Middle-East Journal of Scientific Research 9 (2): 149-152, 2011
ISSN 1990-9233

Presentation of Rejuvenation and Optimization Method and an Analysis of the Metallurgical Effect on Gas Turbine Blades Lifetime Estimation

Asadollah Motallebi and Yaser Sahebi

Department of Mechanics, Khoy Branch, Islamic Azad University, Khoy, Iran

Abstract: In this article, a dysfunctional rotor blade belonging to a 3-MW Ruston PT-85ME steam turbine is analyzed from mechanical and metallurgical perspectives. First, using the quant metric method, the chemical composition of the alloy is determined at several parts of the blade.Then, in order to model the blade, the points of the airfoil curve are obtained using CMM (Coordinate Measuring Machine) and after drawing its 3D model, the tension to the blade is obtained using ANSYS software. Finally, considering the obtained results, a proper estimation of the lifetime of the blade will be provided (using Larson-Miller parameter). Estimating the lifetime gains importance when we want to use a piece more than its design life.

Key words: Rejuvenation and Optimization · Metallurgical Effect · Lifetime estimation · Gas turbine blades

INTRODUCTION

In this article, we study the effects of two recommended heat treatment cycles on the size and volume fraction of primary- phase in order to increase the lifetime of gas turbine blades. Further, the relationship of science of metallurgy is analyzed by taking into consideration the metallurgical effect on the lifetime of interest.

Heat Treatment: Two heat treatment cycles were used (Table 1) and implemented on samples of turbine blade to prolong the lifetime of turbine blades by means of heat treatment and in order to control precipitates of primary-phase, using heat treatment handbook and through studies done on heat treatment of *Nimonic 80A* blades. Nimonic 80A alloy is an example of age hardened super alloys having MC and $M_{23}C_6$ carbides whose strength increases with increasing γ' phase [1].

The two heat treatment cycles - H1 and H2 - implemented to improve and prolong blades' operating lifetime are described below [2].

H_1: Heat Treatment Cycle

- Solution heat treatment at the temperature of 1080°C for 8 hours and then air cooling.
- Age hardening at the temperature of 800°C for 16 hours and then air cooling.

Table 1: The list of implemented heat treatment cycles

	Implemented Heat Treatment Cycles
H_1	1080°C/8h/AC → 800°C/16h/AC
H_2	1080°C/8h/AC → 880°C/24h/AC → 800°C/16h/AC

H_2: Heat Treatment Cycle [3]

- Solution heat treatment at the temperature of 1080°C for 8 hours and then air cooling.
- Stabilization of carbides at the temperature of 880°C for 24 hours and then air cooling.
- Age hardening at the temperature of 800°C for 16 hours and then air cooling.

In the solution stage, all phases except MC carbides are dissolved and they rejuvenate during cooling from the solution temperature of precipitates of γ'. By stabilization at the temperature of 880°C, $M_{23}C_6$ carbide particles precipitate at the grain boundary and some γ' phase is formed. Final age hardening increases volume fraction of γ'(Vfγ') [4].

Analyzing Samples' Microstructure: Metallographic studies were carried out to determine structural specifications and characteristics including shape, type, size and magnitude of various phases in sample heat treated blades using metallographic equipment such as electron microscope and visual analyzer. Metallographic preparation was performed similar to what was done prior to heat treating [5].

Corresponding Author: Asadollah Motallebi, Department of Mechanics, Khoy Branch, Islamic Azad University, Khoy, Iran. Tel: +98-4612550001.

Figures 1 and 2 represents images of samples' microstructure, heat treated using H_1 and H_2 cycles and depict precipitates of γ' as well as MC precipitation distribution within grains and discontinuous distribution of $M_{23}C_6$ carbide sat the grain boundary. Moreover, detrimental phases are formed in the microstructure of heat treated samples due to presence of oxygen in the furnace [6].

As seen in Figure 2, H_2 heat treatment cycle which is comprised of solution treatment, stabilization and age hardening stages has resulted in formation of annealed twins. As a result of H_1 heat treatment cycle, volume fraction of the precipitates of primary-γ' has decreased and precipitates of carbide have increased [7].

