Enhancement Turbine Blades cooling ways for Micro-Jet Engines

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Abstract
In recent years the use of micro jet engine has been increased and it likely to continue to increase because of the ever-increasing uses such as UAV, small missiles. The researches are continued to develop and update these engines in terms of performance, efficiency and continuity of work for long periods in different conditions. The paper presents a unique approach to enhancement and optimize cooling design for turbine blade (Rotor and Stator) to work for long periods withstand the stresses.

Keywords
Micro Jet Engines, Turbine Blades, Materials, Cooling.

1. Introduction

Advancements made in the field of materials have contributed in a major way in building micro jet engines with higher thrust ratings and efficiency levels. The improvements in design of micro jet engines over the years have importantly been due to development of materials with enhanced performance levels. Micro jet engines have been widely utilized in UAV aircrafts and missiles engines. Advancements in micro jet materials have always played a prime role – higher the capability of the materials to withstand elevated temperature service, more the engine efficiency; materials with high elevated temperature strength to weight ratio help in weight reduction. A wide spectrum of high performance materials - special steels, titanium alloys and superalloys - is used for construction of micro jet engines. The manufacture of these materials often involves advanced processing techniques. Other material groups like ceramics, composites and inter-metallics have been focused of intense research and development; aim is to exploit the superior features of these materials for improving the performance of micro jet engines. [4, 7, 10]
The materials developed at the first instance for jet engine applications had high temperature tensile strength as the prime requirement. This requirement quickly changed as operating temperatures rose. Stress rupture life and then creep properties became important. In the subsequent years of development, low cycle fatigue (LCF) life became another important parameter. Many of the components in the aero engines are subjected to fatigue- and /or creep-loading, and the choice of material is then based on the capability of the material to withstand such loads [7].
The paper brings out a detailed analysis of the advanced materials and processes that have come to stay in the components of turbine blades for micro jet engines also takes simulation for maximum temperature that can applied to the turbine blades additional to make possible cooling ways..

1.2 Micro Jet Engine turbine blades and vanes – Cast superalloys

The material creep strength as an important consideration for the micro jet engines, understanding generated between age hardening, creep and ϒ volume fraction and the steadily increasing operating-temperature requirements for the aircraft engines resulted in development of wrought alloys with increasing levels of aluminum plus titanium. Component forgeability problems led to this direction of development not going beyond a certain extent.
The composition of the wrought alloys became restricted by the hot workability requirements. This situation led to the development of cast nickel-base alloys. [8,10]
Casting compositions can be tailored for good high temperature strength as there was no forgeability requirement. Further the cast components are intrinsically stronger than forgings at high temperatures, due to the coarse grain size of castings. Das recently reviewed the advances made in nickel-based cast superalloys [8] Buckets (rotating airfoils) must withstand severe combination of temperature, stress and environment. The stage 1 bucket is particularly loaded, and is generally the limiting component of the gas turbine. Function of the nozzles (stationary airfoils) is to direct the hot gases towards the buckets. Therefore they must be able to withstand high temperatures.
However they are subjected to lower mechanical stresses than the buckets. An important design requirement for the turbine blade materials is that they should possess excellent high temperature oxidation and corrosion resistance.

1.3 Advanced materials

Increase in turbine inlet temperatures, beyond what is possible with superalloys, can be conceived if ceramic materials can be used in place of superalloys in micro jet engine. Turbines would then operate at higher temperatures, yielding higher power with smaller engine sizes. Ceramic materials are known for their capability to withstand high temperatures. In addition they are quite tolerant to contaminants such as sodium and vanadium which are presented in low cost fuels and highly corrosive to the currently used nickel-base superalloys. Ceramics are also up to 40% lighter than comparable high temperature alloys. They also cost much less – their cost is around 5% the cost of superalloys [5,9]. Ceramic materials based on silicon carbide and silicon nitride were identified in 1960's as potential candidates for gas turbine application. Substantial efforts have subsequently been conducted worldwide to identify and seek solutions for key challenges: improvement in properties of candidate materials, establishing a design and life prediction methodology, generating a material database, developing cost-effective fabrication of turbine components, dimensional and non-destructive inspection, and validation of the materials and designs in rig and engine testing. Enormous technical progress has been made, but ceramic-based turbine components still have not found application in gas turbine engines, because of the problem of brittleness [9]. There have been efforts to improve their ductility, e.g., through addition of aluminum to ceramics. Unless the problem of brittleness is overcome satisfactorily, the use of ceramics in gas turbines will not be practical [4, 10].

