Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 10 (2017) 429 – 435

Procedia MANUFACTURING

45th SME North American Manufacturing Research Conference, NAMRC 45, LA, USA

Effect of Vibration on Surface Texture during Machining Multiphase Microalloyed Steel

V.Sivaraman[a*], L.Vijayaraghavan[b], S.Sankaran[c]

[a]*Department of Mechanical Engineering, E.G.S.Pillay Engineering College, India 611002*
[b]*Department of Mechanical Engineering, IIT Madras, India 600036*
[c]*Department of Materials and Metallurgical Engineering, IIT Madras, India 600036*

Abstract

Multiphase ferrite-bainite-martensite (FBM) microalloyed steel produced through two step cooling procedure was turned and compared with ferrite-pearlite (FP) microstructure and tempered-martensite (TM) microstructure to study the effect of vibration on surface finish. The cutting parameters like cutting speed, feed and depth of cut were varied to understand the parameter influence on surface finish due to vibration. The result shows that FBM microstructure steel gives better performance in terms of lower surface roughness and lower vibration compared to FP and TM microstructure steel.

Peer-review under responsibility of the organizing committee of the 45th SME North American Manufacturing Research Conference

Keywords: Multiphase microalloyed steel, surface finish, vibration

1. Introduction

In turning process three different types of vibration like free, forced and self excited are generated. These vibrations are present due to a lack of dynamic stiffness/rigidity of the machine tool system comprising of tool, tool holder, work material and the machine. Free vibrations are generated due to shock and forced vibrations are present due to unbalance, misalignment, mechanical rigidity and gear defects in the machine tools. Frictional chatter occur when rubbing on the clearance face excites vibration in the direction of the cutting force (Fc) and limits in the thrust force (Ft) direction. Thermo-mechanical chatter occurs due to the temperature and strain rate in the plastic

* Corresponding author. Tel.: 91-4365-251112
E-mail address: iitmvs@gmail.com

Peer-review under responsibility of the organizing committee of the 45th SME North American Manufacturing Research Conference
doi:10.1016/j.promfg.2017.07.019

deformation zone [1]. Self excited vibrations are classified into primary and secondary chatter. Primary chatter is caused by friction between tool and workpiece, thermomechanical process or by mode coupling. Secondary chatter is caused by the regeneration of a wavy surface on the work piece. Secondary chatter or regenerative vibration is the most destructive among all vibrations [2]. Chatter vibrations occur due to instability in the dynamic cutting process. Instability occurs when the excitation frequency in cutting is equal/close to one of the natural frequencies of machine tool [3]. Modulated chip thickness that forms due to vibration increases the cutting force dynamically which in turn increases vibration amplitudes and degrade the surface quality [4]. The occurrence of chatter produces following negative effects: 1. Poor surface quality 2. Excessive noise and tool wear 3. Machine tool damage and reduced material removal rate 4. Waste of work material, energy 5. Increased cost in terms of production time, recycling of waste material [5]. Thomas et al. (1996), investigated the effect of tool vibrations on surface roughness during lathe dry turning process. It is reported that correlation between surface roughness and tool dynamic force exist only when operating in the built-up edge range. The built-up edge formation deteriorates the surface roughness and increases the dynamic forces acting on the tool. The built-up edge formation is minimized by increasing depth of cut and tool vibration [6].

