OBSERVATION OF CHIP FORMATION IN DIFFERENT TOOL CONDITIONS AND CUTTING PARAMETERS

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1. Introduction

Metal cutting is a machining process in which a finished surface of desired size, shape, accuracy or finish is obtained by separating the excess layers of material in the form of chips with the aid of a wedge-shaped device called cutting tool [1]. For metal cutting, it is important to optimise surface finish, workpiece accuracy, tool-life monitoring and high productivity. In machining, chip control is also needed as generation of acceptable chips, indicates good machinability.

2. Importance of Chip Control

With the development and application of automated machine tools, productivity of a machine shop improves greatly utilizing better chip control methods. Inappropriate chip control and handling methods may have the following effects [2];

- Injury to the operator
- Poor surface finish
- Damage to cutting tools, workpiece and machine tool
- Loss of machining time
- Increase in scrap
- Delay in delivery of parts
- Increase in cost of production.

In general, efficient chip control has the following contribution;

- Reliability of the machining process
- Production of high quality machine surface
- Increased productivity
- Increase operator safety
- Protect the machine tools and cutting tools.

3. Classification of Chips

Researchers have classified chips in different ways. Historically, Ernst [3] classified three different types of chips:

1. Discontinuous chips, 2. Continuous chips or 'Ribbon' type chips, 3. Continuous chip with built-up edges.

Loladze [4] has classified chips mainly in four different ways:

1. Irregular shaped chips, 2. Continuous chips, 3. Element chips, 4. Jointed chips or partially continuous chips.

Bhattacharyya [1] has classified chips broadly in continuous and broken-off type chips. Each type is further classified in six different types, such as straight or curled type with very high radius, continuous and irregular types of chips, flat helical type with equal curl radius, unequal chip curled radius type, distorted block chips, close coiled helical types.

In case of drilling, chips are classified as conical helical chip, long pitch helical chip, fan-shaped broken chip, transitional chip, folded chip, needle chip.

Yao and Fang [5] have classified chips according to different shapes and sizes as given bellow:

[a] Tubular chips of six different types: large diameter, snarled, continuous long, broken long, medium and short.

[b] Ribbon chips of three different types: snarled, long and small snared.

[c] Helical chips of six types: large diameter, snarled, continuous long, broken long, medium and short.

[d] Cork Screw chips of five types: snarled, continuous long, broken long, medium and short.

[e] Spiral chips of five types: wavy, few turn, full turn, flat and conical.

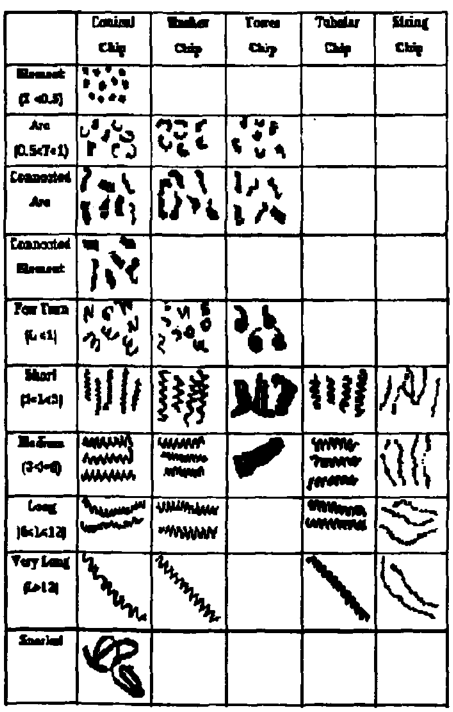
[f] Arc chips of three types: up-curl, side-curl and connected.

[g] String chips of four types: continuous long, broken long, medium and short.

[h] Tooth edge chips of four types: long, short, side-curl arc, and connected arc.

Zhang et al. [6] have categorized chips into five types of shapes and ten sizes [Shown in table 1].

Table 1 Types of chip [6]



Note: T = turn, L = length (cm.)

4. An Overview of Chip Formation

Several notable researchers have invented the chip formation process since the beginning of the century. Historically, I.I. Timme has introduced chip-forming model in 1880. F. W. Taylor has introduced an empirical approach to metal cutting in 1907. Since then a number of researchers have developed cutting models and presented theories on chip formation.

Timme[7] has proposed a model of chip formation (Fig. 1) by considering the interaction of different components, namely the cutting tool, the workpiece, and the chip. A cutting tool starts to penetrate into a workpiece, overcoming its resistance, the resistance to the penetration growing proportionally to the compressed area of the workpiece material, which results in an increase in the penetration force P. This process continues until the force becomes sufficiently large to break up a small fragment of the workpiece material, which moves along a particular sliding plane at angle θ_1, the penetration force decreasing abruptly and a new cycle of chip formation starting to form. This process has a cyclic character and its repetition constitutes the metal-cutting process.