1.4 Problem Statement

Most of the turbine blades in micro-jet engines does not contain a means of cooling such as cooling ways used in jet engines because the small size of both rotor and stator blades and there is many techniques have been developed to enhance the heat transfer such pin-fin passages. The cooling passages located in the middle of the blade airfoils are often lined with rib turbulators. The typical cooled turbine vane is shown in figure (1) [1]. It is very difficult to make holes and pin-fins in blade of micro-jet engines turbine blades for the smallest blade size led to reduces the efficiency of stresses applied on the blade to works many hours provided these engines are few and cannot run for long hours and hard to draw on these engines to fly long distances by small planes or rockets near term.

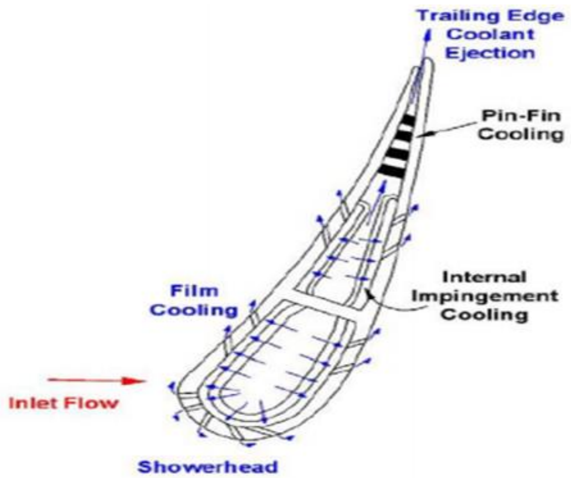


Figure (1) Schematic of a Turbine Vane Cross-Section with Impingement and Trailing Edge Pin-Fin Cooling [1]

The paper will test two designs for blade cooling section badminton through the use of two types of design by using Nickel base supealloy materials as known have a high resistant to high temperatures that are used in manufacturing turbine blades to open future horizons for researchers to find means of cooling in turbine blades of micro Jet engines and to expand the use of long distance and longer work period time.

1.5 Material and Structural Analysis of micro jet engine Turbine Blade

The materials will be test is CMSX-10 alloy and the pacification is showed below:

CMSX-10 (Nickel base Superalloy)

The CMSX-10 alloy is a third generation single crystal (SX) casting material which is used in demanding turbine engine blading applications. The flight engine certified alloy is characterized by it's 6 wt. % rhenium content, high additive refractory element level, and relatively low chromium employment. Based on published data, the alloy is thought to exhibit the highest creep strength and resistance to fatigue of any production Ni-base, cast SX superalloy. [3] CMSX-10 alloy provides an approximate 30°C improved creep strength relative to second generation 3 wt. % containing SX alloys such as CMSX-4 and PWA 1484.
Furthermore, it develops low cycle and high cycle fatigue (LCF and HCF) strengths as much as 2- 3 times better than the best alternatives. Moreover, the alloy also develops an attractive blend of tensile and impact strengths, foundry performance, heat treatability and environmental properties characteristic. Most notably, the alloy provides surprisingly good hot corrosion resistance, despite its novel and relatively low chromium content (2-3 wt. %). Additionally, the alloy performs extremely well in both the aluminide and Pt - aluminide coated conditions. [3] Below in table (1) nominal compositions of cast CMSX-10 [6].

ALLOY	DESCRIPTION	COMPOSITION (WT %)												
CMSX-10	Nickel-base single crystal, known for strengh and castability. Contains Re	Ni	Cr	Co	Mo	Re	Al	Ti	Ta	W	Zr	c	B	Others
		bal.	2	3	0.4	6	5.7	0.2	8	5	…	…	…	0.1 Nb, 0.03 Hf, 6 Re

