Project Title: Economic and technical feasibility study on development of the laser peening technology in order to enhance the fatigue life of turbine and compressor blades

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Project Necessity:

Laser peening (LP), or laser shock peening (LSP), is a surface engineering process used to impart beneficial residual stresses in materials. The deep, high magnitude compressive residual stresses induced by laser peening increase the resistance of materials to surface-related failures, such as fatigue, fretting fatigue and stress cracking. Laser shock peening can also be used to strengthen thin sections, harden surfaces, shape or straighten parts (known as laser peen forming), break up hard materials, compact powdered metals and for other applications where high pressure, short duration shock waves offer desirable processing results.

Laser peening uses the dynamic mechanical effects of a shock wave imparted by a laser to modify the surface of a target material. It does not utilize thermal effects. Fundamentally, laser peening can be accomplished with only two components: a transparent overlay and a high energy, pulsed laser system. The transparent overlay confines the plasma formed at the target surface by the laser beam. It is also often beneficial to use a thin overlay, opaque to the laser beam, between the water overlay and the target surface. This opaque overlay can provide either or each of three benefits: protect the target surface from potentially detrimental thermal effects from the laser beam, provide a consistent surface for the laser beam-material interaction and, if the overlay impedance is less than that of the target surface, increase the magnitude of the shock wave entering the target. However, there are situations where an opaque overlay is not used; in the Toshiba process, LPwC, or where the tradeoff between decreased cost and possibly

somewhat lowered surface residual stress allows superficial grinding or honing after laser peening to remove the thin thermally effected layer.

Project Goals:

Fatigue of different components may cause to make significant repair cost. Two parameters including temperature and corrosion together with passing time play essential roles in mechanical fractures. The final reason of the most fractures is that a crack grows to such a level which the remained material cannot withstand the applied load and resultant stresses. In order to prevent such condition, one solution is to change the cracked component with a new one, but it takes a lot of time as well as cost. Another solution is to reduce the value of applied load, but this solution is impossible in the most cases. An efficient solution is to postpone the crack growth or to stop it, completely.

The mechanical components of power plant turbines are under hard work conditions. On the other hand, due to the vibrations of all system, the applied load varies with time. Therefore, the mechanical and thermal fatigue fractures, fretting fatigue fractures, and fatigue crack growth are common in these components. In recent years, several researchers have been tried to employ different methods in order to enhance the fatigue life of these components. The compressive residual surface stress has demonstrated a good effect for this purpose. The laser peening technology is one of the newest technique in this field which has the capability to create accurate compressive residual stress on the free surface of a component which leads to enhance its mechanical properties.

Abstract:

During the last four decades, the laser-based technologies have been developed continuously in Iran. On the other hand, the 21^{th} century is known as century of laser and photonic, that is not passed more than 20 years. Accordingly, laser and photonic are key technologies which can increase the ability of an industry. Nowadays, different products using laser equipment have been introduced.

On the other hand, the fracture phenomenon due to fatigue cracks, corrosion cracks, and fretting loads is an important reason of the collapse of components subjected to cyclic loading condition such as power plant structures. Various methods have been employed to increase the fatigue life of such components. One of the technologies to accomplish this purpose is the mechanical surface treatment technology which includes different methods. The base of this technology is to create a layer of compressive residual stress on the free surface of the component.

In this project, the technical and economic feasibilities of the laser peening technology for using in power plant industry are studied in order to know a way to reduce the cost of repair and maintain.

Steps and Methodologies:

- Study on the laser device using for laser peening technique
- Study on the residuual stress created via the laser peening technology
- Study on the effec of laser peening on mechanical properties of materials

- Study on using laser peening technology for power plan components
- Study on the advantages of laser peening tecknique
- Comparison of the laser peening technique with other similar techniques
- Study on different laser devices using for peening (Q-switched, continious wave, pulse wave)
- Technichal and economic characteristics of common laser devices using for peening
- Estimation the reduction in maitenance cost of steam turbines using laser peening technology
- Estimation the reduction in maitenance cost of gas turbine compressor via laser peening technique

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

On the basis the discussed matters, it was found the laser peening technique has a wide range of application, the most important of them are as below:

- Incremnt the stiffness and fatigue life of components under cyclic loads such as he blades of turbine and compressor from 2 to 5 times
- Enhancement the fretting fatigue life of the components under errosion such as the blades of steam turbines and bolt joints of rotors from 2 to 3 times
- Increment in the stiffness of welded joints up to 1.5 times
- Enhancement the surface hardness of components under errosion or impact loads such as compressor blade up to 2 times
- Increment the resistence of crack growth for the components subjected to the corrosion and errsion such as steam urbine blades from 3 to 5 times

Accordingly, based on the obtained estimations, it was found that with the aid of the laser peening technology, the costs related to the repair and maintenance of power plan equipment can be reduced between 35% to 55%.

On the other hand, it was indicated that by using Q-switched lasers with lower energy density and devoting some more time, it will be possible to carry out the laser peening process with the desired magnitude and depth of implied surface residual stress.