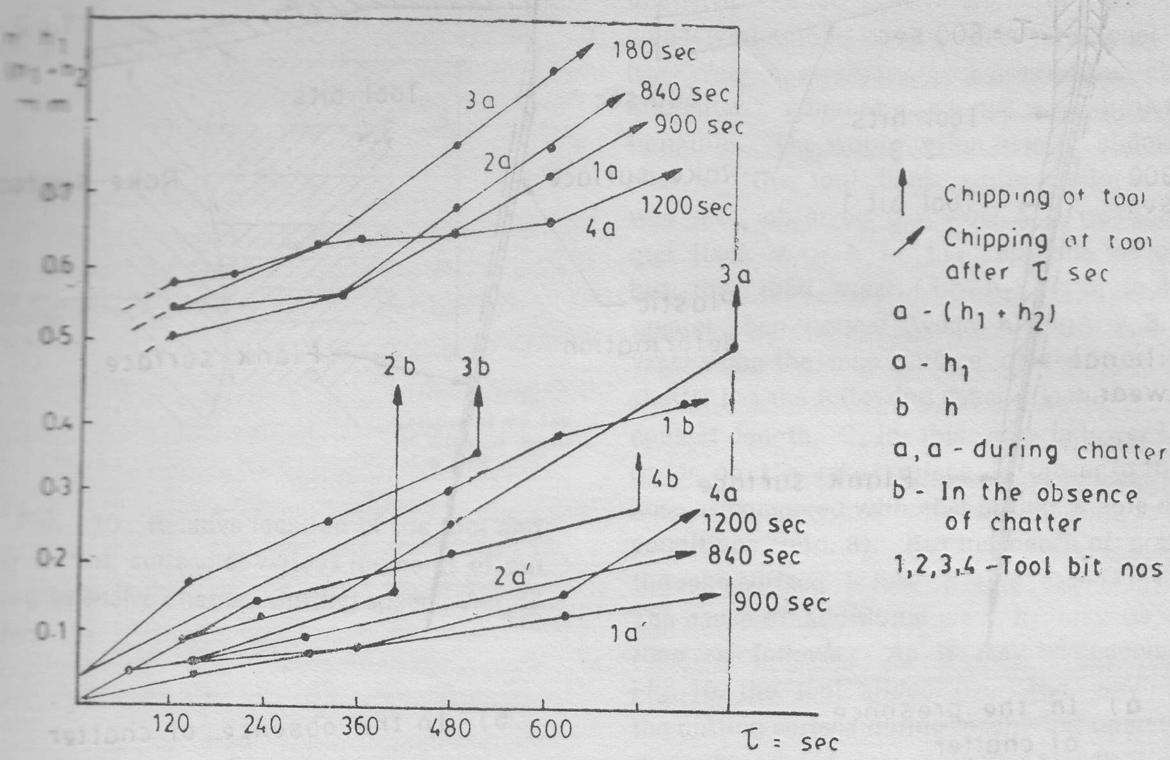
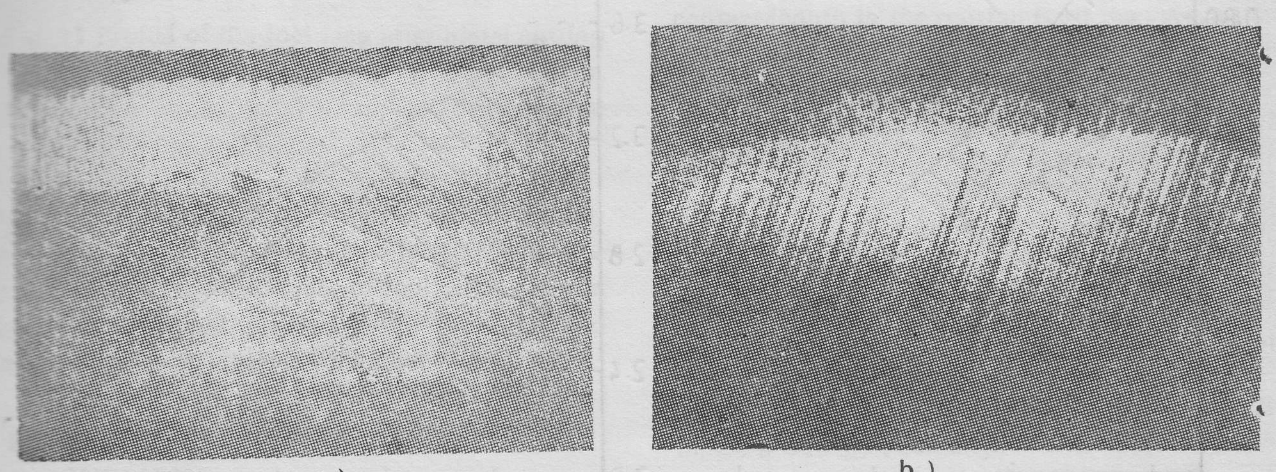