Suyama et al. (2016), studied tool vibration in internal turning of hardened steel using CBN tool. Tool vibration is more critical in turning hardened steel since this operation replace grinding. The influence of cutting conditions, material of the tool bar, tool overhang (L/D ratio) in the workpiece surface roughness and tool life were studied. Radial vibration influence more on surface roughness than tangential direction. The result shows that vibration and material of the tool holder plays a secondary role in surface finish [7]. Upadhyay et al. (2013), developed artificial neural network model to correlate acceleration amplitude of vibrations in axial, radial, and tangential directions with surface roughness. The result shows that acceleration produced in radial direction is more followed by tangential and axial direction. It is also seen that for higher radial acceleration the surface roughness is higher [8]. Abouelatta and Madl (2001), also formed a regression model to predict surface roughness and tool vibration in radial and feed direction during turning free machining steel [9]. Hessainia et al. (2013), conducted turning test on 42CrMo4 steel and predicted the surface roughness and vibration in radial and tangential direction. The optimum parameters were found using response surface methodology (RSM) technique. It is reported that higher speed with lower feed and lower depth of cut gives optimum surface finish. The vibration was measured in terms of acceleration and it is seen that acceleration in the radial direction is more compared to tangential direction [10]. Dimla (2004), studied the impact of cutting conditions on cutting forces and vibration signals in turning with plane face geometry inserts. It is observed that acceleration amplitude were higher in work tool than fresh tool and this discrepancy may due to crater wear, BUE formation at lower cutting speed and alteration in the tool chip contact length. It is also seen that worn tool produces higher resonant frequency than fresh tool [11].

Bonifacio and Diniz (1994), reported that during turning AISI 4340 steel with coated carbide tool the feed rate influence only on surface roughness and did not influence much on vibration signal [12]. Chelladurai et al. (2008), reported that tool vibration increases with increase in depth of cut as well as increase in flank wear. This increase in vibration is due to an increase in cutting force which reduces stiffness of the cutting tool. The amplitude of vibration in terms of acceleration (g) increases with increase in feed rate which results in increased dynamic cutting force. The increase in dynamic cutting force is associated with reduction in the stiffness of the cutting tool. Increase in cutting speed reduces the cutting force and hence reduces the vibration [13]. In this research work the effect of axial vibration on surface roughness were studied for three different microstructure steels by varying the cutting parameters like cutting speed, feedrate and depth of cut.

2. Experimental Procedure

2.1 Material Processing

The medium carbon microalloyed steel (38MnSiVS5) was processed to produce ferrite – bainite-martensite (FBM), tempered-martensite (TM) and ferrite-pearlite (FP) microstructure steel. The processing sequence is shown in Figure 1.

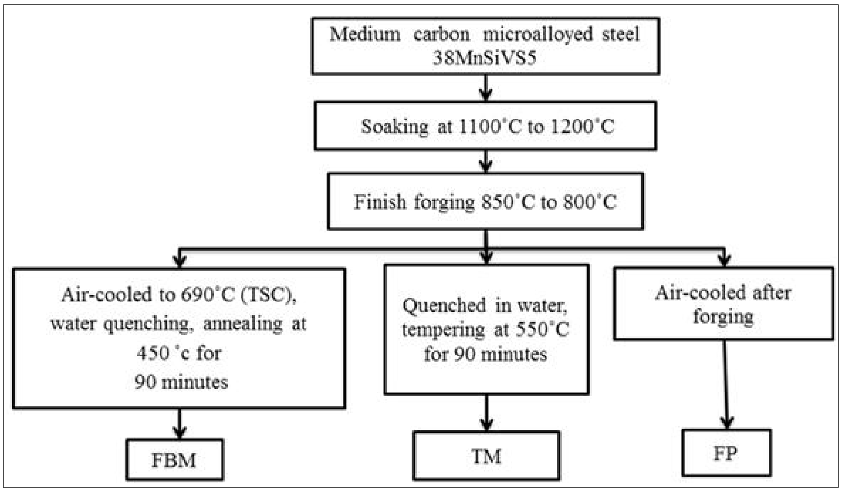

Fig.1. Processing sequence to produce medium carbon microalloyed steel [14]

Table 1 The chemical composition of 38MnSiVS5

C	Si	Mn	P	S	V	N	Cr	Fe
0.38	0.68	1.5	0.022	0.06	0.11	0.066	0.18	Balance

2.2 Machining

The machining was carried out in a conventional high speed lathe with dry environment. Uncoated SNMG 120408 was used as a cutting tool. Two cutting speeds (40m/min and 100m/min) with feedrate (0.05mm/rev, 0.125 mm/rev and 0.2 mm/rev) along with depth of cut (0.1mm, 0.3mm, 0.5mm) were chosen as cutting parameters for machining trials. Mahr perthometer was used to measure the surface roughness and Dytran make miniature (model 3145 AG) accelerometer was used which has a sensitivity of 100 mV/g to measure vibration. The accelerometer was fixed in the tool holder near the cutting insert along the feed direction. The vibration signals are sent to data acquisition card and then the inbuilt Fast Fourier Transform (FFT) analyzer has been used to convert time domain to frequency domain. The vibrations are measured in terms of acceleration. The experimental setup is shown in Figure 2.

