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An Experimental Investigation on Machinability Studies of Steels by Face Turning

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Abstract

The present study is an experimental investigation on the machinability of AISI 51100 and AISI 52100 steels (whose chemical compositions slightly differ) by face turning method. The face turning method makes use of cylindrical shaped steel specimen as a test piece and a triangular P-30 insert as a cutting tool for testing the machinability. The effectiveness of this method is assessed by studying: the cutting time required for the tool to reach flank wear up to 0.3mm (tool life criterion); tool wear development and wear mechanisms involved in machining; tool life studies; and surface roughness investigations of the machined surfaces. These aspects are further tested and verified for its repeatability and reproducibility. The tests are being carried according to some of the indicated in the international standards,ISO 3685:1993(E) and American Foundry Society standard machinability tests. The results presented here demonstrate the ability of the face turning method: to evaluate the tool wear development and tool life; to investigate surface integrity due to tool wear; and to differentiate very clearly the machinability of steels under consideration. The face turning method used here is simple and effective.

1. Introduction

Machinability is an important property of a material which characterizes its ability to be machined. Steel machinability involves interaction of: machining process; steel chemistry and matrix structure; and inclusion chemistry and morphology. The machinability of steels is affected by many factors, such as: machining process, continuous or in-

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termittent; cutting tool geometry; cutting fluid type and application; machining parameters like speed feed and depth of cut; rigidity of holder and machine tool. This intricate combination makes machinability of steels an intrinsic technological property which is complex to understand and difficult to determine. Then the assessment of the machinability of steel becomes a matter of prime activity to make proper decision and improve productivity.

The engineering industries strive to achieve either a minimum cost of production or a maximum production rate in machining. The use of high speed machining has become more relevant in recent years. This means cutting velocities have increased many folds than normal speeds. Bartarya Gaurav (2012) identified approximately 75% of the manufacturing activities in the industrialized countries deal with production of a small batch size with a large variety of products which are diverse in nature. Thus it is becoming increasingly necessary to relate the available engineering raw materials and semi-finished products to specify machinability ratings. It is advantageous for the industries to know in advance the behavior of wear and life of tool with respect of specific steel grades which needs to be processed. Since the chemical composition and mechanical data, is not enough to cover the machining characteristics of the material.

Hiroshi Yaguchi (2006) reported six types of tests to determine machinability of steels performed at specialized laboratories with complex set-ups, which are long term in nature. The main drawback in long term test is that the tools require a fairly long time before reaching the stipulated wear limit. Moreover the long term test is possible only in the industries with research and development centers. Trent, E.M and Wright, P K (2000) reported that such tests are apt to be expensive in material and manpower, not least because of the large scatter in individual test results. This work involves very careful measurement of the very small amounts of wear, the use of a microscope being essential.

Adequate industrial experience and judgment is required for the investigator on what is significant and what can safely be ignored. Such tests are beyond the reach of small and medium industries who are working with four to five grades more variety of commercially available steels. Thus the efforts to minimize consumption of the material and to save time on the long tests have led to the development of short time tests. Face turning operation is one of the short time test taken as method to test the machinability of the steels. This can be conveniently done with minimum amount of resources. Salak A et al. (2006) have successfully demonstrated the face turning method for assessing machinability of five different types of powder metallurgy steels. Flank wear, V_b of 0.3mm was taken as tool life criterion. Karin Bjorkeborn et al. (2008) recommended the Volvo Standard Machinability Test as a potential method for assessing machinability of materials. A common case hardening steel, 20MnCrS5 was chosen here for investigations. With suitable altered heat treatment four varieties of microstructures of the same steel were obtained. The Volvo test makes it possible to rank material by tool wear with relatively small samples and low material volumes. The authors stated that approximately 800 mm length of bar and 50 mm in diameter is needed for testing a material and the other traditional test with respect to tool wear are more costly to perform, both in time and material consumption. Trent E M and Wright P K (2000) reported tool testing standards set by F W Taylor. These tests were all carried out by lathe turning of very large steel billets using single point tool. Such elaborate tests have been too expensive in time and manpower to repeat frequently, and it has become customary to use standardized conditions, with cutting speed and feed as the only variables. The results are presented using what is called Taylor's equation, which is Taylor's original relationship reduced to its simplest form $V\ T^n = C$, where V = cutting speed, T = cutting time to produce a standard amount of flank wear and C, n = empirical constants for the material or conditions used.

