EMERGENCY TURBINE REPAIR PROCEDURES

by

Peter P. Franks, Jr.

Owner/Manager

Mepco, Incorporated

Houston, Texas

and

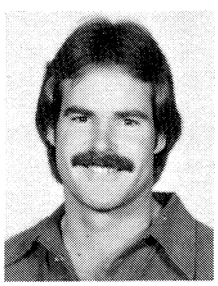
Ben Eades

"HR" Shop Supervisor

Rohm and Haas Texas, Incorporated

Deer Park, Texas

Peter P. (Pete) Franks attended the University of California and the University of Houston. He has been in Maintenance Engineering for 30 years. He has been employed by Union Carbide, Foster Wheeler, Tellepson, and other engineering associated companies, prior to embarking as a Vibration Analyst/Balancer in 1970, when he formed Mepco. He is CEO of Mepco and is active in its daily activities.



Ben Eades is the "HR" Shop Supervisor for Rohm and Haas Texas, Incorporated, located in Deer Park, Texas. He obtained a Bachelor of Science in Park Administration from Texas Tech University in 1979, and a BSME from the University of Texas at El Paso in 1984. His first three years with Rohm and Haas were spent as a maintenance engineer studying/improving PM's, material applications, and quality of repairs. He is currently responsible for supervising the maintenance in three spent acid recovery units and their corresponding environmental unit. He is also involved in the engineering and coordination of capital improvement projects. He is an associate member of ASME.

ABSTRACT

Emergency repairs of a cracked steam turbine disc can be accomplished effectively by using sound basic engineering principles. One such method used to expedite a repair is reported.

INTRODUCTION

Two rateau wheels fully bladed and 21 in diameter, operating in a turbine at 600 psig, 680°F, 3500 hp, 150 psig exhaust, and 3000 rpm experienced singular cracks at each keyway (Figures 1 and 2). Availability of a spare rotor or spare discs was not expedient at the time, necessitating an expeditious solution for the problem.

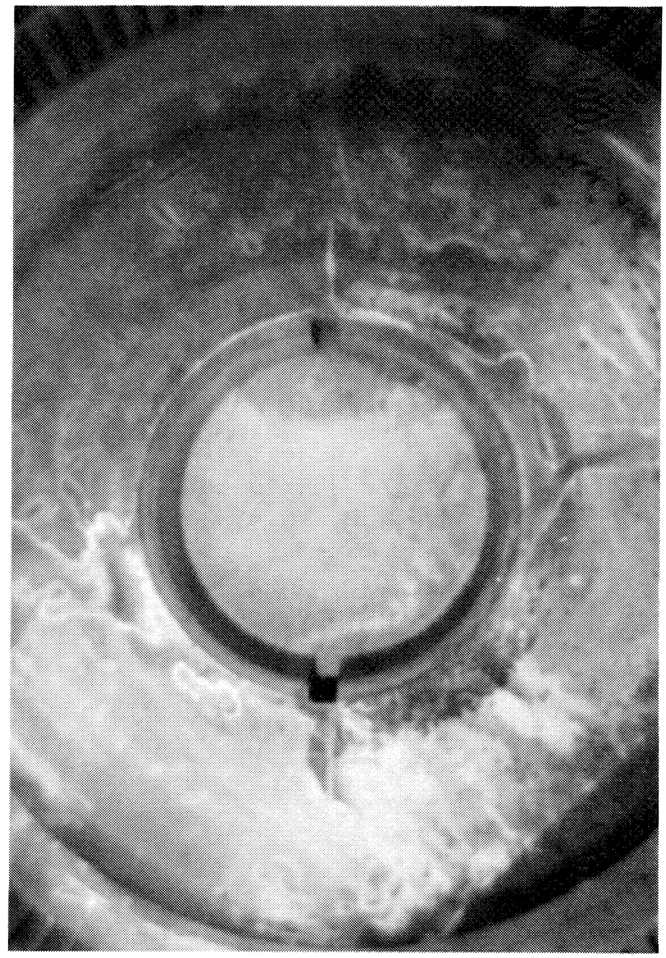


Figure 1. Single Cracks at Both Keyways.

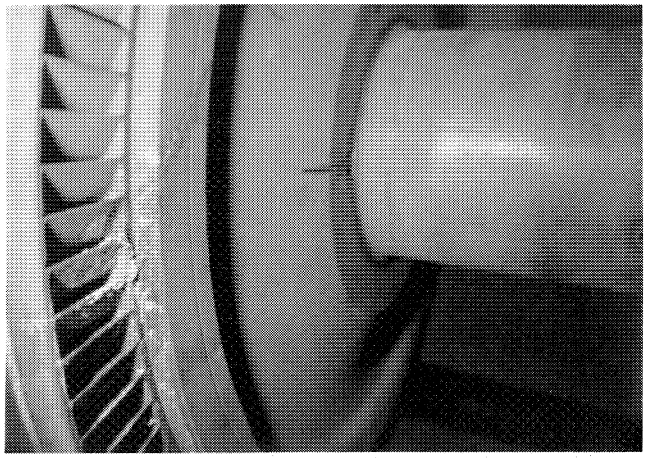


Figure 2. View of Crack.

