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(Full length research article)

Study of Roller Burnishing Process of Polymer Silica Hybrid Nanocomposites

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Abstract

Roller Burnishing is a cold working process which produces a fine surface finish by the planetary rotation of hardened roils over a bored or turned metal surface. Roller Burnishing involves cold working the surface of the work piece to improve surface structure and finish as well as micro-hardness in a single process, with reduction in tool set-up time that is difficult in conventional processes. The increase in the surface strength mainly improves the fatigue behavior of work-piece under dynamic load. Of Late, the properties of composites are improved using fillers in the size of nano level as reinforcement. Fillers like nanosilica provide better performance with some treatment, may be chemical modification to the surface, than natural structure. In this work, nanosilica is modified by 3-aminopropyltriethoxysilane and prepares the hybrid nanocomposite laminates by hand lay-up method. Machining of polymer hybrid nanocomposites is not recommended. A low surface roughness and high hardness was obtained for the same spindle rotation, feed rate and depth of penetration by the burnishing process.

Keywords: *Roller burnishing, surface roughness, hardness, polymer hybrid nanocomposites*

1. 1 Introduction

Roller Burnishing is a Super-finishing process. It is a Cold Working process that produces a fine surface finish by the planetary rotation of hardened rollers over a bored or turned metal surface. Since all machined surfaces consist of a series of peaks and valleys of irregular height and spacing, the plastic deformation created by roller burnishing is a displacement of the material in the peaks which cold flows under pressure into the valleys. The result is a mirror-like finish with a tough, work hardened, wear and corrosion resistant surface [1].

As compared with roller burnishing, ball burnishing is more advantageous for cylindrical component, because the ball can easily move in forward and backward direction along the surface direction or parallel to the axis of the cylindrical component. It will reduce the production time and more accuracy can be maintained by turning and ball burnishing process (simultaneous operation of turning and burnishing). For flat surfaces, the roller burnishing is more suitable compared with ball burnishing.

Experimental work based on 23 factorial designs has been carried out on Turn master T-40 lathe to establish the effect of the combined turning and two ball-burnishing parameters on the surface roughness and surface hardness of aluminum specimen. A pre-machined surface roughness of 0.63-0.75 μm (by turning) can be finished up to 0.11 μm (by burnishing) and improved micro hardness is obtained [2].

Ompraksh et al [3] studied the influence of important ball burnishing parameters on surface finish, depth of work hardening, microstructure and the fatigue life. The burnishing parameters considered were speed, feed and number of passes. It was found that the surface roughness improved initially with an increase in these parameters. After a certain stage, the surface finish deteriorated and fatigue life decreased.

Hssan and Ebied [4] conducted test on brass material on lathe machine. Two burnishing parameters were considered namely, burnishing force and number of the passes, while other burnishing parameters were kept constant. The result was improved fatigue life.

Ingole and Bahedwar [5] studied the effect of lubricants on the surface finish of En8 specimens. Using 23 factorial designs, in terms of surface roughness, model equations were developed. The burnishing parameters considered were speed, feed and force and the other parameters were constant.

Siva Prasad and Kotiveerachari [6] conducted experiment on roller burnishing on aluminum specimens (FIC, IS 734-1967). It was observed that there was a significant effect of force on surface finish as compared

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with speed and feed. All the above information is pertaining to the separate turning and single ball burnishing process.

Jawalkar [7] studies the surface roughness and micro-hardness are the main response variables and the process parameters under consideration are spindle speed, tool-feed, number of passes and lubricants.

Experiments were carried to establish the effect of roller burnishing tool parameters (speed, depth of penetration, burnishing time and initial hardness of five different work piece materials ('Al' and brass of various compositions) on surface hardness, out of roundness and the change in work-piece diameter. The results showed that depth of penetration and burnishing time are the most important parameters controlling the values. The out of roundness increases with a decrease in initial hardness of work-piece material [8] (Fattouh et al., 1988).

