Abstract

Grinding is generally termed as a finishing process and is predominantly used to produce components of desired size, shape and dimensional accuracy. The process of material removal in grinding is generally accomplished by using abrasive grit bonded in the form of wheel. The interaction of the abrasive grit with the surface involves high friction and rubbing thus leading to very high input energy. A major portion of this input energy is converted into heat and gets conducted into the work material causing various sorts of thermal damage on the ground material. Further, the application of conventional wheel like alumina imposes further danger of thermal damage due to its poor thermal conductivity. Thermal damage in grinding impairs the surface integrity of the ground workpiece in the form of surface burn, rehardening, residual tensile stresses of sub-surface layer and even micro cracks. The extent of thermal damage is related to the grinding force and temperature rise in the grinding zone. The level of heat generation and corresponding temperature rise depends not only on the grinding forces rather it is also associated with plastic deformation mechanism, work velocity and wheel speed. Till recently, characterization technique such as microscopy, microhardness were used to assess the subsurface alteration in the ground surface. But, these techniques involves use of acid etch and because of tighter environmental regulations its acquisition and disposal of the hazardous waste involves higher investment. Also, the tested samples attacked by acid etch need further heat treatment to avoid hydrogen embrittlement. The most important residual stress were measured using X-ray diffraction technique. However, these methods are very costly and time consuming and is applicable on very small areas in realistic application. Further, assessment of residual stress require removal of surface layer using electro polishing technique which makes the process destructive and rather more time consuming. Therefore, grinding industry still looks for an alternate option to characterize the ground surface so that it can reduce the cost of production without sacrificing the

product quality.

On the other hand, magnetic Barkhausen noise technique is gaining popularity in the characterization of surface integrity in various areas of manufacturing. It is a fast, reliable and practical method to detect high production volume, also it enables quick in-situ measurement as compared to X-ray diffraction. Magnetic Barkhausen noise (MBN) results owing to discontinuous changes in magnetization as moving domain wall under applied external field overcome microstructural features such as impurities, grain misorientation, crystal defects, grain boundaries and dislocations or even applied or residual stress as these acts as a local pinning sites and hinder the movement of domain wall and hence affects the Barkhausen noise.

The present study aims at exploring the capability of magnetic Barkhausen noise technique in the assessment of surface integrity upon grinding with emphasis on residual stress. The study utilized two work material one having higher magnetic response (unhardened steel) and the other having poor magnetic response (hardened steel).The selection of material is done keeping in view the application of material and also to explore the capability of Barkhausen noise technique under different material conditions. Hardening of the low carbon steel were accomplished using pack carburizing process. To perform pack carburizing samples were kept in a designed steel box and is surrounded by a mixture of (85%Charcoal + 15% $BaCO_3$) which is then heated to a temperature of 920°C and after that it is quenched in water. To remove any left out internal stresses the samples were tempered by heating it to a temperature of 300°C for a period of 45 minute followed by furnace cooling.

The grinding experiments were performed on the both work material with variation in downfeed, work velocity and grinding environment. This variation in process parameter induces different order of surface integrity on the ground surface. In order to have clear understanding of the surface integrity grinding indices like grinding force, specific grinding energy and temperature generated needs to be evaluated as these parameter predominately decides the level of surface integrity.

It has been observed that during grinding of unhardened as well as hardened steel the increase in downfeed and work velocity results into increase in tangential as well as normal grinding force under both condition of grinding (dry and wet). Moreover, decrease in specific grinding energy is observed with increase in downfeed as well as work velocity. The decrease in specific energy with increase in downfeed is due to increase in maximum uncut chip thickness which in turn reduces the undesirable rubbing and ploughing action during chip formation. Under similar grinding condition, wet grinding due to presence of effective cooling and lubrication shows smaller grinding zone temperature as compared to dry grinding condition.

Further, surface integrity were evaluated in terms of subsurface alternation in microstructure, microhardness measurement were performed to characterize the thermally soften and hardened layer. Metallographic study shows that no change in microstructure is observed even at highest value of downfeed as temperature generated in not enough to cause any alteration in the microstructure. High grinding zone temperature followed by rapid cooling induces varying degree of plastic deformation in the subsurface and thereby alters the micohardness of the ground sample. Microhardness of the ground surface increases with the increase in downfeed and work velocity irrespective of grinding condition (dry and wet).

Surface topography examination were carried out using scanning electron microscopy to understand the mechanism of material removal under different condition of process parameter and also it helps in prediction of surface roughness of the ground component which in turns helps in evaluating the performance of the ground surface component in real application as the presence of micron size notches on the ground surface leads to localized plastic strain field because of stress concentration at the tip of the notch under the action of applied stress and is highly susceptible to stress corrosion and fatigue cracks. Under identical grinding parameter condition lower surface roughness is achieved in case of hardened steel as compared to unhardened steel and is due to the fact that increasing material hardness restrict the formation of bulge on the side edges and hence provides better surface finish. The value of surface roughness in case of unhardened steel were lies in the range (0.426 -0.648 μm) whereas those for hardened steel it lies in the range (0.312-0.561 μm).

Lastly, the most important residual stress were examined using peak shift of the X-ray diffraction peak. Peak position of unground sample were taken as reference and thereafter peak position of ground surface were subtracted from the reference to estimate the peak shift. The presence of compressive residual stress reduces initial position of atom and thereby shift the peak position (2θ) to a higher value in accordance with Bragg's law. However, the presence of tensile residual stress increases the initial position of atom and thereby shift the peak position (2θ) to a lower value. A net reduction in peak position is observed throughout the grinding domain, as reduction in peak position due to presence of tensile residual stress is higher as compared to increase in peak position due to compressive residual stress. A linear correlation were observed between peak shift and grinding zone temperature indicating the effectiveness of the concept.

Magnetic Barkhausen noise parameter (root mean square) and average permeability at coercive point (maximum permeability) derived from hysteresis loop were utilized to characterize the effect of thermal damage on the magnetic response of the material. Firstly, the effect of surface roughness on the Barkhausen noise measurement is studied and it was observed that due to very small value of surface roughness it does not have any significant effect on the measurement and is therefore ignored.

A continuous increase in Barkhausen noise (root mean square) and average permeability value is observed with increase in downfeed and work velocity. This is due to the fact that increasing downfeed and work velocity results in higher rise in grinding zone temperature and thus leading to more thermal damage and consequently increases in BN (RMS) and average permeability is observed. Further, wet grinding samples due to lower thermal damage shows lower Barkhausen noise and average permeability value in comparison to dry grinding. In addition to the above, a linear correlation is observed between peak shift on account of residual stress and magnetic parameters (root mean square value and average permeability) in case of unhardened steel. The correlation coefficient between peak shift and root mean square value is observed to be ~0.9707 whereas those between peak shift and average permeability is observed to be ~ 0.951 in case of unhardened steel. However, due to poor magnetic response of the hardened steel, root mean square value of the Barkhausen noise did not provide enough sensitivity towards the change in peak shift although the average permeability still shows a linear correlation with the peak shift. The correlation coefficient between peak shift and average permeability is observed to be ~ 0.8149. Hence, under poor magnetic response average permeability can be used as a magnetic parameter to monitor the residual stress state of the ground work material.