Fig. 5 Influence of chatter on tool flink wear. Cutting speed, V=1.67 m/sec.

conditions (Figs 4,7). Plastic contact length C_1 and coefficient of chip shrinkage, K, were measured using instrumental microscope and curves C_i and $K = \varphi$ (V) are drawn as shown in Figs. 8,9. With the help of the recorded phofilograps of cutting surface trajectory of the tool at various



a) b)

Fig. 6 Photograph of the flank of tool : a) after cutting without chatter b) after cutting with chatter. V=1.67 m sec, 300 sec.

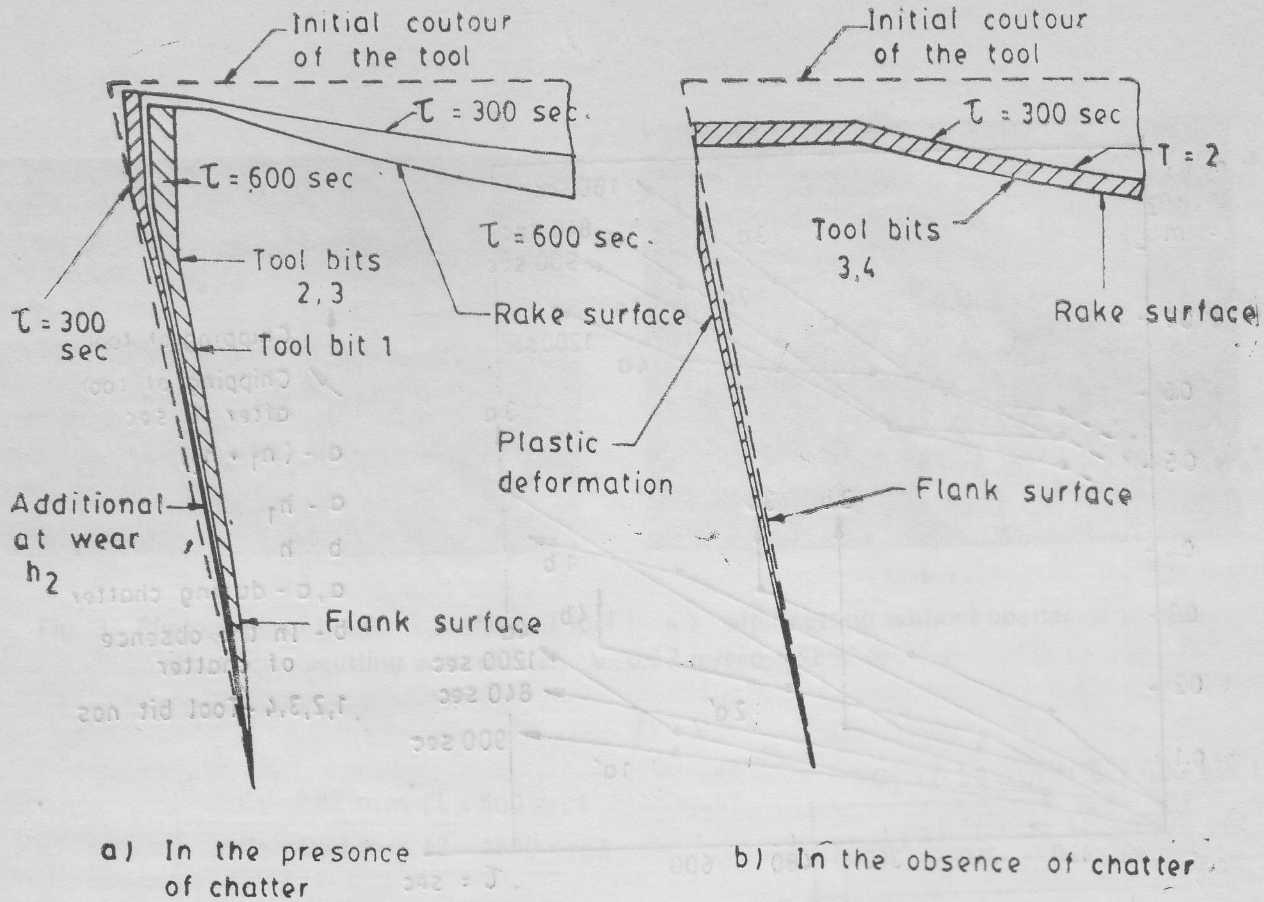


Fig. 7 Pufile of the side flank surface of the tool at various moments of metal cutting with and without chatter.

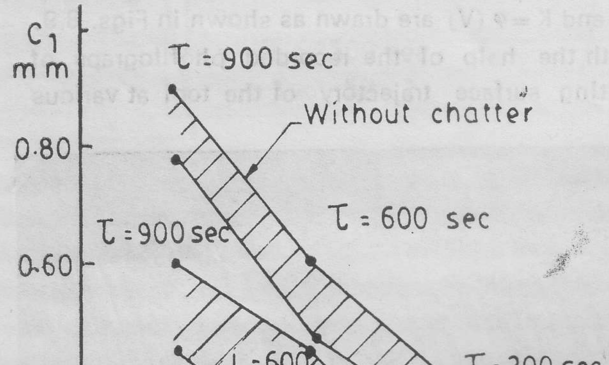


Fig. 8 Dependence of chip-tool plastic contact length C_1 and total length, C on cutting speed V at different intensities of chatter.