The micro-hardness is reported to increase in the burnishing process for En-8 materials (Jawalkar and Walia, 2008) [9]. Roller burnishing being a specialized super finishing process, as in any such processes, it improves the surface finish to a very high degree inherently (Kumar 2006 – 2007, [10]; SHiou and Chang, 2008), [11].

A.M. Hassan and A.M. Maqableh have identified that reduction in the surface roughness and the increase in hardness with increase in the initial hardness of the burnished work pieces [12]. S. Thamizhmanii et al [13] found that surface roughness improves by high spindle speeds, feed rate and depth of penetration on non-ferrous metals like aluminum, copper and brass materials. The heat generated at the deformation zone and friction zones over heat the tool and the work piece [14]. Most of the published work on burnishing was concerned with the effect of the burnishing process on surface roughness and surface hardness [15].

Thamizhmnaii et al reported that the roller burnishing is a very useful process to improve surface roughness and hardness. It will help to impart compressive stress and fatigue life can also be improved. The titanium alloy is a difficult to machine material for burnishing. A low surface roughness and high hardness was obtained for the same spindle rotation, feed rate and depth of penetration [16].

Most of the industrial and domestic operations need size reduction in one form or the other. Crushing, grinding and cuttings are the primary operations for size reduction [17]. Ball mill is the generally used mill used for the preparation of small quantities of materials among many available types.

The burnishing process can be achieved by applying a highly polished and hard ball (or roller) onto a metallic surface under pressure. The applied burnishing pressure exceeding the yield strength of the material causes the peaks of the metallic surface to spread out permanently and fill the valleys. The schematic representation Micro view of burnishing process is shown in figure1.

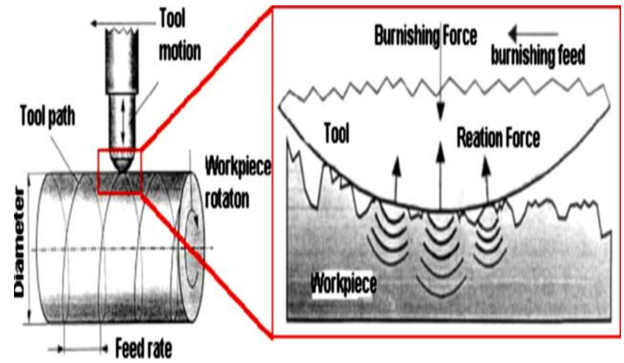

Figure 1 Schematic representation (Micro view) of burnishing process

The surface of the material will be smoothed out and because of the plastic deformation the surface becomes work hardened, the material being left with a residual stress distribution that is compressive on the surface. The changes in surface characteristics due to burnishing will cause improvements in surface hardness, wear resistance, fatigue resistance, yield and tensile strength and corrosion resistance. It can be seen from this Figure-1 that the roller rotates by the effect of frictional engagement between the surfaces of the roller and of the work piece. This process flattens the roughness peaks by causing plastic flow of the metal. It not only improves surface finish but also imposes favorable compressive residual stresses and raises hardness in functional surfaces, which can lead to long fatigue life and high load bearing capacity, surface finish, hardness, wear-resistance, and corrosion resistance.

1.2 Roller burnishing

Roller burnishing is a super-finishing process. It is a cold working process by which improvement in surface finish; dimensional accurate and work hardening can be affected without removing metal. It is a finishing operation and is normally done on parts which are turned, bored, reamed or ground. Any ductile or malleable material with hardness less than 40 HRc can be successfully burnished.

Roller burnishing is a cold working process which produces a fine surface finish by the planetary rotation of hardened rollers over bored or turned metal surface. Hand lay-up Polymer composite material surfaces consist of a series of peaks and valleys of irregular height and spacing. The plastic deformation created by roller burnishing is a displacement of the material in the peaks which cold flours under pressure into the valleys. The result is a mirror like finish with a tough, work-hardened, wear and corrosion resistant. H-Type roller burnishing tool used for present study is shown in figure 2 and working method of roller burnishing on irregular work piece is shown in figure3.

