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Design and Thermal Analysis of Transition Duct in Industrial Gas Turbine

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Abstract

Gas turbine development is constantly moving forward and for higher efficiency hotter turbine inlet temperature is required. Because of that, one of the largest design problems is to find efficient ways to cool the hot parts in the gas turbine. The task was to develop and evaluate new alternative cooling and mounting concepts for a transition duct in the latest gas turbine. Transition duct is a hot part and has the task to guide the hot gas from the combustion chamber to the turbine inlet in a gas turbine.

The transition duct of today is cooled by a relatively large amount of compressor air which needs to be reduced in case of a power upgrade. The current mounting solution requires three combustion chambers to be removed for one transition duct maintenance, which is time- consuming.

A literature study and a market research including patent searches were made to get an overview of solutions used today. The concept was then generated from function/means tree together with morphology matrixes. This was divided into two branches, one for cooling and one for mounting and sealing. The transition duct was modeled in CATIA and evaluated with thermal analysis has been carried out in ANSYS software. Further development and combination of the concepts led to different concept suggestions which will ease and shorten the maintenance and reduce the cooling air consumption with kept material.

Keywords: Transition duct in SGT-750, Can type combustion chamber, temperature and heat flux.

1. INTRODUCTION

The efficiency of gas turbines becomes more and more important simultaneously as the pollution demands get harder. Therefore it is important to keep the flame temperature in the region of effective combustion to avoid pollutions. To keep the overall efficiency high, the turbine inlet temperature should be as high as possible. Due to this, cooling of the hot parts must be more efficient, and cooling air leakage to the combustion chamber must be reduced.

Today the transition duct in SGT-750, which is a hot combustion component, is cooled with impingement cooling, a proven method for cooling of hot parts. Today this cooling method is allowed to consume a generous amount of compressor air to keep the transition duct material at a good temperature. Due to the interest of continued improvements, other cooling methods are of interest to lower the consumption of air and still maintain a good temperature in the transition duct material.

Due to this continued work with improvements, mounting of the transition duct also are of interest. It should be investigated to find even more robust mounting methods with lower vibrations and slighter risk for low cycle fatigue.

Today the transition duct mounting consists of many parts that have to be held in place while fitting and tighten the bolts. To reach all bolts to remove or mount a transition duct, three of the combustion casings has to be removed, the one where the actual duct is located and also the adjacent casings. To lower the maintenance time for service, it is of interest to change this design.

Different cooling methods will be investigated to reduce the air consumption used for the transition duct cooling.

Concepts for new ways to mount the transition duct with fewer parts and with just one combustor casing removed will also be investigated. Seals that are suitable for the mounting concepts will also be chosen.

2. DESIGN METHODOLOGY

The SGT-750, see Figure 1 is intended to be used for both power generation and mechanical drive with a high efficiency. The main feature of this turbine is the short maintenance time and low emissions. The power output in power generation setup is 36 MW with an electric efficiency of 39%. With the mechanical setup, the output is 37 MW, 50’000 bhp with 40% efficiency. To boost the efficiency even more at power generation, the SGT-750 can be used in a combined cycle due to the high exhaust temperature.

