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# Experimental Investigation of Shot Blasting Process on Mild Steel, Die Steel, Cast Iron and Aluminium

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## Abstract

Shot blasting is the process mainly used to make the surface smooth, rough, to remove surface contaminants and for shaping a surface. The effect of steel shot balls on the surface characteristics of four metals Mild steel, Die steel (H11), Cast iron and Aluminium had been studied in this work. Main output response parameters like percentage weight loss, surface roughness, hardness and surface characteristics were studied and a comparison study of steel shot blasting using different blasting times on different metals was made. The impacts of steel shot balls were able to enhance the surface hardness, surface irregularity and roughness of the different metals. The duration of shot blasting influences the magnitude of the resulting surface hardness, roughness and weight loss. The effect on these parameters in current study increases by the duration of shot blasting treatment but occurs with a lower rate after 20 min of processing.

Keywords: Shot blasting, steel shot ball, Surface Roughness, Hardness, Mild steel, Die steel

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## Introduction

Shot blasting consists of attacking the surface of a material with one of many types of shots. Normally this is done to remove something on the surface such as scale, but it is also done sometimes to impart a particular surface to the object being shot blasted, such as the rolls used to make a 2D finish. The tumbling-blast machine consists of an enclosed, endless conveyor belt, a centrifugal blast wheel and an abrasive recycling system. These machines simultaneously tumble and blast the work pieces. As the conveyor moves, it gently tumbles the work and exposes all

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work piece surfaces to the abrasive system. Shot blasting is a method used to clean, strengthen (peen) or polish metal. The shot can be sand, small steel balls of various diameters, granules of silicon carbide, etc This process induces residual compressive stresses into the film structure, thus increasing the coating hardness, but its brittleness too **[1]**. Micro blasting of cutting tips and tools is a very effective and reliable method of advancing the life of tools under the action of turning, milling, drilling, punching and cutting **[2]**. Shot blasting is used in almost every industry that uses metal, including aerospace, automotive, construction, foundry, shipbuilding, rail, and many others. There are two technologies used: wheel blasting or air blasting. Specialized wheel blast machines propel plastic abrasive in a cryogenic chamber, and are usually used for deflashing plastic and rubber components **[3]**.

Some researchers had investigated the effect of abrasive jet deburring processes on the surface finishing of jewellery models built by stereo lithography apparatus (SLA) and the abrasive machining characteristics of a glass-infiltrated alumina used for fabrication of all-ceramic dental crowns using a high-speed dental hand piece and diamond burs with different grit sizes **[2, 4]**. Some other researchers identified the material response of alumina ceramics to the abrasive particle impact in the AJM process and also determined the topographical features such as surface roughness, real surface area and the percentage of surface covered by the adhered shot particles and electrochemical behavior like open circuit potential, electrochemical impedance spectroscopy and cyclic polarization by shot blasted commercially pure Ti surfaces with different materials and sizes of shot particles**[5, 6]**. It was outlined the ways in which micro blasted tools, both coated and uncoated had benefited from shot blasting and resulted in greater productivity, lower cutting forces, improved surface finish of the work pieces and less machine downtime **[7]**. Some researchers had compared the erosion wear of the nozzle made by Monolithic $B_4C$, $Al_2O_3/(W,Ti)C$ and $Al_2O_3/TiC/Mo/Ni$ ceramic composites caused by abrasive