APPROACH TO SOLUTION

The Hartford Steam Boiler Inspection and Insurance Company was the insurer of this turbine, and became very much involved. It was a total union of user, repair shop and insurance company advising to protect all parties concerned. Due to the past history of the rotor, all concerned were confident that this was a one time incidence of stress corrosion cracking due to a new boiler startup (Figure 1). On the basis of this assumption, it was agreed that the following approach be utilized:

- drop affected wheels
- acquire test specimen of material and have analyzed
- use wet metal particle to examine and determine extent of cracking and crack lengths
- bore out cracked area to sound metal and recheck for cracks (wet mag particle)
- purchase and machine a "do-nut" of suitable material to replace the cracked portion that was bored out. (A "do-nut" is a cylindrical piece of metal slightly thicker than the wheel being repaired and having inner and outer radii close to dimensions required for final repair).
- determine hardness of wheels at different representative locations.
- heat treat rough machined "do-nut" to acceptable hardness and weld to disc
- recutting the keyway is not recommended...rather, install blanks in the shaft and shrink on repaired wheels.

The rotor depicted in Figure 3 showed clearly visible damage. A closer view of this is portrayed in Figures 1 and 2.

IMPLEMENTING REPAIRS

Material of construction of the original discs was 8615 modified. The closest material available was 8620. Thorough review was made after purchasing this material and roughing out. It was sent to heat treating to match hardness of existing disc. The disc checked out at Rockwell C (Rc) 24/27 at the hub area. The "do-nut" came back at Rc 28/30, but losing some hardness was anticipated, because of oversizing for final machining. As shown in Figure 4, two different size "do-nuts" were required. They were shrunk and machined on one side only. After welding one side (procedures on Figure 4) with four passes, the discs were machined on the other side into the new weld to ensure full penetration. Welding was accomplished by four passes and then flip/flopping the disc to minimize distortion.

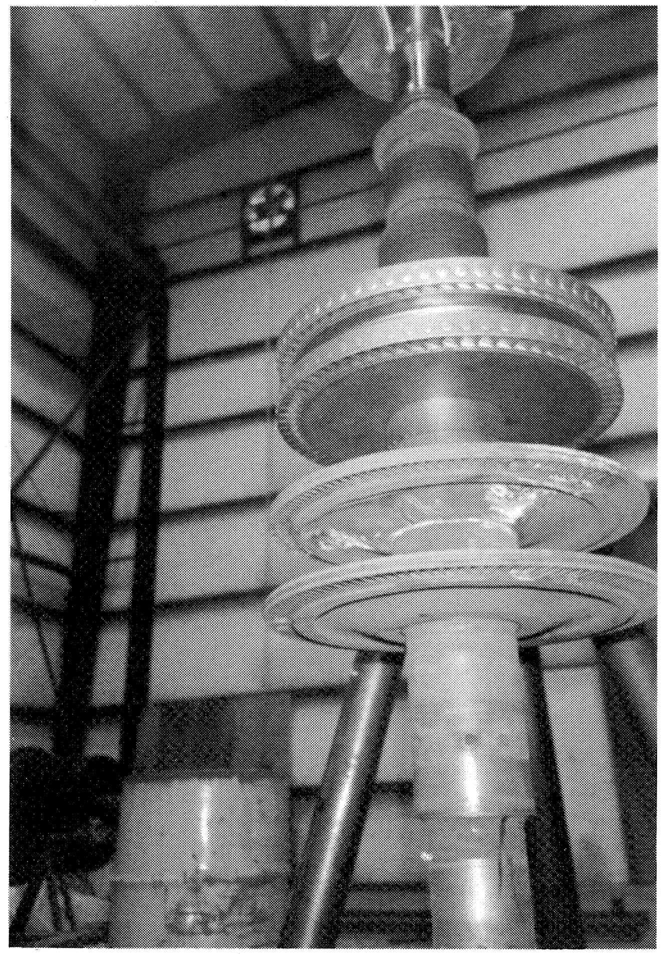


Figure 3. Rotor Before Unstacking.

WELDING PROCEDURE

The welding procedure was submerged arc welding (saw). Preheat to 500°F prior to commencement of welding, and not to exceed 800°F on interpass. A copper heat sink was used to control heat. Filler metal was of 120 k tensile and a neutral flux was used.