Table (1) nominal compositions of cast CMSX-10 [6] P 276

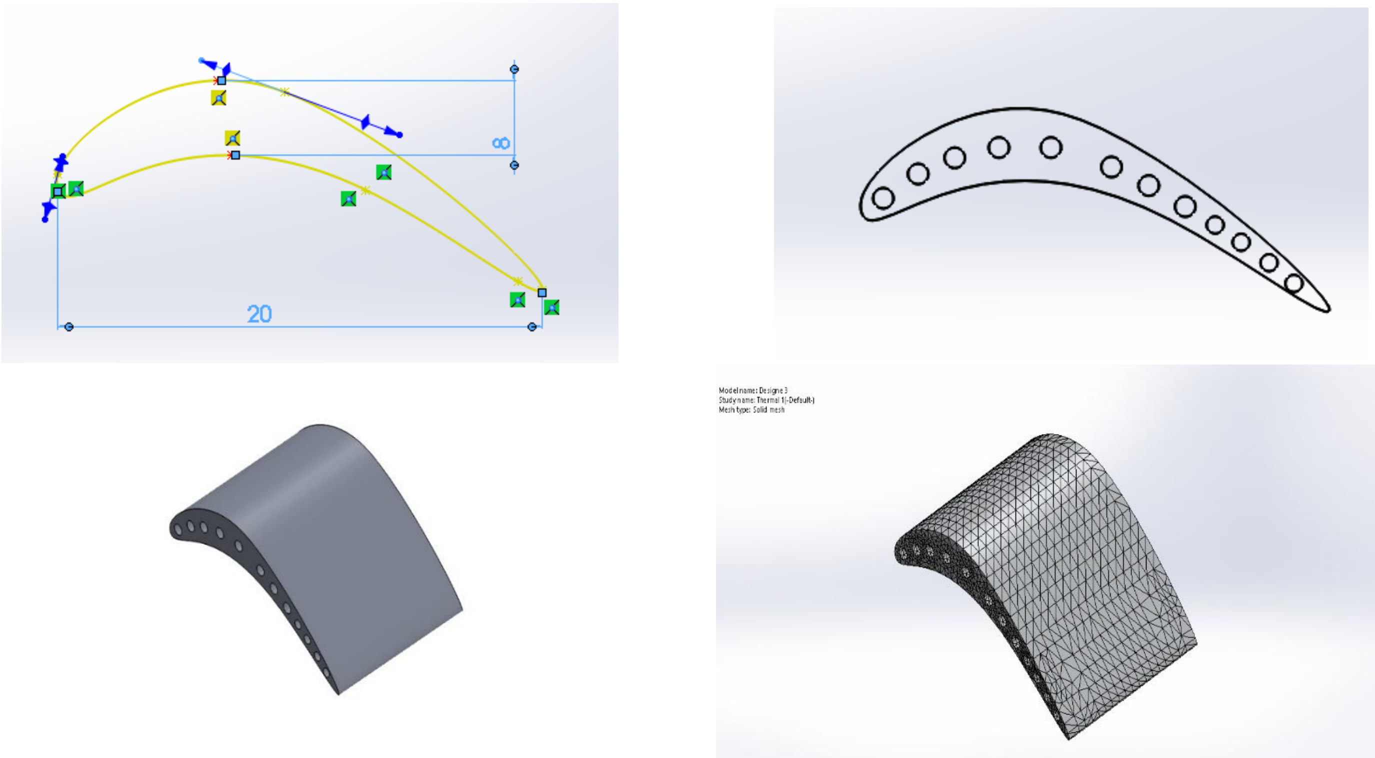
Property	Value	Units
Elastic Modulus	1.15e+011	N/m^2
Poisson's Ratio	0.33	N/A
Shear Modulus	4.9e+010	N/m^2
Mass Density	4730	kg/m^3
Tensile Strength	900000000	N/m^2
Compressive Strength	875000000	N/m^2
Yield Strength	810000000	N/m^2
Thermal Expansion Coefficient	8.6e-006	/K
Thermal Conductivity	10.9	W/(m·K)
Specific Heat	495	J/(kg·K)
Material Damping Ratio	1.15e+011	N/A

Table (2) Material Properties table of CMSX-10

Cooling of components are achieved by air internal cooling, Convection cooling this type of cooling works by passing cooling air through a small passages internal to the blade. Heat is transferred by conduction through the blade, and then by convection into the air flowing inside of the blade. A large internal surface area is desirable for this method, so the cooling paths tend to be serpentine and full of small fins. The internal passages in the blade may be circular or rectangular in shape. Cooling is achieved by passing the air through these passages from hub towards the blade tip. This cooling air comes from an air compressor. In case of gas turbine the fluid outside is relatively hot which passes through the cooling passage and mixes with the main stream at the blade tip. [5]

2. Design (I)

In this design the internal passages in the blade will be circuled by make small holes diameter 2 mm, as shown in Figure (2) and applying inner temp 10 C with the outer temp 1200 C.