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particle impact with dry sand blasting by determining the cumulative mass loss of the nozzles made from these materials, examined the effect of grit blasting parameters on the surface roughness of Ti–6Al–4V alloy as the substrate for plasma-sprayed hydroxyapatite (HA) coatings by using the factorial and Taguchi designs of experiments and prepared the conventional two-layered thermal barrier coatings (TBCs) by electron beam physical vapor deposition with $ZrO_2$-8 wt% $Y_2O_3$ (8YSZ) as top coat and CoCrAl as bond coat on disk-shaped Ni based super-alloy and three kinds of shot peening process with different lengths of operating time were adopted for bond coating also investigated the influence of micro-blasting with corundum in aqueous solution at pressures between 0.05 and 0.3 MPa was applied to CVD TiN/Ti(C,N)/ k - $Al_2O_3$ multilayer coatings deposited onto cemented carbides on the micro-topography, microstructure and residual stresses **[8, 9, 10, 11]**. It was provided an approach to create holes or grooves more efficiently via powder blasting process **[12]**. It was evaluated the spherical steel slag balls obtained from the slag atomization process for use in grit blasting treatment of medical grade 316L stainless steel and studied the effect of steel slag ball blasting treatment on surface structure, roughness and wettability of medical grade 316LVM stainless steel **[13,14]**. Some researchers had investigated the effect of different parameters of the blast cleaning process on properties and quality of brass parts surface, described the effect of shot blasting on plain fatigue and fretting fatigue behavior of Al–Mg–Si alloy AA6061 and studied the effect on surface roughness and surface residual stress of low carbon steel substrates which had been grit blasted using alumina grits of various sizes under varying pressure, time, angle and standoff distances also investigated the effects of $Al_2O_3$ and $ZrO_2$ grains, in dry micro-blasting of coated cemented carbide inserts, on film's hardness and brittleness, cutting edge geometry as well as on tool life **[1, 3, 15, 16]**.

## 1. Experimental set-up

To study the effect of abrasive blasting on the surface of different materials the parameters like surface roughness, hardness, percentage mass loss and surface composition were required to be studied. The materials used as work pieces were Mild steel (99% Fe, 0.101%C, 0.173% Si, 0.532% Mn), Die steel (H11) (90.5% Fe, 0.397%C, 0.865% Si, 5.24% Cr, 1.10% Mo) , Cast iron (91.5% Fe, 2.16%C, 1.16% Si, 0.606 Mn) and Aluminium (92.6% Al, 1.2 % Mn, 6.44% Ni, 0.164% Cr). The blasting material used was round steel shots having 0.425mm diameter and Grade S170. The chemical composition of steel shots ball having carbon 0.6 to 1.25%, silicon 0.2 to 1.1%, manganese 1.25% max., sulphur 0.08% max., phosphorous 0.08% max. Levels of blasting time taken were 5min, 10min, 15min, 20min, 25min, and 30min. Surface hardness, surface roughness, percentage weight loss and chemical composition were selected as output characteristics.

## Results and Discussion

Surface hardness was measured on a computer interfaced surface hardness Tester Model: MVH-2. The values of surface hardness (VHN) of different samples of different blasting times was given below in surface hardness **values table.**

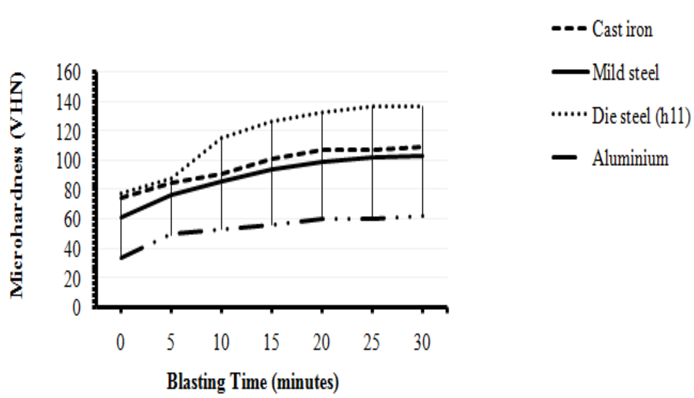

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**Fig 1: Effects of Blasting Time on Micro Hardness**

