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Chip Formation during Turning Multiphase Microalloyed Steel

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***Abstract*—**Machining through turning was carried out in a lathe to study the chip formation of Multiphase Ferrite-Bainite-Martensite (F-B-M) microalloyed steel. Taguchi orthogonal array was employed to perform the machining. Continuous and discontinuous chips were formed for different cutting parameters like speed, feed and depth of cut. Optical and scanning electron microscope was employed to identify the chip morphology.

***Keywords*—**Multiphase microalloyed steel, chip formation, Taguchi technique, turning, cutting parameters

I. Introduction

MICROALLOYED (MA) steels are superior when compared to quenched and tempered (Q&T) steels. The applications of these steels are found in automotive components such as crankshaft, connecting rods etc. [1]. The mechanical properties are similar to that of Q&T steels. The multiphase Ferrite-Bainite-Martensite (F-B-M) microstructure is obtained through a two step cooling (TSC) procedure followed by annealing [2]. Due to two step cooling and annealing, the mechanical properties such as strength and toughness are improved to the level of Q&T steels. It is interesting to study that how the chip formation occur in a steel having multiphase microstructure (F-B-M). Turning process was selected to perform machining of microalloyed steel. Chip formation mechanism plays an important role to determine cutting forces, specific shearing energy consumed during deformation process [3].

II. Experimental procedure

The turning tests were performed on a lathe with a cutting insert of SNMG120408 uncoated tungsten carbide. The process parameters considered for machining are speed, feed and depth of cut. The ranges of different parameters chosen are shown in table I.

The chemical composition of the material is C 0.38, Si 0.68, Mn 1.5, P 0.022, S 0.06 V 0.11, N 0.066, Cr 0.18, Fe balance The energy dispersive spectroscopy of microalloyed steel is shown in figure 2.

TABLE I
UNITS FOR MAGNETIC PROPERTIES

Cutting Speed (m/min)	Feed (mm/rev)	Depth of cut (mm)
40	0.25	0.2
50	0.35	0.4
60	0.45	0.6

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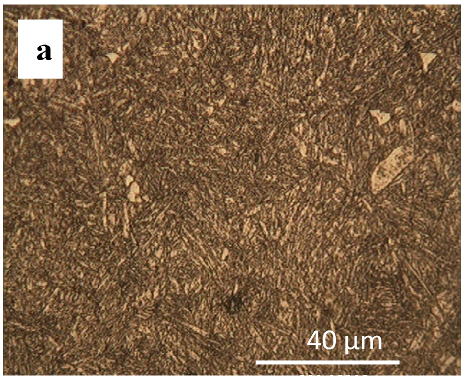
The hardness value of the material is in the range of 400 to 430 HV. Taguchi L9 orthogonal array was used to construct the minimal number of experimental design [4] and is shown in table II.

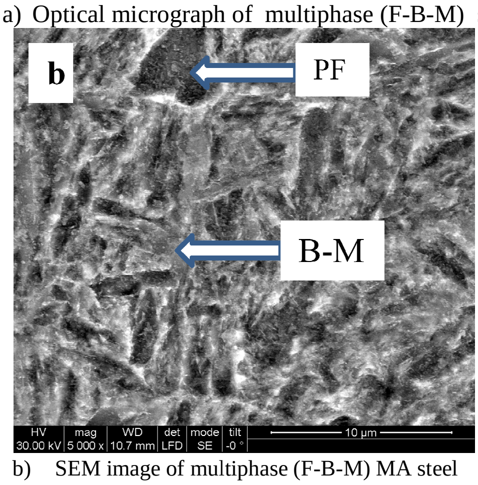
TABLE II
TAGUCHI L9 ORTHOGONAL ARRAY

Experiments	Speed	Feed	Depth of Cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

III. Microstructure Of Multiphase Microalloyed Steel



a) Optical micrograph of multiphase (F-B-M) steel



b) SEM image of multiphase (F-B-M) MA steel

Fig. 1 The optical and scanning electron microscope (SEM) image of the multiphase microalloyed steel is shown

The samples were etched with 2% nital. Polygonal ferrite (PF) and bainite-martensite (B-M) colonies are seen in the microstructure.

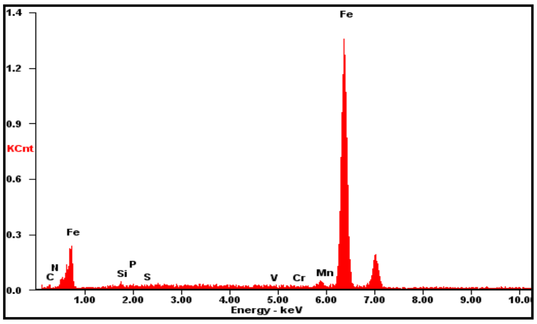


Fig. 2 Energy Dispersive Spectroscopy of MA steel

A. Chip Formation

Chips are formed due to shear between workpiece and cutting edge. During turning both continuous and discontinuous chips were formed. For all the tests conducted, the shapes of the chips formed were categorized in to three types namely spiral, curl and spring. The photograph of the chips formed for various cutting conditions considered are shown in figure 3, 4 and 5. SEM image shows serrated chips of different shapes. The chip formation with saw tooth is also evidenced. This is due to cyclic cracks that initiate at the free surface of the work and proceed downward along a shear plane towards the tool tip [5] and shear flow zone is appeared for selected cutting conditions and is shown in figure 5(b). The chips formed during turning of microalloyed steel is similar to the chips formed during machining of hardened steel [6].

