International Journal of Innovative Research and Review ISSN: 2347 – 4424 (Online)
An Online International Journal Available at http://www.cibtech.org/jirr.htm
2013 Vol. 1 (2) October-December, pp.1-6 /Graceson
Research Article

FABRICATION OF A GRADIENT STRUCTURED SURFACE LAYER ON BULK ALUMINIUM BY MACHINING INDUCED PLASTIC DEFORMATION

[*]Graceson D.N.
Mechanical Engineer, Kanyakumari District, Tamilnadu, India
**Author for Correspondence*

ABSTRACT
A gradient microstructure is obtained on the surface of aluminium alloy AA6063 by machining induced plastic deformation. A high speed steel cutting tool is modified to have blunt tip and a process similar to turning operation is done but without metal removal. The experimental evidences indicate that, after the machining induced plastic deformation process is done, there is a significant improvement in the refinement of the grains in the topmost surface layer compared to the lower layers. The hardness of the surface is enhanced significantly as compared to unprocessed sample. Work hardening and reduction in grain size was the reason for increase in hardness. The tool tip radius and the depth of cut were varied and the results indicate the strong dependence of process parameters on hardness. Thus aluminium alloy AA6063 was processed by machining induced plastic deformation to enhance hardness without changing chemical composition as well as a gradient microstructure at the surface.

Key Words: *Gradient Structure, Machining Induced Plastic Deformation (MIPD), Aluminium Alloy*

INTRODUCTION
Mechanical plastic deformation-induced grain refinement in bulk materials for improvement of material properties has been widely researched in recent years. Such processing increases strength of the material but with the loss of ductility. It is a fact that failures of metallic parts are initiated from their surface due to fatigue. Hence the surface properties of the materials have to be improved to increase their use-life span. Surface nanocrystallization is one such technique that enhances surface properties by refining grains in surface layers alone to the nanometer scale (Li *et al.*, 2008).

Several techniques of mechanical plastic deformation on metallic surface to synthesize a gradient structured layer have evolved in the past decade. They were either found to be complicated or were not able to achieve an optimized surface layer.

The process termed, surface mechanical grinding treatment which has evolved very recently is found to be simple and has achieved optimized results of synthesizing gradient structured surface layer. The plastic deformation induced on the surface of metals plays a key role in improving the surface hardness of the work material and also refines the grain size of the surface layers to nano scale. Surface nanocrystallization is a new topic proposed in the recent years, which is known as one of the important methods to modify surface physical, chemical and mechanical properties and prolong the use-life of machinery parts (Hui-qiong and Xin-min, 2006).

This may have wide spread application in the industry where a huge sum is spend on the fatigue life improvement of the materials. There are various methods to fabricate the gradient structured surface layer by means of mechanical plastic deformation. A few of the recorded methods may be, Surface mechanical attrition treatment (SMAT) (Jiang *et al.,* 2009), Circulation rolling plastic deformation (CRPD) (Xin-min *et al.,* 2004), Ultrasonic shot peening (USSP) (Tao *et al.,* 1999), High energy shot peening (HESP) (Wang *et al.,* 2006), High velocity oxygen-fuel flame supersonic micro particles bombarding (HVOF-SMB) (Kaidong *et al.,* 2009), Surface mechanical grinding treatment (SMGT) (Li *et al.,* 2008), Sand blasting and annealing process (Guan *et al.,* 2005). This paper presents a process where a blunt cutting tool is used to compress a cylindrical sample to produce gradient microstructure on its surface without metal removal.

International Journal of Innovative Research and Review ISSN: 2347 – 4424 (Online)
An Online International Journal Available at http://www.cibtech.org/jirr.htm
2013 Vol. 1 (2) October-December, pp.1-6 /Graceson

MATERIALS AND METHODS

Experimental Work

The experimental work is done on the aluminium alloy – AA6063. The material used in this process is in the form of a cylindrical rod of 300mm length and 80 mm diameter. The tool used in the process is a HSS tool bit. The tool is modified to have a larger tip radius such that it remains as a blunt or hemispherical tip as shown in Figure 1.1.