The figure 1 shows that the surface hardness of all the materials increased with increase in blasting time. This indicates that the physical properties, particularly the hardness and density, of these particles are sufficient to induce plastic deformation and micro structural evolution at the surface. It has been reported that the particle impacts during the shot blasting treatment cause the formation of fine grains, residual stress and martensites which subsequently enhance the subsurface hardness **[Arifvianto et al.].** The duration of shot blasting influences the magnitude of the resulting surface hardness. **As shown in table the VHN (Vickers Hardness Number)** of aluminium was 32.29 before blasting and after 15 minutes it increases to 56.42 and further increases to 62.36 after 30 minutes of blasting. Similarly for mild steel ,die steel and cast iron surface hardness at the was increased with blasting time up to certain period of blasting time then after 20 minutes of blasting there is very less change in the surface hardness value. The VHN of cast iron after 20min blasting was 107.31, after 25 min of blasting it increased marginally to become 108.16. Again after 30 minutes blasting of cast iron it again only increased up to 109.41 Similarly, for die steel (H11) there was a sharp increase in hardness at surface initially but after 20 min of blasting the change is very less than it shows for all the four work piece materials the change in surface harness was very significant and after further increase in blasting time does not make any major change in surface hardness.

Surface roughness was measured using the Mitutoyo model SJ-400. Surface Roughness values in (microns) were taken two times for each trial and average was used for analysis.

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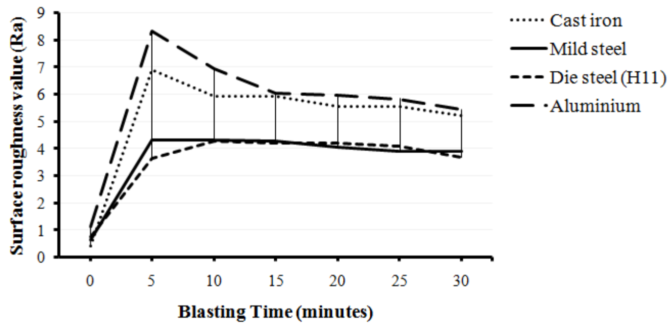


**Fig 2: Effects of Blasting Time on SR**

The figure 2 shows the effect of blasting time on surface roughness. The surface roughness of all the different samples increases rapidly during the first 5 min of the treatment. As for cast iron from Ra=0.43$R_a$ to 6.61 $R_a$. A low rate of roughness reduction occurs after the maximum roughness value is achieved. As for aluminium after achieving the 8.31 $R_a$ value of surface roughness for first 5 minutes it decreased to 6.96 then after 30 min blasting it further decreased to 5.45. The shot blasting for duration longer than 20 min even does not yield a significant roughness reduction and seems to generate roughness saturation after 20 min of blasting for all samples. It also showed that the initial evolution of surface roughness after 5 min of shot blasting is more in softer material aluminium that was 83.1$R_a$ than the harder material Die steel (H11) which was 3.87. The surface roughness evolution during the shot blasting treatment as well as the other surface mechanical treatment seems also being influenced by the change in surface hardness by this treatment. Since the hardness determines material deformation and removal a less hard surface as in the beginning of the shot blasting treatment is more susceptible to severe deformation. The formation of new craters and pile-up therefore occurs easily. The increasing surface hardness during the shot blasting treatment increases the resistance of the surface against impact-induced deformation. Stages I (5) min and II (15 min) of the roughness evolution still result to a less hard surface than that produced in stage III. In stage I, the craters and pile-up are easily and quickly produced by the impact of steel slag balls; yielding a sharp increase of surface roughness. A reduction of surface roughness in stage II indicates that the surface hardness of the specimen still allows the steel slag balls to deform this layer. However, the harder surface layer in stage II than that in stage I decreases the rate of roughness modification The longer blasting duration increases the subsurface hardness and is consequently able to resist further surface deformation. A roughness saturation or stage III is therefore observed after (20) min of the treatment [14].

The mass loss that occurs on the specimen due to the shot blasting treatment was indicated by the percentage of mass reduction of the specimen after the treatment (M) and expressed mathematically in this equation. $\mathbf{M} = \left(\mathbf{1} - \frac{\mathbf{m_{treat}}}{\mathbf{m_{int}}}\right) \times \mathbf{100\%}$. For this case, $m_{int}$ and $m_{treat}$ are the mass of the samples before and after the treatment, respectively.