For decades together, practising engineers and researchers are looking for some methodology to have a common base for the machinability evaluation as the manufacturers are in ambiguity over the selection of appropriate material for their product since numerous new engineering materials enter the market every year. It is usual practice of the researchers to characterise the machinability studies by way of experimentation. Venkatrao R (2006) presented a logical procedure to evaluate the machinability of the work material for a given machining operation and also proposed globally machinability index to evaluate and rank the work materials. However, yet no reports on the application and implementation of the global machinability index is found.

The aim of this work is to present: tool wear development and wear mechanism studies; tool life and surface integrity studies; and chip morphology and crater wear studies under the broad title of machinability of steels by face turning test method.

2. Experimentation Methodology

2.1. Face turning method

In this test, face turning of cylindrical standard steel bars is done from the surface of the centre of the hole, ø6mm, to the circumference of the at constant lathe spindle revolutions, feed and depth of cut. A typical face turning method is shown in Fig. 1. After finishing the first pass, a second face turning from the center of the hole follows. The consecutive passes are repeated up to the critical flank wear (V_b) is reached to 0.3mm. This test method can represent more accurately modern production which often involves short series including mixed cutting cycles and operation. At such stage, a conventional longitudinal operation involving a large number of short (compared to total tool life) cutting and non-cutting cycles was defined by the terminology 'interrupted machining mode,(Salak A et al., 2006).This is in reality the case of this face turning method using workpieces where cut is interrupted after arriving at the outer diameter with repeated tool entry. For very short cycles below the critical time, as can be the case in this method, the tool wear can exceed the corresponding wear in continuous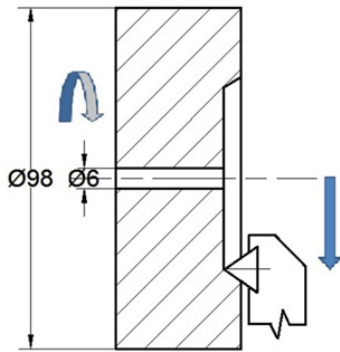 machining. This method can occasionally give a positive result, as interruption appears to facilitate the cooling of the tool and lowers the average temperature of tool giving real tool life. The process parameters are chosen so as to promote rapid tool wear at minimum material removal. The cutting speed for workpiece grade is chosen because of its industrial relevance and are bit higher than the optimum value according to Makarovs' law, 'minimum tool wear occurs at the optimum cutting speed'(Astakhov Viktor P, 2004). In general the cutting speed is so selected that the tool life at the highest speed is not less than five minutes (ISO 3685, 1993). The depth of cut of 0.4mm chosen is enough to get flank wear land with minimum consumption of work material. The feed rate chosen was 0.145mm. Research works have shown that the temperature of the tool is highly affected by the cutting speed than the depth of cut and the feed rate (Sanjeev Saini et al., 2012 and Bartarya Gautav et al., 2012). Further the work material bar diameter of 100mm chosen was also on higher side to aggravate the tool wear. F Boud (2009) investigated that the bar diameter has an influence on the tool temperature and, by implication, on tool wear. The tests are being carried according to guidelines laid in the international standard ISO 3685(1993), tool life testing with single point turning tools.

Fig.1. Typical face turning method.

2.2. Workpiece Material

The work material used here are AISI 51100 and AISI 52100. Their chemical composition is shown in table 1. The hot rolled work piece of ø100mm was pre-machined to ø98mm to remove hard scales, hot rolled skin and unevenness on the peripheral and end surface of the as received material. The pre-machining work also ensures proper cylindricity, concentricity and run-out to prevent vibration. Then a drill of ø6 mm was made at the center along the axis of the work material to facilitate the entry of the tool at the beginning of every pass. Chemical composition of each work material was determined over the cross-section and average values were obtained as shown in table 1. Before conducting the experiments the hardness of all the workpieces over the complete cross-section was determined. The hardness' were within the limits of ± 5% over complete cross-section of the work piece.