Instead of reaming, roller burnishing is sometimes used for finishing reaming or boring since roller burnishing improves the surface hardness, metals that work-hardness rapidly must be at a lower hardness before roller burnishing is done.

In this paper, a systematic study of burnishing parameters on surface finish and surface hardness of hybrid nanomaterial is presented by using combined turning and two ball burnishing process. Three burnishing parameters are considered here, namely, burnishing force, speed and feed. The average size of nanosilica is 57nm, prepared by ball mill shown in figure 4.

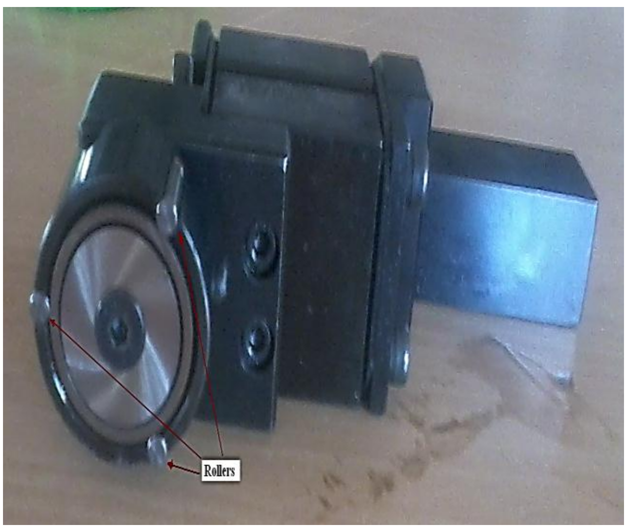

Figure 2 H-Type roller burnishing tool used in the study

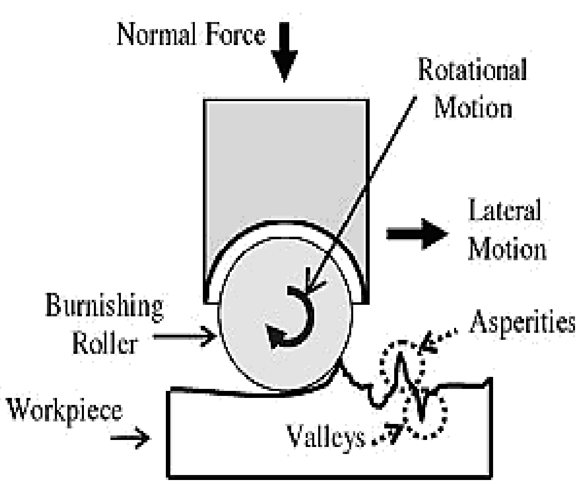

Figure 3 working method of roller burnishing on irregular work piece

Figure 4 ball mill for the synthesis of nanosilica

2.1 Materials Used for preparation of nanocomposites

- The matrix used in the present study was an Diglycidyl ether of Bisphenol-A an di-functional epoxy resin (LY556) system from ECMAS Pvt. Ltd, Hyderabad, an Tri-ethylene tetra amine (TETA) araldite hardener (HY951) was mixed in proportions of 100:12 from ECMAS Pvt. Ltd, Hyderabad.
- The reinforcing nanosilica prepared by ballmilling process and these are organically modified with a 3-aminopropyltriethoxysilane by sonication process.
- Woven roving glass fiber mat (WRM) of 610gsm is taken from Saint-Gobain-Vetrotex India Ltd.
- A 3-aminopropyltriethoxysilane was used to disperse nanosilica in an epoxy matrix.