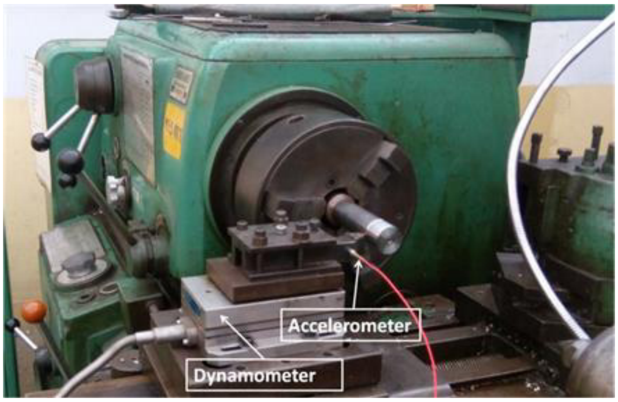

Fig. 2. Experimental setup to measure vibration

3. Results and Discussion

The three different microstructures obtained through thermomechanical processing 38MnSiVS5 steel are shown in Figure 3. Soft polygonal ferrites are seen in FP microstructure and bainite-martensite (BM) colonies are seen in FBM microstructure. Uniform distributions of carbides are seen in TM microstructure.

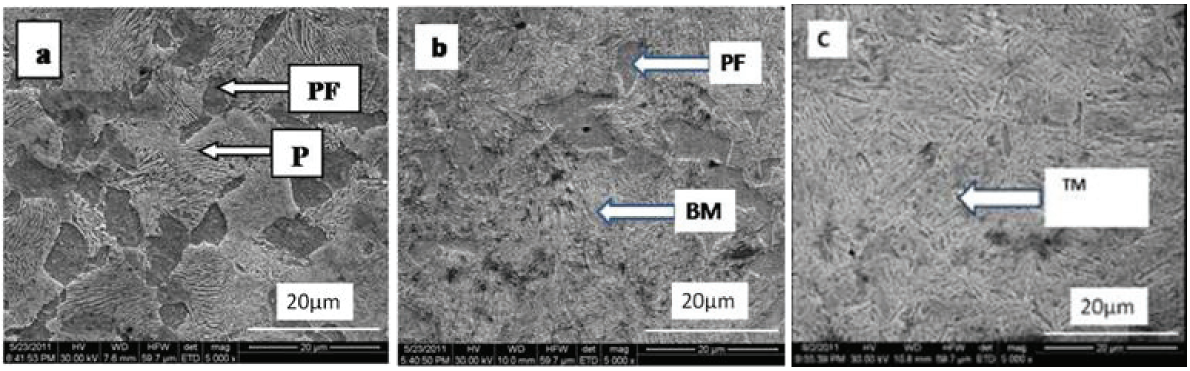

Fig. 3. Scanning electron micrograph of a) FP b) FBM c) TM [14]

The hardness and strength of the materials are given in Table 2. It is observed that the hardness of the BM colonies and TM structures are comparable.

Table 2 Hardness and Strength of three different microstructures [15]

Parameter	FP	FBM	TM
Microhardness (HV0.1)	Pearlite (290 -301) Ferrite (240-265)	Ferrite (270-285) BM (325-345)	330 - 347
0.2% Yield strength (MPa)	721	1284	1185

The stress strain graph of different steel as seen in Figure 4 shows that yield drop is seen in FP microstructure and also exhibit strain hardening. The FBM and TM exhibit high strength compared to TM.