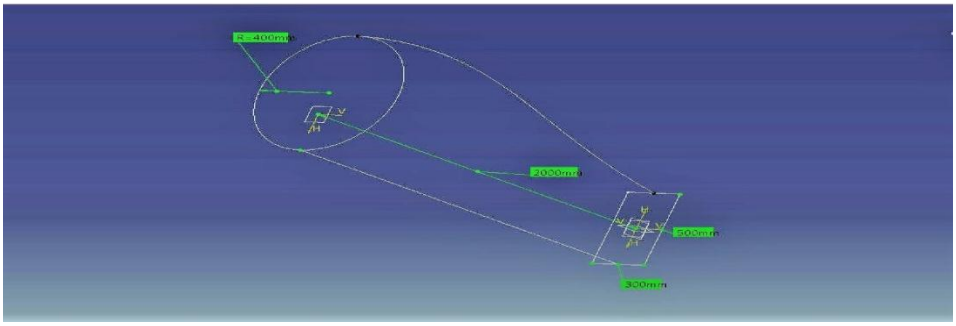


Fig 1. The dimensions of Transition duct

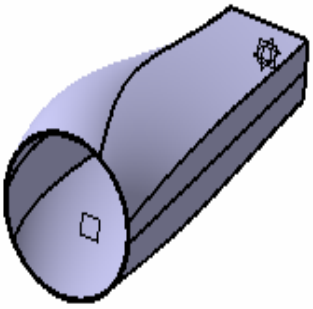


Fig 2. 3D model of transition duct

3. MATERIAL PROPERTIES FOR TRANSITION DUCT

Material	Engineering Constants
ALUMINIUM	Elastic Modulus E1 = 70Gpa Elastic Modulus E2 = 70Gpa Shear Modulus G12 = 52Gpa Poisson's Ratio v12 = 0.33 Thermal expansion α1= 23.6x10- Thermal expansion α2= 23.6x10-6 Thermal conductivity= 205 W/mK

Material	**Engineering Constants**
E-Glass/Epoxy	Elastic Modulus E1 = 15 Gpa Elastic Modulus E2 = 6 Gpa Shear Modulus G12 = 3 Gpa Poisson's Ratio v12 = 0.3 Thermal expansion α1= 7.0x10-6 Thermal expansion α2= 2.3x10-6 Thermal conductivity= 1.35 W/mK
Boron/Epoxy	Elastic Modulus E1 = 207 Gpa Elastic Modulus E2 = 19 Gpa Shear Modulus G12 = 4.8 Gpa Poisson's Ratio v12 = 0.21 Thermal expansion α1= 4.14x10-6 Thermal expansion α2= 1.91x10-5 Thermal conductivity= 0.4 W/mK

4 MATHEMATICAL CALCULATION

The overall heat transfer calculations for the transition duct are calculated with the following considerations.

4.1 CONDUCTION

Conduction refers to when heat flows from one high- temperature stage in one part of a medium to another part in a lower temperature stage until equilibrium is reached. The rate of heat transfer can be written as Equation 1 referring to Fourier conduction law.

Q is the rate of heat transfer through a specific length,

DT/dx is the temperature gradient, $\Delta T = 1173$ K

Thermal conductivity, k

The heat transfer area, $A = \pi (r1 - r2)2 = 0.000314$ m2

(1) For Aluminum,

k = 205 W/m K

Q = 205 x 0.000314 x 1173

= 75.506 Watts

(2) For E- Glass Epoxy,

k = 1.35 W/m K

Q = 1.35 x 0.000314 x 1173

= 0.4972 Watts

(3) For Aluminum,

k = 0.4 W/m K

Q = 0.4 x 0.000314 x 1173 = 0.1473 Watts

4.2 CONVECTION

The heat transfer is described by Newton's law of cooling, Equation 2. The heat transfer coefficient, α is written as Equation 3 and dependent of the fluids conductivity, k, Nusselt number, Nu and a characteristic length, L. Both the Nusselt number and the characteristic length are dependent on the applied situation.

Nu = h L / k

- Air - h = 10 to 100 W/ (m2K)
- k = 0.024 W/mK
- L= 0.2 m

Nu = h L / k = (50 x 0.2) / 0.024 = 416.66

A = 0.434 m2

Q Conv = h A ΔT

= 50 x 0.434 x 1173

= 25454 W/m2 K

5. ANALYSIS RESULTS

According to the thermal analysis and comparing with different materials, Boron Epoxy can be considered for fabricating the transition duct for better cooling of the air flowing towards the turbine.

