A Review - Experimental Investigation on ball burnishing process of surfaces produced by thermal spray

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ABSTRACT

Flame sprayed thermal coating is approach to improve wear as well as overall life of workpiece. but this type of coating have inherent irregularities and defects like micro cracks that cause energy dissipation and surface damage. To Overcome These Complications, Conventional Finishing Processed Such As Grinding have been traditionally employed. However, since this methods essentially depend on chip removal to attain the desired surface finish, these machining chips may cause further surface abrasion and geometric tolerance problem especially if conducted by unskilled operators. Burnishing is a cold forming process in which initial asperities are compressed beyond yield strength against load. The surface of the material is progressively compressed, then plasticized as resultant stresses reach a steady maximum value and finally wiped a superfine finish. This paper is deals with the thermal spray flame coating is used to increase wear as well as overall life of component and post machined by ball burnishing to achieve smaller surface roughness value and improving surface hardness.

Keyword : - *Flame thermal spray coating, Grinding, Surface roughness, Surface hardness, Ball burnishing*

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1. INTRODUCTION TO THERMAL SPRAY

Thermal spraying is widely used to provide corrosion protection to ferrous metals or to change the surface properties of the sprayed items, such as improve the wear resistance, surface hardness or thermal conductivity.

Thermal spraying, a technique of coating processes in which finely divided metallic or nonmetallic materials are deposited in a molten or semi molten condition to form a coating. The coating material may be in the form of powder, ceramic-rod, wire, or molten materials.

Thermal spray is a generic term for a technique of coating processes where the coating is deposited on a prepared substrate by applying a stream of particles, metallic or nonmetallic, which flatten more or less forming platelets, called splats, with several layers of these splats forming the coating. Upon impact a bond forms with the surface, with subsequent particles causing a build-up of the coating to its final improved thickness. Figure1 illustrates the principle of the Thermal spray process.

Process for thermal spray technique is as follow:

- Substrate pre-treatment,
- Solidification and shrinkage of spray particles,
- Phase transformation during temperature changes,
- Metal striking on subtract,
- Heat transfer between coating and substrate towards thermal equilibrium and
- Heat transfer to the environment during cooling of the subtract.

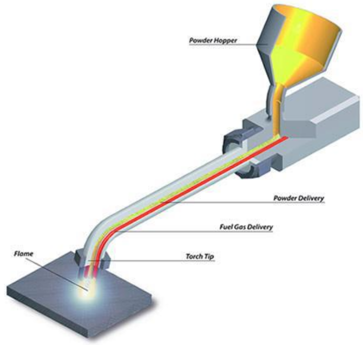

Figure 1 : Thermal Spray Technique – Flame type

Figure 2 : Flame type Ewac Superjet evtalloy gun

1.1 METHODOLOGY FOR THERMAL SPRAY

The flame spray process uses the combustion of fuel to create a flame and thus the heat source and accelerating force for the deposition process term as a thermal spray technique. Flame temperature is controlled by the mix of fuel gasses and oxygen[1]. The pressure regulator is given on flame gun or torch to control pressure of oxy-acetylene. The most recent advance in thermal spraying is flame spraying In these processes a fuel is mixed with oxygen in a combustion chamber, the mix is ignited and the combustion gasses are accelerated down a long convergent divergent nozzle. The nozzle design creates a supersonic combustion jet into which powder can be injected efficiently. The benefits of this process are that the particle velocity on impact is very very high. The resultant coatings are generally very dense, adherent and contain very few oxides. These processes are suited to spraying high quality metallic coatings.
This process consists of generating an energetic gas flow with an appropriate torch or gun, generally flowing into the open-air environment. Thermal spray torches or guns are devices for feeding, accelerating, heating, and directing the flow of a thermal spray material toward the substrate. The feedstock is introduced as powder in case of flame thermal spray technique. The powders are introduced into the jet of hot gases, are accelerated but not necessarily melted before impacting on the substrate (depending on their size and trajectories). Most spray processes operate in air as the surrounding atmosphere, resulting in some coating oxidation, which is drastically increasing with the temperature of the sprayed particles.

Flame Spray torches that work at atmospheric pressure using mostly oxyacetylene mixtures achieving combustion temperatures up to about 2200˚c. Sprayed materials are introduced axially. Flame velocities below 100 m/s characterize this process, and powders are used.