The composite is prepared by hand lay-up method with these materials for the experimentation

3.1 Results and discussion

The percentage improvement of Roughness results before and after burnishing process shown that at feed 0.1 and along speeds(14.15, 22.57, 35.35, 55.46) is 7.5, 34.88, 4.76 and 19.09. At 22.57 m/min and 55.46 m/min speed material got good surface finish rather than other speeds. At feed 0.2 along speeds(14.15, 22.57, 35.35, 55.46) is 7.89, 4.03, 13.85 and 12.58. Roughness of the material before and after burnishing at feed 0.1 and 0.2 shown in figure5 and figure 6.

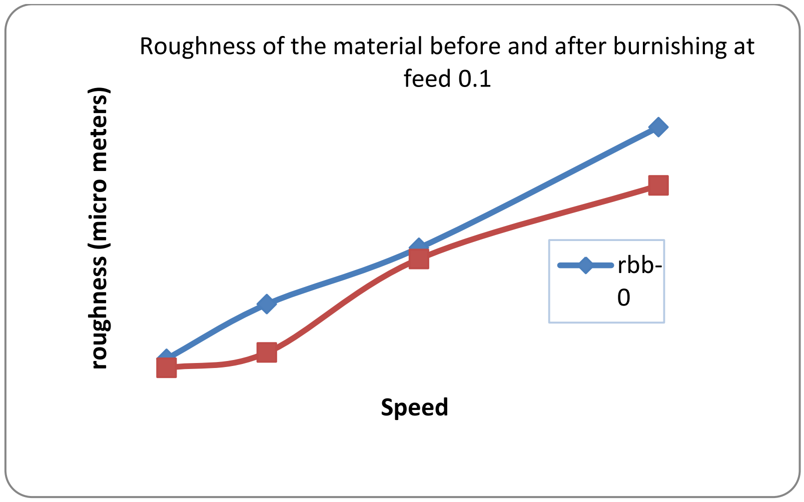

Figure 5 Roughness of the material before and after burnishing at feed 0.1mm

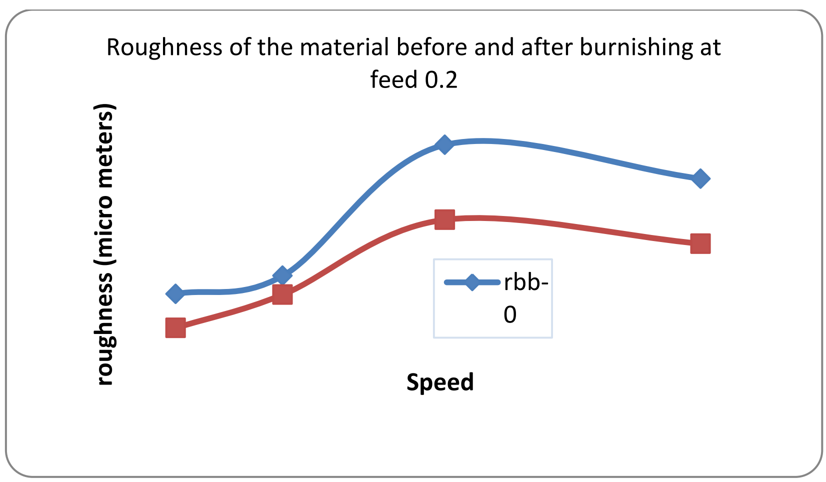

Figure 6 Roughness of the material before and after burnishing at feed 0.2mm

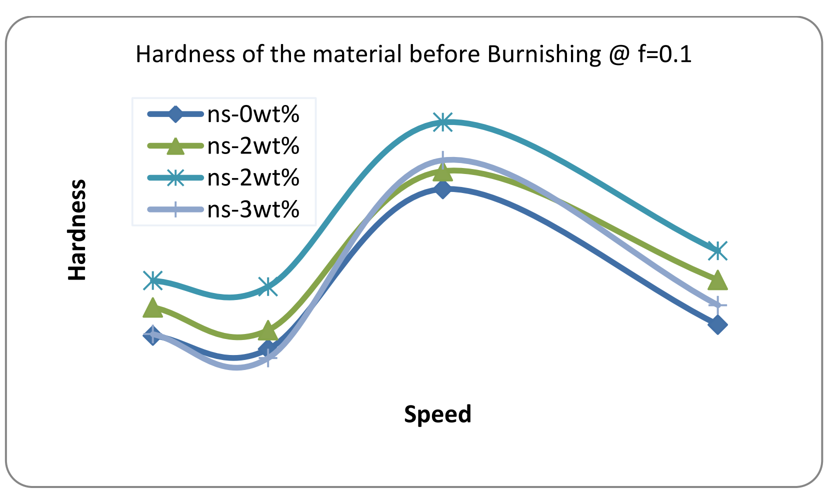

Figure 7 Hardness of the material before burnishing at feed 0.1mm

Hardness of the material is improved by reinforcing the nanosilica in polymer composites. Almost all the casess in the study are identified maximum hardness at 2wt% nanosilica reinforcement both before and after burnishing process. Percentage improvement of hardness is given in table1. Hardness of the material before and after burnishing are shown in figures 7 to 10 at various speed and feeds. Better improvements are identified in hardness with nanoreinforcements after burnishing.

