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# MODELLING AND MANUFACTURING OF GAS TURBINE BLADE USING 3D PRINTING

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**Abstract:** ***Additive manufacturing is an advanced manufacturing technique which can be used to create 3d objects out of information provided in the form of computer input by joining material layer by layer to form a final component. By the use of 3Dprinting, material wastage can be reduced and manufacturing rate can be increased. This technique makes it possible to manufacture complex and novel shapes and unusual material properties, for example propeller, turbine blades etc., like shapes can also be easily printed using this technique. This project explores the effective use of 3Dprinting. In this current work a gas turbine blade was created by modeling in NX CAD10.0. Then the model was analyzed by means of applying the structural and thermal loads in NX Nastran to analyze its load bearing properties. Then the blade is manufactured using 3Dprinting, which was cost effective and has proved that the material wastage was reduced.***

**Keywords:** ***Additive manufacturing, NX 10.0, Turbine blade, 3D printing.***

## 1. INTRODUCTION

The blade in the gas turbine is one of the most important components, in which the blades produce the energy for the turbine with the help of increase in the pressure of the gas and that of the temperature produced in the combustion chamber. These turbine blades are frequently restricting component of gas turbines. In order to be operable in this type of extreme atmosphere, the turbine blades are generally manufactured by the use of materials such as super alloys, which possess various diverse properties such as, means of cooling, like boundary layer cooling, internal air channels, and coatings. Apart from the materials the method of manufacturing of the turbine blade also plays a crucial role. There are various types of manufacturing techniques which are used in the manufacturing of the blade such as Forging, Powder metallurgy and 3D printing etc., Compared to all of these techniques 3Dprinting is the more efficient and cost effective technique because of its ease of manufacturing of the complex shapes and least amount of material wastage.

## 2. METHODOLOGY

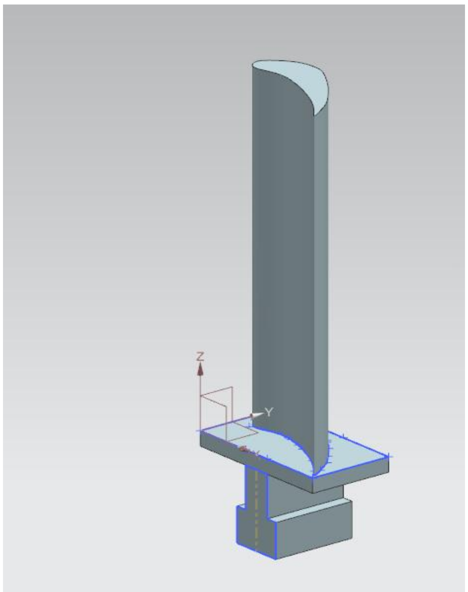
- Defined the Problem.
- Generated the 3-dimentional NX gas turbine models.
- Prepared finite element model of the 3D computer gas turbine model.
- Pre-process was done to the 3D gas turbine model.
- Post process the model for the required evaluation to be carried out.
- Determined maximum stress and displacement induced in blades.
- Determined the nodal temperature and heat flux distribution along the blade.
- Converted the NX model into STL format.
- 3D printer was used for Print the gas turbine blade.

## 3. MODELLING AND ANALYSIS OF GAS TURBINE BLADE

For the modeling the blade profile was generated by using Siemens NX10.0 CAD software. Initially the profile points were created. These points were then combined by drawing B spline curves to acquire a smooth curve. The curve (2D model) is formerly changed into area and volume (3D model) was produced keeping an extruded value of 117mm. Similarly the hub was produced in the same way and these two volumes were formerly united into single volume.

