DESIGN AND PERFORMANCE OF INDUSTRIAL GAS TURBINES AND THEIR ENVIRONMENTAL EFFECTS

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Abstract - The present researcher has been tried to investigate two issues in this article. In this regard two aims were determined which was "explaining industrial gas turbines and their design" and "effects and possible interference of turbines with the environment". Since after considering all other supporting researches, it has been concluded that turbines have environmental negative effects but new versions of turbines have been trying to solve such problems.

Keywords - Industrial gas turbines, turbine's design, negative environmental effects, solutions

I. INTRODUCTION

The Definition of Turbines:
A device in which the kinetic energy of moving fluid flow after collision with the blades can be converted to mechanical energy. The produced mechanical energy is used in the following activities: moving the generators to produce electricity, rotating pumps, enabling the compressor, being used in industrial, civil, military and other affairs.

Fluids Used in Turbines

Air in wind turbines in wind farms, water in hydro water turbine, condensable steam in the steam turbines in fossil fuel power plants such as gas stations, and new power plants such as nuclear power plants, etc., gas (air, natural gas, helium and etc.) in gas turbines

Turbines Used in The Oil and Gas Industry

- Steam turbines

These types of turbines are of the oldest turbines used in industry. In this type of turbine, the steam (which is produced in the boiler) is used for motion in a turbine. The turbines are used less for the following reasons:

1. Boiler and other equipment are needed.
2. The maintenance costs are high.

- Gas turbines

In this type of turbine, a quantity of fuel (mainly natural gas) and compressed air burn in the combustion chamber. Due to burning and heating, gas volume increases. Gas with high volume, pressure and set temperature clashes turbine blades, causing the turbine to spin out. Because of the importance of gas turbines in the oil and gas industry, in the following mainly these types of turbines are explained.

II. REVIEW OF LITERATURE

The first time in 1791 AD John Barber used the method for causing movement via air. In 1903, a Norwegian researcher (AegidiusElling) built the first gas turbine successfully. In this turbine, a rotary / dynamic compressor and number of turbines were used. This turbine was able to produce (11hp) 8kW energy.

In 1904 Elling design it better and by the reduction of exhaust gas temperature from 500 ° C to ° C 400 Elling could produce (44hp) 33Kw energy. This engine worked with 20,000 RPM motor speed. Elling's gas turbine was very similar to Frank Whittle's jet engine, which was built in 1930 in England. This jet engine had a centrifugal compressor and a central turbine. In 1936 in Germany, Hans von Ohain and Max Hahn designed a turbine in which a centrifugal compressor and a turbine close to both were used.
Whittle and Ohain eventually led to the creation of the turbine industry. Cowles paper in 1989 [1] presents an overview, from an industry perspective, of the current, highly empirical approach for assessing the HCF capability. Complicating factors that must be addressed which affect engine HCF material capability are also described. Future directions which would improve the current approach are outlined, emphasizing incorporation of fracture mechanics. Technical challenges which must be addressed to successfully implement use of fracture mechanics for HCF are described, and areas of research recommended. Also he concluded the largest single cause of component failures in modern military aircraft gas turbine engines is high cycle fatigue (HCF), exceeding the number attributed to low cycle fatigue, corrosion, overstress, manufacturing processes, mechanical damage, and materials. The HCF problem is a pervasive one, affecting all engine sections and a wide range of materials. In addition to the impact on engine component reliability, HCF problems cause significant economic impacts through field inspection and maintenance actions, and reduced readiness reliability. Pilavachi in 2002 [4] investigated the use of mainframe gas turbines for power generation which has increased in recent years and is likely to continue to increase. The proportion

of power generation using combined heat and power is also growing mainly due to efficiency improvements and environmental benefits. Mini- and micro-turbines offer a number of potential advantages compared to other technologies for small-scale power generation, particularly for distributed power generation, although there are some technical and non-technical barriers to the implementation of the technology. There is an uncertainty about their market potential but they could be used for power generation in the industrial, commercial and residential sectors. The market potential could increase substantially if the cost, efficiency, durability, re-liability, and environmental emissions of the existing designs are improved. He concluded that the power generation industry uses a large amount of the primary energy demand in the European Union. There is therefore a continuing need for improved energy efficiency within the European Union coupled with a pressing need to reduce emissions. The use of gas turbines for power generation has increased in recent years and is likely to continue to increase, particularly for distributed power systems. The proportion of power generation using CHP is also growing mainly due to efficiency improvements and environmental benefits. There is much uncertainty about the market potential of1. micro-turbines. Manufacturers have to commit themselves and define whether they will produce micro-turbines for a volume or for a niche market. A major problem includes the very high cost of the regenerator. In commercializing advanced micro-turbine designs, manufacturing scale-up techniques will be significant in lowering system costs. Achieving fuel flexible systems will be a major technical challenge. Testing will be needed to determine the optimal combustion conditions for different types of fuel. Interconnection with the electric grid poses a significant barrier to micro-turbines and regulations need to be established. There are advantages and disadvantages in the use of micro-turbines for CHP. The future depends on the market niche for such turbines and on government policy.