Units the Effect of Heat Treatment Cycle on the Size and Volume Fraction of Primary- Γ' Phase: In order to determine the size and volume fraction of primary-precipitates of the images from Visual Analyzer software, we analyzed images that were taken by electron microscope with 18000x magnification of samples after implementing the heat treatment cycle [8].

Graph 1 compares changes in the size of the primary-γ' phase before and after implementing H_1 and H_2 heat treatment cycles on the tested samples. We can conclude from the graph below that the average diameter of the primary-γ' phase in the H_2 heat treatment cycle has decreased in comparison with the H_1 cycle [9].

Considering the fact that precipitates are circular and of the same size, we can generalize surface fraction to volume fraction. Figure 2 represents a comparison of the changes in volume fraction of primary-γ' phase before and after implementing H_1 and H_2 heat treatment cycles on the samples of interest for various heights of the blade under examination [10].

Figure 2 shows that both heat treatment cycles decrease volume fraction of primary- phase.

Testing Hardness: All the available samples were tested for their hardness using Shimadzu HMV-2000 micro hardness tester device, having undergone solution and age hardening in the suggestedH$_1$ and H_2 heat treatment cycles. Test conditions were as follows [11]:

- Applied load 1000 gram-force
- Load application time 18 seconds

And the standard used for determining hardness was ASTM E384. In order to increase the accuracy of experiments; each sample was tested three times.

