PRELIMINARY DESIGN OF MICRO SCALE TURBOJET

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Abstract

During the development of the small gas turbine, the most important calculations comes from preliminary design process which gives a shape of airflow duct and limits available space for each component of the engine. Micro scale jet engines are not simply reduced-scale model of the full-size engines. The basic method of working is the same , but the are special considerations which demands a different approach to the main design. There are few similarities to the first generation of turbojets, for both critical dimensions comes from compressor and combustor. Micro gas turbine in the contrast to jet engines do not possess the mechanical coupling to the group of accessories. All accessories are electric driven. Small fuel pumps supply fuel line with pressure that hardly exceeds pressure that comes from compressor. The lubrication system is connected to the main fuel line. Bearings are lubricated with mixture of kerosene and turbine oil. Main difficulties in the process of preliminary design comes from connecting of the each engine component. Narrow margin that consist limitations from rotational speed, overall dimensions, thermal and centrifugal loads ,overall efficiency and lack of knowledge about design process for small gasturbine makes up challenge for skilled designers.

Keywords: *propulsion, micro gasturbines, preliminary micro gasturbine design, rc gasturbine*

1. Introduction - preliminary design process

In order to design micro turbojet the must be considered typical design process for commercial gasturbines. Design procedure starts from specification, which consists customer requirements and market research. Design points are based on the designers' experience or by reference to similar designs. They should be aware, at least in qualitative terms, of the influence that these parameters on overall performance. The design process begins from preliminary design (Fig. 1). There name preliminary design aren't strictly prescribed. In many cases preliminary design is associated to gasturbine cycle and thermodynamic studies. Gas flow path preliminary design is called „Preliminary meanline design". Meanline design and analysis rest on an assumption that there is a mean streamline running through the machine such that the fluid flow states and velocities on this streamline at any point are representative of the mean of the whole cross-section. Radial and circumferential variations of all the flow parameters are neglected. Such an analysis is simplification of the true flow field, and the objective of a meanline analysis is not to reveal the full details of the flow state and velocity. The given parameters for a preliminary meanline design will vary from one application to another, but will normally comprise some or all of:

- inlet total pressure and temperature,
- mass flow rate,

- pressure ratio,
- rotational speed,
- power or enthalpy drop,
- target efficiency.

