INVESTIGATION OF SHOT PEENING PARAMETERS FOR 236 MW STEAM TURBINE BLADES

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1. INTRODUCTION

The selection of peening equipment, peening media, its shape size and material depends on the shape and material of the workpiece to be peened. The following factors influence them:

a) Shape and cleanliness of the surface;
b) Size and geometry of the components; and
c) Improvement required in mechanical behaviour

For example in steam turbines, the fatigue failure of the turbine blades is commonly found at critical areas viz. fir-tree grooves, holes (at end stage blades) are the area of stress concentration. To inhibit fatigue crack initiation at these aforesaid areas, a calibration procedure was carried out to get the parameters for shot peening of these areas to required intensity. For shot peening of inside surface of fir-tree grooves and holes, a specially designed nozzle and deflector were made to shot peen these areas. Outside surface of the blades can be peened in a conventional manner.

Fig. 1. Steam turbine blade
(4th stage H.P. rotor, 236 MW)
The turbine disc is normally having critical areas viz grooves for blade fastening, coupling and bolt holes. Accessible disk grooves (top three) for blade fastening can be peened with normal external surface peening nozzle, while for the lowest inaccessible grooves deflector peening system has to be adopted. Internal and outside surface of the turbine blade are depicted in Fig. 1.

2. CALIBRATION PROCEDURE FOR HOLE/GROOVE PEENING

The calibration procedure used to obtain proper peening intensity inside is illustrated in Fig. 2.

Fig. 2. Calibration Procedure

First the desired arc height is obtained on an Almen A strip in a conventional manner for the peening conditions to be established. The procedure is identical
to that used to establish peening parameters for flat surfaces. Next a thinner N-strip which has been masked is mounted on the same fixture, but with a length \( w \) exposed which is equal to the diameters of one of the holes to be peened. This N-strip is then peened under the same conditions and time as the A-strip, and its arc height determined. Another N-strip is mounted in a calibration fixture in which a single shaped hole has been made, whose width is equal to the diameter of the hole in the part. The shaped hole is semicircular with flat sides. The distance between its centre and N-strip is equal to the radius of the hole to be peened. The fixture is then placed on a deflector peening system and peening parameters established which will give the same arc height as that measured on the masked N strip that was peened in the standard support block.

It is important, for economic reasons that the oscillations distance of the deflector pin should not exceed the length of the hole in the part. Since the speed of the oscillation is fixed by the peening equipment, peening time is determined by the number of oscillations. Hence the number of oscillations for peening a particular size hole is identical to that determined from the calibration procedure, even though the deflector travel distance may be somewhat different.

3. DEVELOPMENT OF DEFLECTOR AND NOZZLE

Fig. 3. Sectional view of Nozzle and Deflector (All dimensions are in mm)

For the purpose of shot peening of critical areas of the turbine blade, specially designed nozzle and deflector were made. The details of the nozzle and deflector are as shown in Fig.3(a) and 3(b).

The nozzle bore was of 6mm. This nozzle was convergent straight type and it provides a higher velocity than convergent-divergent type nozzle. At a pressure of 0.3 MPa it gave a mass flow of 2.575 kg/min.

As shown in the Fig.3 (a and b) the deflector is having a hole of 6mm dia. and it can be easily fixed in the nozzle for the shot peening purposes. The tail end
of the deflector had a 45° slope, so when the steel shots repelled under air pressure through the nozzle and then passes through the hole in the deflector, it finally collides with the reciprocating deflectors tail end and ricochets off it and redirected 90° perpendicular to the internal surface of the hole.

The nozzle and deflector were made from mild steel and were then carburised and hardened to HRC 55 over the surface. These were for experimental purpose and not for production peening.

4. PREPARATION OF FIXTURES FOR CALIBRATION

There were two fixtures which were used in the hole peening process. Firstly a fixture was made for the calibration procedure as expressed earlier. It had a single shaped hole of dia. 8 mm with its width equal to 8 mm. It had a semicircular hole with flat sides. The fixture is shown in the Fig. 2.

Fig. 4. Deflector peening arrangement for calibration process

Another fixture was made for the calibration process as shown in Fig. 4. The deflector which was used in the calibration process was welded on a L-shaped iron plate on one side and a bolt and wing nut was fixed on the other side, so that this can be tightened on the system as shown in Fig. 8.

5. PREPARATION OF A SAMPLE OF BLADE MATERIAL

A sample from turbine blade was made for the purpose of shot peening of flat surface and circular surface. For this purpose, in a rectangular block of turbine blade material size: height 10 mm, length 41 mm width 36 mm, a semicircular hole of 8 mm dia was made on one corner side (across its 36 mm) while the opposite side was kept flat. The details of this sample is shown in Fig. 5.

6. SHOT PEENING PARAMETERS

The peening intensity recommended by various investigations for 12% Cr steel was 0.30 A to 0.40 A. The shot sizes normally used were S-230 (0.58 mm) and S-110 (0.29 mm). In order to attain the intensity within this range following
controlling parameters were used on pneumatic direct pressure peening system.

a) Throat dia. of nozzle - 6 mm
b) Air pressure - 0.3 MPa
c) Stand off - 190 mm
d) Mass flow rate - 2.575 kg/min.

