# Appropriateness Investigations on Nimonic 901 and Rane 77 made Guide Vanes of Gas Turbine with Showerhead Cooling

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**Abstract:** ***Gas turbines are under the class of high temperature application thermal device. Stability of the material at elevated temperature is difficult to predict conventional methods. The design, engineering offers solution for such cases. The stability can be experimented for such cases using modeling and simulation by means of design engineering softwares. Structural stability of the material depends on the shape, material and load. It is required to analyze the structural stability of such gas turbine components at elevated temperature. The hollow portion like cooling design and greatly influences on the structural stability of them. This research focuses on the material influence on guide vane with showehead type cooling design. The high temperature materials like Nimonic 901 and Rane 77 were considered for this analysis. The Pro –E and ANSYS R14 were employed for modelling and FEM analysis respectively.***

**Keywords:** showerhead cooling, guide vane, gas turbine, Nimonic 901, Rene 77

## 1. Introduction

Gas turbine applications are to be expected at the industries like, power generation, locomotive, aircraft, marine propulsion, and other industrial prime movers. The aim of higher output and thermal efficiency leads to higher operating temperature of thermal devices like gas turbine, In gas turbine the inlet temperature is about 1500°C [1-3]. In some special cases like aerospace, it is much higher, i.e., 1,727°C [4-6] as well as with the higher operating pressure ratio at compressor about 50 [6]. In such circumstances the components often encounter the thermal damages as well as other damages like melting, corrosion, oxidation and erosion [7], the degradation of local or global structural strengths of blades, vanes and other components and it was estimated that half of the lifespan of the blades gets reduced due to small temperature difference by improper cooling [3,6,9]. The specific damages are: blade trailing-edge cracks [8], buckling and risk of blade failure [11], thermal-fatigue [8,10,11]. Hence the perfect cooling is insisted for avoiding them. Many studies were conducted on optimization of lip thickness to slot height ratio (t/H) in trailing edge cooling of blades and vanes [12 -17] in which Kacker et al. [12,13] considered lip thickness constant to estimate film cooling effectiveness, Taslim et al [14,15] varies slot geometries and blowing ratios. The t/H ratio from 0.5 to 1, decrease the overall film-cooling effectiveness by about 10% [14-16]. The decreases of t/H ratio, increases the film-cooling effectiveness [17-19]. [20] considered a a rectangular divergent channel which consists of serpentine shape with ribs, dimples/protrusions, guide vanes, and pin fins at the tip turning the region for his heat transfer studies. [21] studied the cooling performance at tip surfaces of guide vanes and blades at turning regions and insisted the importance of proper design to obtaining desired effects. [22] recommended installing guide vanes in the tip turning regions most suitable way to improve cooling of tip surfaces. [23] insisted that selection appropriate cooling technique with respect to

**Figure 1:** Fixed blade (Guide vane)

configuration is must. The authors suggested two pass channels cooling at moving blades. This research work investigates with materials behaviors at elevated temperature for impingement cooling design on gas turbine fixed blade (guide vane). The Pro-E and ANSYS are employed to design and analysis. ANSYS is generally the preferred tool for analyzing structural stability. [24] used CATIA and ANSYS to design and investigate the structural stability of various components of Two-Wheeled Inverted Pendulum. In later [25] investigated the suitability of Kevlar29/epoxy composite for drive shaft. The influences of cooling designs, such as impingement and shower head type on gas turbine guide vanes which are made up of Nimonic 901[26], RENE 77 [27], CMSX 4 [28] were reported. The sample guide vane of gas turbine is shown in Fig.1. This research investigates the suitability of material for the specified case. Here the case is guide vane of the gas turbine with showerhead cooling design and predefined shape, profiles and dimensions.