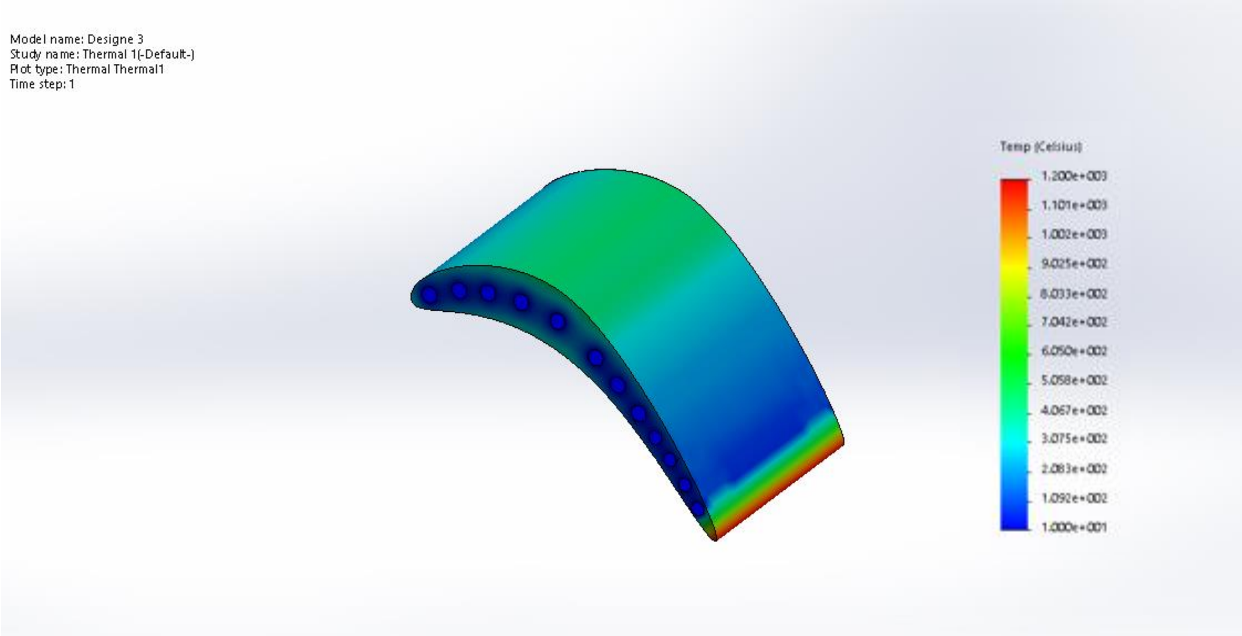


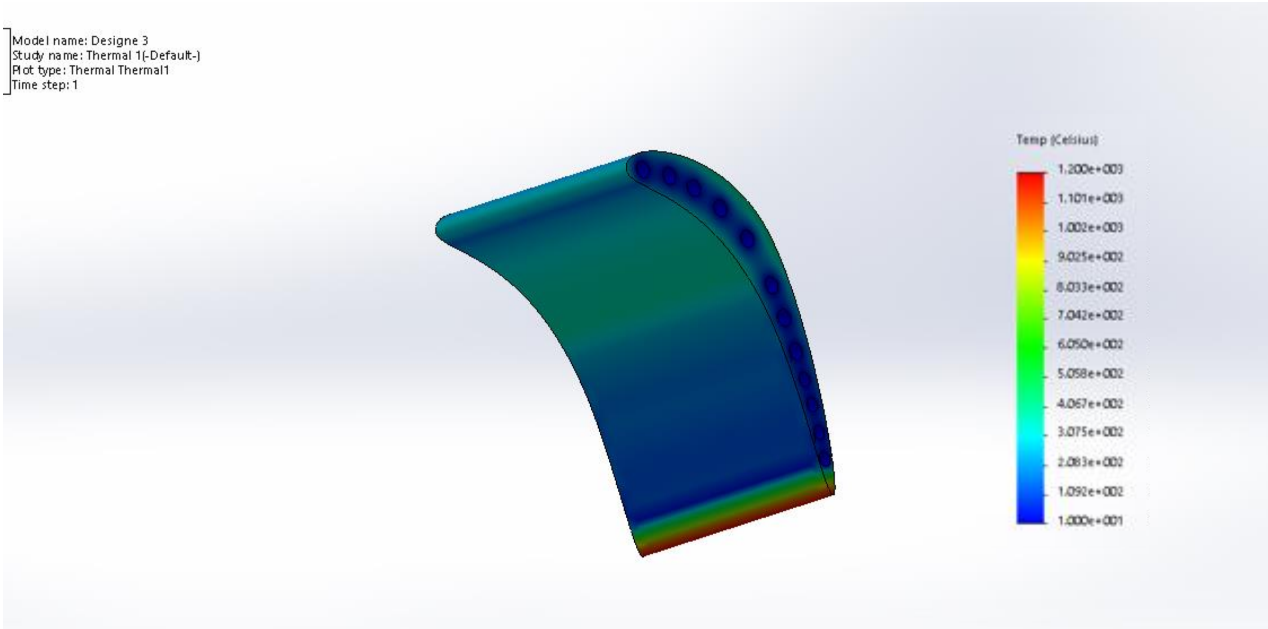
Solid Bodies
Volumetric Properties
Mass:0.0638465 kg Volume:2.35596e-005 m^3 Density:2710 kg/m^3 Weight:0.625696 N

Figure (2) blade dimensions & cross- section design (I)

Simulation & Results

Name	Type	Min	Max
Thermal	TEMP: Temperature	9.99999 Celsius Node: 1	1200.8737 Celsius Node: 72790