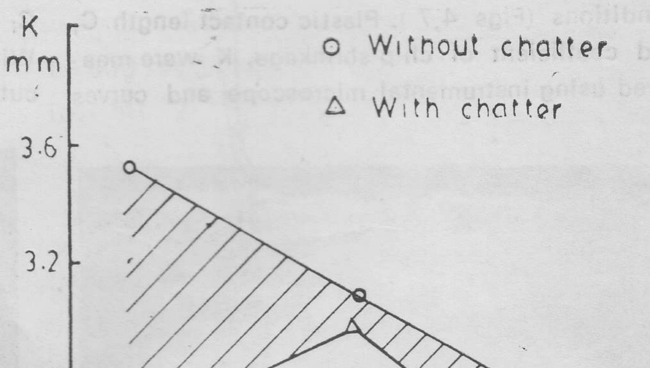


Fig. 9 Dependence of coefficient of chip shrinkage, K on cutting speed, V at different intensities of chatter.

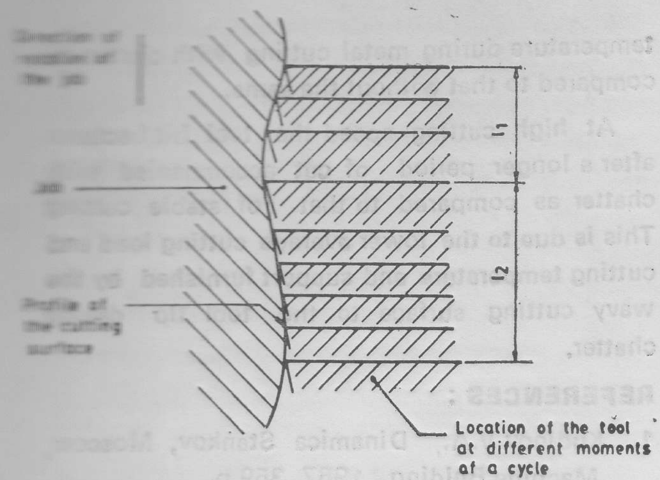


Fig. 10 Relative location of the tool and wavy cutting surface at various moments of cut during intensive chatter. Cutting speed, V=1.67 m/sec

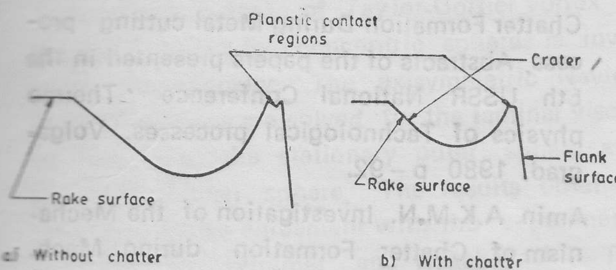


Fig. 11 Profile of the tool face after metal cutting with intensive chatter, a) and without chatter, b). Cutting speed, V=1.67 m/sec. Cutting time τ=450 sec.

moments of cut with respect to the wavy cutting surface is drawn as shown in Fig. 10. Phfilograms of the rake surface of tool after definite amout of of metal removal in the presence and in the absence of chatter are shown in Fig. 11.