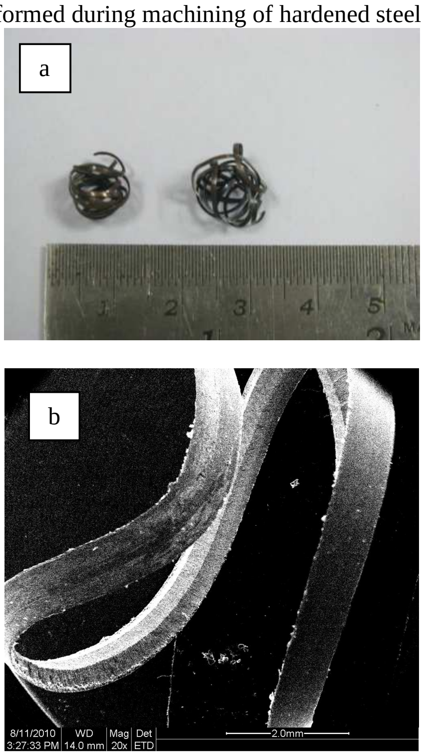


Fig. 3 (a) shows photographic view of cluster chips
(b) SEM image of chips for the cutting condition 1
[V=50 m/min, F=0.45mm/rev, D.O.C = 0.4 mm]

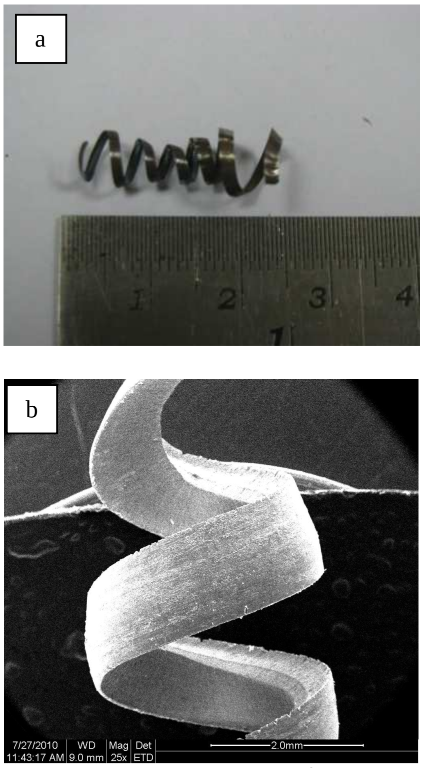


Fig. 4 (a) shows photographic view of spiral chips
(b) Magnified image of chips for the cutting condition 2
[V=60 m/min, F=0.45mm/rev, D.O.C = 0.4 mm]

B. Effect of cutting parameters on chip morphology

It is always preferred to have discontinuous chips for all cutting parameters. For cutting speed of 40 m/min with depth of cut 0.4mm with feed of 0.35 mm/rev, the chip obtained were discontinuous and is shown in figure 5(a). If the cutting speed is increased to 50 m/min with depth of cut 0.4mm and feed 0.45 the chip obtained were spiral/cluster in shape and is shown in figure 3(a), whereas if the speed is increased to 60 m/min with the same feed but with 0.4 depth of cut the shape of the chip obtained was spiral and is shown in figure 4(a).

C. Chip hardness

The Vickers hardness of chips was measured with 150 g load for all the three cutting conditions. For cutting condition 1 the hardness value is in the range of 420 – 510 HV and for condition 2 the range is between 415 and 520 HV and for condition 3 the range is between 418 and 515 HV. The hardness of the chips is increased when compared to base material and this may be correlated to work hardening.

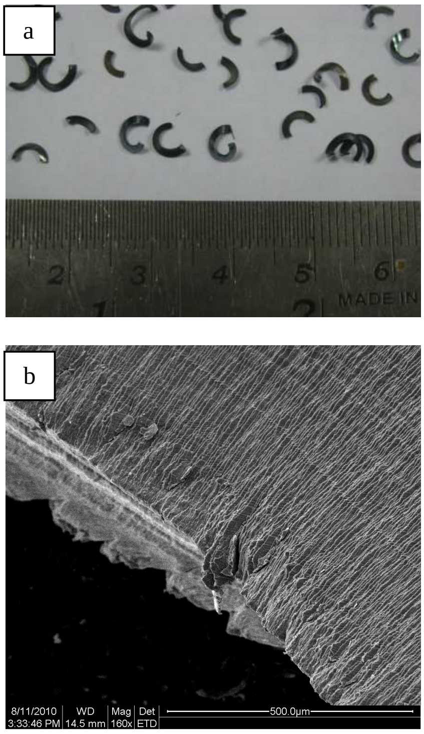


Fig. 5 (a) shows photographic view of discontinuous chips (b) SEM image of chips for the cutting condition 3 [V=40 m/min, F=0.35mm/rev, D.O.C = 0.4 mm]

III. Conclusion

From the experiments it is evidenced that the cutting speed influences the chip morphology. The SEM images of the chips confirm the formation of saw tooth type of chips and also shear patterns are seen with most of the chips.

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