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AERODYNAMIC OPTIMUM DESIGN OF ADVANCED HIGH LOADED TRANSONIC TURBINE AIRFOILS

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ABSTRACT:
The current work handles the event and validation of the way of the automated aerodynamic optimization of turbine cascade blades for top pressure stages of durable gas turbines. Actually, the Reynolds number and also the trailing edge thickness of those profiles is definitely an order of magnitude greater compared to corresponding values of aeronautical gas turbines. To be able to gain better understanding of these major variations, extensive experimental investigations were performed in the High-speed Cascade Wind Tunnel from the College from the German Military Munich on various turbine cascade blades created by ALSTOM. The developed tool is created for that application within an industrial framework and style time scales suitable for industrial needs need to be regarded as well. Within this context a technique composed of the two-dimensional RANS flow simulation approach coupled with a parametric geometry generator as well as an optimization formula is suggested. The primary optimization target within this work was the decrease in the cascade total pressure losses by imposing a set operating point. Each one of these needs was integrated in one value objective function. The outcomes from the suggested statistical design system indicate the present method has the capacity to generate instantly blade geometries with reduced losses and including profile velocity distributions which ensure favorable conditions for that cooling from the blade. The longevity of the technique at altered geometric and mechanical boundary conditions was shown too.

Keywords: Reynolds Number; Aerodynamics; Turbines Optimization; Blade Design;

INTRODUCTION:

Today the earth's climatic change is definitely an indisputable phenomenon, confirmed by studies of countless independent scientific organizations. The main factor from the protocol may be the decrease in the anthropogenic co2 equivalent emissions of six major green house gases1 to a minimum of 5 percent underneath the 1990 level within the commitment period between 2008 and 2012. This goal represents an international challenge that may simply be met by new policies and methods for a typical technology. Right now, 3 large major industrialized countries such as the U. S. States and Australia, which together take into account more than one third from the green house gases released through the industrialized world, haven't yet ratified the protocol [1]. Over the past 2 decades around three quarters from the anthropogenic co2 emissions towards the atmosphere were because of fossil fuel burning. This background highlights the significance of extensive research activities for that decrease in CO2 emissions of thermal power plant facilities. Thus major attempts are being produced in the introduction of the so known as zero-emissions fossil fuelled power plants. Today combined gas cycle processes show efficiencies slightly below 60%. By 2010 an efficiency increase from the combined gas and steam turbine power plants to 62% is anticipated. Major improvement possibility of growing the efficiency is found in the gas turbine. Among the important aspects may be the turbine inlet temperature. The task of the high lift blade/stage design methodology is confirmed because at the moment important OEMs prefer more conservative methods for the upgrade of contemporary industrial gas turbines even when greater reliability is acquired having a certain lack of performance. A simple condition to add mass to highly loaded turbine components is the presence of appropriate design methods based on reliable design tools that have been extensively validated with experimental data. The current work handles the event and use of a computerized design technique of the aerodynamic optimization of two-dimensional turbine blade profiles. This process consists essentially of the Navier-Stokes solver, a parametric geometry generator as well as an optimization formula.

