35 Years of Experience of Flame Hardened LP Blades Running at Power Plant Sites

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Abstract - Water droplet erosion (WDE) of rotating blades is one of the challenges which need to be overcome for operational reliability of a fossil fuel turbine sets. To solve this problem, the martensitic steel blades are flame hardened. Hardness increases within area of flame hardening and it provides resistance to erosion. We have 35 years of positive operational experience with this protection measure.

Key Words: Water droplet erosion, flame hardening, hardness, turbine, experience

1.INTRODUCTION

Water droplet erosion (WDE) of rotating blades is one of the most important factor influencing the operational reliability of a fossil fuel turbine set and thus a determining factor for design configurations. The WDE hazards mainly depends on the steam wetness and circumferential speed of the blades turbine. The enormous volumetric steam flow rates and resulting large mean blade diameters and lengths of blades aggravates the WDE problem. The water droplets impinge on the rotating last stage blades at leading edge suction sides where the relative velocities of steam can be upto several hundred meters per second.

Many alternatives have been tried to mitigate the problem of Water Droplet Erosion in last so many years by OEMs. To increase the resistance of the last stage blades to this type of erosion, the author's company employs a preferred solution called flame hardening process and collected more than 35 years of positive operational experience with this protection measure.

2. EXPERIENCE AT BHEL

For larger steam turbine blades, the conventional method of protecting against water erosion using Stellite strips brazed to the blade surface presented new challenges (fig.-1). The Stellite strips create discontinuities in the blade profile, and if the Stellite strips break, they can also cause local damage and changes to the dynamic characteristics of the blade.

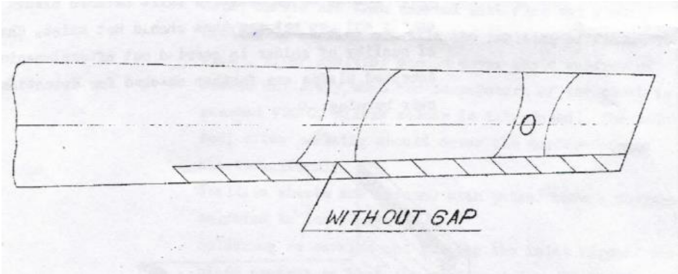

Fig.-1 Stellited strips at inlet edge of blade

Alternate method for protection against erosion is by flame hardening of the blades. This method delivers better results for blade material relative to the above protecting method. Flame hardening of the leading edge instead of Stellite coating or strips is more desirable due to its efficacy during operation at higher speed of the LP turbine blade. This method has been employed by author's company in last 35 years in more than 300 rows of last stage LP blade whereas the fleet leader has already completed more than 2.4 Lac hours. It confirms that the water droplet erosion resistance and the blade life time can be considerably increased by this method.

Flame hardening is suitable for martensitic steels viz. X20Cr13 and X10CrNiMoV12-2-2 being used largely in last stage LP blades.

Requirements:

During flame hardening of inlet edge of low pressure turbine blades, following conditions to be fulfilled:

- The dimensions are to be maintained at the hardening zone
- Sufficient hardness to be ensured in the designated zone
- Sufficient hardening of hardened zone to be ensured
- Residual tensile stresses in the hardened zone are to be avoided
- Proper blade position to be ensured thus avoiding distortion of inlet edge after hardening

