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Optimization of Process Parameters of Shot Peening for AISI 4340 Steel

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***Abstract* - Surface modification is one of the important requirements of various components used in industrial applications. Shot peening is one of the surface modification techniques which is being widely used in automotive industry to enhance fatigue life and surface characterises of mechanical parts. In this thesis, the development of experimental set up for shot peening has been undertaken to investigate the effect of prominent process parameter on surface characterises of a given target surface. The major objective of this work is to investigate the effect of three prominent process parameters, namely Air pressure, Temperature of target surface and Stand-off distance on surface characteristics of AISI 4340 steel. The work material has been chosen keeping in view its applications in local industry related to automotive components. The performance of peening process has been measured in terms of surface hardness, surface roughness and residual stresses. An experimental design approach Response Surface Method (RSM) has been used for the design and analysis of experimental data. The effect of process parameters on performance characteristics has been depicted with the help of ANOVA. Optimal set of process parameters has been obtained on the basis of desirability approach. The optimised combination for best performance came as (Air pressure – 4.83 bars, Temperature of target surface – 30°C and stand-off distance-178 mm).**
***Keywords:* RSM, ANOVA, Surface Hardness, Surface Roughness, Residual Stresses**

I. INTRODUCTION

In recent years the energy saving and environmental problems become a major issue for the industries. So they have to develop their products suitable for environment and at the same time are saving energy. For example the size and weight of the mechanical apparatus are the most important problem. Also these small parts should maintain high efficiency in the mechanical apparatus and they have to full fill the requirement like strength and size. However shot peening has been widely used in order to improve the characteristics of the mechanical parts. [1], this process is improved the fatigue strength and also improve the compressive residual stress and surface hardness of the metal parts. In this process, the control of air pressure, stand-off distance and temperature of target surface is simple and easy. As compared to another mechanical process less wastage of materials and the waste gases occurred in this process. Even by changing the working conditions the shape of work material is almost remain same [2].

Shot peening is the mechanical surface treatments in which large plastic deformation is generated on the surface of the metal. The shot peening process is used in automotive industry; this process treated the castings, gears, springs, propeller shaft and other mechanical parts. In bombardments of steel shot making overlapping indentations on the surface due to indentations the atoms of metal is compressed and also distance between the atoms is reduced. Due to collision of atoms the compressive residual stresses and micro Vickers hardness is higher near the surface [3]. As the amount of the deformation of metal increases the surface roughness increases. In the present shot peening process are carried out using high carbon cast steel spherical shot having size 1 mm diameter and weight 6.5mg.In this study, the optimization of process parameters of shot peening for AISI 4340 steel was investigated. The surface roughness, compressive residual stresses and micro Vickers hardness near the surface were measured after shot peening. The Temperature of target surface using shot peening was also carried out to examine the optimized the processing temperature on the surface layer characteristics.

II. DEVELOPMENT OF EXPERIMENTAL SETUP

The experimental setup consists of following major parts:

1. Air Compressor
2. Hopper
3. Mixing chamber
4. Cabin
5. Nozzle

An experimental setup for carrying out shot peening of plane surface has been developed in the laboratory. It consists of an air compressor (1) which compresses the air and supplies it through control valve (2) and the conduit -I (8) to the mixing chamber (10). A part of compressed air is supplied to hopper (4) through conducted -II (9). The shots present in the hopper are pushed to mixing chamber through control value (5). The shots are supplied at the rate of 150 grams per 10 seconds. The mixture of compressed air and shots from mixing chamber are sent to the nozzle (14). The nozzle provides necessary velocity and pressurised shots strike the work piece (16). The work piece is enclosed in a holder (18) which is insulated. The glass wool is used as insulation material to prevent heat loss from work piece.

A Thermocouple (19) is attached to the holder in such a way that it is very close to the work piece. There are two air pressure gauges (3, 13) for checking the air pressure and an air filter (12) is attached before the air pressure gauge (13) to clean the air[2]&[4].

