THE ADVANTAGE OF NDT ON COST REDUCTION AND PREVENTION OF POSSIBLE DAMAGES OF ROTOR TURBINE PARTS

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The global demand of energy is increasing tremendously day by day. At the same time decreasing the cost in power generation as much as possible is one of the biggest goals in this field. Usually the quality control/inspection (especially NDTs), cost seems to be one of the expenditures of this industry, which most of the time there is an idea to cancel that. None destructive inspections cover the beginning (each part) to the end (final installation in the power plant). Further more, the importance of the parts utilized in turbines, make it necessary to have a wide range of tests with closed criteria for them which rise up the final price of the turbine consequently.
This investigation is a part of a widespread research in which the cost of the quality inspections/NDT of two types of turbine parts has been calculated and finally the influence of each group of parts on turbine crashes and shutdown, have been estimated. Rotor parts as a heart of turbines are so critical to any defects due to their performance (rotating) and their position (center part of turbine). It leads to a grate amount of none destructive testing for these parts. The key component of these quality programs is utilization of the fit for purpose nondestructive testing method. This paper provides the result of limited research and evaluation in finding the fit for purpose criteria when utilizing different nondestructive method and its role on cost reduction and prevention of possible integrity damages of turbine rotor parts for power plants. This investigation shows that the quality plays a big role in decreasing the final costs of turbine and power plants which redound to a significant save of power generation cost.

1. Introduction

The processes of casting, forging, and rolling-welding combinations are the three main processes utilized for production of Turbine body parts, utilized in power plants. Rolling and welding combination process is mainly used to produce the outer body parts of turbine casings. However, the more critical parts such as rotors and internal parts are produced by forging and casting processes. Rotor parts as a heart of turbines are so critical to any defects due to their performance (rotating) and their position (center part of turbine). It means that their rotating action (at least 2500 RPM) face them to many radial tensions (torque) which can be initiator for fatigue defects. At the same time, their position in the center part of turbines-generally with high temperatures and pressures- leads to creep problem, also make it necessary to shout down turbine/power plant for repair.
Obviously, the criticality of these parts requires a higher degree of knowledge, experience, and tighter quality control/assurance procedures. Realization of the production shortcomings and sensitivity requirements for flawless performance of these parts when in operation demands comprehensive quality programs at the manufacturing facilities. However, the weight and size criteria of these forgings

which can be from a few Kilograms and up to 40 tons and their frequent applications in turbines require inspections methods that could cover the following concerns:

1. Defect finding in the beginning steps of production to avoid wasting time and delay in assembling of many turbine parts which can cause the extension of the total production time.
2. Utilizing methods which do not in any way destruct the structures and cause the forgings to become a scrap piece hence wasting money which will increase the total price of turbine.

It is obvious that NDT is the best choice in accomplishment of the above concerns. By utilizing NDT methods, it is possible to find surface and volumetric defects in all stages of the production without destructing the structures.

In this paper, investigation has been done on two types of Siemens Gas (V94.2) Steam (E) turbines which are manufactured by MAPNA[1] group. At the beginning, the characteristics of related forgings (weight and price) have been reviewed and the role of NDT methods in cost reduction and prevention of possible integrity damages of casting turbine parts are shown.

2. Forging Parts of Gas Turbine V94.2

There are 29 forging parts in this type which totally weigh more than 55 tones (Figure No.1). Weight criteria of the parts have been shown in tables 1. Based on a global reference price for the forgings, the final price of parts could be calculated and has been shown in table2.