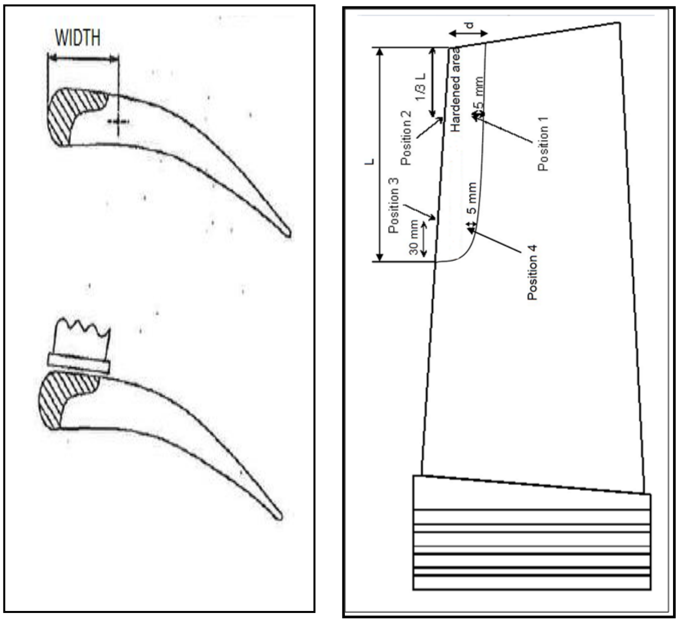

Fig. 2: Flame hardened area in blade vane

The area to be treated will be according to blade drawings, typically it covers one-third of the inlet profile edge. Only blades without outer shrouds are allowed to be flame hardened. Flame hardening can be employed under water bath cooling or with air cooling. Author's company does it by using vertical hardening machine with air cooling (Fig.-3).

Fig. 3: Vertical hardening machine with air cooling

While preparing for flame hardening of inlet edge of LP blade, it is necessary to adjust the clamping table, gas temperature, flow and pressure, type of burner, position of burner, cooling air jet position, volume and flow of cooling air and feed of the machine. Setting of temperature is done between 950^0 C to 1030^0 C depending upon the specified blade material. After ignition the gas burner, it moves along the inlet edge of blade depending on blade geometry speed to heat up the material is pre-determined. Setting of final parameters is done for the whole manufacturing lot after testing of 2-3 blades. Process is qualified to establish Flame Hardening parameters after optimizing (Hardness depth, microstructure, residual stresses etc.).

It is also necessary to do stress relieving heating at 250^0 C for 2 to 3 hours in a furnace so that the natural maxima are removed after flame hardening.

Test blades: Metallographic examination of blades should confirm that there is a uniform structure without changes in comparison to the base material.

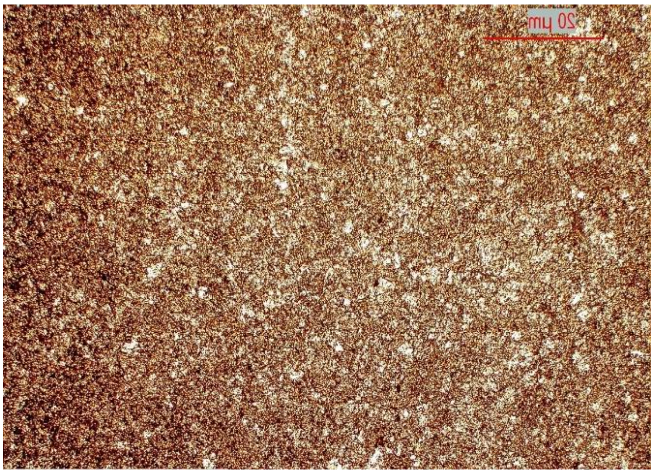

Fig. 4(a): Base metal microstructure

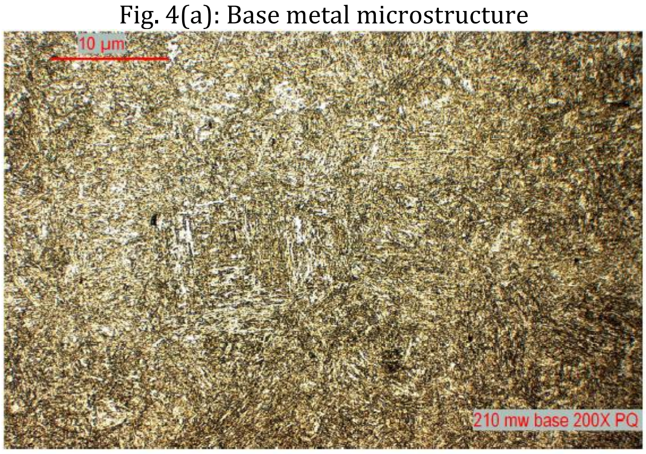

Fig. 4(b): Hardened layer microstructure

Hardness depth profile has to be measured at a distance of 5,10,15 and 20 mm from the leading edge to ensure the proper hardening according to acceptable level of hardness. (Fig. 4(a) & 4(b)).