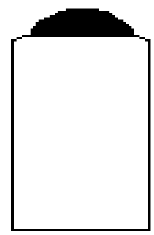


Figure 1.1 (a): Cutting tool with blunt tip

The MIPD was done on an ordinary conventional lathe (Make: Mihir industries). The HSS tool was set on the tool post just as it is done for ordinary cutting processes (Figure 1.2). Normal conventional coolant (servo-cut oil) was used to cool down the tool and the work piece in the machining process.

Figure 1.2: Experimental set-up done for MIPD

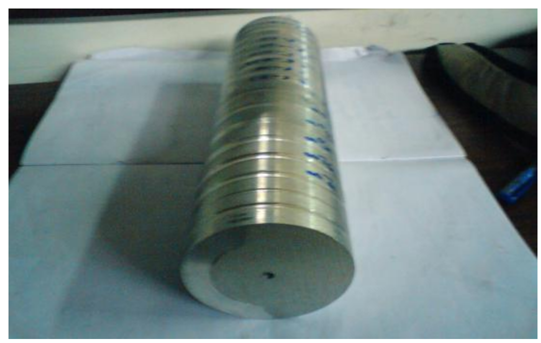


Figure 1.3: Photograph of the MIPD component

The work piece was made to rotate at a speed of 650 rpm and the blunted tool was moved over it for a span of 0.8mm. The depth of cut was varied as 0.15mm, 0.25mm, 0.5mm, 1mm and 1.25mm respectively for different tool tip radius. An unprocessed gap of approximately 2.4mm was maintained after every feed of 0.8mm given for different depth of cuts as indicated in figure 1.3. The process is very much similar to the normal turning process except for the suppression of the formation of chips due to the blunt tool tip. The process involving coolant was carried out using different process parameters which were the radius of the tool tip, t_p and depth of cut, D_c.

The test for hardness on the surface was done using the Rockwell hardness tester (Make: Southern Metallurgical co). The hardness was checked in B - scale which is primarily used for aluminium alloys. The microstructure analysis was done in the cross sections of the worked sample and was studied for variations in the grain size in the surface layer using an Optical Microscope. The micro-hardness was also taken from the edge to core along the surface layers using the Vickers's hardness tester. The surface studied for grain refinement was first polished using emery sheets of increasing grit sizes and then given a fine polish using alumina paste on a clothing disk polisher. Keller's reagent (95 ml Water, 2.5 ml Nitric Acid, and 1.5 ml Hydrochloric Acid, 1ml Hydrofluoric Acid) was used to etch the polished surface.

Research Article

RESULTS AND DISCUSSION

Blunting of cutting tool tip and higher depth of cut successfully eliminated chip removal and created plastically deformed layer on the surface. As the heat generated was high compared to normal turning operation, the use of coolant was essential. The amount of compression followed by plastic deformation was measured from decrease in diameter of specimen after MIPD. There seems to be strong dependence of depth of compression and tool tip radius on hardness of the sample as shown in table 5.1.When the depth of cut was increased the obtained surface seemed to be very rough with minimal removal of metallic particles (Figure 3.1). This also occurred when the coolant supply was not constant. Better surface plastic deformation was achieved with reduced surface roughness for larger radii tool tip. This may be attributed to the increase in the contact area of the tool tip.