Table 1. Chemical composition in % weight

	C	Si	Mn	P	S	Cr	Fe
AISI 51100	1.12	0.26	0.48	0.06	0.05	1.1	Balance
AISI 52100	1.19	0.34	0.53	0.05	0.05	1.49	Balance

2.3. Tool Material

A carbide insert P-30, triangular uncoated, is used for cutting the above work piece material with a general purpose ISO tool holder CTLPR2020L16.

2.4. Face Turning Conditions

Dry face turning was conducted under the following condition - feed, 0.145 mm/rev; depth of cut, 0.4mm; constant revolution of 640 rpm (197 m/min), 800 rpm (246 m/min) and 1000 rpm (308 m/min) of lathe spindle for AISI 51100; and constant revolution of 400 rpm (123 m/min), 640 rpm (197 m/min) and 800 rpm (246 m/min) of lathe spindle for AISI 52100 .bearing steels.

3. Results and discussions
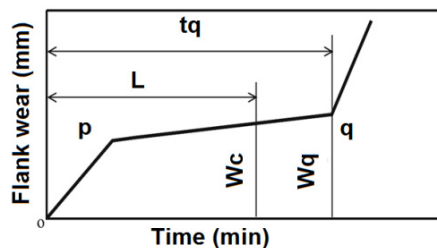
3.1. Tool wear development

Fig.2. Progress of tool wear [13].

Flank wear is used here for tool wear monitoring since it occurs virtually in all single point tool machining (Sanjeev Saini et al., 2012). Standard tool life tests use flank wear criteria to define the end of the tool life. The tool life criteria used here is the flank wear V_b=0.3 mm for a carbide tool, which is as per the guide lines in ISO 3685(1993).

The tool wear development in traditional turning at single speed with time for a carbide tool is shown in Fig.2. The growth of wear on the flank face of tool consists of three distinct stages (wear mechanisms); a short initial region of rapid wear (from point o to point p), an approximately constant wear-rate region or Steady state wear (from point p to point q) and finally a very rapid wear-rate region (above point q) which indicates tool failure (Yorem Koren et al., 1991 and Bouzid Sai W. 2005). The flank wear should be reached before the beginning of the third stage (Wc < Wq) of the wear process (Bouzid Sai W. 2005).