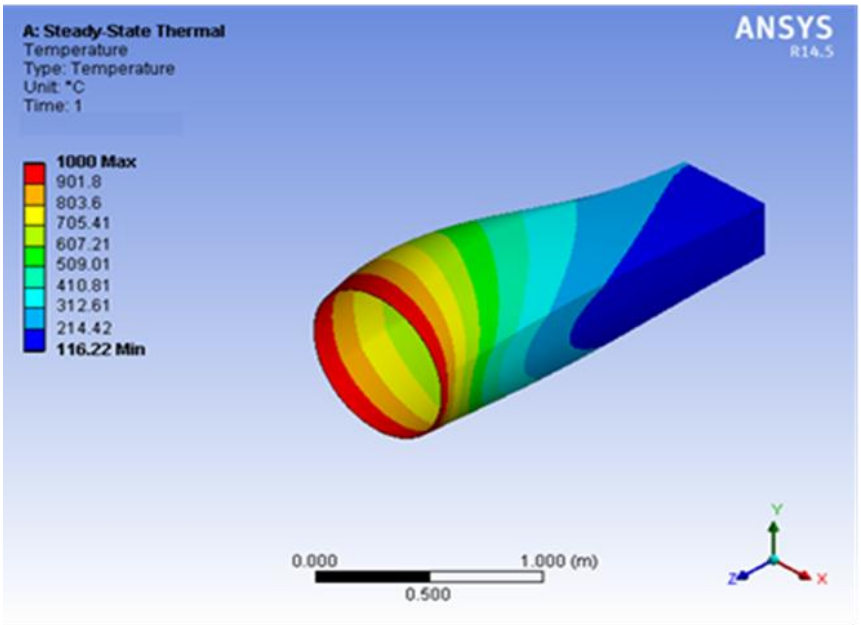


Fig3. Temperature distribution of Transition Duct (aluminum)

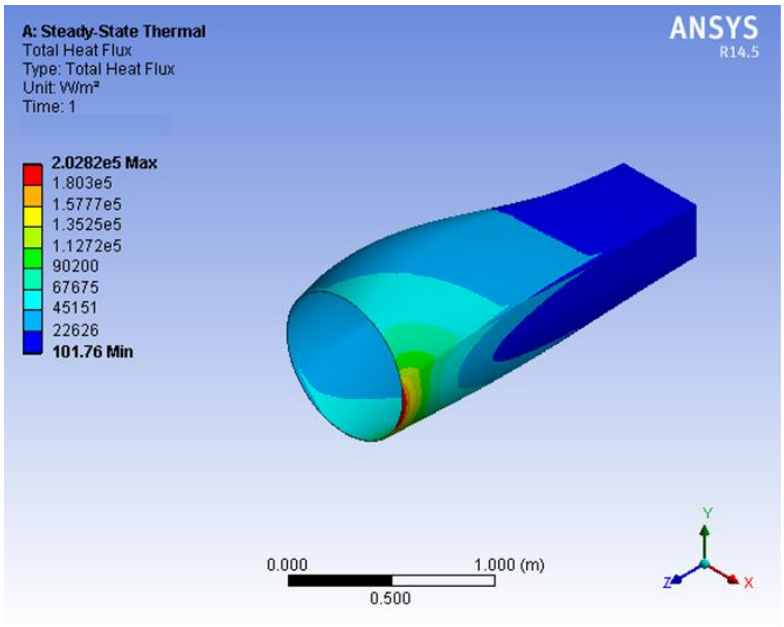


Fig5. Heat flux of Transition Duct (Aluminum)

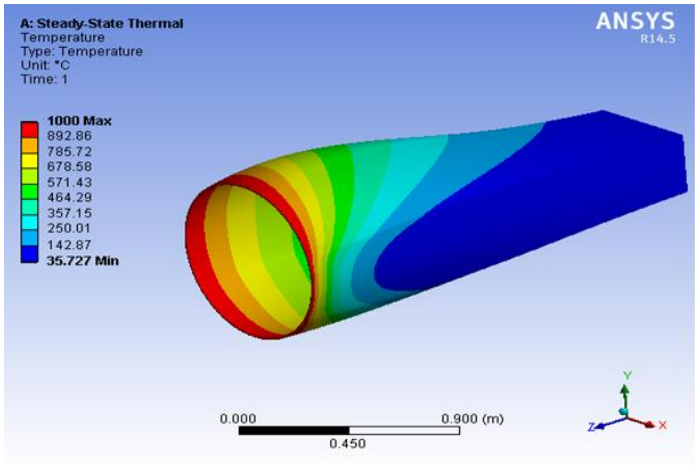


Fig4. Temperature distribution of Transition Duct (E-Glass Epoxy)

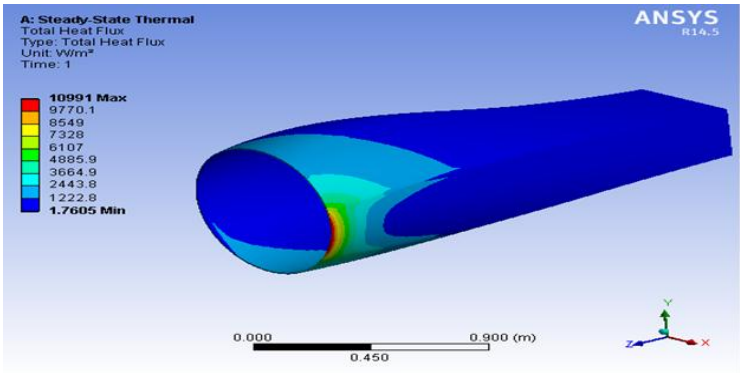


Fig.6 Heat flux of Transition Duct (E-Glass Epoxy)