Table 1 Co-Ordinates of the Blade

| S. no. | X | Y | S. no. | X | Y |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 20 | 49 | 0 |
| 2 | 2.6 | 17.3 | 21 | 49 | 27 |
| 3 | 5.85 | 21 | 22 | 0 | 27 |
| 4 | 10 | 25 | 23 | 19.5 | 0 |
| 5 | 14.8 | 26.6 | 24 | 1 | 13.6 |
| 6 | 22.9 | 25.3 | 25 | 29.2 | 0 |
| 7 | 28 | 22.2 | 26 | 29.2 | 27 |
| 8 | 33.4 | 18.5 | 27 | 19.8 | 27 |
| 9 | 38 | 14.4 | 28 | 15.2 | 27 |
| 10 | 42 | 10.9 | 29 | 18.08 | 27 |
| 11 | 45.5 | 5.70 | 30 | 49 | 0 |
| 12 | 49 | 0 | 31 | 49 | 0 |
| 13 | 6.18 | 12.4 | 32 | 29.2 | 12.49 |
| 14 | 11.2 | 14.4 | 33 | 19.8 | 26.62 |
| 15 | 16.18 | 15.5 | 34 | 19.8 | 15.12 |
| 16 | 21.1 | 14.9 | 35 | 29.2 | 21.25 |
| 17 | 26 | 13.6 | 36 | 0 | 0 |
| 18 | 38.2 | 8.77 | 37 | 19.8 | 0 |
| 19 | 45 | 3.95 | 38 | 19.5 | 15.12 |



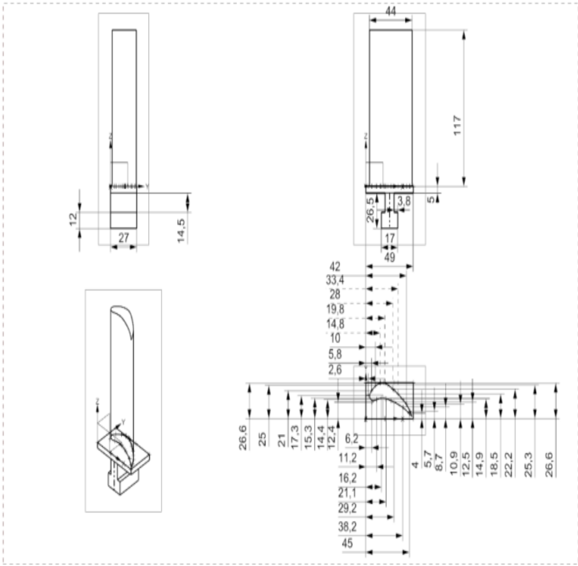
3.1 Model of the Turbine Blade

Table 2 Turbine Blade Data

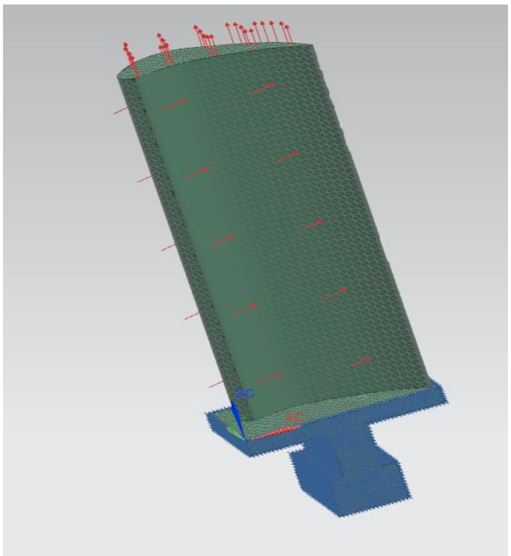
| Parameter | Value | Units |
|---|---|---|
| Absolute flow angle α | $23.85^0$ | deg |
| Absolute velocity $V_1$ | 462.21 | m/s |
| Mass flow of gas the is m | 0.58 | Kg/sec |
| Diameter of the mid span D | 1.308 | m |
| Design speed of the turbine N | 3426 | rpm |

Table 3 Forces applied on the blade

| Force | Value |
|---|---|
| Tangential force $F_t$ | 248.199 N |
| Axial force $F_a$ | 3.82 N |
| Centrifugal force $F_c$ | 22988.69 N |
| Heat load Q | 155.99 W |



3.2 Drafting of the Turbine Blade



3.3 Forces Applied on Blade

Table 4 Property of Nimonic 80a Alloy

| Properties | Nimonic 80a | Units |
|---|---|---|
| Density | 8190 | $kg/m^3$ |
| Liquids temperature | 1365 | $^0C$ |
| Specific Heat | 448 | J/kg |
| Young's modulus | 220000 | $N/mm^2$ |
| Shear modulus | 85000 | $N/mm^2$ |
| Yield strength | 650 | $N/mm^2$ |
| Ultimate tensile strength | 1150 | $N/mm^2$ |
| Thermal expansion co-efficient | 12.7 | $\mu m/m^0C$ |
| Thermal conductivity | 11.2 | W/mK |