The experimental investigations suggests that for machining hard material; crater wear rate is influenced by both ,cutting speed and feed rate while flank wear rate is influenced by mainly by cutting speed(Attanasio A. et al., 2012). Also research works made by Bartarya Gaurav (2012) have shown that temperature of the tool is highly affected by the cutting speed than the depth of cut and feed rate. Two similar bearing grade steel material but with slightly different in chemical composition, namely AISI 51100 and AISI 52100, has been undertaken here for the purpose of study. Their chemical composition is as shown in Table 1. The face turning operation is performed on these samples to investigate the tool wear development and machinability aspects in comparison with its traditional expensive longitudinal turning operation. The discussion regarding the three wear mechanisms in traditional turning made by most researchers is very much applicable to these samples. This difference in their wear development due to slight change in chemical composition, mainly carbon and chromium (thereby their hardness) is evident in the discussion made in the sections ahead. Accordingly both samples were tested for three different speeds. AISI 51100 was tested for the spindle revolution of 197 m/min, 246 m/min and 308 m/min and AISI 52100 was tested for the spindle revolution of 123 m/min, 197 m/min, and 308 m/min. The flank wear on the tool was recorded periodically after every stipulated number of passes for these samples at all testing speeds. The recording was terminated when the flank wear reached its tool life criterion of 0.3mm (V_b). Fig.3 (a) and (b) shows the recording of flank wear of both samples at stipulated different cutting speeds. The wear mechanisms while machining these samples at different stages are discussed inthe following sections.
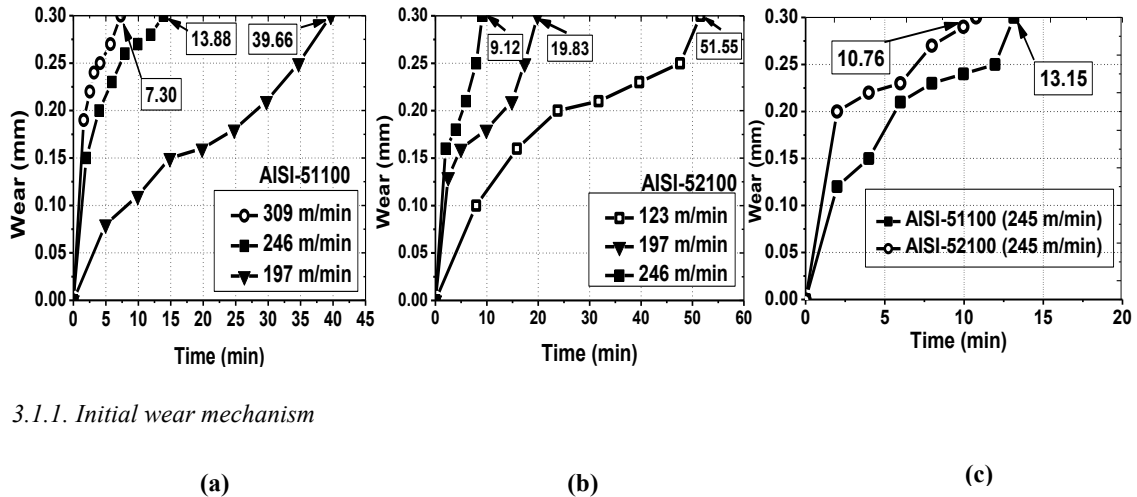
(a)
(b)
(c)

Fig. 3. Tool wear development at different speeds for [from left] (a) AISI 51100 (b) AISI 52100 (c) both work-materials on an another lathe machine at 245 m/min

3.1.1. Initial wear mechanism

The initial wear in this investigation is mainly due to nose wear and contributes to nearly 10% to 15% of the tool life. The initial wear causes some roughness on the flank wear. The greater the roughness value of the flank wear surface, the higher the friction on the tool on the work piece, so that the greater heat generation will occur, which ultimately causes the tool failure (Alden Kendall L., 2005). In the initial wear mechanism, the tool and the work material in contact have surface roughness irregularities in the form of protrusions or asperities. At the tool-work interface, asperities create small contact areas. In the cutting process, the stresses and heat are intensified in asperities resulting in fracture of melting.

At higher range of speeds (246 m/min and above) the initial wear mechanisms is higher as the nose of the tool having thin cutting edge is rubbed off when it comes in contact of the work--material running at an increasingly higher speeds. The active wear mechanisms change to plasticity and/or mild oxidation/diffusion dominated wear. At lower range of speeds (197 m/min and below) abrasion dominates the wear mechanisms.

There is no clear distinction in the end of initial wear mechanism and the beginning is evident that at even lower speeds the initial wear mechanisms fairly exists for high carbon steels.

3.1.2. Steady state wear mechanism

Normal stress and temperature carry over the wear surfaces. The plasticity mechanism that dominates in one wear zone may not dominate in another. Also the maximum tool temperature occurs on the rake surface, at a small distance, about 0.5 to 0.8 mm Trent E M and Wright P K (2000), from the cutting edge. At this point the crater starts to build and the diffusion wear comes into play. The diffusion wear is dominant in machining ductile material. However in the current steel material, the diffusion wear (i.e formation of crater wear) has little presence and does not contribute actively in tool failure. This may be due to the presence of carbides in high carbon steels. Also the chips formed are small, intermittent and arched, about 5mm in length, as shown in Fig. 9 (a) and (b) in turning bearing steel work-material. These chips are unlikely to form built up edge condition on tool due to the presence of hard carbide particles.

