THERMOFLUIDODYNAMIC INSTABILITY IN TG DUE TO FLUCTUATIONS IN THE RATIO OF MIXING

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Abstract
In modern plants for the production of electricity with the gas turbine is frequently the use of gaseous fuel such as natural gas, plant performance are strongly subject to operating conditions and/or operation. In this work we have studied the operating conditions of the mixer assembly - combustor for optimizing the operation of the whole gas turbine plant. Analyzing the behavior of the turbulent flow in the mixer have identified the optimal operating condition which ensures a more uniform mixing since the distribution of the values of the ratio of mixing are closer to the design values[1] [2] [3] [6] [7]. We studied the effects of non-uniform mixing on the birth of fluctuations of temperature and pressure in the mixture that stress fatigue the walls of the combustor to fatigue, also were analyzed pollutant emissions noting the presence of operating conditions for which it minimizes the production of the main pollutants. Therefore, the choice of the condition of operation will be a compromise between the requirements of a proper functioning of the system and safeguarding the environment. The turbine object of study, present in the experimental ENEA were conducted some tests, and a phenomenological description of turbulent flow fields was made with an industrial code (FLUENT) using a parallel platform (CRESCO). We studied the interaction between flow and premixed pilot flame, through the choice of a model for the simulation with a chemical kinetic scheme efficient (GRIMECH), analyzing the effect of the surfaces on the combustion of the mixture reduced, the results in terms of efficiency combustion and pollutants emitted. It is hoped a redesign of the mixer to obtain a more uniform mixing of the current one, and a readjustment of the mixer for the use of alternative fuels such as syngas and biogas a high hydrogen content.

Object descriptions

Since NO_x emissions mainly depend on the amount of oxygen available for the combustion and the flame temperature at which the reaction occurs in combination nitrogen-oxygen (the reaction of formation of nitrogen oxides is always active, but increases the its speed when you exceed the 1600-1900 K), we need that:

- the fuel with adopting measures that reduce the temperature of combustion;
- to perform the pre-mixing of the fuel with the combustion air upstream of the flame so as to make the combustion temperature as uniform as possible, avoiding the presence of hot spots with high production of nitrogen oxides.

Thus the formation of these pollutants can not only be favoured by some conditions in which the combustion process takes place, but sometimes it may even be in competition with the same process of oxidation of the fuel. This is the case of carbon that can be oxidized, in the transition to carbon dioxide (CO_2), at an intermediate level, giving rise to carbon monoxide (CO). In this case it is in the presence of a highly toxic compound for which, in addition to the energy loss in which it was mentioned, it undergoes an objective risk for the population, if exposed to discharges rich in this substance. Therefore, the contemporary control of emissions of NO_x and CO requires a precise control of the flame temperature. Ultimately, it results essential to concentrate attention on the role taken by both the diffusion flames, premixed that those who by their mutual interaction in order to analyse the operation and search for possible optimization of a plant with similar characteristics [2] [6] [7]. The characteristics of the turbine under consideration are shown in Table 1.

Table 1. Characteristics of the analyzed TG

Inlet Temperature [°C]	1190
Power [MW]	68
Operating Pressure [bar]	16.6
Exhaust Gas Flow [kg/s]	192
Exhaust Gas Temperature [°C]	590
Efficiency [%]	36.8
Emissions of NO_x [ppm]	25

Among other features there is the annular combustion chamber, which consists of a single flame tube contained between two circular enclosures (Figure 1).

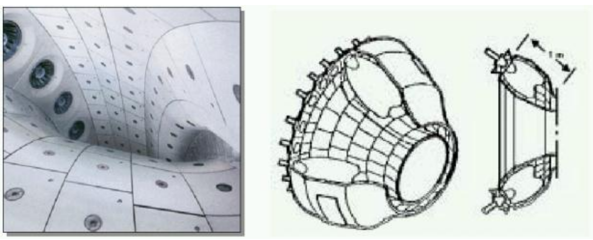

Figure 1. The annular combustion chamber of TG.

The combustion chamber has 24 burners arranged in a ring (one every 15 degrees). Each burner is equipped with an injector driver, operating a diffusion flame, and most of the main fuel injectors, with a flue for the preparation of the air - fuel and diagonal of a vortex (Figure 2).