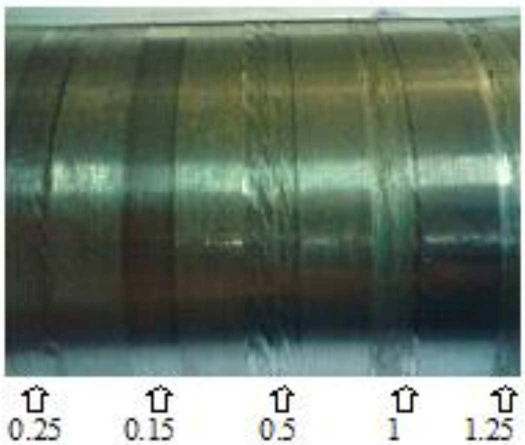


Figure 3.1: Figure of processed areas for different depth of cut

The surface roughness was observed to reduce with increase in tool tip radius. Moreover the hardness of the surface at higher depth of cut for different tool tip radius shows increasing values (Figure 3.2). The increase in the value of hardness with increase in depth of cut may be due to the reduction in the grain size due to severe plastic deformation that occurred in the surface and sub surface.

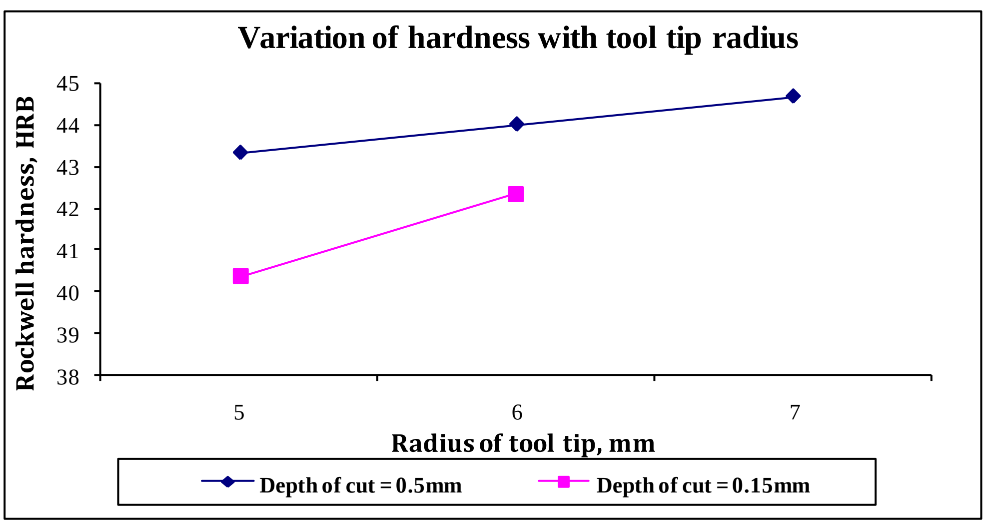


Figure 3.2: Variation of hardness for different tool tip radius

The decrease in diameter seems to increase with increase in tool tip radius as shown in Figure 3.4. This might be large contact area effectively deforming the surface beneath. All MIPD processed sample show higher hardness than unprocessed sample (40 HRB). This is due to the compressive stress, as the tool penetrates deep into the surface layer and deforms the grains downward in the sliding direction resulting in the reduction of original grain size to 1 - 2 µm (Figure 3.5).