3.1.3. Rapid /accelerated wear mechanism

This wear mechanism is also known as tertiary tool wear mechanism. Over a period of time, steady state mechanism enlarges the wear surfaces to a critical size that triggers the rapid wear beyond point q in Fig. 2. The pressures and speed on this enlarged surfaces gives rise to high temperature resulting in rapid oxidation/diffusion and local seizure causing rapid destruction of the tool. Thus a tool change is to be made before this point is reached. Fig.3 (a)

and (b) shows the three wear zones (as discussed) in terms of amount of wear over time (Alden Kendall L., 2005). As the rapid wear progresses, the surface finish on the work-material also deteriorates drastically.

3.1.4. General remarks

The phenomenon of wear mechanisms with three zones is evident at lower range of experimental speeds i.e. 197 m/min for AISI 51100 and 123 m/min for AISI 52100. The scenario of tool wear development changes as the testing speed for both the work materials under consideration is increased at the next higher level (197 m/min and 246 m/min for AISI 51100 and AISI 52100 respectively). The steady state wear zone relatively is reduced to a very short time because of diffusion wear mechanism dominating the abrasion. At still higher level speeds (246 m/min and 308 m/min for AISI 51100 and AISI 52100 respectively), there is no evidence of steady state wear zone. At such higher speeds the wear environmentalters dramatically. More thermal energy is removed by the chip due to decrease in contact time between the tool and chip. The higher velocity increases absolute temperature on the tool wear surfaces.Abrasive wear here becomes less important. The diffusion and oxidation processes dominate in creating and enlarging the wear surfaces (Alden Kendall L., 2005 and Arsecularutne, J. A et al., 2006).

3.2. Machinability tests

3.2.1. Repeatable machinability test

Fig. 3(c) shows the tool wear progress results of AISI 51100 and AISI 52100 tested at two common speeds, 197 m/min and 246 m/min., and the other cutting parameters being kept constant. The results are; 13.88 min and 38.66 min for 246 m/min and 197 m/min for AISI 51100; and 9.12 min and 19.83 min at 246 m/min and 197 m/min for AISI 52100. This result shows that the time required for tool wear for the same speeds is more for AISI 51100 than AISI 52100. Thus machinability of AISI 51100 is better than AISI 52100.

The results show the sensitivity of the applied face turning test method to slight variation in the chemical composition of the two steels used. The effect of the differences in carbon, manganese and chromium is revealed in the tool wear development Fig.3.

3.2.2. Reproducible machinability test

Both the samples are tested on another machine with the same cutting condition and tool but at a different single speed (245 m/min). If the results of this test are consistent with the previous one, it can said to have achieved reproducibility. The tool wear development of this test on both the samples is shown in Fig.3(c) which shows that time taken for the tool to wear for machining AISI 51100 and AISI 52100 are 13.15 minutes and 10.76 minutes respectively.

The repeatability and reproducibility test has proved that machinability of AISI 51100 is better than AISI 52100. In a nut shell the wear mechanisms, tool wear development and machinability tests here in face turning operation is confirmed.

3.3. Tool Life Studies

3.3.1. Tool life equation

The development of quantitative methods for predicting tool life has long been goal of metal cutting research as the tool life has a strong impact in production operations. The tool life model study includes flank wear of the carbide tool in mm and cutting speed in m/min as the parameters under consideration. Flank wear is a major form of tool wear in metal cutting (Bauzid Sai W, 2005). This wear is found to havedetrimental effects on surface finish, residual. stresses and microstructural changes in the form of re-hardened surface layer (Attanasio A et al.,2012 and Venkatrao R 2006).