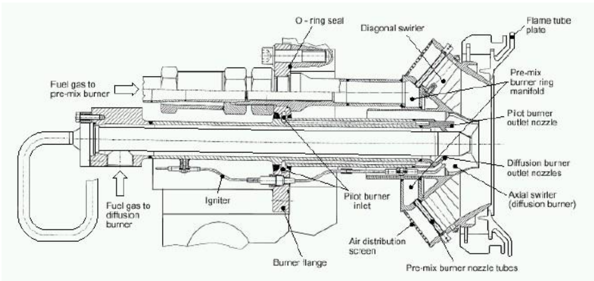

Figure 2. Burner of TG.

In particular, the diagonal vortex, which has an outer diameter of 35 cm and an axial length of 7.5 cm, consists of a row of 18 blades warped (one every 20 degrees) in which the incoming air stream is forced to develop in a helical motion that helps to create a mixing with fuel leaking from 10 equally spaced holes, 1 mm in diameter, placed 5 on the intrados and 5 on the extrados of each pallet. The disadvantages of this configuration are many, in fact, although you can use more fuel jets, getting an uniform distribution of the air-fuel and temperature is very difficult. So, the focused issue is to consider the influence of the mixing ratio distribution on mixer outlet on chemical reactions in the combustion chamber [4] [5]. In order to obtain fast and reliable of the simulations, it was chosen to study the chemical reactions in the combustion chamber near the exit of the mixer, where the premix flow meets with the pilot flame that gives energy. In this phase it is assumed that chemical reactions occur in 24 short cylindrical ducts corresponding to the mixers 24 that surround the combustion chamber.

Methods and instruments

A mixture fuel/combustion for gas turbine is generally poor, then with congenital difficulty of ignition and complete combustion in order to reduce the possibility of formation of NO_x, for which, given a certain value of the ratio of mixing α_t reported at flow rates of gas input, there is no guarantee that the flow resulting premix is present in conditions of plug type ($\alpha = \alpha_t$) in each point of the output of the mixer. Still less likely it is that, in the area of interaction with the pilot flame, this situation is achievable, as is easy to verify experimentally also. Indeed it may happen that the local mixing ratio is much deviated from the theoretical one indicated α_t placing indifferently towards mixtures even poorer, is the richest, all in function of both the geometry of the mixer, that the operating conditions and/or operating of the machine. So we analyse the whole mixing process, obtaining a mixing ratio distribution field. The computing grid test consists of cells obtained with tetrahedral volume sizes ranging from minimum to maximum. The code used for numerical modelling of the problem was that the FLUENT has allowed us to represent the phenomenon in question by setting the problem that is confirmed by experimental results obtained from tests conducted at the facility COMET-HP ENEA. The availability of powerful computing systems, distributed over large geographical areas but connected together by high speed networks, has led in recent years to the development of the concept of ENEA computational grid. The concrete implementation of a computational grid requires the definition of a set of standard tools capable of achieving evenly access to information resources available, both in terms of computing systems that storage of data. Moreover, these tools must be able to ensure the safety of operation of the grid and provide the ability to monitor in every moment its operation. The approach based on the concept of grid computing has made it possible to outline a unified framework for all the high-performance computing systems available within the ENEA, in order to optimize their use within a corporate distributed on throughout the country. The activity of ENEA in fact takes place in 12 centres located in northern Italy, central and southern. The seats more (Brindisi, Casaccia, Frascati and Portici) are each equipped with a computer centre that manages resources installed locally and covering computing needs serial, parallel computing and advanced graphics applications. The system ENEA GRID provides access to all these geographically distributed resources, such as a single virtual system, with a capacity of several hundred integrated global Gflops, distributed parallel systems IBM SP, SGI and Linux clusters. The main components that allow ENEA GRID to provide you with this unique virtual system are threefold: a graphical interface to access java portal on Citrix Metaframe, a resource manager, LSF (Load Sharing Facility) and the file system dis-tributed AFS (Andrew File System) currently available in the Open Source context. The choice of the architectural components of ENEA GRID turned partly proprietary and Open Source in the scope in order to optimize the performance and services offered to the institution and to simplify the management of the system. In the academic field are the subject of several international projects for the construction of computational grids and one of them, GLOBUS, it is becoming a de facto standard for what concerns the basic tools of GRID. At European level, there are several projects, particularly ENEA has participated together with ESA (European Space Agency) project DATAGRID with the creation of a portal that allows access to the protocols ENEA GRID GLOBUS. Fluent in ENEAGRID is available with a number of licenses of the case (ie to simulate different problems) and parallel (ie to use more cores for the same computational simulation).