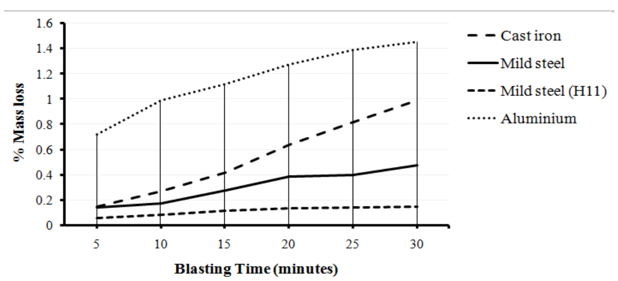


**Fig 3: Effects of Blasting Time on % of Mass Loss**

The figure 3 shows the percentage of mass loss during the shot blasting treatment using the steel shots. The blasting treatment using steel shots for 5–30 min reduces the mass of the samples. The treatment for 5 min is only able to yield a mass loss of 0.057% for the die steel which was very low, but for the softer material aluminium it was 0.722%. After 30 minutes of blasting the Percentage weight loss for aluminium was 1.455 and for die steel it was only 0.152. The mass loss measured during the shot blasting treatment indicates material removal of the specimen surface due to the impact with the steel shot balls. In principle, the mass loss corresponds to the cutting action by the steel slag balls during the shot blasting treatment. The mass loss in the current study increases by the duration of shot blasting treatment but occurs with a lower rate after 20 min of processing. This finding is also influenced by the enhanced surface hardness by the duration of the shot blasting. It is well understood that the rate of surface material removal during the impacts with blasting particles decreases by the increasing surface hardness [17]. The high rate of mass reduction during the first 20 min of shot blasting treatment is due to the relatively low subsurface hardness of the specimen. The shot blasting for 20 min yields a harder surface and subsurface layer than those processed with a shorter time. Therefore, a greater resistance against surface material removal is seen for 20 min of shot blasting [14].

Chemical composition of the work piece base materials and the composition of blasted surfaces is measured using Optical Emission Spectrometer (Model: DV-6). Argon gas is used for composition measurement process. The surface chemical composition of the specimen is altered after the shot blasting treatment. The result of spectroscopy reveals some identical elements at the specimen surface with those at the steel slag ball, such as C, P, S, Ca, Si, Mg and Al together with Fe, Ni and Cr those are also present in the original samples. As the percentage of carbon composition in mild steel and die steel increased marginally that was contributed towards increase in hardness. There was little increase in phosphorous in cast iron which in small amounts, aided strength and corrosion resistance. Phosphorus additions are known to increase the tendency to cracking during welding. Small increase in chromium leads to increase resistance to oxidation. The above spectroscopy test of samples shows that there was very small change in composition of materials at the surface with change in blasting time. After 20mins of blasting there is hardly any change in the chemical composition of treated samples.

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## 2. Conclusion and Further scope of work

The effect of shot blasting treatment using round steel shots, Size = 0.425mm size, Grade = S170 on the surface characteristics of four different metals Mild steel, Die steel (H11), Cast iron and Aluminium was studied in this work. The impacts of steel shot balls are able to enhance the surface hardness, surface irregularity and roughness of the stainless steel. The duration of shot blasting influences the magnitude of the resulting surface hardness, roughness and weight loss. The effect on these parameters in current study increases by the duration of shot blasting treatment but occurs with a lower rate after 20 min of processing. The mass loss during steel shot blasting was very low and not very significant for hard metals. It was well understood that the rate of surface material removal during the impacts with blasting particles decreases by the increasing surface hardness. The surface chemical analysis reveals the presence of several contaminants such as C, S, P, Si and Mg on the specimen surface after being blasted with the steel slag balls. These particles contribute towards improving the surface properties of metals. So the abrasive blasting process is very useful for the situations where nominal surface finish is required with very small mass loss at the surface of these metals with enhanced surface hardness in very less time as compared to other processes.

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