Project Title: Determining the Relationship between Changes in mechanical properties and Remaining Life of V94.2 Gas Turbine Blades

Department:	Technology development plan for condition assessment and life estimation of power plant hot components	***Employer:***	Niroo research Institute
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Project Necessity:

Superalloys are one of the most suitable materials to provide the required properties in gas turbine components, especially blades. The microstructure of the blades undergoes changes during operation due to the combination of high temperature and high load, which depends on factors such as the operating hours of the blades, the working conditions of the turbine and the characteristics of the blades. The resulting changes in the microstructure of the blades lead to a decrease in their mechanical properties. The gradual decline in mechanical properties eventually leads to the destruction and failure of the components. Among the most important mechanical properties of the blades that change over time are properties such as hardness, creep, high temperature tensile and ambient temperature. Due to the relationship between changes in the mechanical properties of the blades and their remaining life, several studies have been conducted in this field and is considered as one of the common methods in assessing the condition of the blades. Therefore, in line with other studies related to estimating the life of hot parts, comprehensive research should be done to achieve a quantitative relationship between changes in the mechanical properties of the blades and their residual life. Determine the time to reach their critical state. On the other hand, more than 160 Siemens V94.2 gas units have been installed in the country so far. Therefore, due to the very high cost of turbine blades and also the high number of Siemens units in the country, the superalloys used in the moving blades of V94.2 turbine are studied in this project.

Project Goals:

- Development of necessary documents to determine the remaining life of Siemens gas turbine blades from changes in the values of mechanical properties of the alloy (such as hardness, strength, ductility and impact energy)
- Reducing evaluation costs
- Increase the speed of life assessment
- Identify and apply new methods of life assessment methods

Abstract:

With the establishment of Mapna Turbine Engineering and Construction Company (Toga) in 1999 and the production of gas turbines model V94.2, the installation of gas turbines in the country has accelerated much more so that in the years 1386 to 1396 more than 150 gas turbines in the country Installed and set up. On the other hand, due to the fact that the gas turbines produced by Tuga Company for use in gas and combined cycle power plants are all of the Siemens V94.2 type or its upgraded models, these gas turbines have become doubly important in the country. Therefore, considering the number of V94.2 units in operation in the country, the issue of assessing the condition and determining the remaining life of critical parts in order to reduce maintenance costs and reduce operating risk is very important.

One of the most sensitive parts with special operating conditions are the blades in gas turbines. These parts are always subject to sudden damage due to their complex shape and conditions. Destructive mechanisms such as creep, fatigue, corrosion, foreign particles and the interaction of these factors can greatly reduce the life of these components. Although the life of these blades is usually predicted by the manufacturer, non-standard use of turbines, unpredictable changes in the operating cycle and microstructural changes that lead to changes in properties cause the actual life of these blades. Parts are different from the life declared by the manufacturer. Even in cases where these parts do not reach their expected life. If the blades of gas turbines suffer from sudden premature failure, they may cause great damage to power plants in various ways. In addition, estimating the actual remaining life of these blades will significantly reduce unit maintenance costs due to reduced repair and replacement costs.

Due to the relationship between changes in the mechanical properties of the blades and their remaining life, several studies have been conducted in this field in different countries and is considered as one of the common methods in assessing the condition of the blades. Therefore, in this project, microstructural changes as well as mechanical properties were evaluated in terms of elapsed life by preparing used blades with different lifespans from the country's gas power plants; By examining and analyzing them, the quantitative and qualitative relationship between changes in properties and residual life of blades for use in destructive and non-destructive methods was determined.

Steps and Methodologies:

Phase 1 - Gather information and preliminary reviews

1-1-Collecting information about V94.2 gas units and superalloys used in blades (mechanical properties and microstructural specifications, etc.)

1-2- Investigation of damages and mechanisms of destruction of blades

1-3- Investigating the effect of operating conditions on the process of destruction of blades

1-4- Statistical study of destruction of blades and technical and economic evaluation of useful use of blades

1-5- Submitting a report

Phase 2 - Identify the criteria and investigate the relationship between mechanical properties and blade life

2-1- Evaluation of criteria related to mechanical properties of superalloys used in blades

2-2- Investigation of changes in mechanical properties (hardness, impact, strength, ductility) in terms of operating time and investigation of microstructural changes of superalloys used in moving blades

2-3- Investigation of different methods for evaluating the condition of the blade based on changes in mechanical properties

2-4- Investigate and determine the quantitative relationship between mechanical properties and remaining blade life

2-5- Preparing different samples worked in different operating conditions and examining their operating conditions

2-6- Submit a report

phase 3 - Performing tests, analyzing the results and preparing quantitative criteria

3-1- Planning to perform various tests on the prepared samples (determining the number of samples from each test, sample map, sampling locations from each blade, test conditions, etc.)

3-2- Prototyping and performing mechanical tests in accordance with the existing standards on different superalloys

3-3- Analysis of test results

3-4- Determining the relationship between changes in the mechanical properties of superalloys used with life

3-5- Preparing the necessary instructions to use the process of changes in mechanical properties in assessing the remaining life of the blades

3-6- Submit a report

Main Results (technical outputs, patents, papers, books, reports, etc.):

1. Microstructural studies of samples prepared from blades of gas turbines have always been considered as one of the most economical and efficient methods of status assessment.
2. Based on the study of the microstructure of the serviceable blades, it can be concluded that by examining the progress of carbide reactions, it will be possible to estimate the microstructural deterioration of the serviceable blades.
3. By comparing the results of high temperature and ambient temperature tensile tests, it can be concluded that the changes in the results of high temperature tensile tests are more logical and more appropriately explain the changes in the remaining creep life. In addition, among the various parameters of mechanical properties, the changes in the measured elongation values are more in line with the residual creep life and can therefore be considered as a criterion for assessing the condition and estimating the residual life.
4. The strength parameters measured by ambient temperature tensile and warm tensile tests are strongly dependent on microstructural changes during cooling of the specimens and therefore can not be considered alone to estimate the remaining life of the blades. This problem is more severe for the results of ambient temperature tensile tests, which can be due to the strong dependence of the ambient temperature tensile properties on the properties of the secondary γ' particles.
5. The trend of changes in the results of the impact test shows a good agreement with the trend of changes in the creep life of different samples. Therefore, performing impact test on small size samples prepared from used blades is recommended as an efficient way to evaluate the condition of these blades.
6. Among the various microstructural properties, the formation of a continuous network of boundary sediments shows a more pronounced effect on the creep properties of nickel-based superalloys. In addition to this microstructural property, changes in the amount of granular and intragranular carbides in the used samples, changes in size and changes in the morphology of primary γ' sediments can also be considered as other signs of microstructural deterioration and mechanical properties of IN738LC superalloy.

- ✓ Technical report of specifications and properties of alloys used in Siemens turbine blades
- ✓ Technical report identifying criteria and investigating the relationship between mechanical properties and blade life
- ✓ Technical report Instructions for using the process of changes in mechanical properties in assessing the remaining life of the blades