Table 1 : Deposition parameters for flame spray coating

Deposition Parameters of thermal spray	**Amount**
Thermal spray gun	EWAC Superjet eutalloy
Spray distance	50 mm
Spray angle	90˚
Powder feed rate	63 g/min
Particle size	80-120 µm
Oxygen flux	1.5 bar , 22 psi
Acetylene flux	0.5 bar , 7.5 psi

Nozzle bore size	1.7 mm
Velocity	24 m/min
Normal force	10 N

1.2 LITERATURE REVIEW

Prashant Shrivastava et al, Investigate the mass wear rate is analyzed using four different powder. Thermal flame spraying using four (0 %WC, 12.5 %WC, 25 %WC, and 50 %WC) different powder is presented, for abrasive wear test purpose. Thermal Spray Analysis gives mass wear resistance followed by 12.5% WC, 0%WC, 25% WC, and 50% WC alloy.[2]

Robert Starosta, he suggests the resistance to contact fatigue of Ni-5%Al alloy coatings and Ni-5%Al-15%Al2O3 composite coatings were evaluated. The hardness of coatings also depends on the finishing methods. Using ball burnishing process overall surface roughness reduces from Ra = 2.5μm to Ra = 0.16μm. Burnishing increases the contact fatigue resistance of thermally sprayed coatings as compared to the turning.Thermally sprayed coatings after burnishing and grinding characterized by a similar of contact fatigue resistance.[3]

liviu luca et al, investigation Experiment shows that, Ball Burnishing can improve both the surface strength and roughness. This increase of surface strength mainly serves to improve fatigue resistance under dynamic loads. Here, Ball burnishing of hardened steel is applied to materials over 45 HRC gives surface roughness is in the range from 0.2 to 0.8 μm. The possibility of burnishing steel components with high hardness around 64 HRC was successfully burnished using ball burnishing process. Roughness comparable to grinding could be obtained through burnishing. In case of burnishing high steel components, When the burnishing feed increases, the roughness increases.[4]

Mr. N. M. Qureshi et al, In this Process, Burnishing process can provide benefits especially as following, Polished surface finish, Dimensional Consistency and accuracy, Minimize the reworks and rejections, More utilization of machining capabilities, No chip accumulation. Using TAGUCHI methodology it gives with low burnishing speed and high feed rate, Ball burnishing process gives best surface finish with surface roughness value 0.2 μRa.[5]

Deepak Mahajan et al, In this paper, ball burnishing method is presented as surface finish method compare to other conventional method such as honing, lapping, super finishing. Ball burnishing process gives maximum efficiency in case of aluminum and steel work piece. Amongst the ball burnishing process parameters burnishing force, speed and feed were considered the most compared to Ball material, No of revolutions and Direction of burnishing. Micro hardness of work piece is also improved with ball burnishing process. [6]

Toshifumi Kubohori et al, In this paper, grind ability of sprayed coatings of Al2O3(-TiO2) investigated. The peeling and falling off of laminated sprayed particles, along with the generation of inter-granular fine cracking that occurs during machining depending on the grinding makes it very difficult to obtain a flat machined surface with this material texture.Using grinding as a post machining, surface roughness upto 3 μm to 8μm. This coating leads to worn out of grinding wheel is major problem.**[7]**

A. Rodríguez et al, In this paper, ball-burnishing process uses as a mechanical surface treatment for improving productivity and quality of rotating shafts. This process provides good surface finish, high compressive residual stresses, and hardness increment of the surface layer. As a consequence of plastic deformations, compressive residual stress states, work hardening, micro-structural alterations and a favorable roughness are produced; improving fatigue strength and wear resistance. Therefore, these surface treatments prevent crack initiation, retard propagation of small cracks, improve corrosion resistance, and even improve wear behavior. After several experiment, it is possible to burnish using the certain maximum speed supported by the machine, reducing processing times, gives maximum hardness and better surface finish compare to other processes.[8]

D. B. Patel et al. carried out experiment on aluminum workpiece, process on ball burnishing tool which have hardened steel ball. The process done on conventional lathe machine. For analysis of surface roughness, Taguchi method is used for determine experiment and S/N ratio with smaller is better condition. They determined that the optimal parameters for speed is 120 rpm, feed is 0.1 mm/rev, force is 15 N and passes is 2.[9]