Cutting speed is chosen as major machining parameter in tool studies because it is inferred that the cutting speed has major influence on the tool life/wear. Feed rate and depth of cut has little influence on the tool life [12, 6]. Thus three wear tests at three different cutting speeds were plotted for AISI 51100 and AISI 52100 in Fig. 3(a) and (b).The time required for tool failure (Vb=0.3mm) and the corresponding speeds for: AISI 51100 is 7.30 min at 308
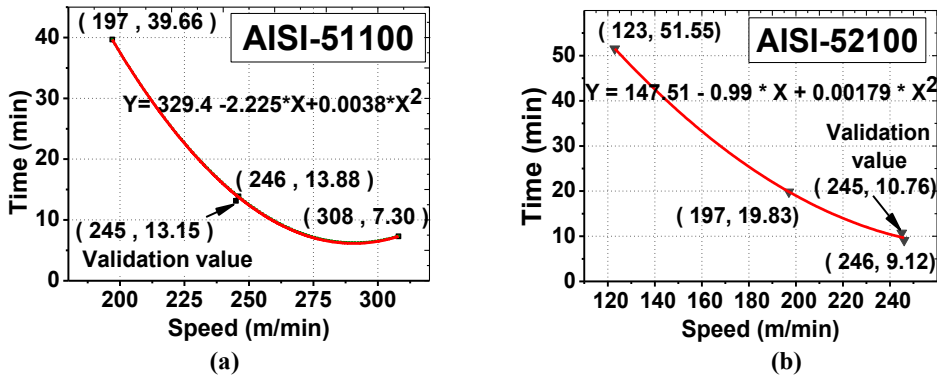
Fig. 4**.** Tool life curve with an equation for a line of best fit and a validation value for
each work-material(a) AISI 51100(b) AISI 52100

m/min, 13.88 min at 246 m/min, and 39.66 min at 197 m/min ; and for AISI 52100 is 9.12 min at 246 m/min,19.83 min at 197 m/min and 51.55min at 123 m/min.

A line of best fit was drawn between the ends of the test wear points for both the samples.

The proposed model for Tool life plot for AISI 51100 is a polynomial quadratic equation given by,

y = Intercept + $B1*x^1$ + $B2*x^2$ where,
Intercept =329.4; B1=-2.225 and B2= 0.0038
Goodness of fit: SSE =1.42 e-014, R_{square} =1, Adjusted R_{square} = 0.998, RMSE= 0.03285
The proposed model for Tool life plot for AISI 52100 is a polynomial quadratic equation given by,
y = Intercept + $B1*x^1$ + $B2*x^2$ where,
Intercept =147.5; B1= -0.99 and B2 = 0.00178
Goodness of fit: SSE =7.10 e-015, R_{square} =1, Adjusted R_{square} = 0.998, RMSE=NaN

The sum of squares due to error, SSE has a value closer to 0, indicating that the model has a smaller random error component and that the fill will be more useful for prediction. R_{square} measures how successful the fit is in explaining the variation of the data. It is the square of the correlation between the response values and the predicted response values. R_{square} value closer to 1 indicates that a greater proportion of variance is accounted by the model. The adjusted R_{square} statistic can take on any value closer to 1 indicating a better fit.

Root Mean Squared Error, RMSE, is also known as the fit standard error and the standard error of the regression. RMSE value closer to 0 indicates a fit that is more useful for prediction.

