

Heat Treatment of Steam-Turbine Rotor Blade by Induction Hardening

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Abstract— The moving blade working in wet steam is exposed to the steam of small water droplets that cause the erosion of blade's leading edge. Hardening of blade's leading edge improves the resistance of material to erosion effect. Flame hardening process is used to achieve hardness in required depth at leading edge, but it is not achieved consistently in first attempt so by using induction hardening, required depth will be achieved.

Index Terms— Flame Hardening, Induction Hardening, Steam Turbine Blade, Heat Treatment, Ultrasonic hardness, Vicker hardness.

1 INTRODUCTION

Flame hardening technique is known to be very useful in the strengthening of steels owing to various advantages such as the ability to harden regions locally, a simple operation, a high-speed and low-cost processing, and an applicability to a large and long surface area. It is thus of particular concern for the steam or gas turbine steel blades with relatively large and long surfaces that need to be strengthened for a protection from the erosion-related problems.

1.1 Problem Definition

Hardness in depth of 1mm is required in turbine-rotor blade at leading edge for better performance but by using flame hardening it is not achieved consistently in first attempt.

1.2 Problem Description

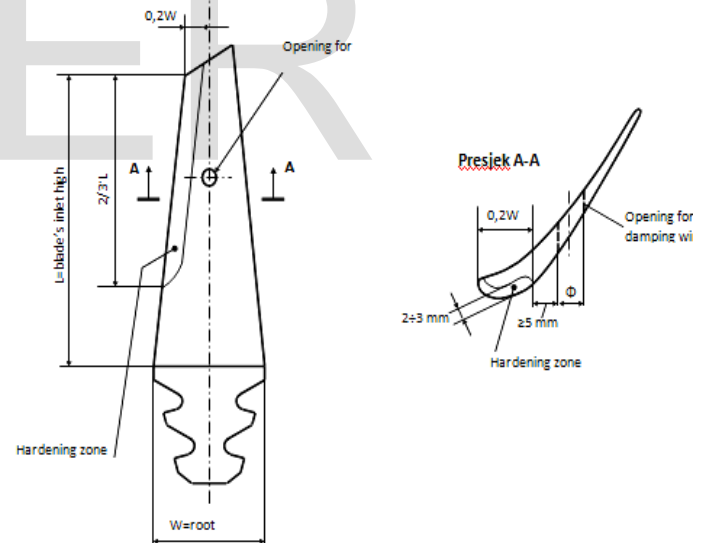
Purpose: The moving blades working in wet steam are exposed to steam of small water droplets that cause the erosion of the blade's leading edge- upper part. Hardening of the blade's leading edge improves the resistance of material to the erosion effect.



damping properties. And it is the one most commonly used material for HP blades in steam turbine.

- Chemical composition of material is C- 0.18-0.24, Si- Max 0.5, Mn- 0.4-0.9, Ni- 0.3-0.8, P- Max 0.025S- Max 0.015, Cr- 11-12.5, Mo- 0.8-1.2 and V -0.25-0.35

Leading edge hardening zone: Leading edge hardening zone is presented on the following illustrations.

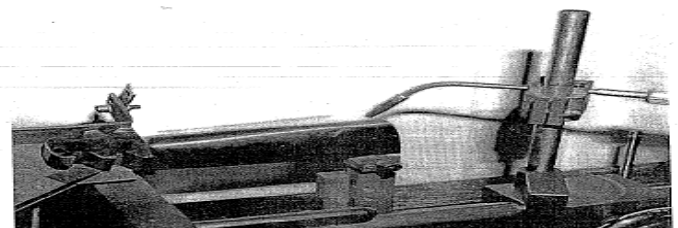


2 FLAME HARDENING EXPERIMENT

2.1 Description of Flame Hardening Device

Field of application:

- Moving blades of the last stages of the industrial steam turbines, using the following materials for the blades: X20CrMo13, X20CrMoV121, X22CrMoV121.
- X22CrMoV121 is one such a material which has a Creep Strength, Creep-fatigue Resistance, Notch sensitivity and

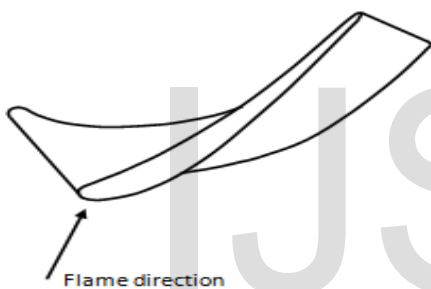


- Look to the device See picture
- Device characteristics:
Hand operated burner support leading,
Movable to the blade's leading edge,
Clamping fixture adjustable for each root type
- Adjustable burner's stop position in the purpose to define hardening length
1. Multi-hole nozzle burner (multi flame heating nozzle(shower))

Nozzle main hole dia : 3 mm
Burner distance : 10 mm
Burner slope : 15 degree

2. Gas mixture: Oxygen pressure 5 bar;

The burner distance represents the average distance between the burner and the blade's leading edge of twisted blade, see illustration



Flame direction of the downward directed burner to the blade root.