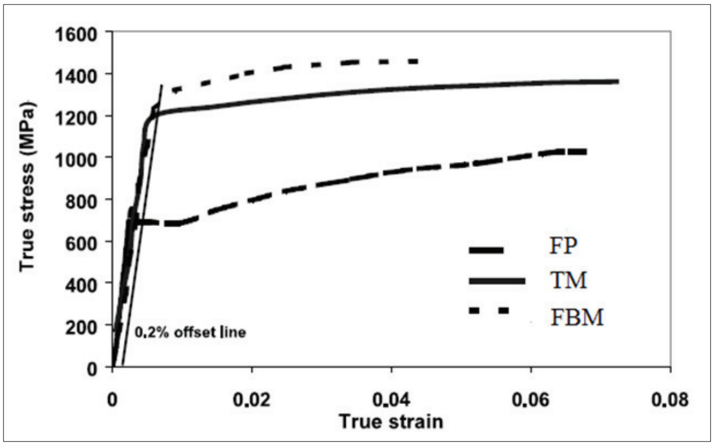

Fig. 4. Stress-Strain graph of three different steels [15]

3.1 Effect of Vibration on Surface Finish

The three different microstructures namely ferrite-pearlite, ferrite-bainite-martensite, tempered martensite were machined for different cutting conditions to understand the effect of vibration on surface roughness. The acceleration is measured in terms of G. The acceleration and surface roughness obtained for minimum and maximum range of cutting speed with different cutting conditions are shown in Table 3. The frequency and time domain signal for dry run and cutting speed 40 m/min, 0.125s mm/rev feed rate with 0.3 mm depth of cut is shown in Figure 5.

Table 3 Acceleration (g) and surface roughness (Ra)

S.NO.	Speed (m/min)	Feed (mm/rev)	DOC (mm)	Ra (μm) [FP]	Ra (μm) [TM]	Ra (μm) [FBM]	Gn [FP]	Gn [TM]	Gn [FBM]
1.	40	0.05	0.1	3.43	0.96	1.21	0.87	0.64	0.51
2.	40	0.125	0.3	4.80	2.22	1.40	1.30	0.81	0.75
3.	40	0.2	0.5	4.23	2.38	1.96	1.19	0.67	0.59
4.	100	0.05	0.1	4.19	0.99	0.61	0.63	0.47	0.39
5.	100	0.125	0.3	0.88	0.75	0.73	0.86	0.63	0.45
6.	100	0.2	0.5	1.39	1.93	1.74	0.47	0.59	0.51

It is observed that there is a correlation exists between vibration and surface roughness. The chosen feed and depth of cut confine machining to the nose region of the tool. Under such micro machining conditions feedrate will be proportional to the edge radius of the cutting tool. With lower cutting condition of 40m/min, 0.05 mm/rev, 0.1 mm the surface finish is poor for FP structure compared to TM and FBM. The acceleration corresponding to the above cutting condition is also higher. For the same cutting speed, as the feedrate is increased to 0.125mm/rev along with 0.3 doc., the surface roughness and acceleration are increases for FP. This is mainly due to the presence of BUE. Similarly increase in acceleration for TM and FBM is reflected on the surface finish. For higher cutting feed of 0.2 mm/rev and depth of cut of 0.5 mm the cutting become steadier due to this the acceleration is getting reduced for FP. It is observed that increase in feed and depth of cut reduces the vibration for constant spindle speed. By increasing the spindle speed from 40 m/min to 100 m/min the vibration is getting reduced this is evidenced from the decrease in acceleration values for 100m/min compared to 40m/min. Compared to TM and FBM, FP microstructure steel exhibit higher acceleration. This is mainly due to the affinity between the work material and cutting tool is more due to the presence of polygonal ferrite. This results in the formation of BUE and is shown in Figure 6. Even though the strength is increased for FBM steel compared to TM, the acceleration are low this is due to the presence of soft polygonal ferrite and bainite along with small amount of martensite. The soft polygonal ferrite along with bainite suppress the vibration and help to deform smoothly during machining. This is not happening with TM due to the uniform distribution of carbide.