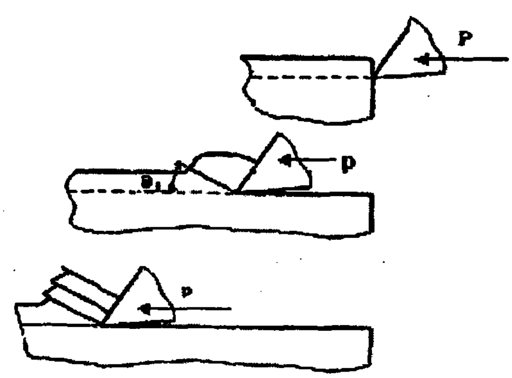


Fig. 1. The model for chip formation proposed by Timme

Bhattacharyya [1] has explained the phenomenon of chip-formation very elaborately. Fig.2(a) shows the formation of discontinuous chips where cracks form periodically along a line of maximum shear stress. Between the cracks the material is extruded and forms discontinuous chips and poor surface finish.

Fig.2(b) indicates the chip formation of ductile materials, which are machined at very low speed and smaller rake angle ($\gamma \leq 0$). In this case, a crack runs in front of the tool. The bottom surface of the extending crack is uncontrolled and produces poor surface finish.

Fig.2(c) shows a continuous chip, which slides along the tool face. This is ideal type of chip formation.

Another type of continuous chip with wedge-shaped shear zone is shown in Fig.2(d). Soft materials having relatively high friction at the tool face are susceptible to this type of chip formation.

Fig.2(e) indicates the chip formation, when a soft material is machined at slow speed and a large uncut layer of thickness in presence of high friction at tool face.

A continuous chip can be produced using an effecting cutting fluid [Fig.2(f)]. Here chip is closely curled and therefore the contact length between the

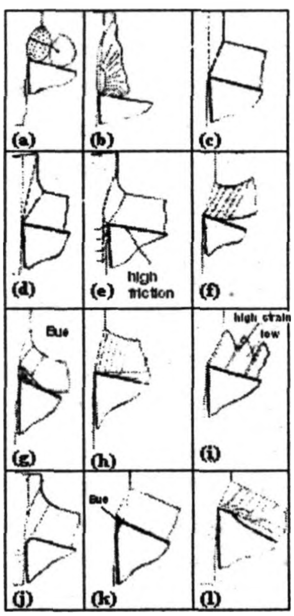


Fig. 2. Model for chip formation [1]

chip and tool will be small and hence, consumption of relatively small amount of energy.

Fig.2(g) shows another variation of continuous chip containing built-up edge (BUE).

The phenomenon of secondary shear as the chip slides along the tool face can be shown in Fig.2(h). Here surface velocity of the chip is much less compared to the main bulk of the chip.

Continuous chip with characteristic irregular shape is also a possibility as shown in Fig.2(i). This type of chip is formed for the material having poor thermal conductivity and tendency to soften at a relatively low temperature frequency.

Fig.2(j) shows when the cutting edge is blunted to a tip curvature of appreciable amount compared to thickness of uncut thickness. This has similar effect of Fig. 2(e).

Fig.2(k) indicates a tool with negative land. The negative rake region will tend to trap a small but stable BUE, which protects the cutting edge and extend tool life.

In Fig.2(l), incorporation of a land is shown, which decreases the contact length between the tool and the chip.

Astakhov et al. [8] have proposed a model of chip formation, which is mentioned bellow.

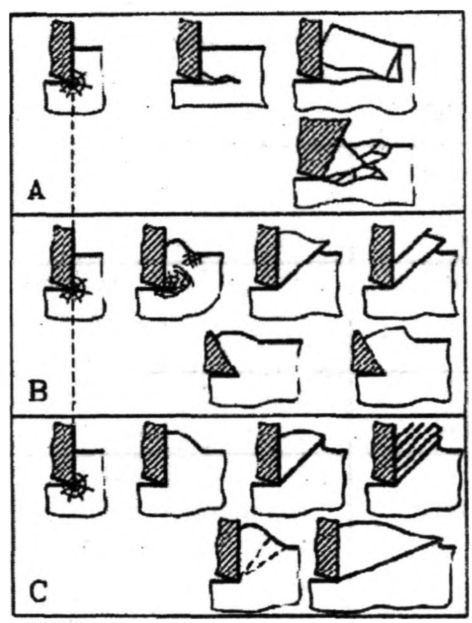


Fig.3. The proposed model for chip formation [8]

Region A of Fig.3 shows the model of chip formation of the work material, which has mainly elastic properties. When cutting edge has been penetrated, the maximum stress is developed in front of the edge. When this stress reaches its limit, a crack is formed in front of the cutting edge. The propagation of this crack results in the formation of the chip.