There were made some tests related to the field in the mixer on the cluster GROW for the calculation of the parallel performance. The simulation used as a benchmark (simulation tests aimed at providing a measure of performance of the computational grid) is 20 iterations starting from the initial solution. The simulations were done with a single core computational (serial simulation) and with increasing number of cores up to 160. For parallel simulations has been left the automatic criterion domain decomposition. The simulations were performed with Ansys Fluent version 12.1

Table 2. Operating conditions for the mixer of the gas turbine AE64.3A

Conditions	Q_a $[kg/s]$	Q_c $[kg/s]$	α_{eff} $[-]$	T_a $[K]$	ρ_a $[kg/m^3]$	p_{in} $[Pa]$	T_c $[K]$	ρ_c $[kg/m^3]$	M_c
1	0.323	0.011	29.71	680	0.524	101325	300	0.717	0.222
2	0.452	0.015	29.70	680	0.524	101325	300	0.717	0.279
3	0.645	0.022	29.67	680	0.524	101325	300	0.717	0.354

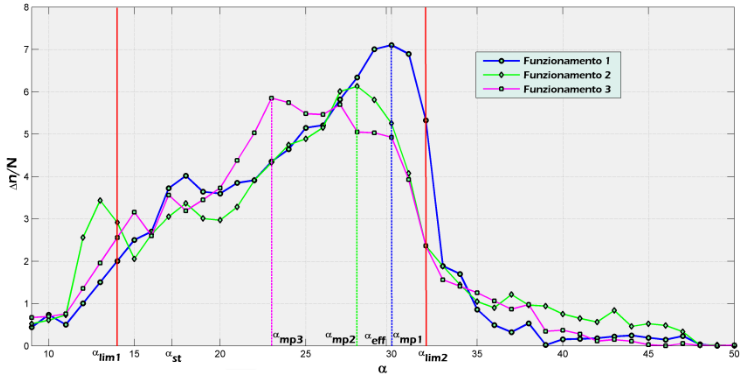

Figure 3. Mixing Ratio Distribution Curve

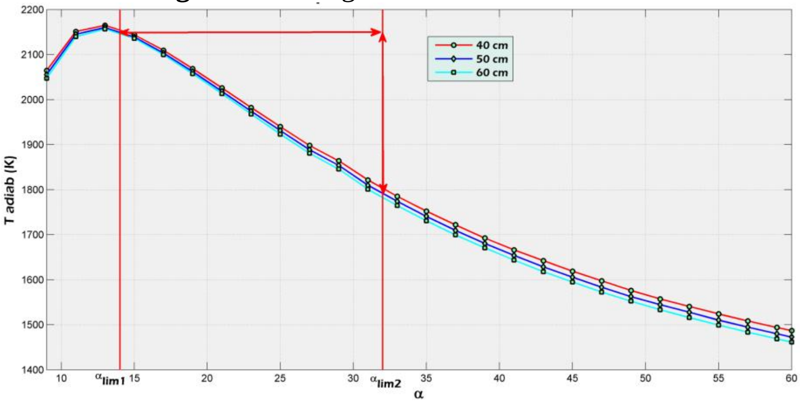

Figure 4. Adiabatic temperature flame

Conclusions

Analyzing the behavior of the turbulent flow in the mixer it is understood that the condition of operation 1 is the best because it provides a more uniform mixing of other operating conditions and because the distribution of due to mixing is the

nearest to the design value, while analyzing the combustion chemistry and reactive turbulent flow into the combustor the effects of non-uniform mixing on the growth of fluctuations are attributable to temperature and pressure effect to the mixture that stress fatigue the walls of the combustor. In particular the condition 1, due to a more uniform mixing, is the best for a good reduction of the structural problems. There were also analyzed the pollutant emissions and it was found that the operating condition 1 is the one that maximizes the production of main pollutants while the condition 3 is the optimal under the aspect of the environmental sustainability. Therefore, the choice of an operative condition will be a solution which is a good compromise between to obtain the requirements for a proper functioning of the system and the environmental condition safeguarding.
In perspective it is desirable to redesign the mixer to obtain a more uniform mixing of what is done currently, also in order to obtain a turbine exercise more environmentally sustainable. It's necessary a plant readaptation in the mixer details for use alternative fuels instead to traditional ones which possess a raised-and hydrogen content. Another possible object to study is the pilot flame that is the tool for adjusting the operation of the combustion chamber, support combustion in critical conditions and, for the essential function that covers and problems of instability of which is affected, it is necessary to study depth in view of a potential improvement.

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