METHODOLOGY

A simple condition for that effective use of automatic optimization procedures inside the aerodynamic design procedure for turbo machinery balding may be the assessment from the reliability and application limits from the applied flow simulation tools [2]. Within this context extensive experimental investigations were performed within the High-speed Cascade Wind Tunnel in the College from the German Military in Munich on three different ruthless turbine cascade blades created by ALSTOM. These reference profiles feature geometries and operating conditions typical for top pressure cutting blades of contemporary durable gas turbines. Our Prime Speed Cascade Wind Tunnel ensures the reproduction of Mach- and Reynolds figures usual for durable turbo machinery. The acquired data are utilized to build an experimental database for that validation procedure for the developed aerodynamic design method. The datum profile, named T150, represents the mid-span section of the turbine rotor blade for top pressure stages of huge scale stationary gas turbines. The aerodynamic loading of the profile is moderate. Beginning out of this reference profile, two further design approaches were investigated. The resulting turbine cascade blades were indicated as T151 and T152. Two different design strategies were worked for. While for the style of T151 the aim was the decrease in the amount of parts having a consequent increase from the blade spacing, for T152 rather an optimization from the profile Mach number distribution was went after to allow favorable conditions for that blade cooling. The decrease in the amount of blades inside the stage is connected with reduced wetted surface, friction losses and reduced cooling air mass flow per stage. And so the design technique for T151 worked for that aerodynamic optimum. However it should be stored in your mind that growing the aerodynamic loading produces a rise from the cooling air mass flow per blade pitches because the increase from the adverse pressure gradients influences the efficient action from the profile film cooling. This boosts the mixing flow losses. In addition, a lower quantity of blades is connected with greater blade sections for mechanical reasons [3]. Thus, the interior cooling channels from the blade need to be modified too, having a consequent increase of the amount of blade cooling channels. The gradients within the back-diffusion region from the suction side were reduced, the rate magnitude overall pressure side was elevated along with a continuous acceleration within the entire blade surface was realized. The look operating conditions for those three cascades are very similar. The aerodynamic analysis of turbine cascade models at Reynolds number levels usual for durable gas turbines requires appropriate experimental facilities. Our Prime Speed Cascade Wind Tunnel in the College from the German Military in Munich using its test section dimensions and it is power unit offers optimal conditions with this task. Our Prime Speed Cascade Wind Tunnel is really a continuously operating closed loop test facility by having an open loop test section [4]. The primary feature of the experimental facility may be the possible ways to vary Mach and Reynolds number individually from one another. The preferred Mach number is acquired by modifying the amount of revolutions each minute from the axial compressor. The Mach number range within the test section could be varied between .2 and 1.05. By partially evacuating pressure tank the Reynolds number could be varied within the range .2•106m-1<Re/l<1.6•107m-1, where l is the cascade chord length. In order to determine the profile pressure distribution, the central blade in the test section (blade number 3 in Figure 3.3) was instrumented with pressure tapings of 0.6 mm diameter on the suction and the pressure side. The number of tapings and their distribution over the profile was designed to catch the main gradients of the designed profile Mach number distributions. The integral cascade performance parameters are then obtained using the conversion procedure by Amecke. The data acquisition was carried out using a pressure scanner of the type 98RK. The control of the measuring devices and evaluation was performed using the in-house software programmed WINPANDA. A particularly interesting method for the flow visualization over the blade surface is represented by the oil flow pictures. Secondary flow structures can be investigated using this technique without excessive effort. The surface of the measuring blade is uniformly covered with a mixture of oil, petroleum and fluorescent powder. At the desired operating conditions

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the visualization of the flow structures on the painted surface is possible due to the behavior of the oil mixture depending on the local wall shear stresses. In regions of high flow velocities, where no separation bubble occurs, the oil mixture is almost completely removed from the blade surface. On the other hand, the oil mixture accumulates in regions of local flow separation or in regions where low flow velocities occur, because of the lower wall shear stresses. In turbulent boundary layer regions, due to the increased momentum and mass exchange near the wall, low quantities of oil mixture are removed. The identification of separation bubbles requires particular attention. In fact, in this case the relative high quantity of paint accumulated in the separation bubble region has to be carefully removed towards the trailing edge. This is done by increasing the compressor rotational speed for a short period of time. In this way the two lines delimiting the separation bubble region can also be well identified, but the flow configuration in the blade region upstream of the bubble is washed away. Due to the higher gradients near the wall at higher Reynolds numbers the most evident results were obtained at a lower Reynolds number level. The turbine cascades T150, T151 and T152 were investigated in a wide operating range at various incidences. The effects of Mach- and Reynolds number on the aerodynamic behavior of the cascades were investigated as well. A comparison of the isentropic profile Mach number distributions for the different turbine cascades at reference operating conditions is shown. In the front part of the suction surface of the datum-profile T150 the flow accelerates with quite high gradients to a Mach number slightly below 0.8. In this initial zone, however, a well marked discontinuity in the velocity gradients, associated with local diffusion phenomena can be identified. This zone is followed by a second one in which the velocity level remains almost constant. A third acceleration zone can be detected between 50% axial chord and the position of the peak Mach number on the suction surface. In the following diffusion region a flow deceleration takes place towards the exit Mach number. On the pressure surface near the leading edge T150 features a suction peak, indicating the presence of a short separation bubble. Downstream the flow decelerates down to the pressure surface local minimum. Then flow acceleration occurs towards the exit Mach number. The pressure side acceleration features higher gradients near the trailing edge, starting from 80% axial chord length. Numerical simulations indicate that a boundary layer relaminarisation is expected to take place in this region on the pressure side. The suction side acceleration for T151 and T152 takes place more continuously than for the datum profile, presenting thus more advantageous conditions for an efficient profile film cooling. However, the increased aerodynamic loading of T151 produces a back diffusion region of higher gradients on the suction side. These results from the higher suction surface peak Mach number, located as far downstream on the suction surface as for T150, and from the lower exit Mach number featured by T151. The reduction of the exit velocity level for