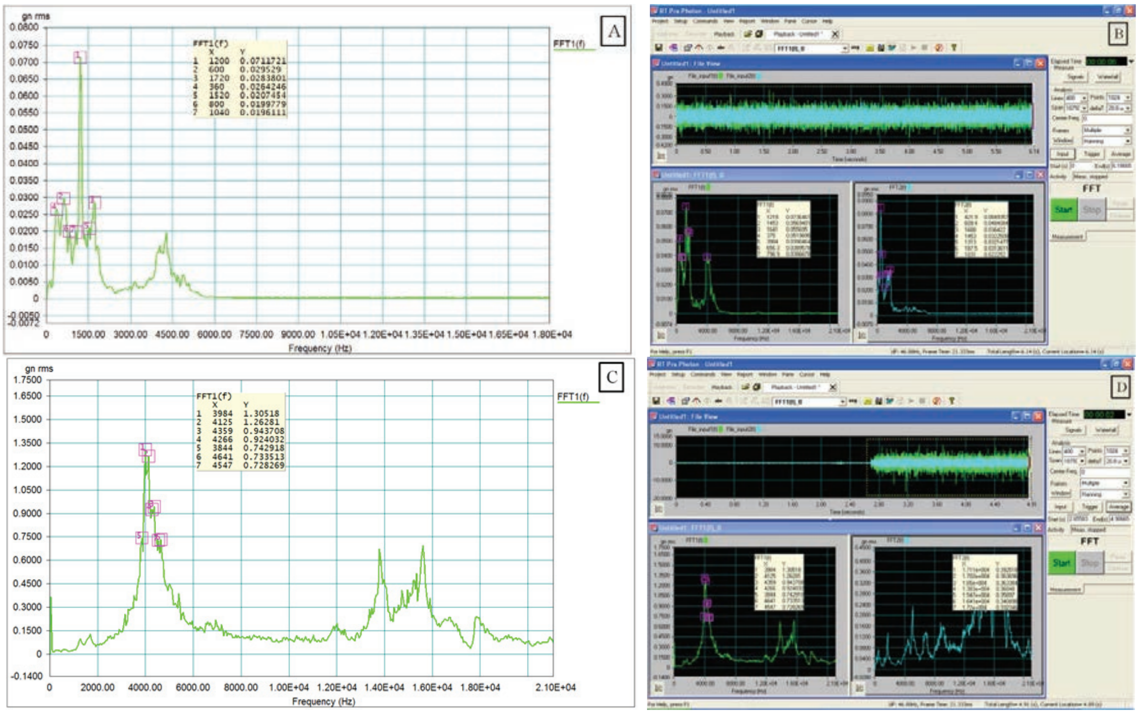

Fig. 5. Response signal during turning (a,c) frequency domain (b,d) time domain. [a,b] with an idle spindle speed of 450 rpm [c,d] during machining with cutting condition 40m/min, 0.125 mm/rev, 0.3 mm doc.

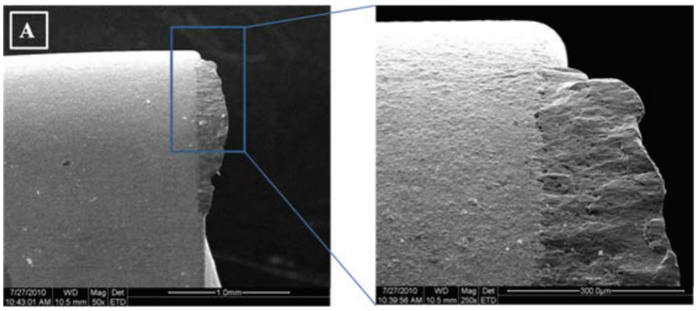

Fig. 6. Formation of BUE for ferrite-pearlite (FP) microstructure at cutting condition 40m/min,0.05mm/rev and 0.1mm.

4. Conclusion

The machining of three different microstructure steels like FBM, TM and FP were carried out to study the effect of cutting parameters on vibration and surface finish. Based on the experimental results following conclusions are drawn.

- The study on the influence of vibration on surface roughness revealed that at lower cutting conditions like cutting speed 40 m/min, feed rate 0.05 mm/rev with 0.1 DOC the acceleration observed is more for FP followed by TM and FBM. TM produce good surface finish compared to TM and FBM at lower cutting conditions due to the presence of uniform carbides.
- The formation of built-up edge increases the magnitude of vibration and surface roughness at higher feedrate and also it is observed that the increase in spindle speed from 40 m/min to 100 m/min reduces the vibration.