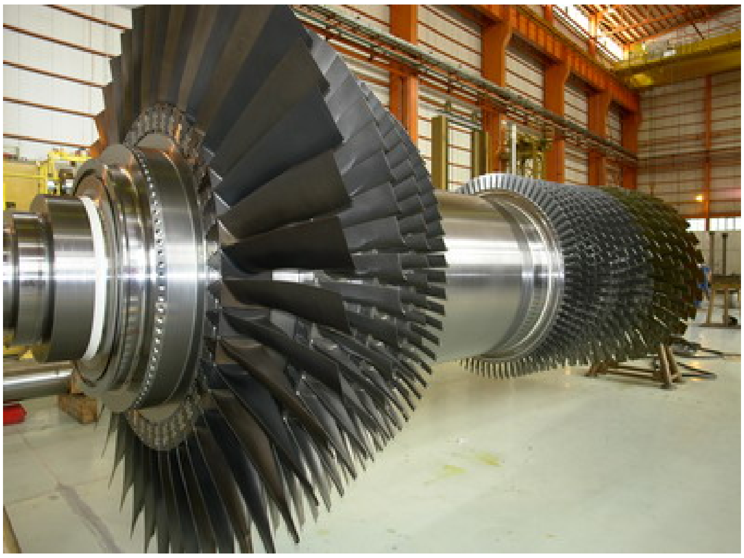


Figure1. Assembled view of rotor of gas turbine V94.2

Table 1. Weight criteria for gas turbine (V94.2) forging parts

Alloy Type	Weight Criteria (Kg)		Total Weight (Kg)
	Min.	Max.	
26NiCrMoV145MOD	222	5,550	21,091
26NiCrMoV115	208	3,481	34,231

Table 2. Cost estimation for gas turbine (V94.2) forging parts

Type	Unit Price (€/Kg)	Weight (kg)	Total Price, (€)
26NiCrMoV145MOD	20	21,091	421,820
26NiCrMoV115	15	34,231	513,465
Gas turbine forging parts			935,285

3. Forging Parts of Steam Turbine E-Type

There are two different parts of forgings in this type which totally weigh more than 41 tones. Weight of the parts have been shown in tables 3 and based on a global reference price, the final price of forging parts could be calculated and has been shown in table 3.

Figure1. Assembled view of rotor of gas turbine V94.2

Table 3. Cost estimation for steam turbine (E-Type) forging parts

Type	Unit Price (€/Kg)	Weight (kg)	Total Price (€)
26CrMoNiWV88	16.25	38,826	630,922.5
S355J25G3+N	15	2,750	41,250
Steam turbine forging parts			672,172.5

4. Discontinuities in forgings

Forging as an important process to manufacturing the metallic parts, break the grain boundaries so final microstructure has a compact structure with fine grains. It means that most of the porosities and shrinkage and gas (in the initial alloy will be disappeared after forging. Due to previous lines, the final parts will have improved mechanical properties.
Although forgings benefits, there are some internal (volumetric) discontinuities like lamination, disperse and concentrated shrinkages in these parts. The elongated shaped discontinuities (i.e. crack) can cause stress concentration and decrease the fatigue strength. Furthermore, due to the application of cycle loading on these turbines caused by rotating of the rotor components, fatigue strength is very critical and its weakness can cause lots of problems for turbines and power plants. This makes the detection of external defects very important.

5. Quick review of NDT methods

VT, MT, PT, UT & RT are five methods which are normally utilized for detecting discontinuities in casting parts. Both of PT & MT methods are applied for detecting surface and near surface discontinuities. UT and RT is utilized for detecting volumetric discontinuities.

6. NDT methods utilized for forging parts of Gas TurbineV94.2 & Steam Turbine E-Type

Referring to the specification for these forgings, the extent of examination for each NDT method could be extracted. Generally almost all accessible surfaces of turbine parts are subject to inspection.
In many cases to find the volumetric defects, 100% UT is required and it shall be repeated in several directions by several probes. In some companies, automatic or semi automatic techniques have been used to test the forging parts due to their symmetry. Generally these parts have thick sections so RT is not advice for volumetric tests. For external or surface inspection, MT is the main method and PT may be used in some cases, especially when the parts have complicated shapes or limited access for MT.

Table 4. NDT extent utilized in forging parts.

Method	MT	UT	VT	PT
Gas Turbine Forgings	%100	%100	%100	Optional
Steam Turbine Forgings	%100	%100	%100	Optional

7. Cost estimation

1- Thermal turbine inspection costs:

According to the available information and inspection methods necessary for forging parts utilized in turbine production in MAPNA group, the inspection cost for a day of an inspector plus equipment on an average is about 160€ (man/day). The total inspection time for nondestructive inspection of forging parts for each gas and steam turbine unit can be approximately about 6 and 6.5 inspection days respectively.
The inspection cost for each type will be found by multiplying the number of the inspection days to the cost of one day (160€) so the these costs will become 960€ for each unit of gas turbine and 1040€ for each unit of steam turbine. This cost will become 2960€ for a conventional combined cycle unit (Two gas turbines and one steam turbine).
Inspection cost (conventional combined cycle) = Gas turbine cost*2 + Steam turbine cost. The total cost then is: 960*2 + 1040= 2960€

2- Thermal turbine production cost:

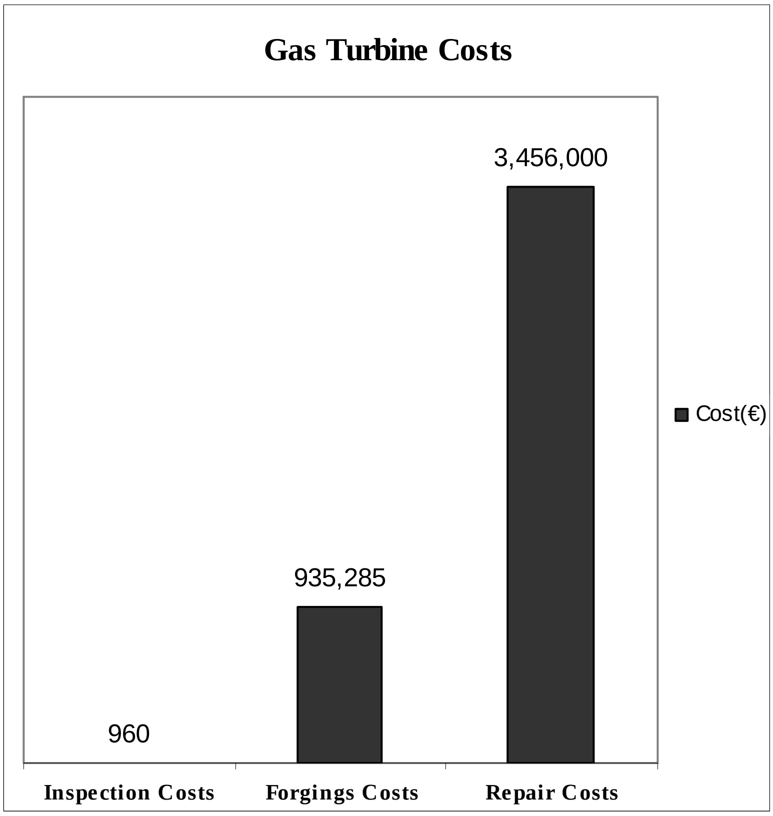
In accordance with tables 2 & 3, the production cost of a V94.2 gas turbine forging parts is equal to 935,285€ and this cost for a steam turbine E-type is equal to 672,172€. Consequently, conventional combined cycle unit production costs can be estimated at 2,542,742€. Production cost (conventional combined cycle) = Gas turbine cost*2 + Steam turbine consisted of 935,285*2 + 672,172 = 2,542,742€

3- Thermal turbine repair cost upon breakdown:

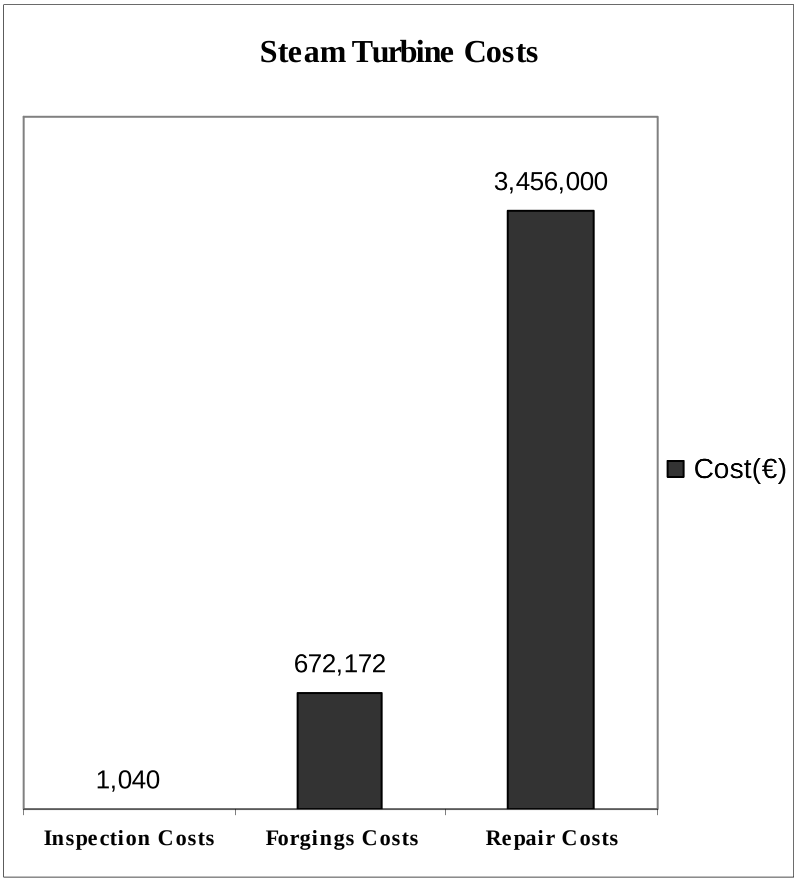
To show the value of inspection through nondestructive testing we consider the cost of a turbine forging part failure which could shut down a plant. If we assume a 60 day period (minimum time) for essential repairs and commissioning of the replacement turbine then only loss of production due to this failure can be calculated. This cost for each hour is €2400 (based on power plants cost in Iran) for one turbine (without taking other minor costs into consideration) and at €7200 for a conventional combined cycle unit (Two gas turbines and one steam turbine). The total breakdown cost can be estimated as follows:

Gas/Steam turbine shut down costs (for essential repairs) = 60*24*2400 = €3,456,000

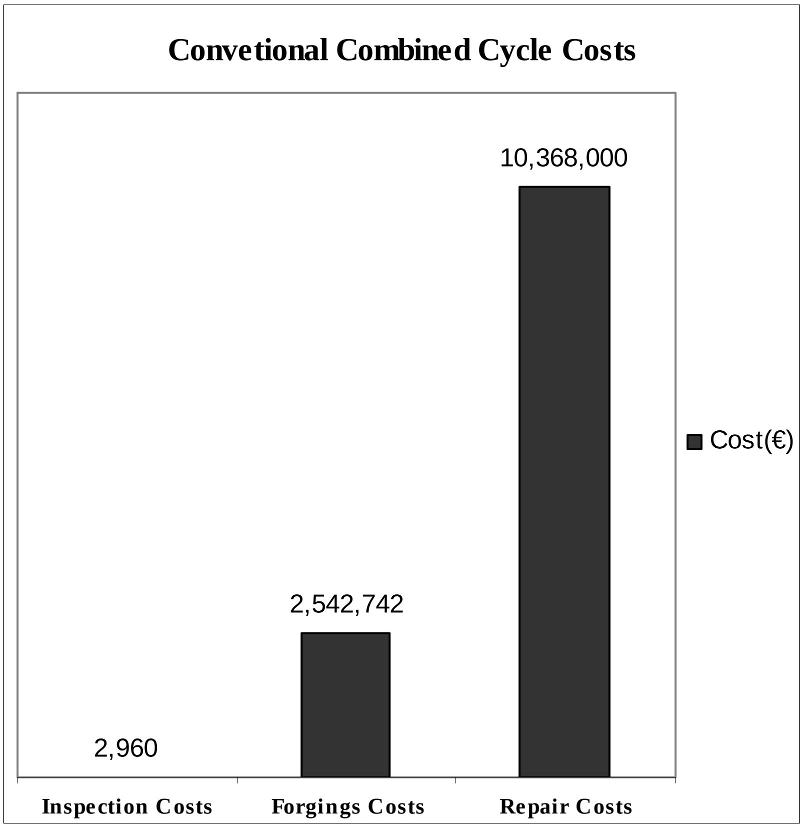
Conventional combined cycle shut down costs (for essential repairs) = 60*24*7200 = €10,368,000



Graph 1: Inspection and repair cost for gas turbine



Graph 2: Inspection and repair cost for steam turbine



Graph 3: Inspection and repair cost for conventional combined cycle turbine

8. Conclusion

As discussed in this investigation due to the high sensitivities of forging parts utilized in thermal turbines, non-destructive testing plays an important role in reducing the manufacturing and repair costs. When quality control programs contains utilization of the fit for purpose nondestructive testing methods the overall cost reduction can be realized in the following stages of production:

1- The inspection to forging production cost for V94.2 gas turbines is only 0.1 %.
2- The inspection to forging production cost for E-Type steam turbines is only 0.15 %.
3- The inspection to essential repair cost for gas turbines is only 0.027 %.
4- The inspection to essential repair cost for steam turbines is only 0.029 %.
5- The inspection to forging production cost for conventional combined cycle is only 0.12 %.
6- The inspection to essential repair cost for combined cycle is only 0.028 %.

Nowadays almost all of the manufacturers and producers of turbine parts take advantages of nondestructive testing methods to realize these cost savings. In many instances these savings are not quantified and inspectors have difficulty in securing inspection activity budget. This paper as a part of widespread research in calculation of the cost of the quality inspections/NDT of two types of turbine parts and estimation the influence of each group of parts on turbine crashes and shutdown can serve as one of the tools in establishment of comprehensive QA/QC program at power generation industry.

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