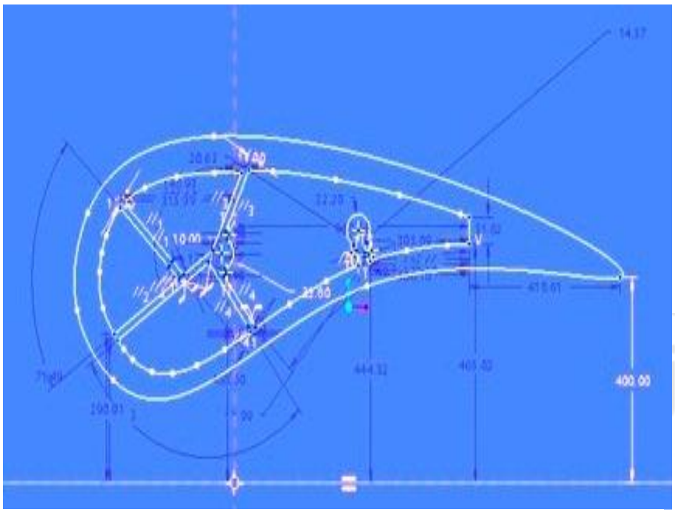

**Figure 2:** 2D model of Guide vane

## 2. Materials and Methods

The super alloys which specifically suitable for high temperature applications like Rene77 and NIMONIC 901 were considered in this investigation. The design approach is used for investigating the structural stability of gas turbine guide vanes at elevated temperature.

### 2.1 Nickel Alloy 901/ Nimonic 901

It is also nickel based super alloy widely applicable at high temperature environments. Superior creep resistance, high yield strength, good forging characters, etc. at elevated temperature are the merits of this material. Its significant properties were included in the structural stability analysis by using ANSYS.

### 2.2 RENE 77

It is preferred for high temperature applications about 1000$^{o}$C like aviation, petroleum, gas turbine, space flight, ship, etc. because of its significant properties at elevated temperatures like excellent oxidation resistance, with stand at long term stress, creep properties, reliable in physical and chemical properties, good impact and toughness strengths etc. values of such unique properties were included in the analysis by using ANSYS.

### 2.3 Structural Analysis

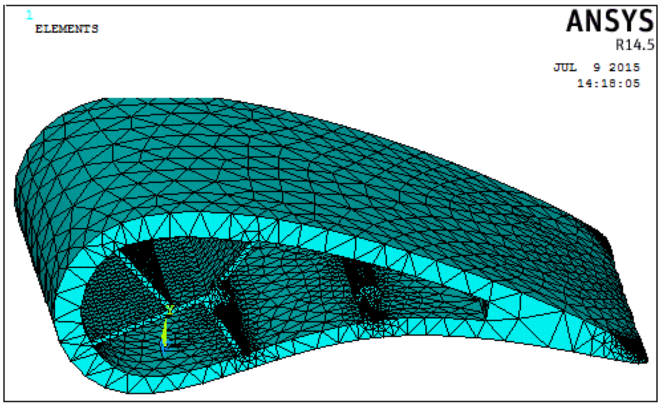


**Figure 3:** Meshed model of Guide vane.

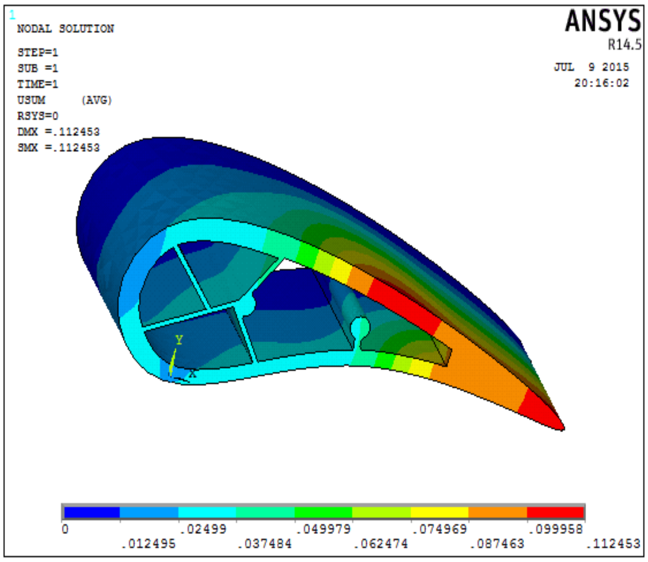


**Figure 4:** The displacement analysis for NIMONIC 901 blade

The modelling works were carried out Pro/E and analysis works were done at ANSYS 14.5 work bench. The dimensional particulars of the guide vane with Showerhead cooling design is shown in Figure 2. The 3D meshed model is presented in Figure 3. The structural analysis like stress analysis, strain analysis and displacement analysis were considered. The comparative study of materials involved in manufacture them is focused on this research. The young's modulus 201000 Mpa, material density 0.00000814 kg/mm3, Poisson Ratio 0.24 were considered for NIMONIC 901 made blades. In case of RENE 77 made blades, the young's modulus 200000 MPa, Poisson Ratio 0.30, material density 0.000077 kg/mm3. In the meshed model made with 186 nodes, and pressure 0.188 N.mm2. The displacement analysis carried at ANSYS 14.5 work bench. The displacement with respect to turbine load was observed and shown them for