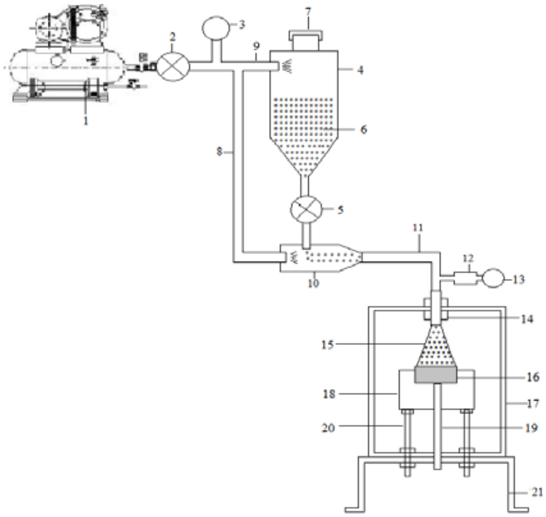

Fig. 1 Schematic diagram of Experimental set up for shot peening

1. Air compressor
2. Air control valve
3. Air pressure gauges
4. Hopper
5. Shot control valve
6. Shots
7. Cap
8. Conduit (I) communicating with the mixing chamber
9. Conduit (II) communicating with the hopper
10. Mixing chamber
11. Air and shot transport hose
12. Air filter
13. Air pressure gauge
14. Nozzle
15. Stream of Shots from nozzle
16. Work piece
17. Cabin
18. Work piece holder with ass wool
19. Thermocouple
20. Elevated nut bolt
21. Stand

TABLE. I CONDITIONS OF SHOT PEENING

1	Shot material	High carbon cast steel	Diameter = 1mm
2	Work piece material	AISI 4340 steel	Diameter = 28mm
3	Air pressure	Bar	2.07 to 4.83
4	Temperature of target surface	°C	30 to 300
5	Stand-off distance	mm	80 to 200

A. Measurement of residual stress, hardness and surface roughness

The compressive residual stress, Vickers hardness and surface roughness in the peened work pieces were measured. The work piece was cut by wire EDM the dimensions of the work piece are 10mm X 10mm X 5mm, and then the Vickers hardness on the surface was measured. The Vickers hardness test and the determination of residual stress were carried out with a micro Vickers hardness tester and X-ray diffractometer. The compressive residual stress was obtained from the X-ray diffraction method by removing the surface layer of the work piece using electrochemical polishing. The surface roughness was measuring by surface roughness tester.

1. Surface roughness

The effect of air pressure on the surface roughness on the surface of work piece is shown in Figure 1.1. As the air pressure increases, the surface roughness increases. It is due to the reason that when air pressure is increased the balls strike on the surface with more impact. Therefore more surface roughness increases with increase in the air pressure.

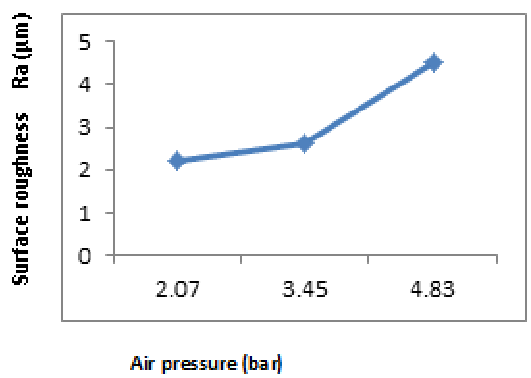

Fig. 2 Effect of Air pressure on Surface roughness on the surface

2. Vickers hardness

The effect of air pressure on the Vickers hardness on the surface of work piece is shown in Figure 1.2. As the air pressure increases, the Vickers hardness increases. It is due to the reason that when air pressure is increased the balls strike on the surface with more impact. Therefore more Vickers hardness increases with increase in the air pressure.

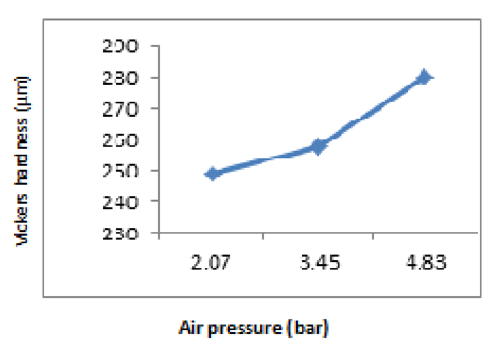

Fig. 3 Effect of Air pressure on Vickers hardness on the surface

3. Compressive residual stress

The effect of air pressure on the induced residual stresses on the surface of work piece is shown in Figure 1.3. As the air pressure increases, the induced compressive residual stresses increases. It is due to the reason that when air pressure is increased the balls strike on the surface with more impact. Therefore more compressive residual stresses increases with increase in the air pressure.