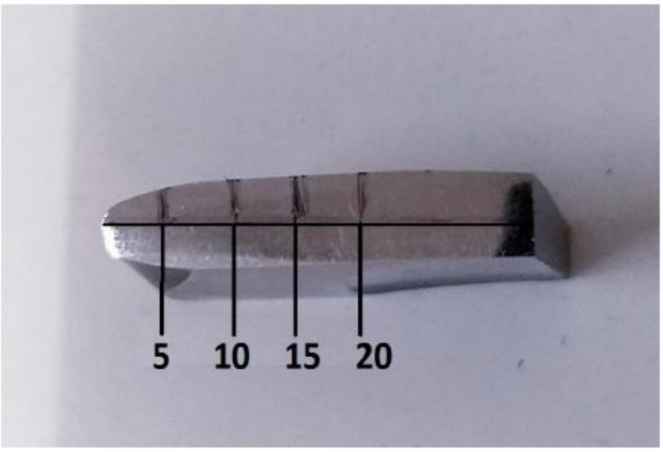

Fig. 5: Hardness depth profile at marked zone (top view of leading edge of the blade)

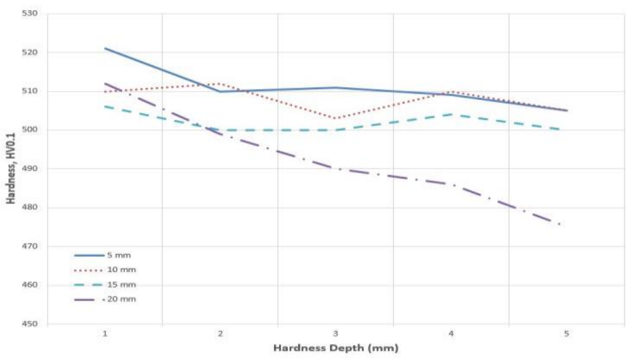

Fig. 6: Hardness depth profile of a typical 12 % Cr Martensitic stainless steel.

Residual stresses in turbine blades to be measured either by X-ray diffraction technique or electro-magnetic effects testing (EMAGATRONIC testing method). Both give quantifiable information regarding the residual stresses of the blade vane surface and thus can be used to check both the blade manufacturing process and LP turbine blade condition in power plants. The surface of the hardened zone on the suction side exhibits significant compressive stresses. The compressive residual stresses help to avoid stress corrosion cracking in the blade vane.

Author's company BHEL has supplied a number of low pressure turbine blades with flame hardening with positive feedback from the sites. Large rating fossil fuel turbine sets of 210MW, 250MW, 500MW, 800MW employing last stage blade heights upto approx. 1100 mm are in operation at number of sites in India and in which to avoid water droplet erosion (WDE), flame hardening has been done on inlet edge of blade vanes. With the flame hardening process the turbine blades made of martensitic steels can be treated with a minimum geometrical change and the reproducibility of the flame hardening process is high and non-conformance is very minimal.

Now-a-days state of the art turbine blades have been developed with precipitation hardening steels (17-4Ph steel) and with or without shroud at outer diameters to fulfill the high operational requirements and to overcome the limitation of flame hardening process. In above cases controlled hardening of inlet edges is not feasible with Flame Hardening. Laser Hardening with shot peening on entire profile is being used for such applications. The process is automated and is having shorter time for handling the blades and apt for mass production.

3. CONCLUSIONS

Flame hardening of martensitic steel blades is very successful method to provide resistance against water droplet erosion.

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REFERENCES

[1] Based on own experience at BHEL