Region B of Fig.3 indicates the model of chip formation of the material, which has elastroplastic properties. This is a common case in the cutting of most engineering materials. Here, the stress concentration in front of the tool tip leads to the formation of the plastic zone.

The model of chip formation of the material having mainly plastic properties is shown in region C of Fig.3. In the cutting of highly plastic materials, the chip is only able to transmit an insignificant bending moment because of its low rigidity. Thus, chip failure takes place only along the shear plane.

5. Experimental Investigations

Generation of the chip-form mainly depends on tool geometry, tool condition, and cutting parameters. Some experiment has been carried out for observing the chip formation in different tool conditions. Details of the experimental conditions are given in table 2.

Table 2 Experimental conditions

Machine tool	NH22 Lathe, HMT Ltd. (India), Power: 11kW, Speed: 40-2040 rpm
Cutting tool	SNMA12048, uncoated P30 inserts, Sanvik, geometry: -6°, 6°, 6°, 6°, 15°, 75°, 0.8mm
Tool holder	R174.1-2525-12 (Sandvik), overhang 22mm.
Job material	Low carbon steel (C25), Composition: C 0.25%, Si 0.18% S 0.03%, Mn 0.62%, P 0.22%, Hardness: HRB 76
Rod size	ϕ150mm X 750mm
Machining conditions	Cutting velocity VC=118-184 m/min, Feed, SO = 0.1 - 0.24 mm/rev, Depth of cut, t = 1.5mm, Environment: dry

Uncoated carbide P30 insert have been used in the work. Cutting velocity, V_C, and feed, S_o, have been selected considering the normal operating range of the industry and depth of cut, t, remain constant.

The C25 bars have been machined by longitudinal turning in dry environment. The chips produced in every cutting condition have been collected and classified according to shape and colour. Chips are classified in basic three types like Coiled & Flat continues, "C" or half round and irregular type.

Average flank wear, V_b, of the P30 carbide insert has been measured at regular intervals under an optical microscope.

6. Results And Discussion

The experiment has been carried out in five different machining conditions and chip formations in different tool wear conditions have been observed and results are presented in Fig. 4 through Fig. 8, where chip types and colour observed are presented against the value of the tool flank wear corresponding to gradual tool wearing.

From Fig. 4, at V_C = 118 m/min and S_O = 0.1 mm/rev, the irregular type chips are not available. With the increase of tool wear, the generation of "C" type chips also increases.

Fig.5, corresponding to increased velocity of 184 m/min where chip breakability is found to reduce. Here instead of "C" type chips, irregular type chips are available. It is observed that, with the increase in tool wear, colour of chips becomes black.

Feed has been increased to 0.24 mm/rev and V_C is kept same as fig. 4 in the other experiment [Fig.6]. It is found that, "C" types were generated from the beginning.

In the high speed (V_C) and feed (S_o) condition, initially coiled and some irregular chips have been found [Fig.7], but with the increase in tool wear, chip breakability increases. Here "C" type black chips are generated indicating high frictional temperature generation.

At V_c = 148 m/min and S_0 = 0.16 mm/rev. it is observed that, the chip colour becomes black [Fig. 8].

Observation shows that although there is a change in chip-form pattern with the progress of tool wear, it is difficult to make a distinct correlation between them. However, changes in chip forms are evident with cutting conditions.

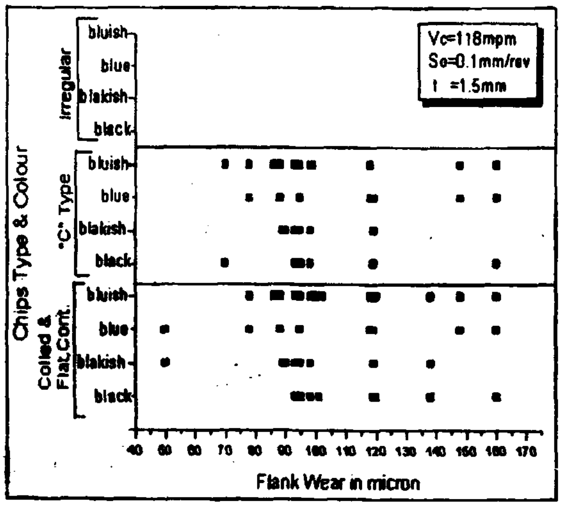


Fig. 4. Chip types and colour at low cutting speed and feed.