EXPERIMENTAL RESULTS AND DISCUSSION

From Fig. 2—11, the following observations regarding the special nature of tool wear during intensive chatter were made. Tool flank wear consists of normal wear, h_1 and additional wear, h_2. Wear, h_1 resembles tool wear in the absence of chatter. Whereas additional wear, h_2 is typical in nature. The worn Portion here is almost parallel to the tool flank surface (Fig 4, 7). It was also observed that wear h_1 is less than normal flank wear, h in the absence of chatter, but the total wear, (h_1+h_2), is 3 to 4 times greater than normal wear, h (Fig. 2, 3, 5, 6). Wear along the rake surface of the tool during chatter has the following special features : Plastic contact length, C_1 in this case is lower i.e. the crater on the rake surface is closer to the tool nose as compared with that during stable cutting conditions (Fig. 8). But tne depth of crater on the rake surface is less in this case (Figs. 4, 7). The cause of additional wear, h_2 may be explained as follows : As it may be observed from Fig. 10, the tool slides over the waviness of the cutting surface during machining operation. In the portion l_2 of any wave the tool flank surface is in maximum contact with the cutting surface but in the portion l_1 the tool flank has relatively smaller contact length. So the wear, h_2 is the result of external friction between the tool flank surface and cutting plane in the range l_2. Smaller value of h_1 compared to h is due to smaller contact length in the portion l_1 of the wave than that in the absence of chatter. Lower Intensity of wear along the rake surface during chatter may be explained as follows : During chatter the coefficient of chip shrinkage, K (and consequently the average cutting load) is lower than that during stable cuttiug (Fig, 9,). This leads to lower length of the crater (Fig. 11). Depth of crater is lower due to lower average cutting temperature during chatter (1) and consequently lower rate of diffusion type wear.

During investigations of tool wear at V=1.67 m/sec a strange phenomenon was observed. As shown in Fig. 5, the termination of the curves h, h_1, $h_2=\varphi$ (t) with vertical or inclined lines ending in arrows indicates fracture of the tool tip. As it may be observed from the given figure that tool wedge fratures at the given cutting speed (V=1.67 m/sec.) after relatively longer periods of cut for all the investigated tool bits during chatter than during stable cutting, which was not all expected. The cause of overall life until fracture of tool in machining construction steel may be explained as follows. During stable cutting at the given speed, feed and depth of cut the cutting temperature and cutting load are such that the tool tip plastically deforms downwards and the tool material flows towards the flank surface resulting in its bulging shape (Fig. 7). After a definite period of cut when the plastic deformation exceeds the fracture limit the tool wedge undergoes brittle fracture. The case is quite different during chatter, when the average cutting temperature and cutting load are lower as compared to stable cutting. Moreover, during chatter the tool is supported by the waviness of the cutting surface and conseqently the fracture limit of the tool tip is reached later as compared to stable cutting.

CONCLUSION :

From the above results fallowing conclusion may be drawn ;

Tool flank wear during intensive chatter consists of normal wear, h_1 and additional wear, h_2 and the magnitude of total wear is 3 to 4 times higher than that during stable cutting. Additional wear, h_2 is due to rubbing of the tool flank surface over the wavy cutting surface of the job.

Total chip-tool contact length, C is lower and depth of the crater on the tool face is less during chatter than in stable cutting. These are respectively due to lower coefficient of chip-shrinkage,..K and lower value of average cutting temperature during metal cutting with chatter as compared to that without the same.

At high cutting speed the tool bit fractures after a longer period of cut accompanied with chatter as compared to that of stable cutting This is due to the lower average cutting load and cutting temperature and support furnished by the wavy cutting surface to the tool tip during chatter.

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