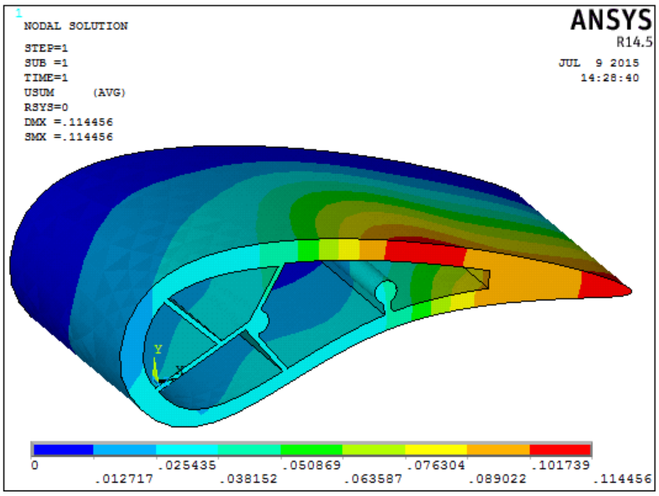


**Figure 5:** The displacement analysis for RENE 77 blades

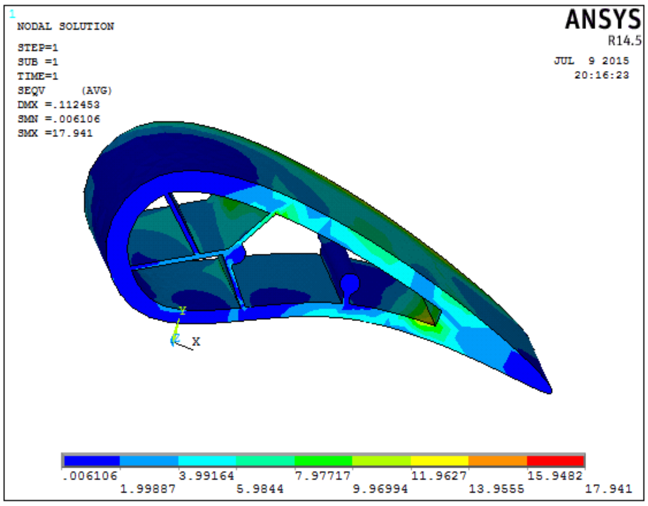


**Figure 6:** Stress analysis for NIMONIC 901 blade

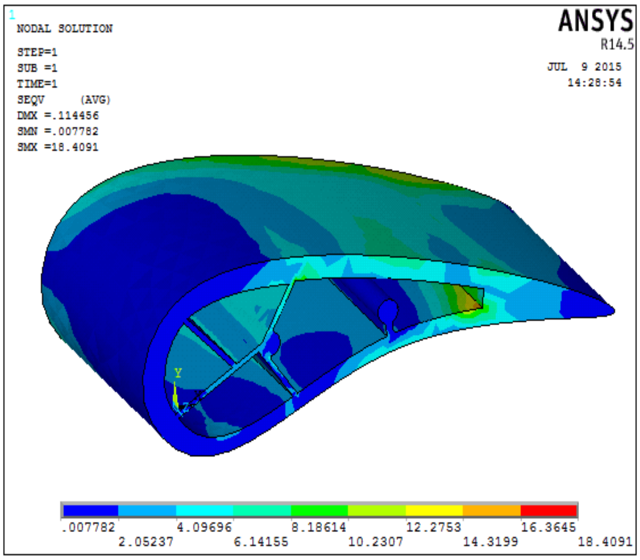


**Figure 7:** Stress analysis for RENE 77 blade

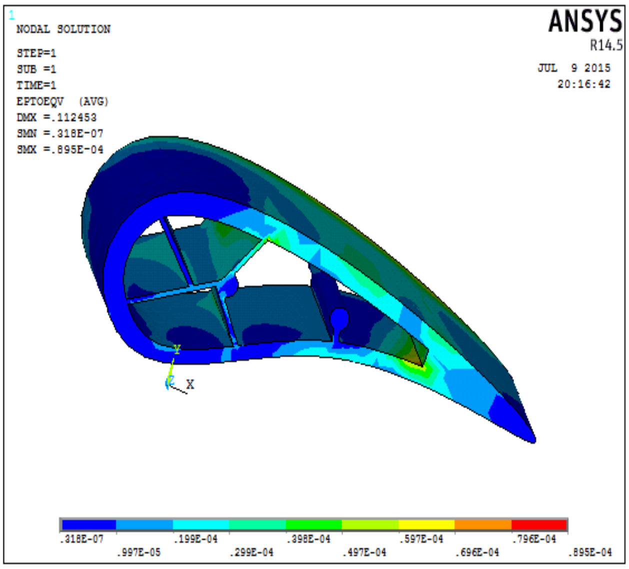


**Figure 8:** The strain analysis for NIMONIC 901blade

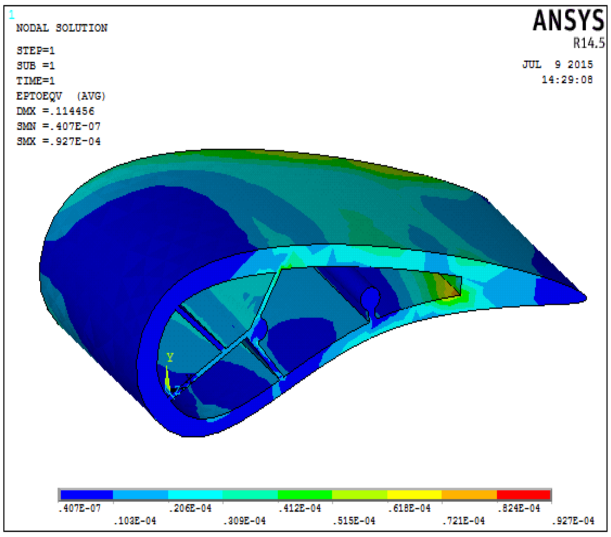


**Figure 9:** The strain analysis for RENE 77 made blades

NIMONIC 901 made blades in Figure 4 and for RENE 77 made blades in Figure 5. The maximum displacements were observed on the concave side of