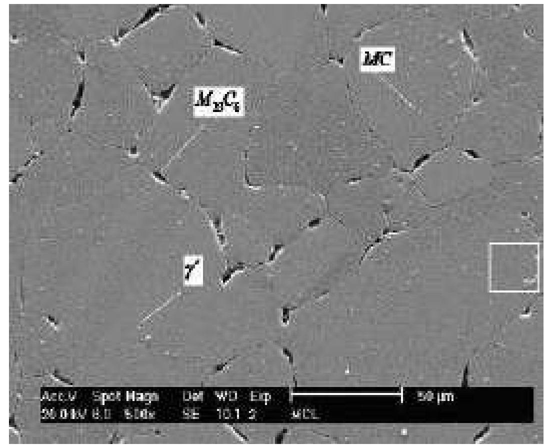

Fig. 1: Image of the sample microstructure of H_1 heat treatment cycle

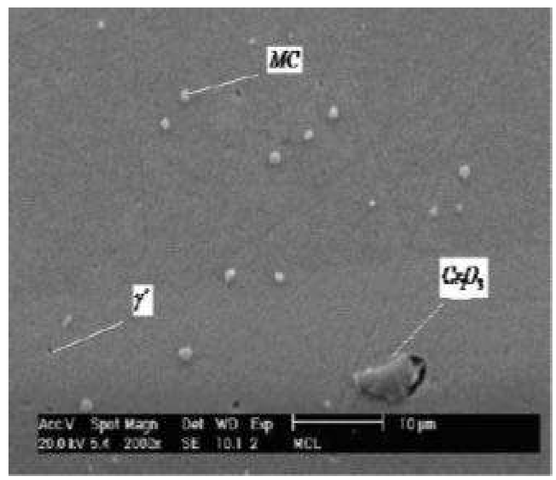

Fig. 2: Image of the sample microstructure of H_1 heat treatment cycle

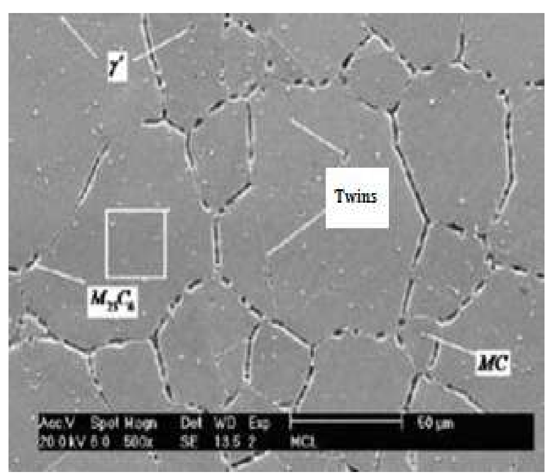

Fig. 3: Image of the sample microstructure of H_2 heat treatment cycle

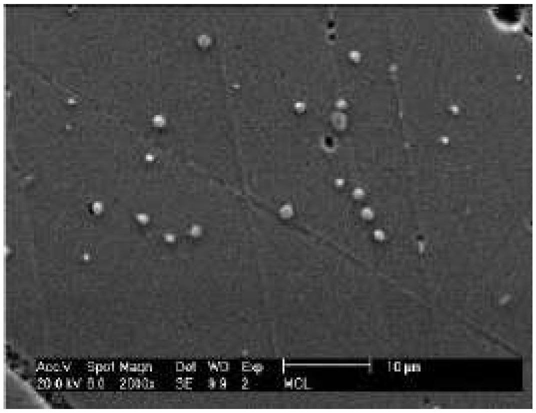

Fig. 4: Image of the sample microstructure of H_2 heat treatment cycle

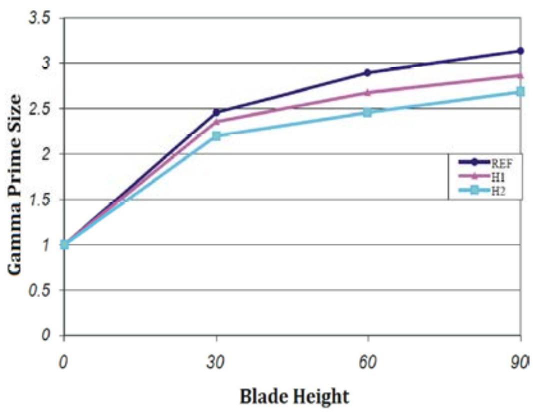

Fig. 5: Comparing changes in the size of primary-● phase before and after implementing H_1 and H_2 heat treatment cycles

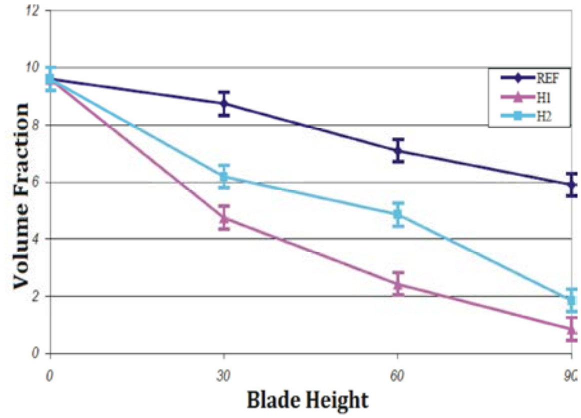

Fig. 6: Comparing volume fraction of primary-● phase before and after implementing H_1 and H_2 heat treatment cycles

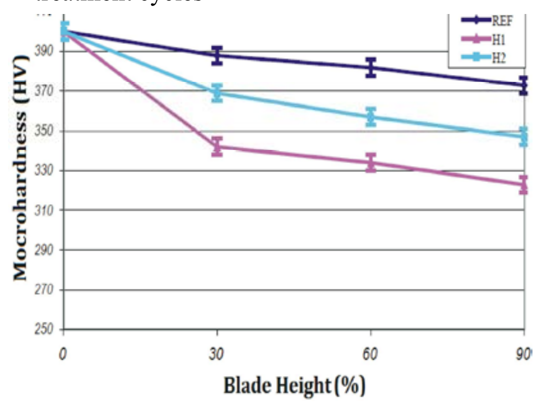

Fig. 7: Comparing changes in micro hardness (Vickers) of samples before and after implementing H_1 and H_2 heat treatment cycles

Figure 3 represents a comparison of changes in micro hardness (Vickers) before and after implementing H_1 and H_2 heat treatment cycles on the samples of interest for various heights of the blade under examination.