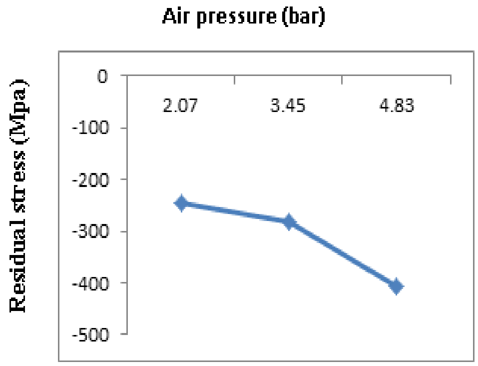

Fig. 4 Effect of Air pressure on Residual stresses on the surface

B. Effect of temperature of target surface on performance:

1. Surface roughness

The effect of temperature of the target surface on the surface roughness on the surface of work piece is shown in Figure 2.1. As the temperature of target surface increases, the surface roughness increases. It is due to the reduction of flow stresses, as the amount of plastic deformation increases with the increase in temperature. Therefore more surface roughness increases with increase the temperature of target surface.

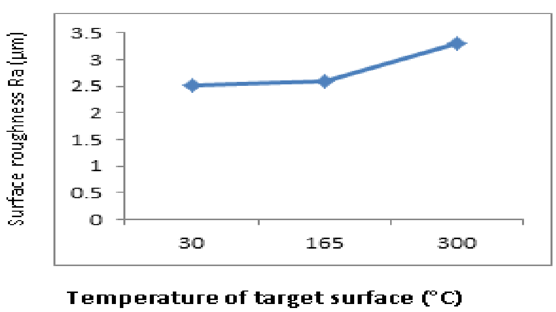

Fig. 5 Effect of Temperature of target surface on Surface roughness on the surface

2. Vickers hardness

The effect of temperature of the target surface on the Vickers hardness on the surface of work piece is shown in Figure 2.2. As the temperature of target surface increases, the Vickers hardness increases. It is due to the reduction of flow stresses, as the amount of plastic deformation increases with the increase in temperature. Therefore more Vickers hardness increases with increase the temperature of target surface.

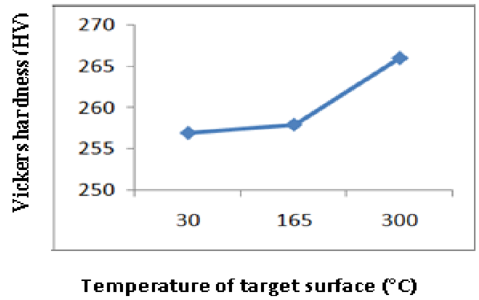

Fig. 6 Effect of Temperature of target surface on Vickers hardness on the surface

3. Compressive residual stress

The effect of temperature of the target surface on the induced compressive residual stresses on the surface of work piece is shown in Figure 2.3. As the temperature of target surface increases, the induced compressive residual stresses increases. It is due to the reduction of flow stresses, as the amount of plastic deformation increases with the increase in temperature. Therefore more compressive residual stresses increases with increase the temperature of target surface.

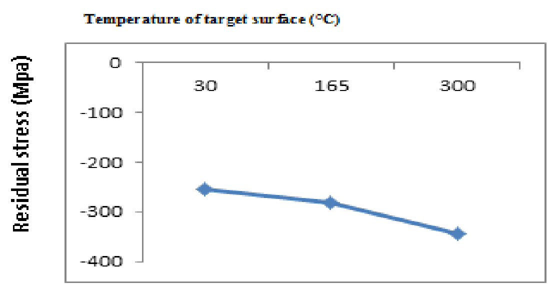

Fig. 7 Effect of Temperature of target surface on Residual stress on the surface

C. Effect of stand-off distance on performance

1. Surface roughness

The effect of stand-off distance on the surface roughness on the surface of work piece is shown in Figure 3.1. As the stand-off distance increases, the surface roughness decreases. It is due to the reason that when the divergence angle of jet increases the shot particle jet width expands as the stand-off distance increases. Therefore surface roughness decreases with increase the stand-off distance.