Information of Reid's book published in 1971 [6] was presented in textbook fashion concerning the occurrence of deposits, the effect of impurities in fuels (especially alkalies, sulfur and vanadium) and the mechanisms responsible for metal corrosion in boilers. Minerals in coal were classified into the shale group, clay group, sulfur group, carbonate group, and associated minerals (quartz, feldspar, garnet, hornblende, gypsum, apatite, zircon, epidote, biotite, augite, prochlorite, diaspore, lepidocrocite, magnetite, kyanite, staurolite, topaz, tourmaline, hematite, penninite). Both pyrosulfates and alkali iron trisulfates were specifically linked to corrosion deposits. Numerous tables, graphs, and chemical equations are included in the text of this detailed presentation of state of the art knowledge concerning external corrosion and deposits.

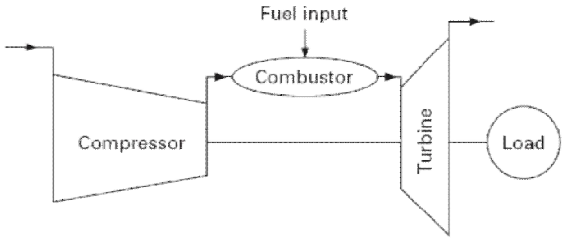
Rowen's paper in 1983 [7] provided simplified mathematical representations of heavy-duty gas turbines that are suitable for use in dynamic power system studies and in dynamic analyses of connected equipment. The full range of heavy-duty, single-shaft gas turbines, from 18 MW (24,000 HP) and 106 MW (142,000 HP), is covered, as well as both liquid and gas fuel systems, parallel and isolated operation, droop and isochronous governors, and the impact of both air- and hydrogen-cooled generators on the characteristics of the model. Alterations to the models, for the purpose of further simplification, are also discussed. This new edition of Mattingly and Von Ohain's book in 2006 [3] has updated the material and expanded the coverage, and we anticipate that it will be equally well received. An interesting feature of the first edition was a very extensive foreword by the jet engine pioneer, Hans Von Ohain. Indeed, it is so extensive and comprehensive that it is more a historical overview and introduction than a foreword. We deem it so useful that it is included in this edition as well. This Second Edition has ten chapters, seven appendices and more than 850 pages.

III. AIMS

1. Explaining industrial gas turbines and their design
2. Effects and possible interference of turbines with the environment

Gas Turbine

The basic requirement to produce energy in a turbine is that entrance pressure (inlet pressure) should be higher thanthe output pressure (outlet pressure). In order to increase this pressure in turbine mainly compressors are used. So in turbines, compressors are placed prior to turbines.



Schematic layout of a single-shaft gas turbine.

Above figure shows an example of uni-axial turbine where the shafts of compressor and turbineare connected to each other. If the fluid used in the turbine is only air, in this case, the outlet fluid of the compressor turbine is expanded and because of energy loss in the compressor and turbine, energy output of turbines will be less than the energy used in compressors and then the system will be stopped. If the amount of gas as a fuel is added to the air to offset the energy used in turbines,in this case, after burning