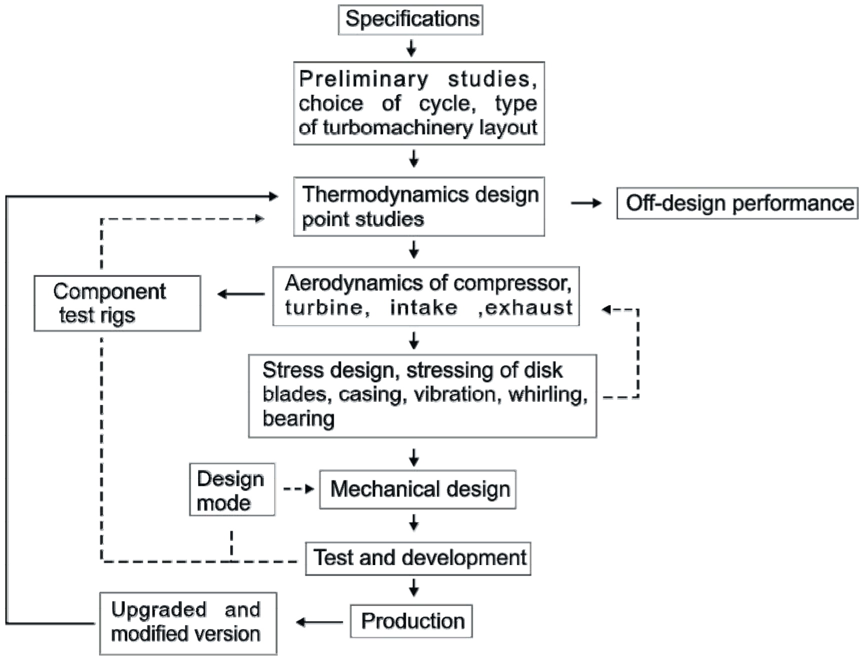

Fig. 1. Design process of comercial gasturbine

There are two types of approach that will be called „eastern” and „western”. „Western” approach is strictly correlated width parameters called degree of reaction, stage loading and flow coefficient. Based on this choices and popular correlation chart for example „Smith chart” for axial turbines. Refers to „western” approach „eastern” is based strictly on physics and aerodynamics with few mostly construction recommendations. For estimate stage efficiency and loss component correlations are required additional geometric information such as inner and outer radius, axial chord, blade spacing or blade number and tip clearance. In stage design some parameters must have initial values to start the meanline design. These include stage loading and flow coefficients for „western” design , and degree of reaction for both approach. Reaction affects, and is affected by, the blade design in many ways. The meanline velocity triangles are determined by the choice of reaction, and this in turn determines some of the principal features of the blade design. The velocity triangles show that a low-reaction design will require a large acceleration and turning of the flow in the stator blades, and a high inlet velocity to the rotor blades. In a very high reaction design, the acceleration in the stator is small, but that in the rotor is large. Both effects lead to a lower efficiency than is possible with blades of moderate reaction where both the stator and the rotor contribute significantly to the acceleration of the fluid. The choice of reaction also has an influence on the mechanical design of the blade. As the design proceeds, modifications to these parameters may be made as the stage is gradually optimized Gasturbines preliminary design refers also to accessories and fuel system too.

2. Preliminary design of micro turbojet

Micro jet engines are not simply reduced-scale models of full-size engines. The basic method of working is similar, but there are special considerations demands a different and usually simpler design. In 2008 in our facility is in development micro jet engine *mSO-1*. This engine was „design for the scratch” without any micro turbine tested before. First limitation comes from time period that engine must be designed, lack of experienced workers involved in micro gasturbines (Fig. 2).

Knowledge is also limited some of principals didn't work with micro-turbines, „Smith charts" and so on. Limits comes also from simplified technology and lack of test rigs. But mostly limiting factor is small number of designers involved in project. Commercial engines are designed by hundreds of engineers, micro turbojets by few people.

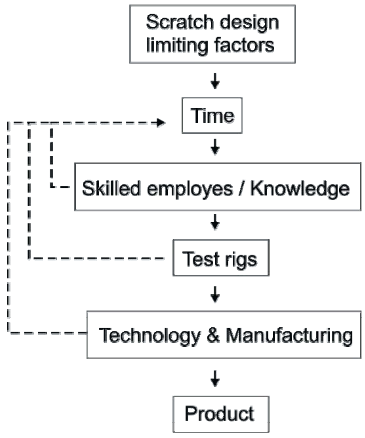

Fig. 2. Limiting factor for micro jet engine

In result of erlier conisderations, whole preliminary design process must be seriously modiefied (Fig. 3). Limitations on design also comes from technology and thermoaerodynamics. Design proces are made by continious desing mode. Continius design means that engine is designed by number od iterations. After manufacturing of single component, each next sections is redesign again until the last one is finished.

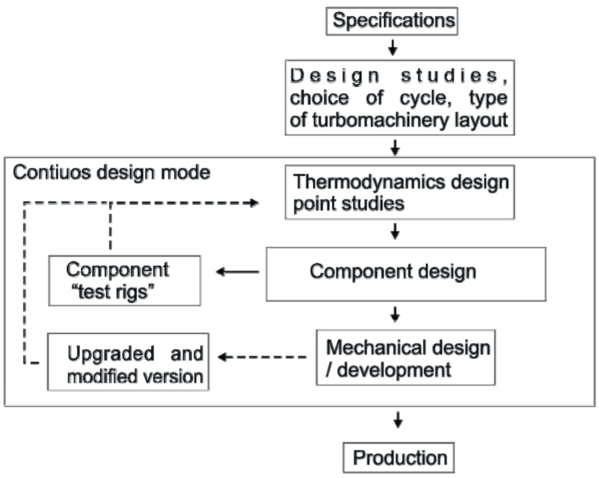

Fig. 3. Modyfied design process of micro gasturbine

Design process starts from design studies, at starting point number of available information is limited. In comparison to the toady full scale turbine's preliminary meanline parameters for the micro gasturbine are:

- inlet total pressure and temperature - without changes,
- mass flow rate - 100-600% smaller,
- rotational speed - 300-800% larger,
- pressure ratio for compressors - 100-150% smaller,
- pressure ratio for turbine stage - without changes,
- target efficiency for radial compressor - 15-20% smaller,
- target efficiency for axial turbine - 15-20% smaller.

