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Application of CFD Analysis on the Performance of Combustor Gas Turbine

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ABSTARCT:

The new calculation methods developed continuously in order to solve the problems in Various fields of engineering. One of these areas is the gas turbine, where the challenge is To make the most efficient gas turbine and reduce emissions, which is bad for the Environment. One of the main parts of gas turbines could be improved is The combustion chamber. In order to improve the combustion chamber, both experimental and numerical methods for calls. means numerical optimization The need to model the most important phenomena in the combustion chambers, As the turbulent swirling flow, chemical reactions, heat transfer, and so on. In this project We are trying to design a simple way after a minute, for the year industrial combustion Interest, which can be tested in a relatively short time, and can produce reliable results. toHere the issue is important to perform sensitivity studies of the network to ensure that this form Results separate network revenue. Another topic of interest is the choice of turbulence Model and how that affects the choice of the sensitivity of the network. heat transfer models are also Important to evaluate. Different models of disorders and heat transfer models made with And they will analyze these results and general engineering. After this project, we have made One way that can be numerically reliable, independent and fast network.

INTRODUCTION:

Gas turbines are common power generators which are used mainly in power generation systems and propulsion systems. Most of the gas turbines are internal combustion machines while the rest are fired externally. The sizes of gas turbines can vary from 500kW to 250MW according to their applications (Energy and Environmental Analysis (an ICF International Company), 2008). Especially for high power applications the gas turbines are widely used compared to conventional reciprocating engines due to its high power density. Absence of the reciprocating and rubbing members inside the gas turbine is also a positive point compared to reciprocating engine and that will enhance gas turbines‟ reliability.

A typical gas turbine mainly consists of three components namely compressor, combustion chamber and turbine. The three main components of a gas turbine are illustrated in figure 1. Atmospheric air is compressed by the compressor then heated inside the combustion chamber and finally expanded inside the turbine. As a result of that the turbine produces work to the surrounding. Some fraction of that work is used by the compressor while the balance work can be considered as the net work.

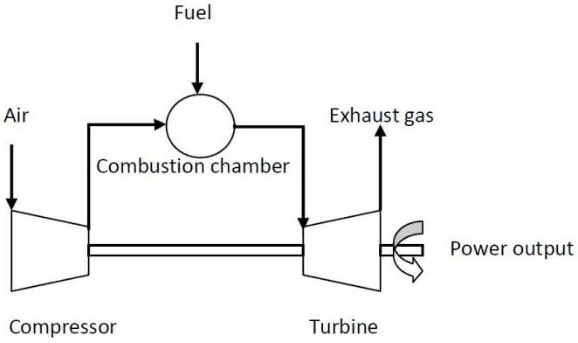


Figure 1: Typical open gas turbine

1.1 Gas turbine theory

The Brayton or the Joule cycle is commonly used to analyze the gas turbine systems and the figure 2 shows a Temperature-Entropy (TS) diagram representation of an ideal Brayton cycle. In figure 2, from point 1 to point 2 the air is isentropically compressed and the heat is supplied at constant pressure from point 2 to point 3. Finally the air is isentropically expanded from point 3 to point 4. In practice, the compression process and the expansion process always increase their entropy along the flow path due to the various losses inside the machines. Practically, the process from point 2 to point 3 also experiences the pressure drop along the flow path due to losses. Hence, the overall performance of the gas turbine highly deviates from the ideal cycle.

LITERATURE REVIEW:

Gas turbine Energy is needed in order to make machines work. One of the best forms of energy is electrical energy. It can be carried over distances and can be produced almost anywhere with proper tools. There are several devices that produce electrical energy such as solar panels, wind turbines and gas turbines. In this project we will focus on gas turbines. Gas turbines produce electrical energy from burning a combustible mixture of fuel (e.g. natural gas or evaporated hydrocarbons) and air. When the gas mixture burns, the volume of the gas will increase. This expansion in gas volume makes a rotor of a turbine rotate and this rotation may then be converted to electrical energy.

The solution of heat transfer phenomena in Internal Combustion Engines is a very challenging task considering the number of systems (intake and exhaust ports, coolant subsystem, lubricant oil subsystem), the different heat transfer mechanisms (convection, conduction and radiation) and the quick and unsteady changes inside the cylinder that take place at the same time. These difficulties had led to a lot of experimental and theoretical work over the last years. A review of these works can be found in Borman and Nishiwaki [1], and Robinson [2].

Several authors [3-6] have documented the relevance of the understanding of heat transfer phenomena at the earlier stages of engine design, when the thermal endurance and stability of the composing combustion chamber parts have to be assured. Since engine efficiency and emissions are affected by the magnitude of engine heat transfer, which is directly related to the magnitude of combustion chamber wall temperatures [7-13], it is also during the design stage, that the strategies to control these temperatures, as well as heat and mass transfer involved in the engine cooling system, especially during cold start and transient regimes, must be envisaged. Among others, coolant temperature control is being considered as part of various technology solutions to control material temperatures, given the linear dependency between them [5, 14].