## 4. STRUCTURAL AND THERMAL ANALYSIS RESULTS

In order to analyze the structural and thermal properties of the component the prototype of turbine blade was opened in NX 10.0 software in advanced simulation. Then the blade was examined successively structural analysis with thermal analysis. The material was used in the blade is nimonic 80a. The accumulation of aluminum and titanium, the material is more toughened, and the material has better oxidation and corrosion resistance property. The tensile and creep rupture point of the material is large at high temperature. The model was discretized by using 10 nodded tetrahedral solid elements. Then by using the velocity triangle, found the centrifugal, axial & tangential forces for the component. The Loads and constrains were applied onto the turbine blade. Then solve the model and obtain the structural analysis results. Similarly, in the same manner the thermal analysis is also carried out onto the component by using thermal/flow solver. The Thermal loads and convection constrain were applied. The temperatures and heat flux on the gas turbine blade were identified by doing Thermal analysis.

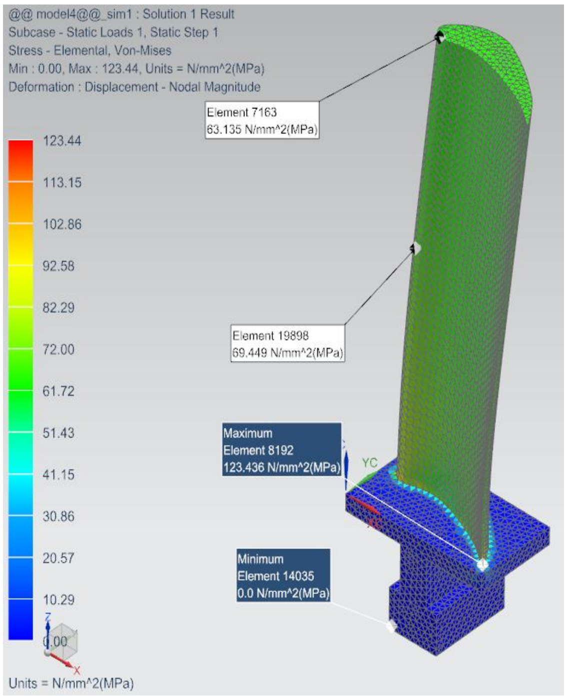



Fig 4.1 Von-Mises Stress

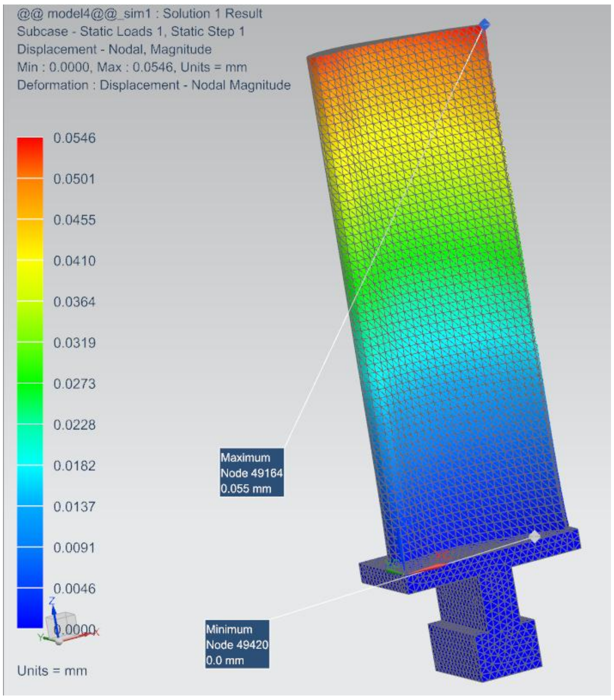



Fig 4.2 Total Displacements

The Fig 4.1 shows stress distribution in the turbine blade due to mechanical loads stress detected was 123.43 N/mm$^2$ which was maximum at the root of the blade and least at the tip of the blade.

The Fig 4.2 shows displacement in the turbine blade due to forces maximum elongation (displacement) of 0.055 mm detected at the blade tip sections and least elongations at the root of the blade.