3.3.2. Tool life validation test

In the reproducible tests, where the two steels were tested on another machine at 245 m/min, the tool life was 13.15 mins and 10.76 mins for AISI 51100 and AISI 52100 respectively. This was verified in the proposed tool life model equation as shown in Fig. 4(a) and (b). The error bars for each observed point is in 95 percent confidence range. Further the speeds calculated for 60 mins tool life (also known as Machinability Index) as according to the model equation is 171 m/min and 108.8 m/min for AISI 51100 and AISI 52100 respectively. Thus the validation test of the face turning operation for both the samples ensured the reproducibility and repeatability of the proposed tool life model and machinability studies. Also it can be deduced from the above validated test results that AISI 51100 has better machinability than AISI 52100.
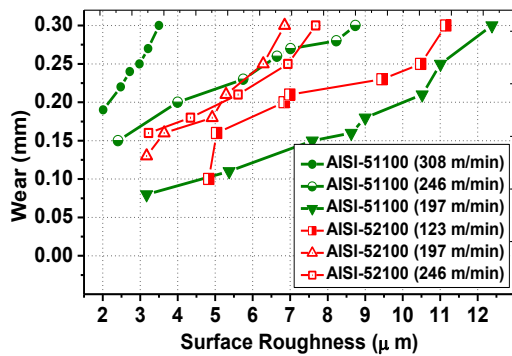
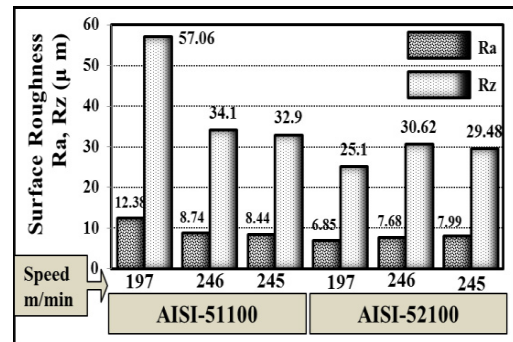Fig. 5. Surface roughness recorded at different speeds for AISI 51100 andAISI 52100

Fig. 6. Surface finish, Ra and Rz, after machining at different speeds for AISI 51100 and AISI 52100.

3.4. Surfaceroughness

The roughness of the machined surface is a result of an interaction of the workpiece properties and the tool material and geometry under the cutting conditions used. The important parameters which affect the roughness of the machined surfaces are the tool nose radius; feed, cutting speed and depth of cut (Sanjeev Saini et al. 2012) tool nose radius, feed and depth of cut are kept constant throughout the whole experimentation. Therefore the effect of cutting speed and wear on surface roughness is considered for discussion. The surface roughness test was recorded periodically simultaneously along with the flank tool wear measurement. Surface roughness tester, SJ-301, with resolution of 0.01μm least count was used for this purpose. After every stipulated number of passes performed by the face turning operation, the machined surface was evaluated for the surface roughness. The parameters Ra, Rz and Rq were measured by the Surface roughness tester at three different places on the machined surface. The averages of these three values have been taken for the purpose of reporting. The results recorded this way are presented for both the workmaterials (AISI-51100 and AISI-52100) at three different speeds in the Fig. 5.

The surface roughnesses of turning have been made as a function of feed, tool radius, and end and side cutting edge angles. The surface roughness obtained from these calculations represents the best finish commonly produced by that particular turning tool and thus provide an indication of the minimum surface roughness possible with a designated tool shape and feed rate. The actual surface roughness may be poorer due to built up edge or any other unknown reason. The present face turning investigation with respect to wear development and surface roughness for AISI 51100 and AISI 52100 is shown in Fig 5. It is very evident for all the cutting speeds that as the tool wear development progresses the surface roughness increases (i.e. surface finish deteriorates).

The Fig. 5 depicts that for lower range of speeds (197 m/min AISI 51100 and 123 m/min AISI 52100), the surface roughness values are spread over a broad range and a high Ra value. This is a case of abrasion wear. The formation of new cutting edges is more until the final wear (V_b=0.3 mm) occurs.Whereas at higher speeds (308 m/min AISI 51100 and 197 m/min AISI 52100), the surface roughness values lie in a narrow band and has a comparatively lesser Ra value. Here the wear phenomenon may be due to mild diffusion/oxidation. Because of increased speed, the temperature at tool-chip-workpiece region is high. No newer cutting edges are formed. The cutting edge loses it sharpness into roundness quickly giving rise to a better surface finish. For the highest speed used here in the study 308 m/min, the surface roughness value Ra is 2 to 3.5 μm, and for the lowest speed 400 rpm the roughness value Ra is 3 to 12 μm.For assessing the possible effect of the carbon and chromium composition on mechanical properties of the specimen, the roughness of the machined surface was taken both as mean value of the highest roughness peak Rz and the mean arithmetic deviation of the roughness Ra. The results are shown in the Fig.6. The roughness of a machined surface is a result of interaction of the workpiece properties and the tool material and the geometry under the cutting condition used. The results prove the influence of the base workpiece properties on the roughness as well as the suitability of the cutting method used in defining the machinability via surface finish.
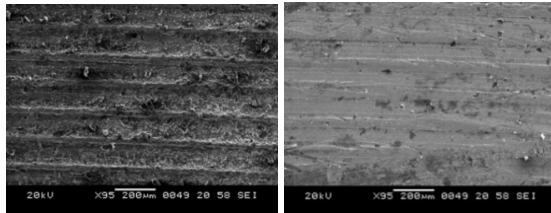
Fig. 7 SEM images of machined surface obtained after the tool life criterion has reached at 245 m/min for (a) AISI 51100 and (b) AISI 52100.
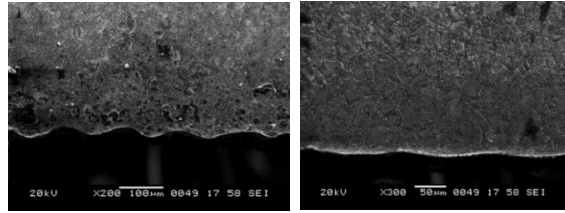

