

对转涡轮特有叶型自动设计程序*

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作者曾为国家“七五”攻关课题完成了一套涡轮叶栅自动设计程序^[1]。在给定了叶栅进、出气马赫数,进气角与工质等熵指数后,此程序就能自动选择其它设计参数并计算出良好叶栅。但它是为常规涡轮叶型而编制的,未包括对转涡轮所特有的进、出气向量均在轴向同一边的叶栅(见图 1 下半,本文简称为小折转叶栅)^[2]。本文将此自动设计程序推广到对转涡轮,叙述了相应的物理考虑与数学处理,且给出多个算例。

1 对小折转叶栅的特别考虑

上述自动设计程序是用中心流线法解析解编制的。有关此法可详见文献[3]。主要的设计自变参量是相对栅距 $\bar{t}$ (以叶栅轴向宽度为分母),选定(中心)流线形状 $y_m(Z)$ 及其上的拉瓦尔数分布 $\lambda_m(Z)$ 。对进气角绝对值小于 10 的小折转叶栅,仍可沿用原有程序;而当推广应用到进气更偏离轴向的小折转叶栅时,其主要改进如下:

相对栅距 $\bar{t}$ 选取公式仍沿用原程序;但为避免 $\bar{t}$ 太大,当进气角 $\beta < -34$ 时,公式中的 β_i 即以 -34 代入,亦即令 $\bar{t} < 1.2$ 。

由于小折转叶栅的安装角较大,弦长比轴向宽度大得更多,为使前、后缘厚度适当,与常规叶栅设计相比,小折转叶栅设计程序中后缘线处轴向流密比叶栅远下游处增大的倍值改取较高值(由原来的 1.06 改为 1.095);而且令前、后缘不必修改再迭代的可用相对厚度值范围取较大数,以适应这种叶栅特点及变工况的要求。

为使展开出发的流线更处于流道当中,使展开距离两边差不多远,小折转叶栅设计程序的选定流线由原来的中心流线改为离吸力面为 55% 流道流量的流线。

对小折转叶栅,展开出发的选定流线解析函数形式改用抛物线与等 β' 线^[1]的加权组合,以前者为主。而选定流线上的速度分布则仍如常规叶栅那样选用误差曲线的左支 $\lambda_m = ae^{-n(z-1)^2} + b$,不过 n 值由常规叶栅的 2 改为 $2.5 + 0.45\beta/\pi$ 。

2 程序功能及算例

按上述考虑,已编成实用的叶栅自动设计程序,对常规叶栅与小折转叶栅都能达到如文献[1]所叙述的极快速的自动设计功能。用袖珍计算机 Sharp PC-1500 计算所输出的一组典型叶栅形状及其速度分布与拉瓦尔数等高线图可见图 1。这组叶栅的排气角度与拉瓦尔数均

为 -70 与 0.7 ，但进气角 β 各不相同。因为用小的袖珍计算机，进、出气边的小圆半径均未加上，否则画出后会更好看些。本程序的应用范围为马赫数与排气角绝对值各小于 1.3 与 75° ；基本上复盖了对转涡轮的所有范围。已试算过数百个算例，工作可靠。