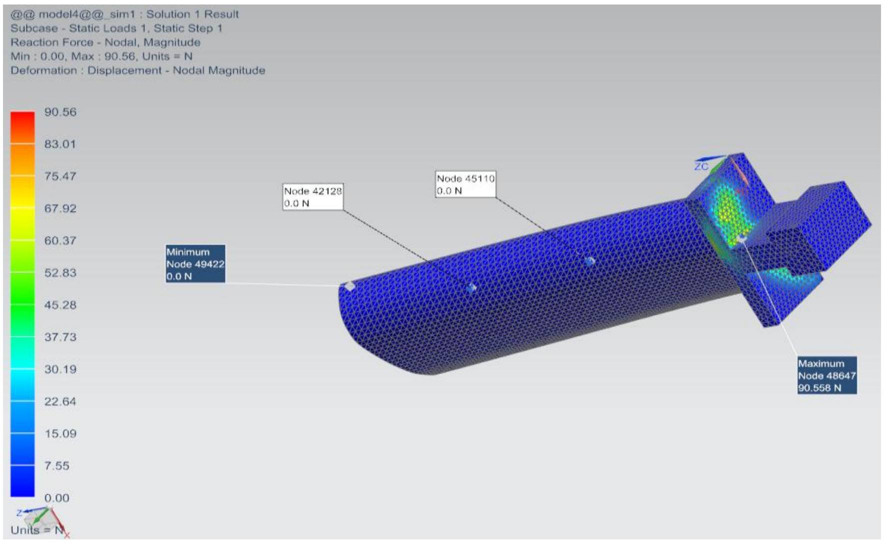



Fig 4.3 Reaction Force on the Blade

The Fig 4.3 shows reaction force in the turbine blade due to forces maximum reactions forces are detected at the root section is 90.558 N and remaining portion is zero.

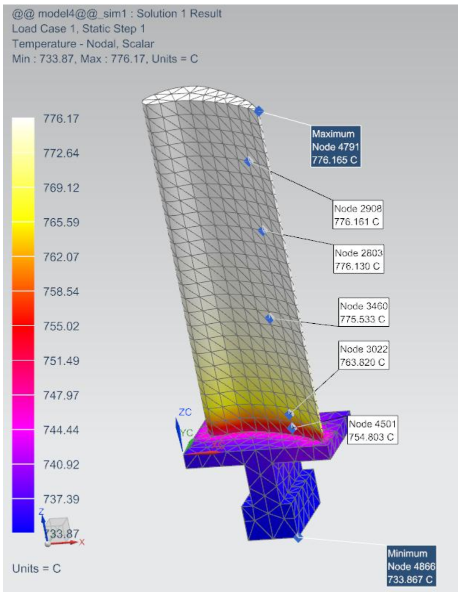



Fig 4.4 Temperature Distribution on Turbine Blade

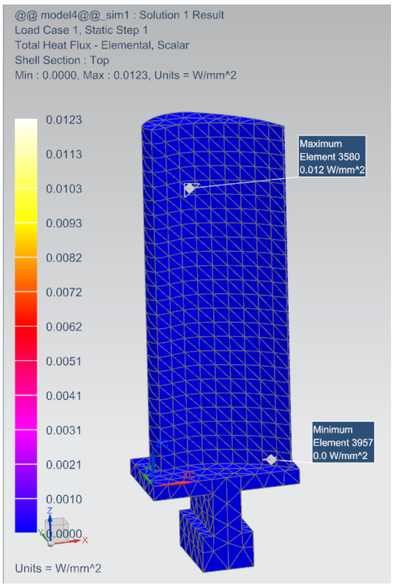



Fig 4.5 Heat Flux

The Fig 4.4 shows Temperature distribution in the turbine blade due to thermal load maximum temperature of 776.161 $^{0}$C detected at the tip section and lowest temperature detected at the root of the turbine blade.
The Fig 4.5 shows total heat flux detected on elemental was maximum 0.012 W/m$^2$ at top of the blade.