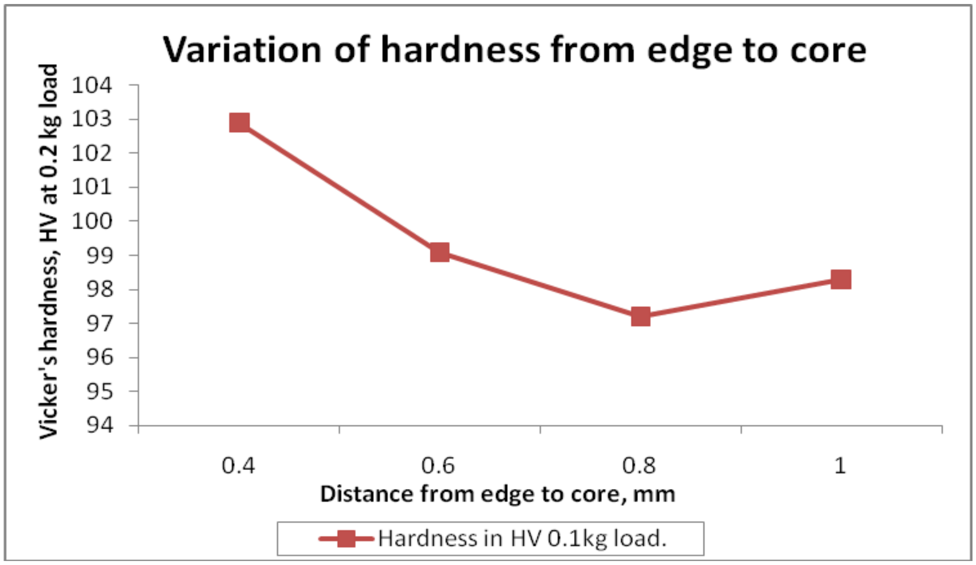


Figure 3.3: Variation of hardness from edge to core

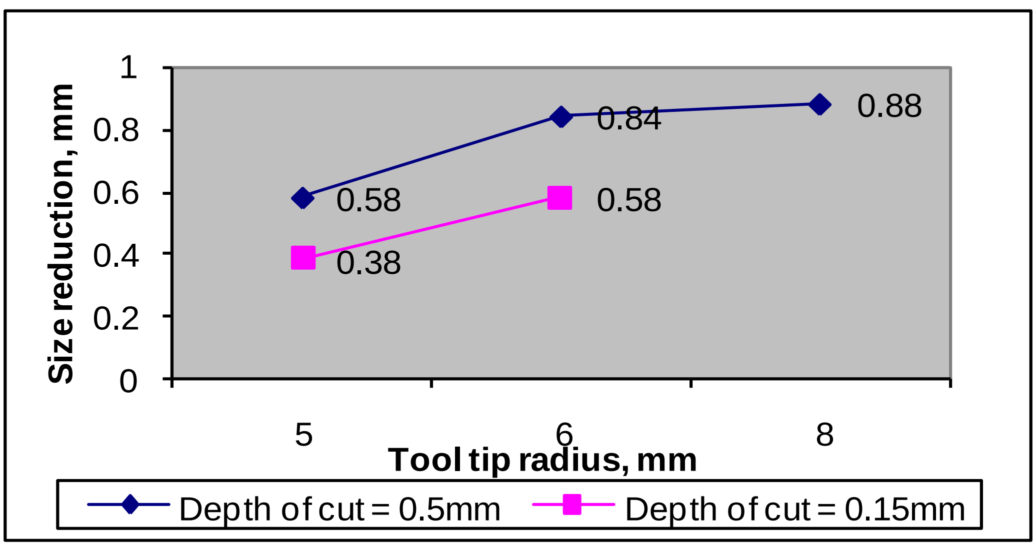


Figure 3.4: Variation of hardness from edge to core

The micro-hardness was taken on the work piece dissected along the longitudinal direction. The hardness values were found to decrease from 102 – 89 HV and so on along the edge to the core and also the deformed portion show high hardness than inner core as shown in Figure 3.3.

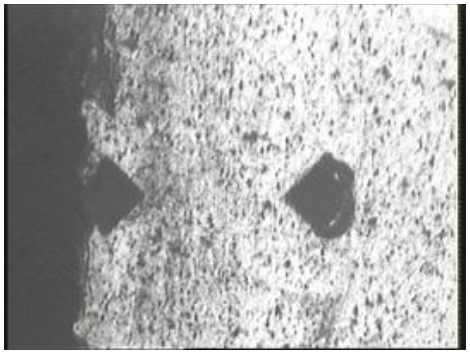
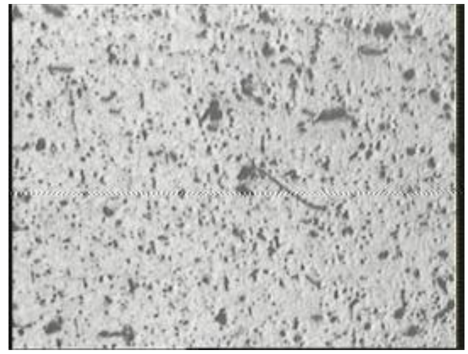
(a)  (b) 

Figure 3.5: Microscopic images at the
(a) Edge and magnification: 150X **(b) Core of the work piece**
Etchant: Keller's Solution

The specimen was prepared in longitudinal section so as to examine grains close to MIPD area. The banding of the grains at the edge was due to cold working and it can be noted from Figure (3.5 a). Some fine particles of Mg2 Si are found to be dispersed in a matrix of aluminium solid solution.