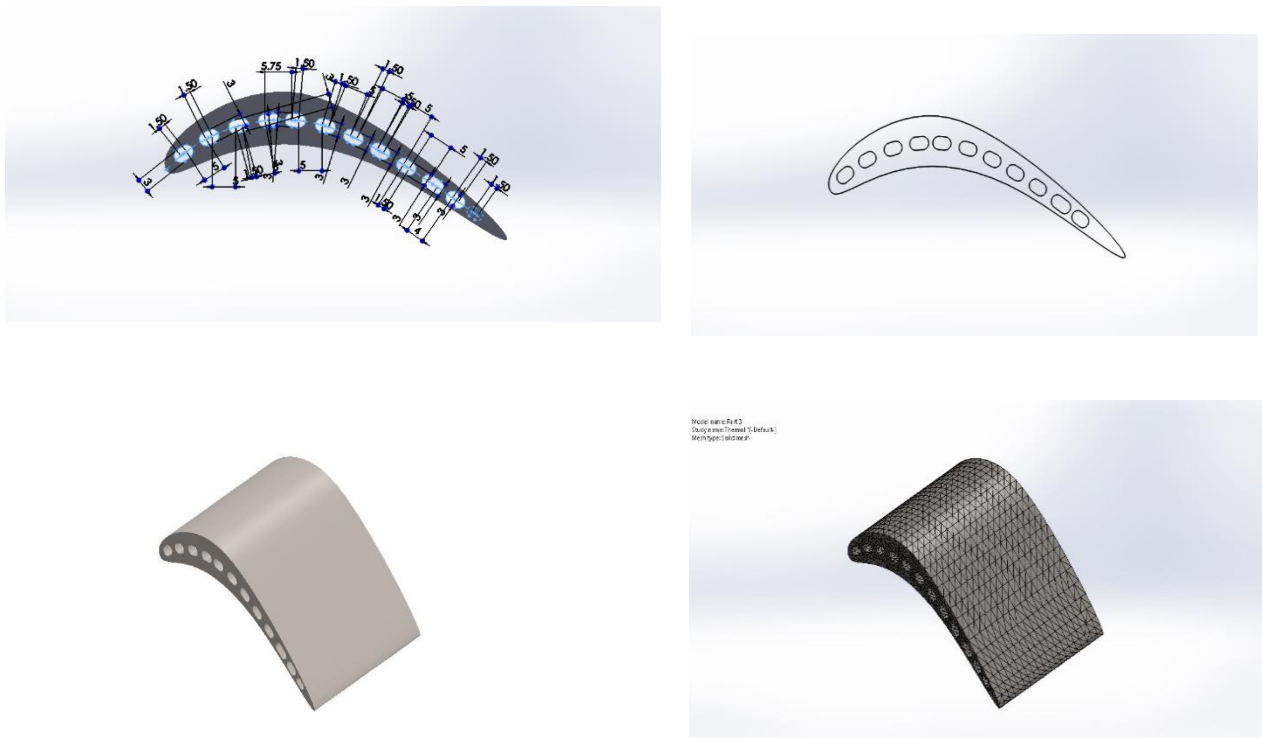
Thermal Simulation

Figure (3) blade thermal simulation design (I)

In this type cooling is processed through the design of small holes with a diameter of 2 mm in blade feather body and passes the air inside these holes at a temperature of 10 Celsius and the outer surface temperature is 1200 C. The results were very satisfactory, but was not taken into consideration the estimated stresses that can be borne by the secrecy in this design.The design focuses only on the possibilities of cooling for this