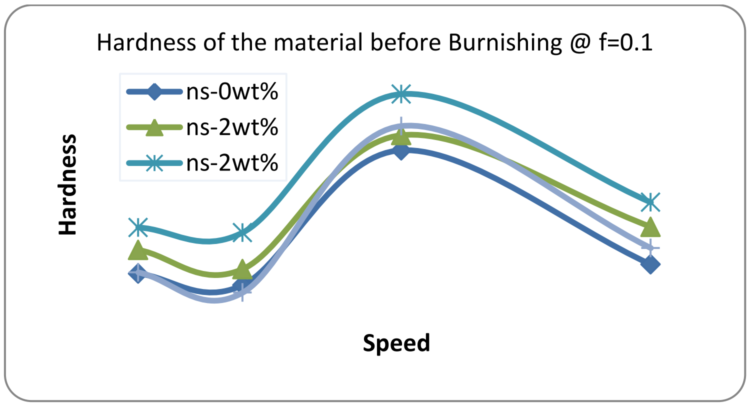

Figure 7 Hardness of the material before burnishing at feed 0.1mm

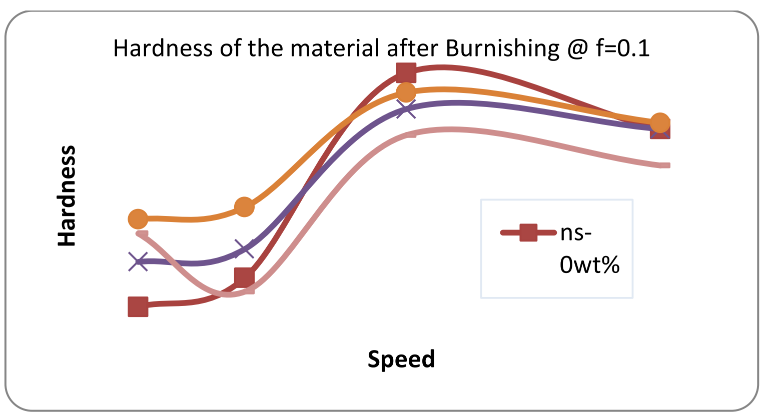

Figure 8 Hardness of the material after burnishing at feed 0.1mm

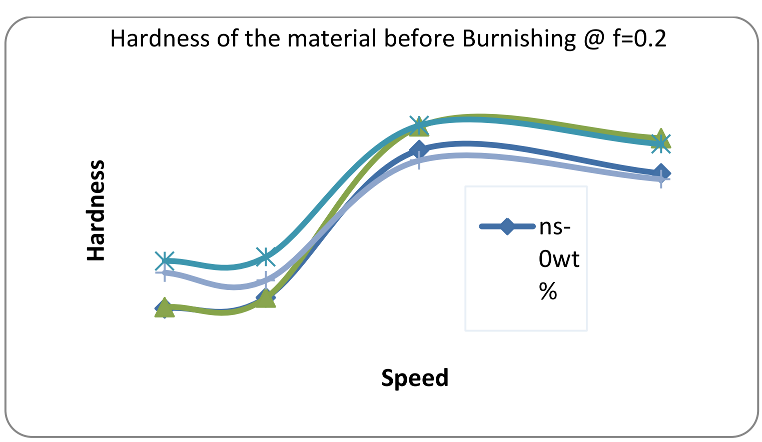

Figure 9 Hardness of the material before burnishing at feed 0.2mm

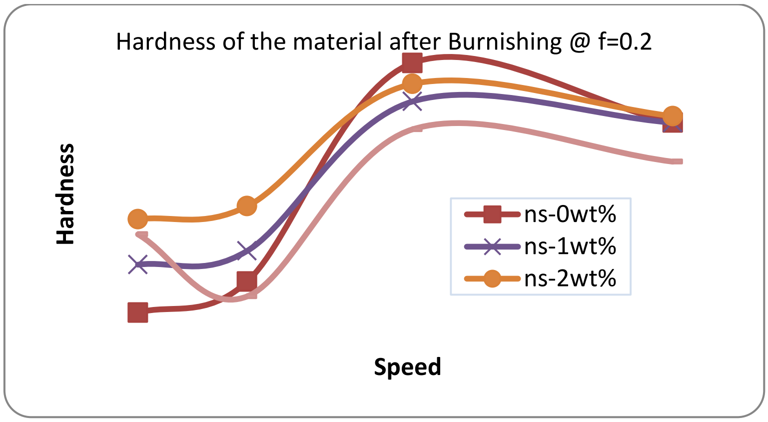

Figure 10 Hardness of the material after burnishing at feed 0.2mm

Table1 Percentage improvement of Hardness with pure and nanosilica reinforced polymer hybrid nanocomposites before and after burnishing process

% Improvement of hardness with pure composite (before and after burnishing)					
S.No	Feed	Speed	Wt % of nanosilica	Before Burnishing	After Burnishing
1	0.1	14.15	1	3.24	21.96
2	0.1	14.15	2	6.29	28.16
3	0.1	14.15	3	0.16	18.82
4	0.1	22.57	1	2.22	26.96
5	0.1	22.57	2	7.28	41.51
6	0.1	22.57	3	-1.04	31.36
7	0.1	35.35	1	1.76	12.56
8	0.1	35.35	2	6.56	17.89
9	0.1	35.35	3	2.83	12.67
10	0.1	55.46	1	5.08	22.95
11	0.1	55.46	2	8.37	21.54
12	0.1	55.46	3	2.22	14.62
13	0.2	14.15	1	0.34	21.48
14	0.2	14.15	2	13.91	31.79
15	0.2	14.15	3	10.48	28.35
16	0.2	22.57	1	-0.3	20.75
17	0.2	22.57	2	11.63	30.58
18	0.2	22.57	3	4.96	10.76
19	0.2	35.35	1	4.69	8.11
20	0.2	35.35	2	4.92	10.83
21	0.2	35.35	3	-2.11	3.8
22	0.2	55.46	1	7.38	9.98
23	0.2	55.46	2	6.15	11.04
24	0.2	55.46	3	-1.23	3.66

From the experimental results we can observe the following results

1. Increase in burnishing speed up to about 35.34 m/min leads to a decrease in mean roughness. With a further increase in burnishing speed mean roughness gradually increases.
2. It is better to select low speeds because the deforming action of the burnishing tool is greater and metal flow is regular at low speed.
3. The increase in burnishing depth of penetration causes an increase in the amount of surface deformation as the tool passes along the surface of the work piece. This will lead to an increase in the work hardening of the surface layers, which have been affected by plastic deformation, so that surface micro hardness will increase via the increase in burnishing depth of penetration.