![Diagram of sample dimensions]

**Fig. 5.** Details of the sample made from turbine blade material (All dimensions are in mm)

7. SATURATION CURVE

To get the requisite intensity for the peening of blade material, we had plotted a saturation curve taking peening time (secs) on the x-axis and arc height (mm) on the y-axis. Arc height is the deflection of Almen A strip due to shot peening. Fig.6 shows the shot peening of an Almen A strip and Fig.7 shows the saturation curve. The saturation time, for the shot size S-230, obtained from the saturation curve was 30 seconds with an arc height of 0.37 mm.

8. CALIBRATION PROCESS ADOPTED FOR HOLES/GROOVES

As described earlier in the calibration procedure an N-strip which had been masked was mounted on the fixture but with a length ($w = 8$ mm) exposed which was equal to the diameter of the one of the holes to be peened. The N-strip was then peened under the same conditions and time as A-strip and its arc height determined, and which was equal to 0.70 mm.

In the second step, an N-strip was mounted in the calibration fixture as described earlier to get an intensity of 0.70 mm. For this, we increased the pressure from 0.3 MPa to 0.4 MPa and shot peened the N-strip by means of deflector peening arrangement as shown in Fig.8.
After 20 oscillations of the deflector, we achieved the desired intensity of 0.70 mm on N-strip.

9. SHOT PEENING OF THE OUTSIDE SURFACE OF THE TURBINE BLADE

Shot peening of the outside surface i.e. flat faces of the blade was carried out in the same conditions as established for the flat surface of the sample i.e. peening time 40 seconds etc. Here it is noted that the internal surface of the blade was masked properly during the peening of the outside surfaces.

10. SHOT PEENING OF A SAMPLE OF TURBINE BLADE MATERIAL

As described earlier that a sample was made for the purpose of shotpeening of flat surface as well as circular surface. Before the starting of shot peening it was noted that the hardness of the turbine blade material was Rockwell C50, while the hardness of standard Almen A-strip was equal to Rockwell C47, so we made slight changes in the peening time and number of oscillations.

Firstly the flat side of the block was peened under the conditions established for a flat surface on Almen A-strip earlier except increase in the saturation time from 30 seconds to 40 seconds. Secondly, the other side i.e. opposite corner
side having a semicircular hole was peened under the established conditions in the calibration procedure except increase in the number of oscillations from 20 to 25.

Fig. 7. Saturation curve for Almen - A strip using shot size S - 230
11. SHOT PEENING OF A FIRTREE GROOVE OF A TURBINE BLADE

For this purpose, a turbine blade was fixed on a channel by means of a wooden part and thin iron strips. Arrangement is shown in Fig. 9. The same specially designed deflector was used for shot peening. The shot peening of a firtree groove of a turbine blade is shown in Fig. 10. Here shot peening was done under the same conditions as established in the calibration procedure with 25 oscillations. Here it is noted that the dia. of the circle inscribing the two corners of the fir-tree groove was 8 mm.

12. OBSERVATIONS

The hardness and surface roughness of the turbine blade material were noted before and after peening and they were as follows:
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Characteristics of turbine blade material</th>
<th>Before peening</th>
<th>After peening</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Hardness</td>
<td>50 HRC</td>
<td>56 HRC</td>
</tr>
<tr>
<td>2.</td>
<td>Surface roughness of the sample:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Flat side</td>
<td>1.66 μm</td>
<td>3.80 μm</td>
</tr>
<tr>
<td></td>
<td>b) Circular side</td>
<td>1.66 μm</td>
<td>3.16 μm</td>
</tr>
<tr>
<td>3.</td>
<td>Surface roughness of the fir-tree groove:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Flat side</td>
<td>0.90 μm</td>
<td>3.04 μm</td>
</tr>
<tr>
<td></td>
<td>b) Near the curvature</td>
<td>0.90 μm</td>
<td>2.68 μm</td>
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![Diagram of turbine blade fixing on a channel](image-url)

Fig. 9. Fixing of turbine blade on a channel

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13. CONCLUSION

By seeing the changes in the hardness and surface roughness of the turbine blade material, it is clear that the hardness was increased sufficiently and the surface roughness were increased within the prescribed limit i.e. 4.00 μm.

It is observed the specially designed nozzle and deflector were quite satisfactory for the shot peening of critical areas of a turbine blade.

By examining the fir tree groove of the turbine blade which was peened, it is evident that after 25 oscillations we got 100% coverage with desired intensity and surface roughness. And so the validity of the calibration procedure is justified.

Further surface roughness was controlled by secondary peening with smaller size glass beads (G25) at an intensity 0.4 N (0.4 mm on N strips). This gave surface roughness 0.3 μm. Glass beads were also beneficial particularly for used blades in removing black oxide layer over the surface.

14. REFERENCE