Fig. 8 Cross-sectional edged machined surface (SEM) obtained after the tool life criterion has reached at 245 m/min for (a) AISI 51100and (b) AISI 52100.

3.5. SEM investigations

From the Fig. 7 images, it is very evident that for AISI 51100 the tool marks are dominant whereas for AISI 52100 the tool marks are unclear. The AISI 52100 is harder than AISI 51100.The AISI 52100 work piece being harder has abraded the tool cutting edge. For the same cutting conditions and same tool, the effect of hardness is seen in the SEM images. The tool has penetrated more in AISI 51100 resulting in higher surface roughness value than AISI 51100 and this is evident from the values in Fig.6. The hard material disallows the formation of newer tool edge in machining AISI 52100. This is also clear from the increasing surface roughness values obtained in the Fig.6. Thus the tool wear for machining AISI 51100 steel material is mainly due to abrasion. Whereas the tool wear in AISI 52100 steel material is both, first due to abrasion and then due to adhesion. AISI 52100 is harder than AISI 51100 mainly due to presence of more chromium. Chromium has positive effect on hardenability and is an important alloying element in steels. It is present as a solid solution in steels. In addition to hardenability and solid solution effects, chromium forms several important chromium carbides that are necessary for wear resistance in steels [17]. Thus investigations from SEM also depict the sensitivity of face turning test method.

3.5.1. Surface profile investigations

The cross-sectional edge of the machined surface SEM image after the tool wear of 0.3mm is reached for both the samples is shown in Fig.8. The geometrical irregularities, feed marks and roughness depth of both the samples are correctly trapped in the Fig.8. The depth of profile as shown in this figure is more for AISI 51100 than AISI 52100 for the reasons explained in earlier section. The SEM investigations demonstrate the sensitivity and effectivity of face turning method at a greater depth.

4. Conclusions

The following results are presented from the current studies.

- The face turning method presented here for tool wear development of bearing steels represents the contemporary machining involving interrupted cuts and the development of tool wear and machinability aspects for the two work-materials is in line with traditional longitudinal turning method
- Behavior of wear mechanism of carbide tool for the said steels is in good agreement with the published literature. The face turning method demonstrated good sensitivity even for slight change in the percentage of chemical compositions of carbon, manganese, and chromium in these steels. The SEM and surface profile investigations reveal varying effect of alloying elements (namely chromium in AISI 52100) on machinability.
- The face turning method of machinability test can be used to monitor engineered changes in industries to improve machinability, as development of tool wear for the two work materials is in line with traditional machining methods.
- The machinability of AISI 51100 is better than AISI 52100, considering tool wear, surface finish and chip morphology.

- The tool life equations for the AISI 51100 and AISI 52100 are proposed and validated tool life lies within a permissible limit of ±5%.
- The face turning method is easy, short, effective and simple. It fulfills many of the criteria for the characterization of the machinability of steels.

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