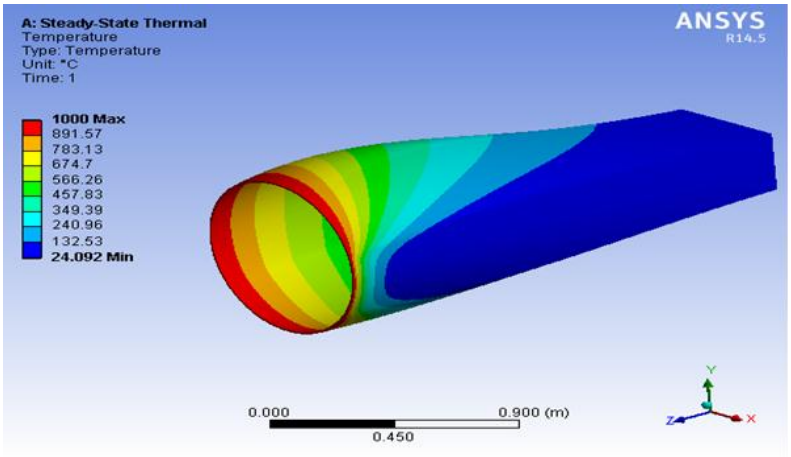


Fig7. Temperature distribution of Transition Duct

(Boron Epoxy)

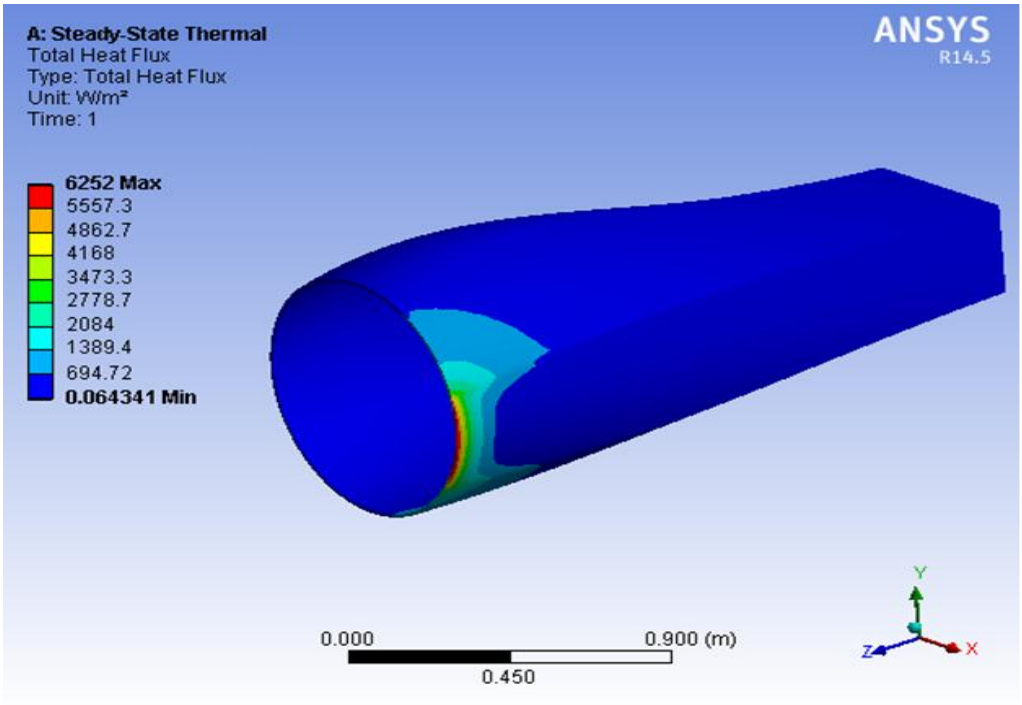
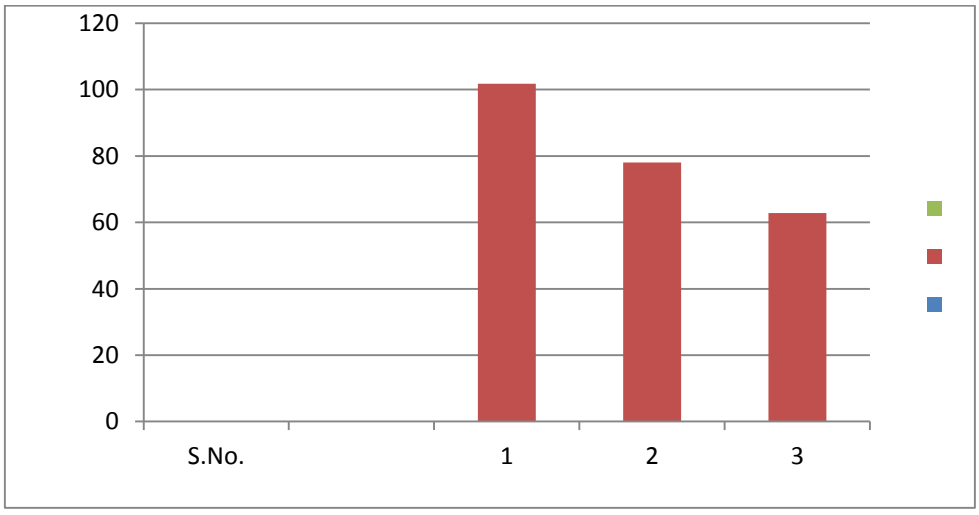