- The presence of polygonal ferrite in FP microstructure leads to greater affinity between work material and cutting tool. This results in higher acceleration for FP compared to FBM and TM.
- The presence of soft polygonal ferrite and bainite in FBM supress the vibration and help to deform smoothly during machining by producing better surface finish compared to FB and TM microstructures.
- At higher cutting speed due to steadier machining FP performs better than FBM and TM in terms of lower vibration and good surface finish.

References

[1] Wiercigroch, M. and E. Budak (2001) Sources of nonlinearities, chatter generation and suppression in metal cutting. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, 359 (1781), 663-693.

[2] Siddhpura, M. and R. Paurobally (2013) Experimental investigation of chatter vibrations in facing and turning processes *Proceedings of World Academy of Science, Engineering and Technology*. World Academy of Science, Engineering and Technology (WASET),62.

[3] Zhang, S., S. To, G. Zhang, and Z. Zhu (2015) A review of machine-tool vibration and its influence upon surface generation in ultra-precision machining. *International Journal of Machine Tools and Manufacture*, 91, 34-42.

[4] Kumar, M.G. and P.V.P. Shashikumar, (2014) Investigations and analysis of chatter vibration in centerless bar turning machine, *AIMTDR*, December 12th–14th, IIT Guwahati, Assam, India. 707(1-5).

[5] Quintana, G. and J. Ciurana (2011) Chatter in machining processes: A review. *International Journal of Machine Tools and Manufacture*, 51 (5), 363-376.

[6] Thomas, M., Y. Beauchamp, A. Youssef, and J. Masounave (1996) Effect of tool vibrations on surface roughness during lathe dry turning process. *Computers & industrial engineering*, 31 (3), 637-644.

[7] Suyama, D., A. Diniz, and R. Pederiva (2016) Tool vibration in internal turning of hardened steel using cbn tool. *The International Journal of Advanced Manufacturing Technology*, 1-11.

[8] Upadhyay, V., P. Jain, and N. Mehta (2013) In-process prediction of surface roughness in turning of ti–6al–4v alloy using cutting parameters and vibration signals. *Measurement*, 46 (1), 154-160.

[9] Abouelatta, O. and J. Madl (2001) Surface roughness prediction based on cutting parameters and tool vibrations in turning operations. *Journal of Materials Processing Technology*, 118 (1), 269-277.

[10] Hessainia, Z., A. Belbah, M.A. Yallese, T. Mabrouki, and J.-F. Rigal (2013) On the prediction of surface roughness in the hard turning based on cutting parameters and tool vibrations. *Measurement*, 46 (5), 1671-1681.

[11] Dimla, D. (2004) The impact of cutting conditions on cutting forces and vibration signals in turning with plane face geometry inserts. *Journal of Materials Processing Technology*, 155, 1708-1715.

[12] Bonifacio, M. and A. Diniz (1994) Correlating tool wear, tool life, surface roughness and tool vibration in finish turning with coated carbide tools. *Wear*, 173 (1), 137-144.

[13] Chelladurai, H., V. Jain, and N. Vyas (2008) Development of a cutting tool condition monitoring system for high speed turning operation by vibration and strain analysis. *The International Journal of Advanced Manufacturing Technology*, 37 (5-6), 471-485.

[14] Sivaraman, V., S. Sankaran and L. Vijayaraghavan (2016) Effect of cutting parameters on cutting force and surface roughness during machining microalloyed steel: Comparison between ferrite-pearlite, tempered martensite and ferrite-bainite-martensite microstructures. Proc IMechE, Part B: J Engineering Manufacture. DOI: 10.1177/0954405416635479

[15] S Sankaran, V., Subramanya Sarma and K.A Padmanabhan (2003) Low cycle fatigue behavior of a multiphase microalloyed medium carbon steel: comparison between ferrite–pearlite and quenched and tempered microstructures, Materials Science and Engineering: A, Volume 345, Issues 1–2, 25 March, Pages 328-335.