Hardening procedure:
Accessories: Flame hardening device
Burner: Annealing furnace

2.2 Operation Sequence

- Blade has to be gripped into the clamping fixture.
- Burner has to be chucked into the support.
- To align the blade's leading edge to the burner nozzle.
- To adjust the burner's stop position to the hardening length.
- To adjust flame's temperature to 950degree (yellow-red).
- To move the burner by continuously rotation of the support hand wheel.
- Automatic turnout the burner at the stop position (at the end of the hardening length).
- Take out the blade from the clamping fixture.
- Cooling of the blade at rest air.

- All blades of the one stage have to be collected and tempered in the annealing furnace at the temperature 230degree. Hold time-2hours, maximum heating rate-50 degree per hour.
- Cooling in the furnace maximum cooling rate 40degree per hour.
- Checking of the blade on cracks(cause by hardening)by dye-penetrant test.

2.3 Result

Instrument Used: Ultrasonic hardness tester			
Place of Testing:MET-HEAT ENGINEERS PVT. LTD., Baroda			
Blade details No.	Location (At Flame hardened edge)	Hardness Observed (HRC)	Vickerhardness(HV 10)
01	Location 1	35.7	-
02	Location 2	27.3	-
03	Location 1	47-48	478-483
04	Location 2	45-46	450-455
05	Location 1	49-50	500-514
06	Location 2	47-48	478-483
07	Location 1	52-53	548-554
08	Location 2	49-50	500-514

Checking of two blade per one stage-

1. Surface hardness should be 48-50HRC, 500-550 HV.
2. Surface hardness limit values are unconditionally obtained.

2.4 Protocols



Fig.3.4 Ultrasonic tester

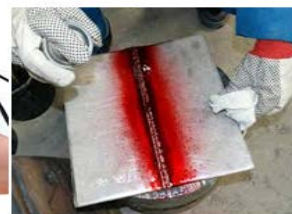
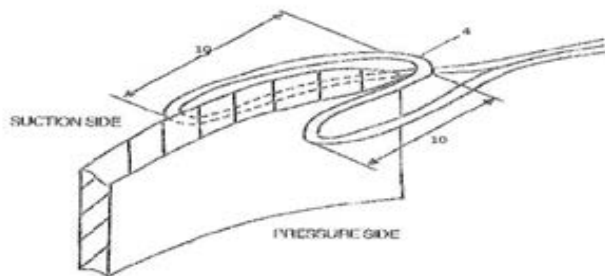
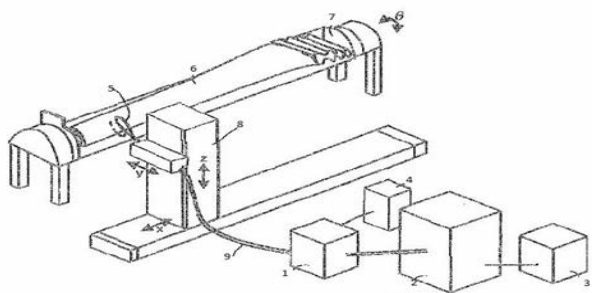


Fig.3.5 Dye penetrant test

3 INDUCTION HARDENING EXPERIMENT



1.Machining box	6.Blade
2.Power source	7.Bed
3.Water cool chiller	8.Drive unit
4.Output monitoring unit	9.Feeder
5.U-shape heating coil	10.Coil length

3.1 OPERATION SEQUENCE

- Blade is clamped into fixture on the bed
- Blade is encovered by copper coil
- Coil can be moved in both lateral and horizontal direction
- Electric source supplied is as follows:-
- Power - 22 kW, Frequency- 44 kHz
- Parallelly, water is supplied for cooling purpose
- Blade is cooled down by forced air by means of fan

3.2 RESULT

Table:-Project at Heat treatment sales and services			
Instrument:- Ultrasonic hardness tester			
Place of testing:- Heat treatment sales and services			
Blade details No.	Location	Hardness Observed (HRC)	Vickerhardness(HV 10)
1	Location 1	40-42	-
2	Location 2	44-46	-

4 RESULT AND DISCUSSION

4.1 Flame Hardening Cost (Rs)

- For 1 blade Cost-280/- (flame hardening instrument cost) - 70/- (labour cost)
- Total cost per blade- 350/-
- Flame hardening cost for 100 blades= 350*100=35000/-
- Rejected blade cost per blade-225/-
- Average rejected blades per 100 blades- 35/-
- Repair and Reprocess cost for 100 blades= 35*225= 7875/-
- Total flame hardening cost= 35000+7875= 42875/-

4.2 Induction Hardening Cost(Rs)

- Induction coil design cost -25000/-
- For 1 blade cost-475/-
- 100 blade cost= 475*100=47500/-
- Total Induction hardening cost = 47500/-

4.3 Comparison Between Processes

Process	Direct cost(per blade)	La-bour cost(per blade)	Initial cost(per blade)	Total cost(per blade)
Flame hardening	280	70	-	350
Inductionhardening	475	-	25000	475
			Cost difference (per blade)	RS.125/-
				-

4.4 Conclusion

From the estimated cost it is obvious that flame hardening is more economical process than induction hardening but "Give them quality, that's the best kind of advertising", slogan is true for this case. According to the results got for Flame Hardening and Induction Hardening cost, we can conclude that in the Flame Hardening the number of the rejection of blades from the lot is more due to the lack of required hardness. That we have achieved in Induction Hardening and most important benefits of Induction Hardening is to get more number of life of the blades to fulfill our working requirements.

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