Fig8. Heat flux of Transition Duct (Boron Epoxy)



1. Aluminum 2.Eglass 3.boron

Fig10. Heat flux (y-axis) versus three different materials

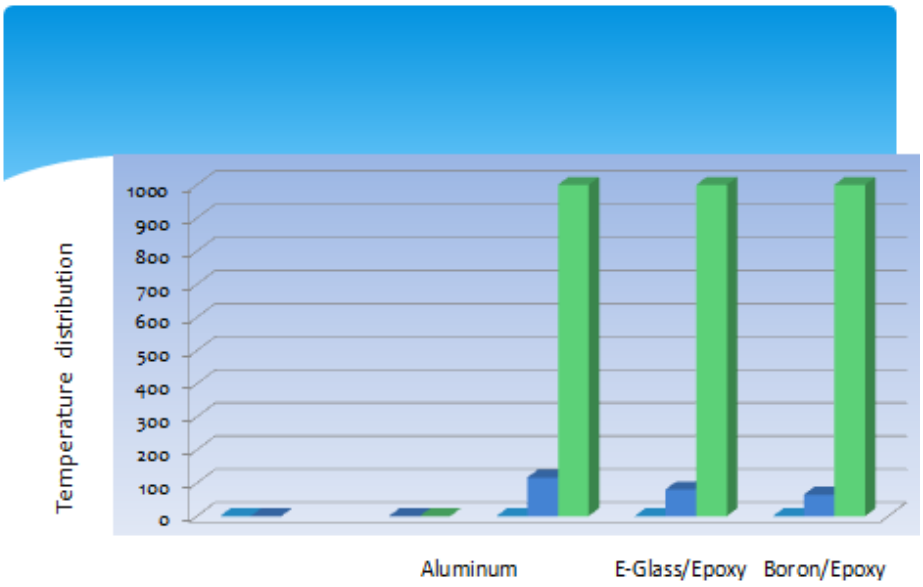


Fig9. Temperature distribution (0C) versus three different materials

Table 1 1.Temperature distribution and heat flux in the. Transition duct and compared with three materials

SI.NO	Material	Temperature distribution (℃)		Heat flux(w/m^2)	
		MIN	MAX	MIN	MAX
1	Aluminum	116.22	1000	101.76	2.0282 e5
2	E-Glass/Epoxy	80.35	1000	1.76	0.10991 e5
3	Boron/Epoxy	24.09	1000	0.064	0.062525

6. CONCLUSIONS

The task was to develop and evaluate new alternative cooling and mounting concepts for a transition duct in the latest gas turbine. The transition duct of today is cooled by a relatively large amount of compressor air which needs to be reduced in case of a power upgrade. The current mounting solution requires three combustion chambers to be removed for one transition duct maintenance, which is time- consuming.

The concept was modeled in CATIA and evaluated with thermal analysis, carried out in ANSYS software. Further development and the combination of the concepts for cooling and mounting concepts for transition duct in gas turbine led to different suggestions which will ease and shorten the maintenance and reduce the cooling air consumption with kept material temperature.

According to the thermal analysis and comparing with different materials, Boron Epoxy can be considered for fabricating the transition duct for better cooling of the air flowing towards the turbine.

7. REFERENCES

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