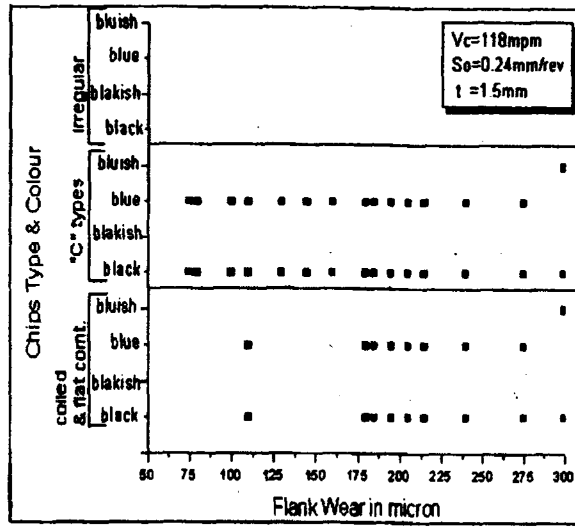


Fig. 6 Chip types and colour at low cutting speed and high feed.

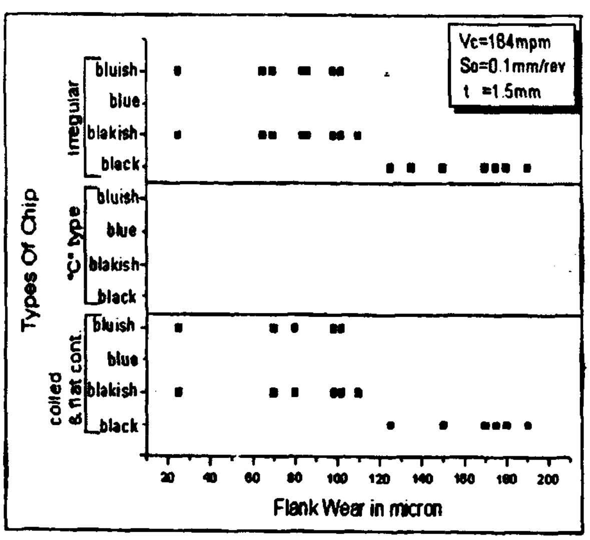


Fig. 5 Chip types and colour at high cutting speed and low feed.

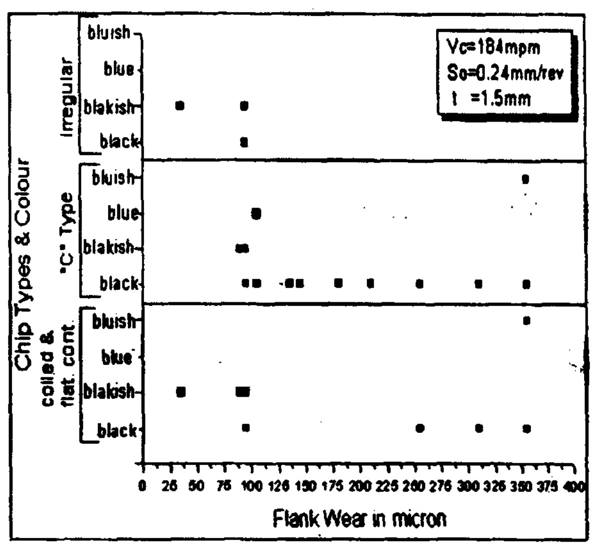


Fig. 7 Chip types and colour at high cutting speed and high feed.

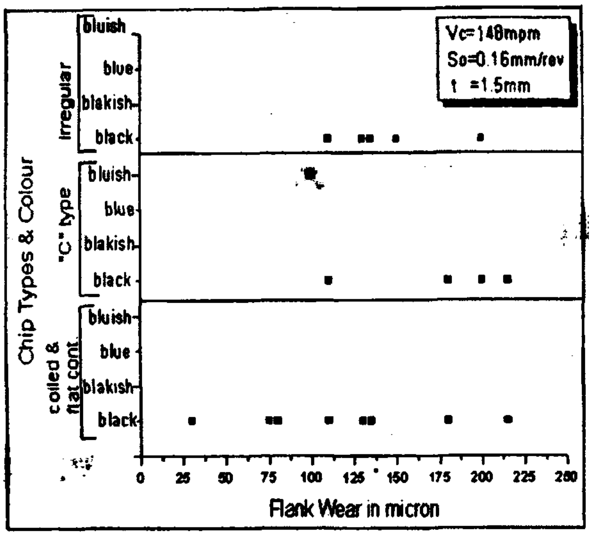


Fig.8 Chip types and colour at medium cutting speed and medium feed.

7. Conclusion

The following conclusions may be drawn based on the present investigation:

1. Chip formation pattern is dependent on machining parameters like cutting speed, feed.
2. Types of chip varied with change of cutting tool condition.
3. A regular pattern is followed in chip colour formation. With increased of tool wear and higher speed and feed, the chip colour becomes black which is natural due to higher rubbing force and temperature due to enhanced tool - work contact area.
4. It is difficult to predict a particular chip form pattern in a definitive way corresponding to the tool condition and cutting condition as well.

8. References

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