Table 5 Structural Analysis Results

| Solution | Mechanical | Units |
|---|---|---|
| Resultant Displacement | 0.0046 to 0.0546 | mm |
| Vonimisses Stress | 0.00 to 123.44 | N/mm$^2$ |
| Reaction force | 0.00 to 90.56 | N |

Table 6 Thermal Analysis Results

| Solution | Thermal | Units |
|---|---|---|
| Nodal temperature | 733.87 to 776.17 | C$^0$ |
| Total Heat flux on element | 0.0000 to 0.0123 | W/mm$^2$ |

## 5. 3D PRINTING RESULTS

### 5.1 3D Printing

In the current research work SSt 1200es 3Dprinter was used for the 3D printing. The software which is used in the SSt 1200es 3Dprinter is Catalyst ex 4.56 version. In order to print the component by using 3D printing initially the prototype was created the in NX 10.0. CAD software was used for convert the CAD file into STL file format and then converted STL file was dumped into catalyst software. The catalyst software divides the dumped file component into a number of layers, then these layers were printed one by one by using this technique.in the 3D printing Mainly there are two types of materials were used in the printing purpose they are model material and supporting material. The model material was same as that of the component material and the supportive material was used only for the support of the base model. This process involves mainly two nozzles, one with the diameter of 0.2 and other with 0.3mm. From smaller diameter nozzle model material and from the larger diameter nozzle support material was released. After that the component was passed to the agitation tank. The agitation tank was used to separate the component material from model material each other. from 3D printing blade was manufactured within a total time of 2 hours 59 min and the wastage from the process is very less and negligible, also the overall Tooling and machining cost of the component is very less.

Fig 5.1 3D Printing Machine

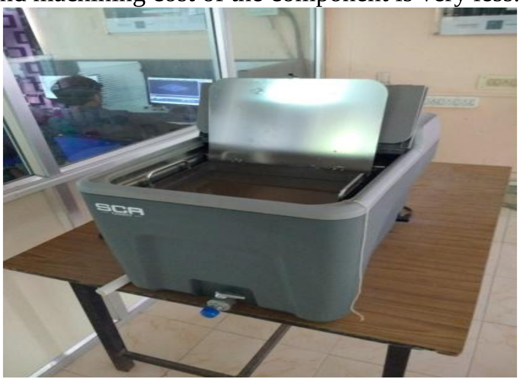


Fig 5.2 Agitation Tank

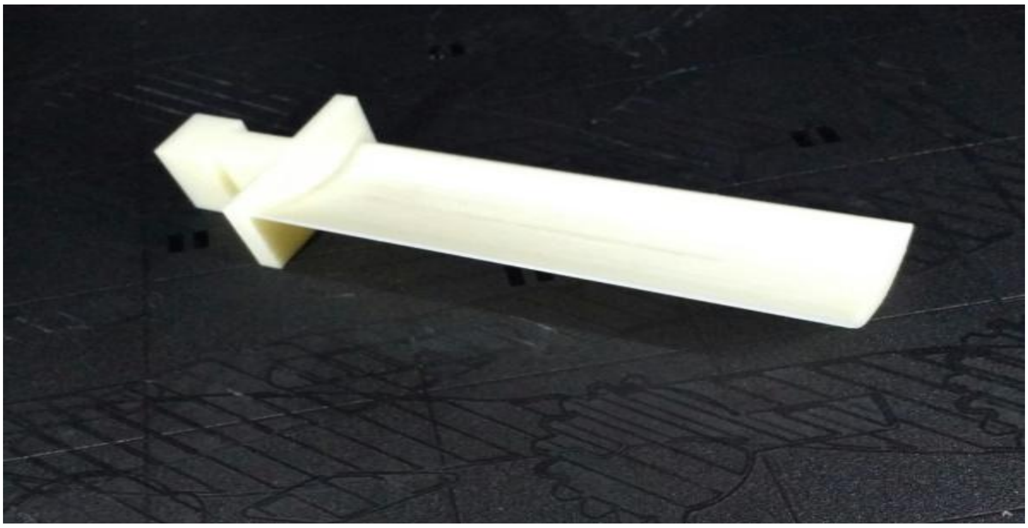


Fig 5.3 3D Printed Turbine Blade

## 6. CONCLUSION

In this current work the structural analysis and thermal analysis of gas turbine rotor blade was carried out in a NX10.0. The maximum elongation was detected at the blade tip segment and the minimum elongation was found out at the root of the blade. Likewise, the maximum stresses were detected at the root of the turbine blade and minimum stresses were identified at the tip section of the blade. The temperature also has an important outcome on the total stresses in the turbine blades. Maximum temperatures were detected at the blade tip segment and minimum temperature at the root of the blade Temperature is linearly decreasing from the tip of the blade to the root of the blade section. Here by using 3D printing technique the overall cost of tooling and machines was decreased. The overall costs due to the complexity of the shape and the machining process and also the amount of unwanted material was negligible amounts compared to other remaining manufacturing process.

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