Analyzing the Metallurgical Effect on the Lifetime of Samples and Recalculating the Rejuvenated Life: Using LSW theory and considering mean radius of primary precipitates for the unused blade (blade root)and heat treated samples, the lifetime of the heat treated blade is obtained (Table 1) [1].

$$\bar{r}_t - \bar{r}_0 = K \quad (1)$$

In this relation, $\bar{r}_t$ and $\bar{r}_0$ are the mean radius of γ' particles at t and 0 time points respectively. Also K is the growth coefficient factor which is equal to 0.089 for this blade and at the temperature of 880°C.

It means that the lifetime of a turbine blade with operational life of 20000 hours has increased up to 6838 and 10210 hours by implementing $H_1$and H_2cycles respectively. In other words, lifetime of an operating blade has become 13268 and 9890 hours respectively.

Table 2: Results of the effect of heat treatment cycles on lifetime increase

Heat Treatment Cycle	Maximum Mean Radius of γ' Particles $(\bar{r}_t)$	Time Lapse (hr)	Increased Lifetime (hr)
H1	2.88	13263	6838
H2	2.69	9890	10210

RESULTS

Based on the results obtained, we can make the following conclusions:

- In S1, S2 and S3 samples, with the increase of height of the blade, mean diameter of primary- phase coarsens and volume fraction of primary- phase decreases and these structural changes decrease strength and hardness.
- By implementing H_1 and H_2 heat treatment cycles on sample used turbine blades, we can rejuvenate some phases to increase strength and lifetime of the blades.
- Implementing H_1 and H_2 cycles leads to 6838 and 10210 hours increase in lifetime respectively. In other words, lifetime of an operating blade has become 13268 and 9890 hours respectively.
- A comparison of the microstructure of samples which have been heat treated with H_2 cyclewith themicrostructure of the reference blade (root) reveals that volume fraction and mean diameter of the primary- phase is closer to the reference blade and as a result, H_2 cycle is more effective than H_1 cycle.

REFERENCES

1. Cohen, H. and G.F.C. Rogers, 1987. Gas Turbine Theory, Longman scientific andThechnical.
2. Donachie, M.J., and S.J. Donachie, 2002. Technical Guide, Second Edition, ASM Internationals.
3. Sims, C.H., N. Stoloff, W. Hagel, 1987. High temperature materials for aerospace and industrial power. New York: A Wiley-Inter Science Publication, pp: 46-52.
4. Bayard, O., F. Santos, J. Gioscia, F. Jacques, F. Leal, 2008. Presentation of a Protocol for Penile Rejuvenation. Soares.
5. Boemi, L., 2009. Local Club Members welcome to speak on Facial Rejuvenation. Know more about Individualized Facial Rejuvenation.
6. Kichena, P.K., 2010. Formation (metallurgical effect). When a body cools, the outer layer cools quicker and contracts first. The inner, softer parts try, during this process.
7. Clone, L., 2011. Tasman Receives Encouraging Metallurgical Results from Norra ... the metallurgical effect of which must be tested with extensive research.
8. Beavers, J.A., 2011. Effects of Environmental and Metallurgical Factors on the Stress Corrosion Cracking of Carbon Steel in Fuel-Grade Ethanol.
9. Krukovsky, P., 2004. Lifetime modeling for MCrAlY coatings in industrial gas turbine blades ... time te are used as input values for the model parameters estimation.
10. Danielewski, M., R. Filipek, R. Kozubski, W. Kucza, P. Zieba, Z. Zurek, 2005. Lifetime Estimation for MCrAlY Coatings on Industrial Gas Turbine Blades Based on Diffusion-controlled Processes Moddelling. Defect and Diffusion Forum 237-240. pp: 985-992.
11. Mok, S.J., M.S. Chang and S.M. Kang, 2009. Improving plan about lifetime prediction of gas turbine throughout ... We also provide exact information for lifetime prediction of blade by combination ... Life estimation, Lifetime estimation, Recycling, Turbines.