The definition of the requirements for the coolant temperature control and the engine control strategies require detailed knowledge about the thermal engine behaviour. So, an accurate prediction of the metal temperatures and heat flows through the cylinder head, piston and the cylinder liner boundaries is important to engine design, performance prediction and engine diagnosis.

Aforementioned explains the continuous work on engine heat transfer and thermal management carried out by many research groups. In the framework of a research program concerning heat transfer in Diesel engines, the authors [5, 6] already discussed the convenience of using a reduced thermal model for calculating the cylinder head, piston and liner temperature, while conducting combustion analysis. *The aim of the present work is to improve the thermal resolution of the mentioned model, and also to extend its capabilities in order to* *incorporate it into a more comprehensive engine thermal management model. The developed tool can be used in the modelling of different cooling system architectures to assess their impact on oil, coolant and metal temperature, thus saving on extensive and time consuming test work. With this aim the following procedure has been chosen:*

1. A more detailed partitioning of the engine geometry into nodes, without loosing the functionality and readiness of the program that characterize the concise wall temperature predictive model reported in [13].

2. The assessment of engine energy balances, as well as the rate of heat rejection to the coolant system.

As a result, in addition to the calculation of metal temperatures, the thermal model allows the calculation of the heat fluxes through combustion chamber elements (in which the engine enclosure has been divided) and engine boundaries and, in particular, with the calibrated engine predictive thermal model it can be estimated the engine heat rejection to the coolant.

The presentation of the work is organized as follows: first, a brief description of the electrical equivalent model of the engine is explained, including a brief explanation of the combustion chamber nodes. After that, the modelling of the boundary conditions is treated, that is: the model of heat transfer between the in-cylinder gases and combustion chamber walls; between the gas and the intake/exhaust runners; between the coolant and the liner and cylinder head; between the oil and the piston; between the oil and the liner; between the piston and the liner. Then, a short explanation of the model code is described, followed by a comparison between experimental and model results. Finally, the main conclusions of this work are given.

RESULTS & DISCUSSION:

The experimental work comprises two stages. The first stage is intended to provide engine steady state temperature measurements to run the computational program in the optimization mode. The outcome of this stage is the attainment of the optimized model to predict the thermal behaviour of Diesel engines geometrically similar to that used in the model development process.

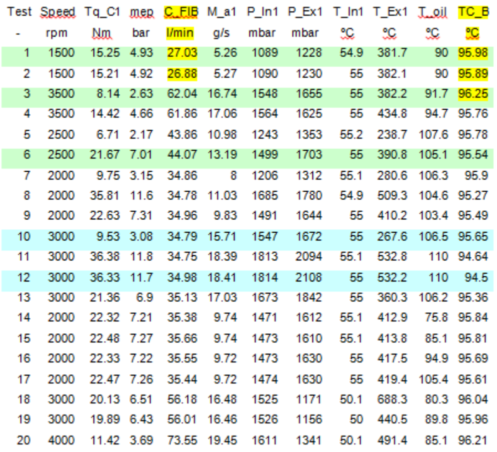
In the second stage, another set of tests is used to obtain measurements of the engine temperatures over elementary transient step changes with the aim of assessing the predictions of the model for heated engine transient operation. Known the initial and final points of transient engine operation, the model with the optimized parameters is used to calculate temperature evolution of the engine temperatures and heat fluxes for a given transient time. An interpolation procedure in the time domain, allows a comparison of predicted and experimental transient thermal responses of the engine.

For the first stage, the program is run in the predictive mode and the predicted temperatures are compared to the measured ones, obtaining the model temperature errors separately for piston, liner and cylinder head, as well as the global model error. After that, the program is requested to optimize the initial model parameters in the optimization mode, and the resulted optimized parameters are re-entered to the model to recalculate the engine temperatures and obtain the global error, the final errors in the predictions of piston, liner and fire deck temperatures, the heat fluxes between engine nodes and the engine heat balance.

For the second stage, the program is run in the predictive transitory mode, after optimizing the model parameters.

The test matrix with the mean variables used during the optimization process of the thermal model for the engine under study is presented in table 3. 32 steady state tests were conducted with variation of the speed and load. The temperatures of the 32 tests are compared to those obtained experimentally for all measured points.

Table 3. Mean variables of the tests performed and used to tune the model up.