J. A. Travieso-Rodríguez et al. investigate the ball burnishing process to rectify the surface finish of AA 92017 and Steel G10380 with concave and convex surfaces. Along with speed and feed, considering the curvature radius as parameter using the tungsten carbide ball as a ball burnishing ball material. After investigate the process, they concluded that for AA 92017 better results obtain with smaller radius in convex surfaces and with bigger radius in concave surfaces. For steel 1038, as parameter on milling machine the prior peak height, affect the overall indexes of surface roughness.[10]

M. vinitha et al., focuses on fused Deposition Modeling(FDM) is one of the best rapid prototyping processes proved to be. The surface hardness also increased as the spindle speed, feed rate and depth of penetration was increased. A higher surface hardness value obtained at 1400 spindle rotation 0.35 mm depth of penetration.[11]

2. EXISTING PROCESS

Currently, with the help of cylindrical grinding machine- thermally sprayed workpiece being grind. Grinding is a material removal and surface generation process used to shape and finish components made of metals and other materials. The precision and surface finish obtained through grinding can be up to ten times better than with either turning or milling. Grinding employs an abrasive product, usually a rotating wheel brought into controlled contact with a work surface. The grinding wheel is composed of abrasive grains held together in a binder. These abrasive grains act as cutting tools, removing tiny chips of material from the work. As these abrasive grains wear and become dull, the added resistance leads to fracture of the grains or weakening of their bond. The dull pieces break away, revealing sharp new grains that continue cutting. In cylindrical grinding, the workpiece rotates about a fixed axis and the surfaces machined are concentric to that axis of rotation. Cylindrical grinding produces an external surface that may be either straight, tapered, or contoured.

Figure 3 : Grinding on thermally sprayed workpiece

In the current process, Thermally sprayed extruder screw finishing process, grinding as a post machining process to smoothen the surface roughness of workpiece surface. The diamond type of grinding wheel is used to smoothen the workpiece of wear resistance surface produced by thermal spray. Grinding firstly removes the extra chips or burrs & secondly gives required finish size of workpiece. Average roughness of thermally sprayed extruder screw is nearly about 50µm and hardness is also 60.5 hrc. Now applying Grinding as a post machining gives overall surface roughness under 10 µm and hardness is 60.5 hrc. Here the workpiece surface roughness nearly decrease up to certain level after the no effect found on workpiece. Even after some time of experiment, grinding wheel rapidly worn out and there is no change in surface hardness before and after grinding [12]. So by using grinding as a post machining gives only change in surface roughness and there is no further change in other output parameters. So grinding gives finished size of workpiece with good surface roughness without changing other output parameters.

Table 2 : Thermally sprayed workpiece before grinding

Surface Roughness(μRa)	Surface Hardness(hrc)
30	60.5

Table 3 : Thermally sprayed workpiece after grinding

Surface Roughness(μRa)	Surface Hardness(hrc)
10(Avg)	60.5

In any particular industry, cost is main major factor to think over it. Here, Thermally sprayed hardened workpiece must be require post machining for smoothen the workpiece surface. Here because the workpiece having hard coating on it, cylindrical grinding is generally used to smoothen the workpiece surface. In Ahmedabad GIDC, price for thermally sprayed surface is 3.5 Rs/mm(considering length). So, Cost for 300 mm long screw is nearly about 1050 Rs.

Table 4 : Cost of Workpiece for grinding

Size of workpiece	Price(Rs.)
Ø58 x 300 mm	1050.00

3. INTRODUCTION TO BALL BURNISHING :

Ball Burnishing is a cold working surface finishing process which is carried out on material surfaces to induce compressive residual stresses and enhance surface qualities [9]. A burnishing tool typically consists of a hardened sphere which is pressed onto/across the part being processed which results in plastic deformation of asperities into valleys. In burnishing process in which initial asperities are compressed beyond yield strength against load. The surface of the material is progressively compressed then plasticized as resultant stresses reach a steady maximum value and finally wiped a superfine finish[13]. The principle of the burnishing process is based on the rolling movement of a tool (a ball or a roller) against the workpiece surface, a normal force being applied at the tool. At the same time, compressive stresses are induced in the surface layer, followed by strain hardening and a series of beneficial effect on mechanical properties. The most basic burnishing tool is one designed for use in a conventional lathe and CNC lathe machine tool. As chuck on the machine tool rotates the workpiece, the burnishing tools apply the force on it for fast and efficient finishing. Applying extra heat to the object during the process often increases the effects of burnishing In Burnishing rigidly fixed tools creates a solid kinematic link with the workpiece as in turning process. The burnisher is fixed on a machine tool at tool post. With rigid burnishing the burnisher is indented into the surface for a predetermined depth which varies from several microns to several hundredths of a millimetre. The depth depends on the plasticity of the material, surface roughness and burnishing ball radius. The tool is pressed elastically towards workpiece by spring or hydraulically means. Burnishing with a rigidly fixed tool can be recommended for processing of especially precise machined parts for high-precision machines.