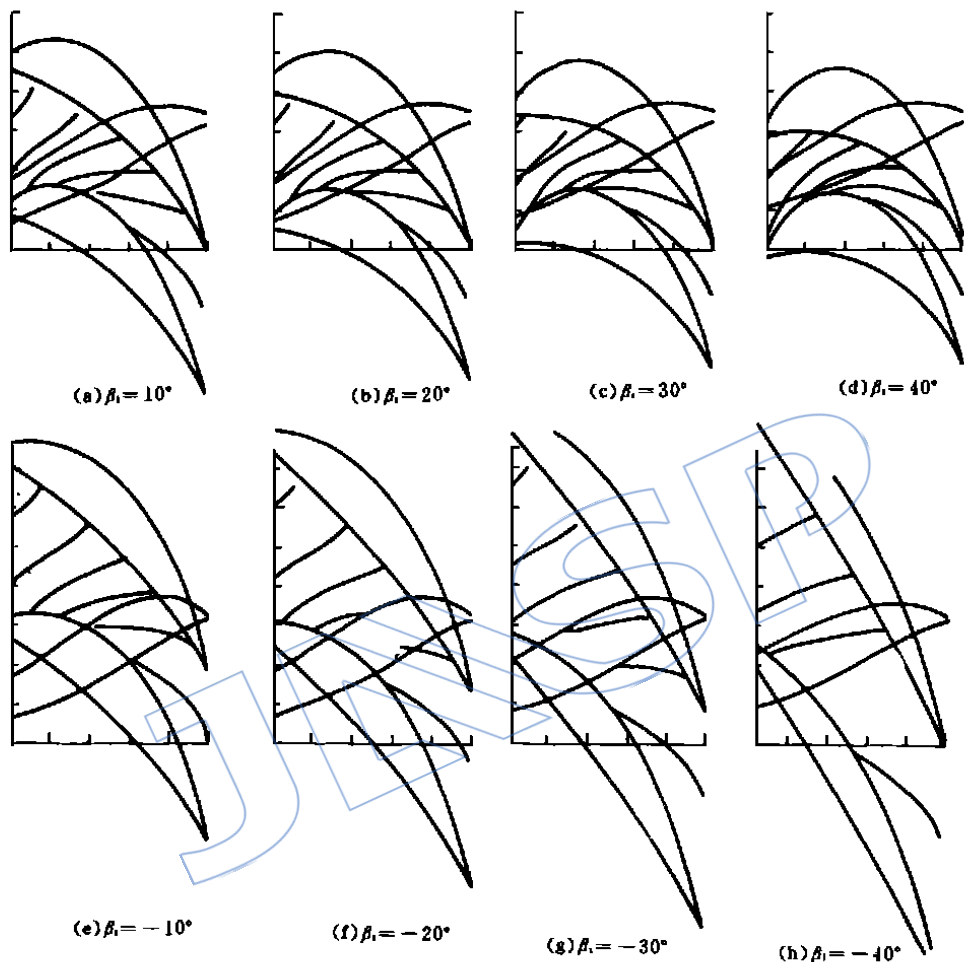


图 1 涡轮叶栅自动设计程序算例

另外，从图 1 可见，其它参数相同，进气角大小相等、符号相反的叶栅按此程序会得到相似的良好速度分布，也间接说明本程序配套选取各个自变设计参量的可行性与可靠性。

参 考 文 献

- 1 蔡睿贤，何泳梅. 透平叶栅自动设计程序. 工程热物理学报, 1992, 13 (3)
- 2 蔡睿贤. 对转涡轮基本分析. 航空学报, 1992, 13 (1)
- 3 蔡睿贤. 平面叶栅的中心流线法解析解. 机械工程学报, 1966, 14 (1)

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established, which can be applied to the turbine blade of the advanced aeroengine.

A NEW WAY TO SOLVE STEADY CREEP PROBLEM WITH FINITE ELEMENT METHOD

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ABSTRACT In this paper, a new way to solve steady creep with finite element method is presented for temperature-dependent material properties of symmetric body. According to different material properties, initial strain rate method and general tangential stiffness method are provided. A computing program is compiled. Some examples are analysed numerically to check its convergency and applicability.

ON ENGINE PARAMETER ESTIMATION WITH FLIGHT TEST DATA

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ABSTRACT This paper introduces the parameter estimation research for the turbine inlet temperature and compressor exit pressure by using the engine variables measured under the different flight conditions. The parameter estimation method is multiple linear regression analysis. The independent variables in the regression equations have been selected from six measured engine variables based on the comprehensive optimal principle about variable selection. The regression models which have been established only include three measured engine variables. The curves of the parameter estimation results shown in this paper demonstrate that the estimation accuracies of these models are satisfactory. This paper also presents the data treatment methods of engine variables recorded on-line with special equipment.

AN AERODYNAMIC DESIGN PROGRAM FOR CONTRA-ROTATING TURBINE CASCADES

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ABSTRACT An extremely simple, rapid and universal turbine cascade design program is developed for contra-rotating turbine cascades. With its simplest operating condition, only four data are necessary to be input for obtaining the geometry of a good enough cascade. They are just the input data for designing a cascade— the inlet Mach number and flow angle, the outlet Mach number and the specific heat ratio of working substance. Therefore, it means that the design can be accomplished without any additional human

decision. The program is based on the Mean-Stream-Line Method. It is given in detail how to select the independent design functions of this method in programming. This program enables to be operated with a very small computer, even a pocket computer such as the Sharp PC-1500.

SPECIAL COLUMN: LIGHT-WEIGHT GAS TURBINE R & D OF LIGHT WEIGHT GAS TURBINE IN CHINA

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ABSTRACT

This paper introduces the engineering research of aeroderivative gas turbines in recent ten years in aspects of such as generator modified; power turbine research; alternative-fuel combustibility. The advanced and applied researches aim at meeting the demands for industrial and marine propulsion, such as prolonged life, improved performance, enhanced reliability and satisfactory variability.

ACOUSTICAL PROPERTIES OF SOUND ABSORBING STRUCTURES AT HIGH TEMPERATURE

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ABSTRACT

The acoustical properties of sound absorbing layers used in gas turbine exhaust silencing component at high temperature with temperature gradient were investigated by analysing the effect of temperature on the acoustical properties of porous materials. Some experimental results are given and a good agreement is found between theoretical prediction and measurements of acoustical properties at various temperatures up to 500°C.

PERFORMANCE IMPROVEMENT OF GAS TURBINE WITH STEAM INJECTION

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ABSTRACT

This paper describes how to choose and modify the WZ-5 gas turbine for steam injection testing and how to evaluate testing parameters and programmes. Testing results indicate that when the steam is injected 3.6t/h into the WZ-5 gas turbine, its power output and thermal efficiency increase 40% and 25% respectively. Moreover, the steam injection does not deteriorate the exit temperature profile in the turbine, which ensures a long term reliability of operation for the engine.