kind of blades, at the end of blade tip observed that temperature is very high cause there is no cooling passages closer this zone as shown in figure (3).

3. Design (II)

In this design the internal passages in the blade will be elliptical by make small holes 2 mm in dimension and the model information as shown in Figure (3).

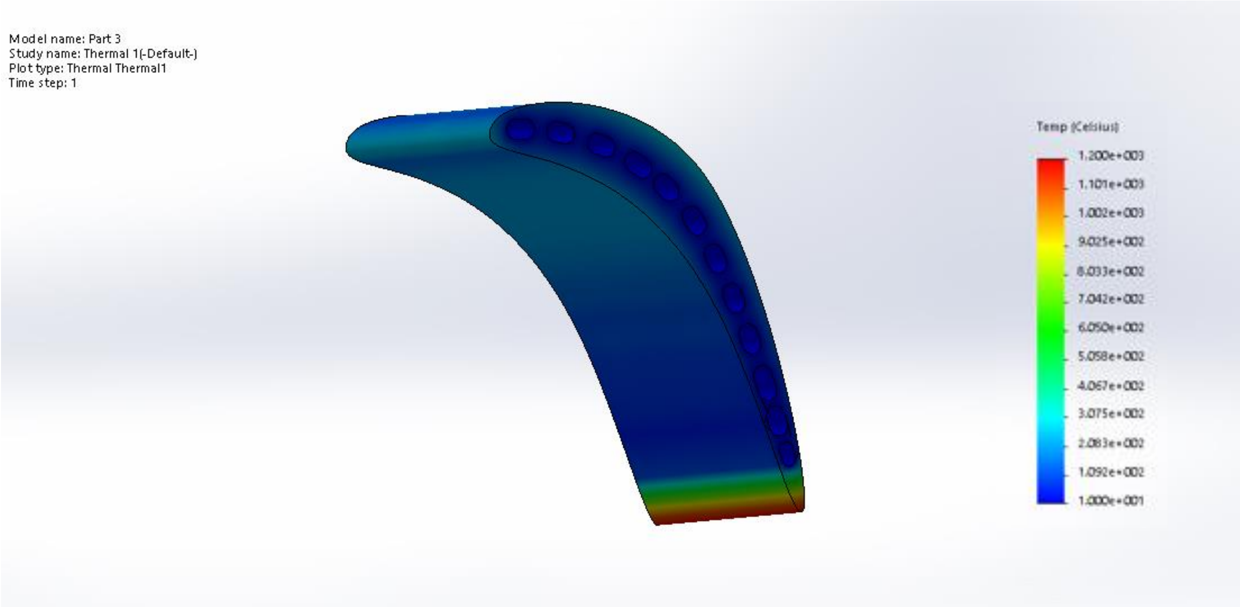


Solid Bodies
Volumetric Properties Mass:0.116571 kg Volume:2.4645e-005 m^3 Density:4730 kg/m^3 Weight:1.14239 N

Figure (4) blade dimensions & cross- section design (II)