Conclusion

The Machining Induced Plastic Deformation process was successfully done on aluminium alloy AA 6063 by modified turning operation. The influence of process parameters radius of tool tip and depth of cut on surface hardness was studied. The hardness seems to increase with decrease in tool tip radius and also increase in the depth of cut. The microstructure results indicate the reduction in grain size near the surface compared to the core which arises due to plastic deformation. The surface roughness was observed to reduce with increase in tool tip radius.

AKNOWLEDGEMENT

I acknowledge the Central Workshop, Department of Mechanical Engineering, Anna University Chennai, CEG Campus, India, for the experimental assistance. The author also wishes to acknowledge all his friends who had helped in shaping up this project.

REFERENCES

Guan XS, Dong ZF and Li DY (2005). Surface nanocrystallization by sandblasting and annealing for improved mechanical and tribological properties. *Nanotechnology* **16** 2963-2971.

Hui-qiong YE and Xin-min FAN (2006). Surface nanocrystallization of 7A04 aluminium alloy induced by circulation rolling plastic deformation. *Transactions of Nonferrous Metals Society of China* **16**(2) 656-660.

Jiangwei Ren, Aidang Shan, Junbao Zhang, Hongwei Song and Junliang Liu (2006). Surface nanocrystallization of Ni3Al by surface mechanical attrition treatment. *Materials Letters* **60** 17-18 2076-2079.

Jianhua Jiang, Jiangwei Ren, Aidang Shan, Junliang Liu and Hongwei (2009). Surface nanocrystallization of Ni3Al by surface mechanical attrition treatment. *Materials Science and Engineering* **520** 80-89.

Kaidong Xu, Aihua Wang, Yang Wang, Xuanpu Dong, Xianglin Zhang and Zaowen (2009). Surface nanocrystallization mechanism of a rare earth magnesium alloy induced by HVOF supersonic micro particles bombarding. *Applied Surface Science* **256** 619-626.

Li WL, Tao NR and Lu K (2008). Fabrication of a gradient nano-micro-structured surface layer on bulk copper by means of a surface mechanical grinding treatment. *Scripta Materialia* **59** 546–549.

Research Article

Liu G, Lu J and Lu K (2000). Surface nanocrystallization of 316L stainless steel induced by ultrasonic shot peening. *Materials Science and Engineering* **286**(1) 91-95.

Tao NR, Sui ML, Lu J and Lua K (1999). Surface nanocrystallization of iron induced by Ultrasonic shot peening. *Nanostructured Materials* **11**(4) 433-440.

Tiansheng Wang, Jinku Yu and Bingfeng Dong (2006). Surface nanocrystallization induced by shot peening and its effect on corrosion resistance of 1Cr18Ni9Ti stainless steel. *Surface and Coatings Technology* **200**(16-17) 4777-4781.

Xin-min FAN, Lin ZHU and Jie-wen HUANG (2004). Surface nanocrystallization of Ti6A14V induced by circulation rolling plastic deformation. *Transactions of Nonferrous Metals Society of China* **14**(s2) 190-192.

Ying-hui Wei, Bao-sheng Liu, Li-feng Hou, Bing-she Xu and Gang Liu (2008). Characterization and properties of nanocrystalline surface layer in Mg alloy induced by surface mechanical attrition treatment. *Journal of Alloys and Compounds* **452**(2) 336-342.