gas, the system will continue to operate but will not produce any additional energy. To produce energy in a gas turbine, more gas should be added to it. This energy is burned in the combustor (combustion chamber or combustor) between the compressor and the turbine.Power output from the gas turbine depends on the following components' efficiency: compressor, combustion chamber and turbine. As the higher efficiency these components have, higher thermal efficiency and higher energy turbines will generate. Gas turbines have been developed during the past 50 years and today its advanced turbine with poly trophic processes act with efficiency higher than 90%! In a particular category, gas turbines can be categorized in two categories: simple cycle gas turbine that has the following components: compressor, combustion chamber and turbine. Complex cycle gas turbine in addition to the above components has the following components: intercoolers to reduce energy consumption during compression in the compressor, re-heaters to increase the power output of the turbine and heat exchangers for turbine heat exchange with the environment and maintaining the temperature of the system. Ordering components of gas turbines (gas turbine layouts) In recent years, various arrangements are obtained for gas turbines components. Some of these arrangements are suitable for purposes such as power generation, in which the speed of the load part (which is generator here) is fixed. Others are used in cases where the speed of the load (pumps or compressors) varies. The environmental impact of turbines Combustion processes that occur in the turbine lead to emissions of the following polluting gases: carbon monoxide (CO), nitrogen oxides (NOx), and unburned hydrocarbons (UHC). NOx due to combustion process at high temperatures is produced by oxidation of nitrogen in the air. CO and UHC are also produced due to the low efficiency of combustion and incomplete combustion of fuel. NOx contributes to air pollution, acid rain and reduces the thickness of the ozone layer. CO is a poisonous gas. UHC is not only a toxic gas but also in combination with NOx can lead to air pollution. Water vapor (H2O) and carbon dioxide are other gases produced in the combustion process in gas turbines (CO2) which are produced due to the oxidation of hydrogen and carbon. Although H2O and CO2 gases are non-toxic, but greenhouse gases are leading to global warming. To reduce environmental pollution in recent decades, combustion systems with dry low emission of toxic gases and pollutants (dry low emission, DLE) are produced.The DLE combustion systems significantly reduced emissions of toxic gases like UHC, NOx and CO, but the toxic gases as H2O and CO2 can only be reduced by increasing efficiency of thermal turbines. In case of combined cycles, the amount of H2O and CO2 emissions are reduced. In combined cycles hot exhaust gases are used again in the cycle and thus the overall thermal efficiency of the turbine increases. You can also absorb CO2 output by solvents such as methanol amine (MEA) and prevent entering it to the atmosphere. Today's control systems, especially in the case of DLE gas turbines are quite complex. These systems are designed in such a way to determine the appropriate ratio between fuel and air, and emissions of toxic gases and pollutants like UHC, NOx and CO in the limit.

CONCLUSION AND IMPLICATIONS

Other works studied particular types of gas turbines such as that of aircrafts [2], rockets, and also mini- and micro-gas turbines, their external corrosion and deposits and so on. But just a few of them investigates performance and operability of gas turbines and also their environmental side effects as what Razak did. This study has concluded that last decade gas turbines with their explained designs had their environmental effects but to a great extent this problem resolved by this newly designed turbines. In general, arrangements of turbine components are as follows: the uniaxial gas turbine, the two axial turbines with a power turbine, the tri-axial turbines with a power turbine, and the gas turbine axle. Each of the above arrangements can examined and their advantages and disadvantages can be explained in further researches. Also the important factors in choosing where to install the expansion turbines and economic considerations surrounding the use of expansion turbines can be probes by other researchers.

REFERENCES

[1] Cowles, B. A. (1989). High cycle fatigue in aircraft gas turbines—an industry perspective. International Journal of Fracture, 80(2), 147-163.

[2] Kerrebrock, J. L. (1977). Aircraft engines and gas turbines. MIT press.

[3] Mattingly, J. D., & Von Ohain, H. (2006). Elements of propulsion: gas turbines and rockets (pp. 276-277). Reston, Virginia: American Institute of Aeronautics and Astronautics.

[4] Pilavachi, P. A. (2002). Mini-and micro-gas turbines for combined heat and power. Applied thermal engineering, 22(18), 2003-2014.

[5] Razak, A. M. Y. (2007). Industrial gas turbines: performance and operability. Elsevier.

[6] Reid, W. T. (1971). External corrosion and deposits: boilers and gas turbines.

[7] Rowen, W. I. (1983). Simplified mathematical representations of heavy-duty gas turbines. Journal of engineering for power, 105(4), 865-869.

[8] Stodola, A. (1945). Steam and gas turbines. P. Smith.

[9] WILLIAM, W. B. (1984). Fundamentals of gas turbines.

[10] Wilson, D. G., &Korakianitis, T. (2014). The design of high-efficiency turbomachinery and gas turbines. MIT press.

[11] www.fa.wikipedia.org

[12] Iranian Ministry of Energy website Croyostar Co., Energy Recovery Solutions Bulletin.

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