Simulation & Results

Name	Type	Min	Max
Thermal	TEMP: Temperature	9.99999 Celsius Node: 1	1200.8737 Celsius Node: 72790



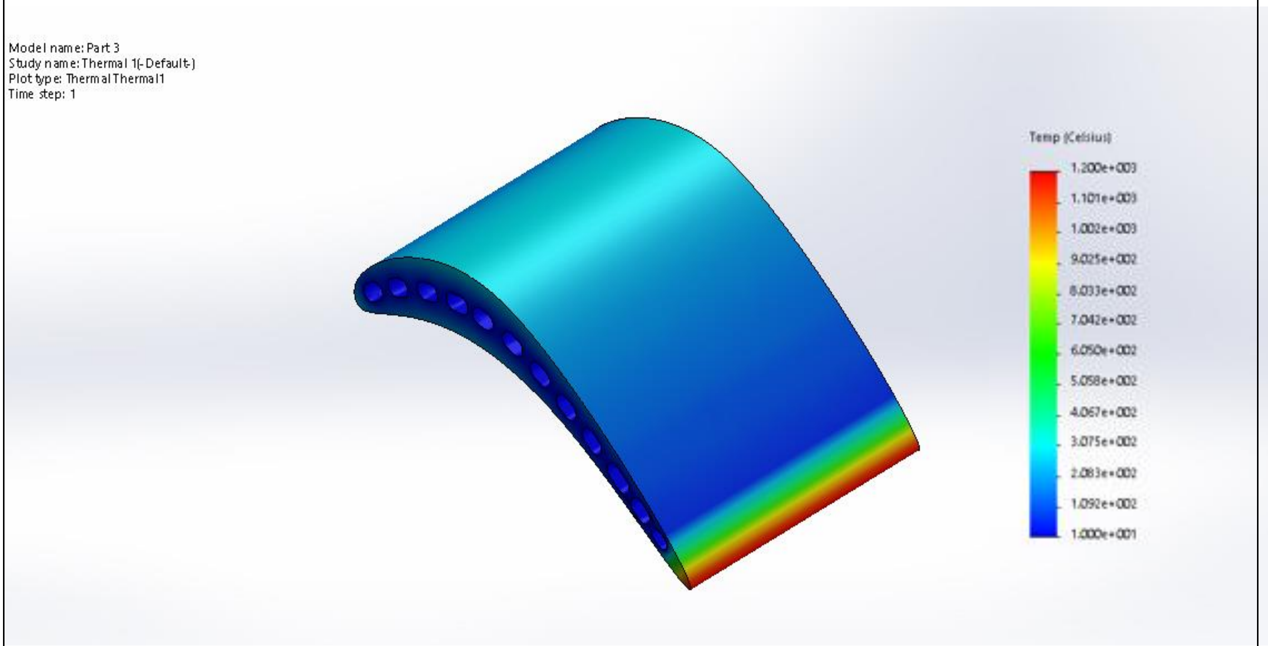


Figure (4) blade thermal simulation design (II)

In this type cooling is processed through the design of small elliptical holes with a diameter of 2 mm in blade feather body and passes the air inside these holes at a temperature of 10 Celsius and the outer surface temperature is 1200 C.The results were very satisfactory, but was not taken into consideration the estimated stresses that can be borne by the secrecy in this design. The design focuses only on the possibilities of cooling for this kind of blades. At the end of blade tip observed that temperature is very high cause there is no cooling passages closer this zone as shown in figure (4).

Conclusion

Superalloys especially CMSX-10 well-known in their resistance to high temperatures, where up to 2000 Celsius therefore used this material widely in the manufacture of turbine blades in jet engines in addition to these materials cannot withstand long periods of time with continued high temperatures without cooling. So there is a several ways used to cooling to be in acceptable temperature and still working for long periods. Turbine blades for micro-jet engines not including cooling ways for the small blade Therefore, it is difficult to work for the long-time.

The paper testes two methods designed to cool micro- jets turbine blades by make a small passages in circular and elliptical design does not exceed a diameter of 2 mm. The simulations show of both designs got very good result by keeping the outer blade body temp under the allowable limits thus can be for these engines work for long periods which opens the future prospects of the search to find a new technology for the design of optimal methods of cooling the micor-jet -turbine blades.

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