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T151 is a direct consequence of the increased blade spacing at a fixed cascade mass flow. On the other hand, the profile velocity distribution on T152 features improved characteristics with respect to the other two blade profiles. The deceleration to the exit Mach number in the rear part of the suction surface of T152 occurs under quite moderate gradients [5]. The continuous acceleration and the higher velocity level featured by T152 on the pressure surface are particular advantageous for an efficient action of the profile film cooling in this region as well. In fact, while an increase of the exit Mach number from Ma2th=0.75 to Ma2th=0.85 produces an increase of the integral total pressure loss coefficient for T150 and T151 of about 10%, with respect to the reference operating conditions, the related increase for T152 is only 2%.

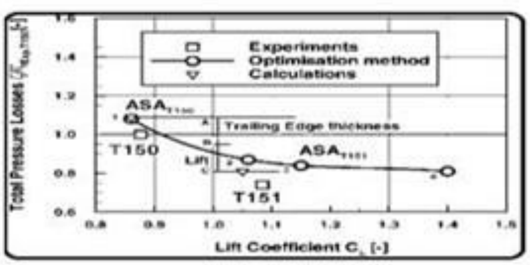

Fig.1. Predicted total pressure losses

CONCLUSION:

The style of turbine cascade blades for durable gas turbines has to take into consideration various frequently counteracting aspects deriving in the interaction of various disciplines. A significant aim went after in the introduction of modern turbine beadings is really a reduced quantity of blades. Each one of these aspects led to elevated manufacturing costs. In addition, this design technique is connected with advantageous effects under an aerodynamic perspective like reduced wetted surface and reduced amount of cooling air mass flow per stage. In our work a computerized design way of the aerodynamic optimization of two-dimensional turbine blade profiles for that application right in front stages of durable gas turbines was created and validated. Three different designs were investigated. The datum profile T150 is in contrast to a very loaded design (T151) along with a further design (T152) featuring moderate aerodynamic loading but smooth profile velocity distribution to have an efficient cooling from the blade. The option of a 1-equation turbulence model approach produced from the requirement to simulate thin boundary layers, typical for that present high Reynolds number range, staying away from an excessive quantity of nodes close to the blade solid wall, as needed by two-equation models. The outcomes acquired around the reference cascades indicate an over-conjecture from the integral total pressure losses coefficient of approximately 10%, as the computed cascade deflection exceeds the measured values of the value between 1.5° and a pair of.0°. The grid generation method operates maintaining a set mesh topology and adapting the mesh mainly within the boundary layer region where mesh lines orthogonal towards the wall surface are needed to guarantee a precise reproduction from the boundary layer development. The primary optimization target from the developed procedure may be the decrease in the cascade total pressure losses imposing a set operating point. A mix of polynomial and exponential functions was shown to become suited perfect for the current problem. The look method was created for that application within an industrial framework. The developed method was validated at various aerodynamic loadings. The outcomes from the related flow calculations indicate that fifty Percent from the total pressure loss reduction between your reference profiles T150 and T151 is due to the lower trailing edge thickness. The overall formulation employed for the current method facilitates the extension of their application field towards the optimization of turbine profile blades for gas turbine aero engines.

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