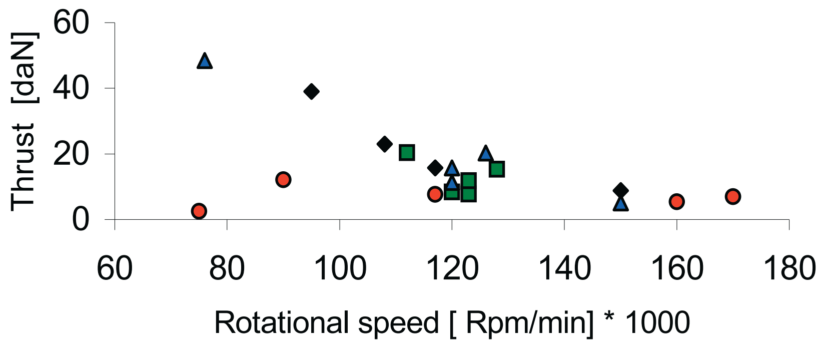

Fig. 4. Preliminary meanline parameters - rotational speed

Fig. 4 presented simple chart that shows shaft rotational speed in reference to thrust of micro turbine. There are a four groups of manufactures , diamonds - AMT Netherlands, square-JetCAT USA, triangles-SWB Turbines, circles - remaining manufactures. Majority developments of the micro turbines comes from KJ-66 project there are group of engines at rotational speed from 100-140k rpm. Lower speeds are characteristics for earlier developments such as FD-64 and modern axial design. Below Tab. 1 presents parameters that was taken to design of *mSO-1* micro gasturbine. To simplify design and made development process a lot faster, compressor rotor KKK1624 was taken from automotive turbocharger.

Tab. 1. Design process of comercial gasturbine

Parameter	Status	Process
Engine		
Mass flow rate	Design parameter	Initial
Compression Ratio	Design parameter	Initial
Rotational speed	Design parameter	Initial
Exhaust gas temperature	Design parameter	Initial
Thrust	Design parameter	Initial
Compressor		
Mass flow rate	Known	Reverse enginnering
Diameters	Measure	Reverse enginnering
Blade height	Measure	Reverse enginnering
Angles & stagger	Measure	Reverse enginnering
Axial velocity	Estimated	Reverse enginnering
Degree of reaction	Estimated	Design
Stator	Estimated	Design
Combustor		
Fuel flow	Known,Estimated	Design process
Mass flow rate	Estimated	Design
Flow velocity	Estimated	Design
Air distribution	Known / Estimated	Design
Turbine		
Required Power	Estimated	Design
Efficiency	Known	Desing
Degree of reaction	Initial	Design
Expansion Ratio	Estimated	Desing
Diameters	Estimated	Design
Angles & stagger	Estimated	Design
Jet pipe		
Inlet area	Known	Design
Exit area	Estimated	Design
Rotor system & lubrication system		
Diameters	Known	Design

3. Summary

Modern micro gasturbines are developing rapidly, there are available all layouts typical for a large scale gasturbine. As far as similarities of design between large scale gasturbine and micro gasturbine are concern, the layout of the machine and basic thermoareodynamics laws are obligatory. Correlations typical for gasturbines couldn't be taken to account because efficiency of micro gasturbines is relatively poor. Eg. minimal efficiency of typical gasturbine process presented on Smith's chart is greater than 88%, and maximum efficiency of micro gasturbine seldom exceeds 76%. Micro gasturbines are very sensitive to boundary layers effects and properly chosen tip clearance. Rotor design is limited by centrifugal force and length. Contradiction exists among requirements placed through rotor and combustor. The combustor should be longest , for a proper burning of the mixture. However shortest rotor gets highest rotatation speed and affect pressure ratio and thrust in positive way. Micro gasturbine makes up challenge for skilled designers because preliminary design process for micro gasturbines is much more sensitive in all design areas than design process for large scale gasturbine.

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