Design and Optimization Radial Gas Turbine Blade

Rahul Mishra[1], Yogesh Kushwaha[2] and Praveen Singh[3]

[1] Shri Rawatpura Sarkar Institute of Technology-II New Raipur Chhattisgarh(INDIA)

Received: 16 December 2012 Accepted: 31 December 2012 Published: 15 January 2013

Abstract

The combustion chamber of an automobile gasturbine engine can be designed to produce a gas temperature distribution at the inlet of the turbine increasing from blade root to blade tip. It is shown in the paper, by means of comparative calculations, that by using such distributions of temperatures blade life can be substantially increased, or else, un expensive materials can be used. Such gas temperature distributions produce non-isentropic flow conditions. It is developed in the paper a method for the aerodynamic design of blades within a non-isentropic flow and it is also shown that if the blades are designed by taking an average gas temperature, as it is usually made, important errors are introduced in the resulting shape of the blade, which reduces the efficiency of the turbine.

***Index terms*—**

1 Introduction

he turbine is one of the most important components of a gas-turbine engine regarding to life and cost. Blades and disc bear large stresses at high temperature, to such extent, that super alloys or high-alloy steels must be used. Therefore, life and cost of such turbine are always critical. In automobile applications both power/weight ratio of the engine and fuel consumption are very important parameters, which implies that high working gas temperatures have to be selected. This makes more difficult all design problems of the turbine, especially considering that in the high competitive market of automobile vehicles, life and cost of the engines are extremely important. As a result, a careful design, of the turbine in order to increase its life, or else, in order to make possible the use of un expensive materials is of fundamental importance.

Blade temperature at the root, where stresses usually reach their maximum value, can be reduced by imparting to the gas flow a radial temperature distribution increasing from blade root to blade tip. This can be achieved by means of a proper design of the gas-turbine combustion chamber. Radial temperature distributions have been utilized in turbojet engines

In this case the flow is not isentropic, which introduces an essential difficulty in the aerodynamic design of the blade. Such difficulty has been customarily avoided by designing the blades taking an average value for the gas temperature. However, it will be shown that the blades cannot be properly designed disregarding the actual radial distribution of the gas temperature, because in such a way very important errors are introduced in the gas velocities and, then, in the blade shape.

2 a) Fundamental Asumptions

The assumptions on which the model of the process will be based are those usually admitted in the aerodynamic of turbo machinery, but considering the non-isentropic character of the Ideal fluid.

They are as follows:

1) Ideal fluid except friction losses which could be considered by taking a polytrophic exponent k instead of the isentropic exponent.

2) Axial symmetry and stationary conditions.

3) Radial or quasi-radial blades.

4) Non isentropic flow. The first assumption implies that the flow is isentropic along each stream line, but the entropy constant is different for every stream line.

5) Radial deviations of the stream lines will be disregarded.

3 b) Numerical Application

A practical application has been performed for the compressor turbine of an automobile gas turbine of 150 HP approximately. Blade temperatures are more important in that turbine than in the power turbine, in which gas temperatures are lower. A preliminary design of such turbine has been made, from which the following pertinent data are taken: The geometric characteristics of the blade are shown in Fig. **??**. Blade thickness has been selected from stresses considerations. Once the size and shape of the blade have been determined and the gas temperature T 0 is known, blade temperature is calculated by assuming one-dimensional and stationary heat flux conditions within the blade, by means of the equation: T Authors ? ? ? : Faculty of Mechanical Engineering Shri Rawatpura Sarkar Institute of Technology-II New Raipur Chhattisgarh, India. E-mails : rahul.mishra.10j@gmail.com, yogesh.1389@gmail.com, singh.praveen96 @gmail.com Such distribution of temperature is approximately the best for the case studied. The super alloys needed for the isentropic case can be substituted, for the same 10,000 hours life, by stainless steel. On the other hand, if stainless steel would be used with isentropic flow, the life of the blade would be only 1,000 hours approximately.

4 II.

5 Result and Optimization

The optimization procedure evaluates the objective function by means of the thermal code.

The Nusselt numbers have been evaluated by means of Florschuetz correlation equation, Florschuetz etal. **??**1981]:

Where the parameters A, B, m and n depend on geometric factors, z is the pitch of the holes and G is the mass flux.

The design variables involved in the Nusselt number evaluation are: 1. Impingement : hole diameter, position and pitch.

6 Film cooling : hole position, diameter, compound angle

When the optimization procedure is started, a population of possible solutions, codified in string structures, is randomly initialized. A fitness value is assigned to each string based on the value assumed by the objective function. A fitness value is assigned to each string based on the value assumed by the objective function.

7 Midplane Stator Nozzle

Since the hot gas impacts the nozzle at the leading edge, the presence of impingement holes in this area is necessary to limit the temperature values. The pressure conditions at the leading edge make difficult to open film cooling holes in this area because of hot gas ingestion in the meatus. Moving towards the trailing edge, the pressure conditions become positive for positioning film cooling holes both on the pressure and suction side.

III.

8 Conclusions

1. By means of a proper selection of radials distributions of gas temperature increasing from blade root to blade tip, the life of an automobile turbine could be substantially increased in many cases, or else, less expensive materials could be utilized instead of super alloys. 2. For such non-isentropic flows the aerodynamic design of blades has to be made considering the actual gas temperatures distributions, and not by taking an average value of the temperature. Otherwise, the efficiency of the turbine would be reduced. [1]

Figure 1: (

[Jameson ()] *Aerodynamic shape optimazation using the adjoint method*, A Jameson . 2003.

[Rao ()] J S Rao . ASME-2000-GT-0569. *Elastic Plastic Fracture Mechanics of a LP Last Stage Steam Turbine Blade Root*, 2000.

[Rao (2003)] 'Recent Advanced in India for Airframe & Aeroengine Design and Scope for Global Cooperation'. J S Rao . *Society of Indian Aerospace Technologies & Industries, 11th Anniversary Seminar*, (Bangalore) 2003. February 8, 2003.

[Struct ()] 'User's Manual v7. 0'. Opti Struct . *Altair Engineering Inc* 2003.

[User's Manual v7.0 Hyper Mesh ()] 'User's Manual v7.0'. *Hyper Mesh*, (Troy, MI, USA) 2003.

[Users Manual v7 Hyper Study ()] 'Users Manual v7'. *Hyper Study*, (Troy, MI, USA) 2003.