Conclusion

The results of the burnishing process are quite complicated, and many factors affect its results. How to find the optimal burnishing conditions and how to control the results are very important for industry. From this study, the following conclusions can be drawn

- It is better to select low speeds because the deforming action of the burnishing tool is greater and metal flow is regular at low speed.
- The recommended spindle speeds that result in high surface micro hardness and good surface finish are in the range from 22.57m/min.
- Nanosilica with 2wt% of reinforcement will gives better hardness properties in polymer hybrid nanocomposites.

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References

1. www.mech-india.com/faq.htm
2. www.brightburnishingtools.com/burnishingtechnology.htm
3. U M Shirsat & B B Ahuja, (2004), Parametric analysis of combined turning and ball burnishing process, *Indian Journal of Engineering & Materials Sciences*, vol. 11, pp.391-396.
4. G Omprakash, Jayabalan, A S Raju, (1981), *Proc fourth ISME Conf Mech Eng*, Roorkee, 155.
5. A M Hassan & A M Ebied, (1998), *J Inst Eng (I)*, vol.79, pp.97-105.
6. M W Ingole & A S Bahedwar, (2002), *J Inst Eng (I),* vol. 83, pp.69-76.
7. T Siva Prasad, B Kotiveerachari, (1988), *J Inst Eng (I),* vol. 69, pp.55-62.
8. C. S. Jawalkar and R. S. Walia (2009), Study of roller burnishing process on En-8 specimens using design of experiments, *Journal of Mechanical Engineering Research* vol. 1, Issue. 1, pp.038-045.
9. M Fattouh, MH El-Axir, SM Serage (1988) ,Investigations into the burnishing of external cylindrical surfaces of 70/30 Cu-Zn alloy, *Wear*, Vol. 127, pp.113-137
10. CS Jawalkar, RS Walia (2008), Experimental Investigations into Microhardness in Roller Burnishing processes on EN-8 and Aluminium Specimens using design of experiments, *Proc. of the 2nd Intl & 23rd AIMTDR Conf.*, IIT Chennai, pp. 733-739
11. S Kumar (2006-07), Study of Surface Integrity of Roller Burnished Surfaces, *Work on M.E. Thesis, Production Engineering Department*, Punjab Engineering College, Chandigarh, India.
12. F J SHiou, CH Chang (2008), Ultra precision surface finish of NAK 80 mould tool steel using sequential ball burnishing and ball polishing, *Journal Mater, Process. Tech*. vol. 201(1-3-26), pp.554-559.
13. A.M. Hassan, A.M.Maqableh, (2000), The effect of initial burnishing parameters on non-ferrous components, *Journal of Materials Processing Technology*, vol 102, pp.115-121.
14. S. Thamizhmanii, B. Saparudin, S. Hasan, (2007), A study of multi-roller burnishing on non-ferrous metals, *Jounal of Achivements in Mechanical and Manufacturing Engineering*, vol. 22, issue 2, pp. 95-98.
15. E.M. Rubio, A.M. Camacho, J.M. Snchez-Sola, M. Marcos, (2006), Chip arrangement in the dry cutting of aluminium alloys, *Journal of Achievements in Materials and Manufacturing Engineering*, vol. 19, pp.11-18.
16. J.F. Kahles, M. Field, D. Eylon, F.H. Froes, (1985), *Journal Metallurgy*, vol. 37, Issue 4, pp.27-35.
17. S. Thamizhmnaii, B. Bin Omar, S. Saparudin, S. Hasan, (2008), Surface roughness investigation and hardness by burnishing on titanium alloy, *J of Achievements in Materials and Manufacturing Engineering*, vol. 28, issue 2, pp. 139-142.
18. John Alden, John Hall, (2007), *Design aspects of large ball mills*, vol. 10, pp.31-38.