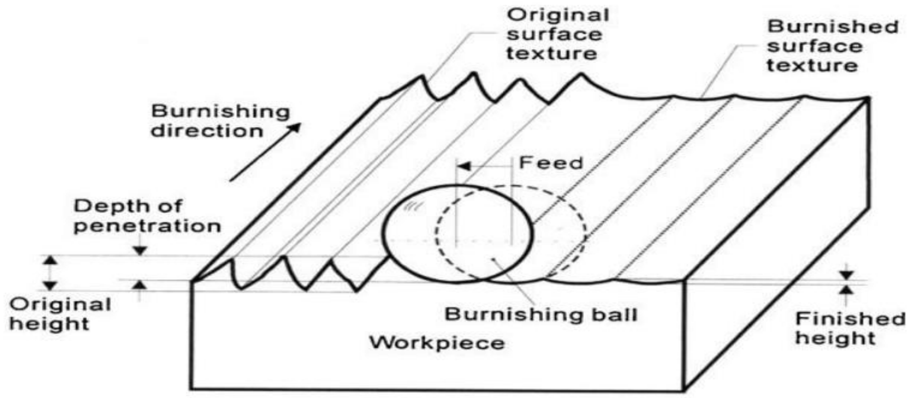

Figure 4 : Schematic diagram of ball burnishing process

Here deforming element is a tungsten carbide ball. There is a point contact and rolling friction between ball and work-piece. Deformation is localized in zone adjacent to the ball. For the same radial force, gives high specific pressure, better surface finish, more fatigue strength, micro hardness and depth of work hardened layer[14].

3.1 WORKPIECE PREPARATION

EN41B is a workpiece material which is chromium aluminum molybdenum nitrating steel. The material offers high wear resistance together with toughness and ductility. EN41B is defined by its suitability for nitrating which gives the material a hard, wear resistant case. EN41B is harder wearing than EN40B and offers excellent abrasion resistance.

Normal Hardness of material before thermal spray was 17 hrc.

Parts to be involved in experiments were cylindrical shaped, 60-mm diameter, made of carbon steel, carburized and thermally sprayed hardened at 57-63 HRC. In this experiment, the whole ball burnishing process is done on convention lathe machine. For estimating the significant factors of influence and their trends in the process, a screening experiment was planned. The output parameter taken into consideration was the mean roughness *Ra* , and hardness hrc. No of passes, burnishing feed *fb* and speed *s* were the burnishing parameters.

3.2 TAGUCHI METHOD

Taguchi's approach has been built on traditional concepts of Design of Experiments (DOE), such as Full factorial, fractional factorial design and orthogonal arrays based on signal –to-noise ratio, robust design and parameter and tolerance designs. DOE is a powerful statistical technique introduced by R.A. Fisher in England in 1920s to study the effect of multiple variables simultaneously [Philips (1989)]. Since, the research work concentrates on the experimental work, the number of experiments is to be conducted, the effect of the individual parameters on the ball burnishing operation, either independently or combined have to be studied. Therefore, the well known Taguchi technique is chosen and adopted in the present research work. In order to reduce the total number of experiments "Sir Ronald Fisher" has developed the solution: "Orthogonal Arrays". The orthogonal array is a distillation mechanism by which the engineers can select the experimental process. The array allows the researcher engineer to vary multiple variables at one time and obtain the effects such that set of variables has an average and the dispersion. Taguchi employs the design of experiments using specially constructed table, known as "Orthogonal Arrays" (OA) to treat the design process, such that the quality is build into the product during the product design stage. Orthogonal Arrays are the special set of Latin squares, constructed by Taguchi to lay-out the product design experiments. experiments were planned according to taguchi's orthogonal array, which has rows corresponding to the number of tests (24 degree of freedom) with columns at five levels. the first column of table was assigned to speed, the second to the feed rate, the third column was to no. of tool passes. It means experimental number must be conducted using the combination of levels for each independent factor (speed, feed, and no. of tool passes)[15]. This orthogonal array is chosen due to its capability to check the interactions among factors. The experimental results are then transferred in to a Signal to Noise (S/N) ratio. The category the-smaller-the-better was used to calculate the S/N ratio for surface roughness and the-higher-the-better was used to calculate the S/N ratio for surface hardness[16].