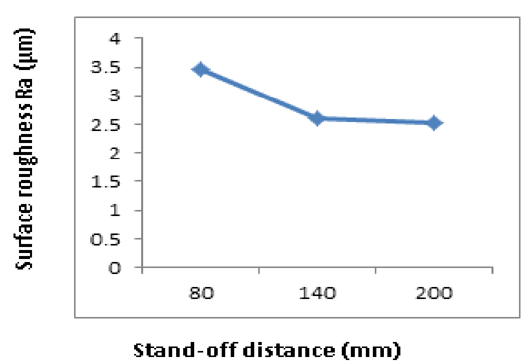

Fig. 8 Effect of Stand-off distance on Surface roughness on the surface

2. Vickers hardness

The effect of stand-off distance on the Vickers hardness on the surface of work piece is shown in Figure 3.2. As the stand-off distance increases, the Vickers hardness decreases. It is due to the reason that when the divergence angle of jet increases the shot particle jet width expands as the stand-off distance increases. Therefore Vickers hardness decreases with increase the stand-off distance.

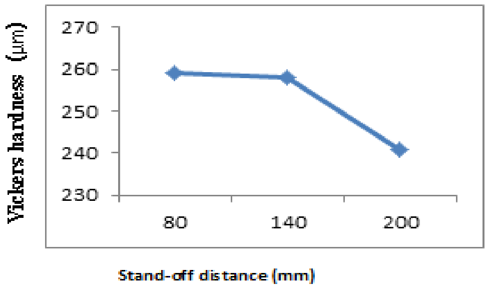

Fig. 9 Effect of Stand-off distance on Vickers hardness on the surface

3. Compressive residual stress

The effect of stand-off distance on the induced compressive residual stresses on the surface of work piece is shown in Figure 3.3. As the stand-off distance increases, the compressive residual stresses decreases. It is due to the reason that when the divergence angle of jet increases the shot particle jet width expands as the stand-off distance increases. Therefore compressive residual stresses decreases with increase the stand-off distance.

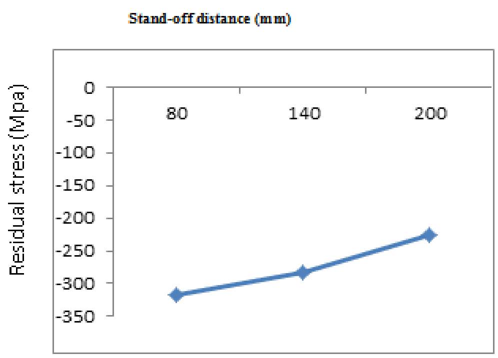

Fig.10 Effect of Stand-off distance on Residual stress on the surface

III. CONCLUSION

On the basis of experimental work, following conclusions have been drawn:

1. Shot peening of AISI 4340 surface could improve compressive residual stresses by a factor of 2-4 as compared to those at initial surface obtained by surface grinding. There is about 1.5 times increase in surface hardness of samples obtained by shot peening under various conditions.
2. There is deterioration in surface finish of the shot peened surface. On an average there is 3% deterioration.
3. The optimum combination of process parameters on the basis of desirability approach which give minimum surface roughness and maximum Vickers hardness is as follows:

TABLE II EXPERIMENTAL OBSERVATIONS

Parameters		C	Response R1	Response R2
A	B			
Air pressure (bar)	Temperature of target surface (°C)	Stand-off distance (mm)	Surface roughness Ra(µm)	Vickers hardness (HV)
4.83	30	178	2.87	277.65

4. As the air pressure increases the Vickers hardness, residual stress and surface roughness on the surface of work piece increases.
5. As the temperature of target surface increases, the Vickers hardness, residual stress and surface roughness get improved.
6. With increase in stand-off distance the Vickers hardness, residual stress and surface roughness decreases.

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