Test	Speed	Tq_C1	mep	C_FIB	M_a1	P_In1	P_Ex1	T_In1	T_Ex1	T_oil	TC_B
-	rpm	Nm	bar	l/min	g/s	mbar	mbar	°C	°C	°C	°C
1	1500	15.25	4.93	27.03	5.26	1089	1228	54.9	381.7	90	95.98
2	1500	15.21	4.92	26.88	5.27	1090	1230	55	382.1	90	95.89
3	3500	8.14	2.63	62.04	16.74	1548	1655	55	382.2	91.7	96.25
4	3500	14.42	4.66	61.86	17.06	1564	1625	55	434.8	94.7	95.76
5	2500	6.71	2.17	43.86	10.98	1243	1353	55.2	238.7	107.6	95.78
6	2500	21.67	7.01	44.07	13.19	1499	1703	55	390.8	105.1	95.54
7	2000	9.75	3.15	34.86	8	1206	1312	55.1	280.6	106.3	95.9
8	2000	35.81	11.6	34.78	11.03	1685	1780	54.9	509.3	104.6	95.27
9	2000	22.63	7.31	34.96	9.83	1491	1644	55	410.2	103.4	95.49
10	3000	9.53	3.08	34.79	15.71	1547	1672	55	267.6	106.5	95.65
11	3000	36.38	11.8	34.75	18.39	1813	2094	55.1	532.8	110	94.64
12	3000	36.33	11.7	34.98	18.41	1814	2108	55	532.2	110	94.5
13	3000	21.36	6.9	35.13	17.03	1673	1842	55	360.3	106.2	95.36
14	2000	22.32	7.21	35.38	9.74	1471	1612	55.1	412.9	75.8	95.84
15	2000	22.48	7.27	35.66	9.74	1473	1610	55.1	413.8	85.1	95.81
16	2000	22.33	7.22	35.55	9.72	1473	1630	55	417.5	94.9	95.69
17	2000	22.47	7.26	35.44	9.72	1474	1630	55	419.4	105.4	95.61
18	3000	20.13	6.51	56.18	16.48	1525	1171	50.1	688.3	80.3	96.04
19	3000	19.89	6.43	56.01	16.46	1526	1156	50	440.5	89.8	95.96
20	4000	11.42	3.69	73.55	19.45	1611	1341	50.1	491.4	85.1	96.21

CONCLUSION:

A lumped parameter thermal model (lumped capacity method), obtained as an extension of the three nodes concise wall temperature model performed and reported by our research group [15], has been implemented and validated using experimental data issuing from thermal steady state and transient conditions. Global measurements of engine variables from the test bench along with instantaneous values of in-cylinder media properties, effective valve sections, flows, and local measurements of temperatures in the engine solid masses, coolant and oil were used during the development process. The updated model allows a higher degree of discretization and provides local and global heat flow and temperature field information to support not only energy, but also other relevant issues as thermal loads required for structural analysis, thermal management studies, and interfacing to engine cooling systems models. The model uses a geometric template that can be used for a set of engines with certain degree of structural and geometrical similarity.

To appreciate the predictive capability of the model, there were compared measured and calculated metallic temperatures for 32 different steady state tests and 31 transient processes. The heat transferred to the coolant was also calculated as the final end of the engine heat balance. A second engine was used to validate thermal steady state and transient predictions. The model gives numerical results closed to the experimental ones on a wide range of operating conditions. The model can be used as a design tool for thermal performance optimization and energy management system.

The next phase of the research project is the development of a reduced order thermal system in which the presented developed model will be coupled to an external to the engine radiator cooling loop, completing an engine cooling system. This will allow studying the impact of different cooling strategies on on oil, coolant and metal temperature.

Actual engine speeds, mep and other mean variables, as well as instantaneous in-cylinder parameters for an engine subject to the acceleration schedule of NEDC have been experimentally recorded, and used to predict the engine metal temperatures evolution and heat balance, given the availability of the model. This part of the work shown the predictive capability of the model to assess the warming-up process of Diesel engines. The refining of this feature is under work.

It should be mentioned in the pressure plots and pressure profile of cases, pressure distribution may vary with number of iteration and that is the reason the plots and charts may vary. The variation of the pressure fall into acceptable error range for numerical error, thus the results were accepted. The conclusion from the grid-study is that the mesh-size that is used for the 500K case is enough, or in other words the results are grid-independent. These conclusions are based on steady-state simulations and were not tested on transient simulations due to limitations of time in the project. This is also important to check in the future work. The 500k mesh size would imply that the number of cells for a full 360o model would be approximately 16M cells. By consider all the three cases; the recommendation is to use the k-ω SST model with heat transfer for the steady-state simulations. Because this models

Further study and enhancement of the program comprises a more detailed calibration of the engine model, introducing friction model data from an engine of known dimensions and masses, and a more accurate prediction of the component thermal transients interfacing the model to the back of an engine cycle simulation model.

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