4. CONCLUSIONS

From studying literature, it is noticed that improved roughness comparable to grinding could be obtained through burnishing. The possibility of burnishing steel components with high hardness, around 64 HRC, could be proven. When the burnishing feed increases, the roughness increases.

In this study the To carry out experimental determination of the effects of the various burnishin g process parameters such as speed, feed and no. of passes on the material and measures surface roughness and hardness. Analysis the effect of burnishing parameter on material using Taguchi’s Orthogonal array method and signal to noise ratio method.

Economic studies prove that burnishing obtains surface quality corresponding to grinding, for costs corresponding to turning.

The following advantages may result from the burnishing process

1. Mirror like surface finish
2. Dimensional Consistency / Repeatability
3. Increase in Surface Hardness
4. Reduces the Reworks and Rejections.
5. Cost reduction.

5. ACKNOWLEDGEMENT

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6. REFERENCES

1. Kleiner M, Geiger M, Klaus A (2003) Manufacturing of lightweight components by metal forming. Ann CIRP 52(2):521–542
2. Prashant Shrivastava, T.K Mishra, “A.C Saxena, Effect of WC Concentration on Abrasive Wear Properties of the Thermally Sprayed WC -Ni Coatings process”, International Journal of Scientific and Research Publications, Volume 3, Issue 6, June 2013, ISSN 2250-3153
3. Robert Starosta, “Effect of burnishing on the contact fatigue of regenerative thermally sprayed coatings”, Journal of KONES Powertrain and Transport, Vol. 20, No. 1 2013
4. liviu luca, sorin neagu-ventzel, ioan marinescu, burnishing of hardened steel components – an alternative method of finishing, the university of Toledo, 2801 w. bancroft, mime dept., nietschke hall, toledo, oh 43606
5. Mr. N. M. Qureshi, Mr. Vaibhav B. Patil, Mr. Basavaraj D. Teli, Analysis of Effect of Ball and Roller Burnishing Processes on Surface Roughness on EN8 Steel, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 4 Issue 06, June-2015
6. Deepak Mahajan, Ravindra Tajane, A Review on Ball Burnishing Process, International Journal of Scientific and Research Publications, Volume 3, Issue 4, April 2013 ISSN 2250-3153
7. Toshifumi Kubohori, Yasuyuki Inui and Toshirou Ikuta, Evaluation of Grinding Characteristics of Th ermal Spraying Ceramics Film, Japan Thermal Spraying Society
8. A. Rodríguez , L.N. López de Lacalle, A. Celaya, A. Lamikiz, J. Albizuri, Surface improvement of shafts by the deep ball-burnishing technique
9. D.B. Patel and T.M. Patel, “Determination of optimal ball burnishing parameters for surface roughness of aluminum alloy”, Journal of Mechanical Engineering and Sciences Volume 4, June 2013 , pages 472-478.
10. . J. A. Travieso-Rodríguez, G. Dessein, H. A. González-Rojas, “Improving the Surface Finish of Concave and Convex Surfaces Using a Ball Burnishing Process”, Open Archive Toulouse Archive Ouverte (OATAO), Vol 26, 2011, Pages 1494-1502.

11. M. Vinitha, A Nageswara Rao & M. Kedar Mallik, "Optimization Of Speed Parameters In Burnishing Of Samples Fabricated By Fused Deposition Modeling", International Journal Of Mechanical And Industrial Engineering (Ijmie), Volume-2, Issue-2, 2012, Issn No. 2231 –6477.

12. Packeisen A (2000) Material aspects of grinding wear resistant alloys. Fortschr-Ber VDI Reihe 5/610
13. R.L.Murthy and B.Kotiveerachari,"Burnishing of metallic surfaces-a review " Precision Engineering
14. Tomasz Dyl, "The burnishing strengthen shafts neck of centrifugal pumps", Journal of KONES Powertrain and Transport, Vol.18, No. 2 (2011).
15. Ugur Esme, "Use of grey based Taguchi method in ball burnishing process for the optimization of surface roughness and microhardness of AA7075 aluminum alloy", mtaec9, 44(3)129(2010).
16. Aysun Sagbas, "Analysis and optimization of surface roughness in the ball burnishing process using response surface methodology and desirability function", Advances in Engineering Software 42 (2011) 992–998.