DEVELOPMENT OF THE 1D DESIGN METHODOLOGY FOR AXIAL TURBOMACHINES

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This paper attempts to establish a mean-line preliminary flow path design method that can quickly carry out two-dimensional design of aeroengine turbomachinery, including compressor and turbine. This method can be used for initial engine design, multidisciplinary optimization, and avoids unreasonable design schemes. Based on the sequential quadratic programming (sqp) algorithm, the mathematical problem of turbomachinery design is transformed into a problem of nonlinear constraint optimization. This program can generate the optimized two-dimensional design scheme of turbomachinery in a short time under the condition of determining constraints and optimization objectives. The program is implemented through the following parts:

1. Using open-source C++ library CoolProp[1] to calculate arbitrary equations of state, avoid errors caused by calculations using constant specific heat models.
2. Integrate existing research results to establish more accurate loss models in compressor and turbine.
3. The sqp algorithm embodies the latest progress in nonlinear programming methods, and has good performance in terms of efficiency, accuracy, and successful solutions.
4. Set the initial parameters, constraint conditions and independent variable parameters for the compressor and turbine respectively. Both the compressor and the turbine will take the highest total to total efficiency as the optimization goal.
5. After optimization, the thermodynamic parameters, geometric parameters and velocity triangles of each stage are obtained, and the diagram of the flow path is generated based on the geometric parameters.

Table 1 – Comparison of low-pressure compressor optimization results and real engine data[1]

	Optimization results	Data from real engine	Deviation
Outlet total temperature	289.34	291.1	-0.605%
Efficiency[2]	0.8991	0.8649	3.954%
RPM[3]	4892	4892.87	0.0178%

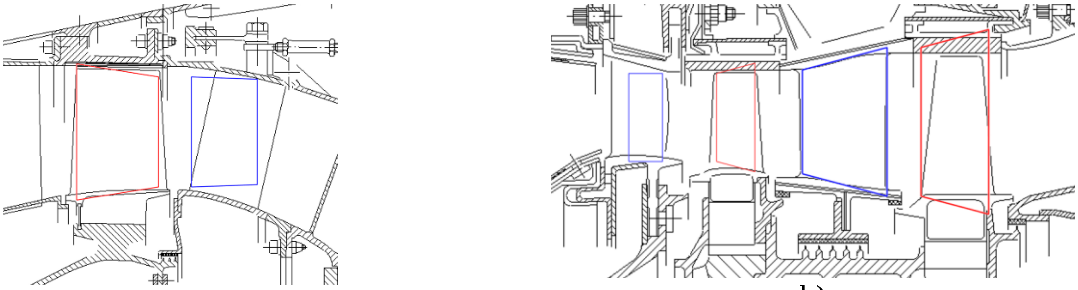
[1]The real engine refers to V2500. [2]Total to total efficiency. [3]Rotational speed, per minutes

Table 2 – Comparison of low-pressure turbine optimization results and real engine data[1]

	Optimization results	Data from real engine	Deviation
Outlet total temperature	1166.91	1003.44	16.29%
Efficiency[2]	0.9339	0.896	4.23%
RPM[3]	13374	13374.25	0.00187%

[1]The real engine refers to V2500. [2]Total to total efficiency. [3]Rotational speed, per minutes

Tab.1 and Tab.2 have shown the method has a good performance in turbomachinery design. The optimization results are acceptable and very close to real engine data. Comparing Tab.1 and Tab.2 we can see that outlet total temperature in turbine optimization results has a bigger deviation than it in compressor optimization results. According to Agromayor R[2], a similar approach is used in evaluating non-aero turbine has less deviation in efficiency. In aircraft engine design, turbine cooling system plays an important part. Therefore, the reason for this result is that turbine cooling was not taken into account in this method, rather than the mistake of the method itself.



a) b)

Fig. 1-a) comparison of flow path of compressor[1]; 1-b) comparison of flow path of turbine[1]
[1] The engine geometry used for verification is V2500

Fig.1-a) shows the optimization results fit the real engine well, stator in engine has a deflection due to the flow path combination with high pressure compressor. Fig.1-b) correctly shows the positional relationship between the two stages of turbine. Optimization results tell us the first stator almost has zero flaring angle, and the actual geometry validates this result. In addition, the third blade has the largest width which is also validated. It is reasonable to suspect that the fact that turbine blades are less compliant than compressors is due to the aerodynamic effects of the turbine blade cooling system. Due to its position, the actual width of the first stator blade is larger than the optimization result, which is also in line with engineering practice.

In a word, this method works as expect, and it can be used for the preliminary design of the engine.

Reference

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