HEAT TREATING

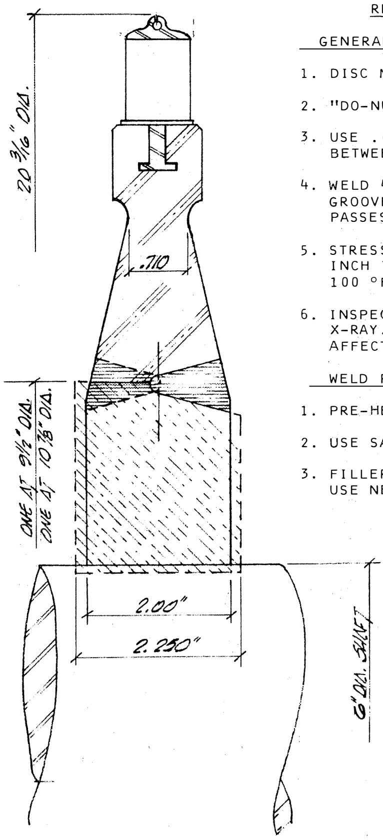
Immediately after completion of welding, the disc was placed in an oven that had been preheated to 500°F. Temperature was increased 100°F/hr until attaining 1050°F. This temperature was maintained for one hour per one inch thickness. Cool down was 100°F/hr/in thick to 200°F.

FINAL INSPECTION

Machined, then wet, mag particle was used to determine integrity of weld. Hardness was checked diagonally, across the weld, to determine if there was a definite "hard" area in the heat affected zone. None was found. X-rays were used at different angles and exposures to further establish integrity.

MACHINING/BALANCING

Discs were final-machined and hardness was checked again. This hardness test was used to determine the shrink fit stress. A few points were lost after machining, and insurer, customer, and



RECOMMENDATIONS

GENERAL NOTES

1. DISC MATERIAL IS 8615 MODIFIED
2. "DO-NUT" MATERIAL IS 8620
3. USE .001"/INCH DIAMETER SHRINK BETWEEN PIECES.
4. WELD 4 PASSES FIRST SIDE; MACHINE GROOVE OPPOSITE SIDE AND WELD 4 PASSES. THEN FLIP/FLOP WELDING.
5. STRESS RELIEVE AT 1075 °F/HOUR/ INCH THICKNESS. BRING DOWN AT 100 °F/HOUR.
6. INSPECT VIA WET MAG PARTICLE AND X-RAY. CHECK HARDNESS AT HEAT AFFECTED ZONE DIAGNONALLY.

WELD PROCEDURE

1. PRE-HEAT TO 550 °F.
2. USE SAW
3. FILLER METAL IS 120 K TENSILE AND USE NEUTRAL FLUX.

Figure 4. Cross Section of Turbine Disc.

repair shop agreed to 0.0022 in to 0.0025 in/in of diameter shrink was sufficient to achieve the desired fix.

Discs were installed on a precision ground mandrel and balanced. Shaft keyways were plugged and fitted with 4140 keys and ground true on diameter. The wheels were shrunk on and the unit was trim balanced. Some of the equations used are:

Determination Of **Max. Tangential Stress** For 3600 RPM Condition.

$$\sigma_{t\,max} = \frac{\gamma\omega^2}{4g}\left[(3+\mu)b^2 + (1-\mu)a^2\right]$$

$$\frac{(.283\#/\text{in.}^2)\,(377)^2}{4\,(386\ ^{\text{in.}}/\text{sec}^2)}\left[(3+0.3)9.5^2 + (1-.3)\,3^2\right] = 7{,}922\text{ psi}$$

Determination Of **Radial Stress** For .015" Interference Fit.

$$\sigma_r = -p = -\frac{E\Delta}{4a}\left[1 - \frac{a^2}{b^2}\right]$$

a = 3*b* = 9.5

$$-p = -\frac{(30\times10^6)(.015)}{(4)(3)} - (1 - .099) = 33{,}787\text{ psi}$$

Determination For **"Donut"** Only

a = 3" b = 5.5"

$$-p = -\frac{(30\times10^6)(.015)}{(4)(3)}\left[1 - \frac{(3^2)}{(5.5^2)}\right] = 26{,}342\text{ psi}$$

Determination Of **Tangential Stress** With .015 Interference Fit.

$$\sigma_r = \frac{E\Delta}{4a}\left[1 - \frac{a^2}{b^2}\right]$$

$$\delta_t = \frac{(30\times10^6)(.015)}{(4)(3)}\left[1 + .11\right] = 41{,}625\text{ psi}$$

R_c 24 Good For 122K psi Tensile Which Makes These Quick Checks All Acceptable!

Reference:
Design Of Machine Elements - M.F.Spotts
Formulas For Stress And Strain - Roark & Young

CONCLUSION

In an emergency situation, there are ways available to the engineer to achieve a desired goal, using sound engineering practice. This has been evidenced by the repair of this steam turbine. *Repair was further enhanced by using shrink fit only (without keys) to eliminate stress risers.* Cooperation on the part of the Hartford Steam Boiler Inspection and Insurance Company, and the customer was absolutely unique and positive at all times. This is the final ingredient for a successful fix.

DISCLAIMER

It is not the intent to present accepted repair procedures for cracked discs. The intent is to apprise users of another way to repair cracks in turbine discs. All formulas, equations and references given are just a smattering of the investigation that was made prior to the final acceptance fix. Judicious use of this information is suggested!!