cooling passage near by its sharp turning. The stress analysis for the above said blades (Figure 6 for NIMONIC 901 made blades and Figure 7 for RENE 77 made blades.

**Table 1:** Results of Structural analysis

| Guide Vane made up of | Displacement (mm) | Stress ($N/mm^2$) | Strain |
|---|---|---|---|
| NIMONIC-901 | 0.11245 | 17.941 | 8.95E-05 |
| RENE-77 | 0.11446 | 18.4091 | 9.27E-05 |

## 3. Results and Discussions

The influence of NIMONIC-901 and RENE 77 materials for fabricating gas turbine guide vanes with the showerhead

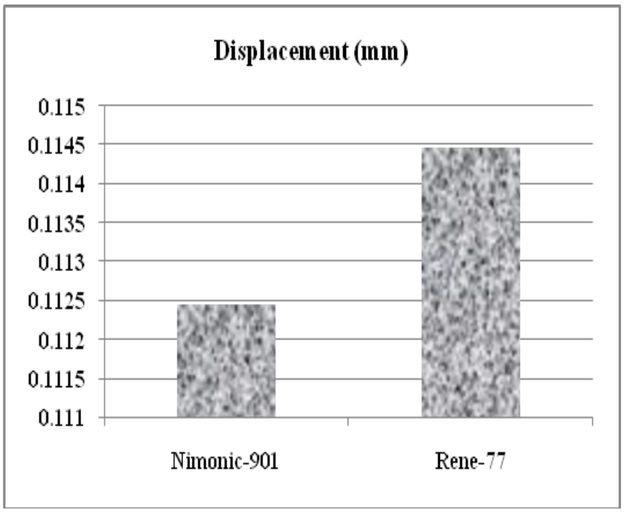


**Figure 10:** The Results of Dispalacement analysis

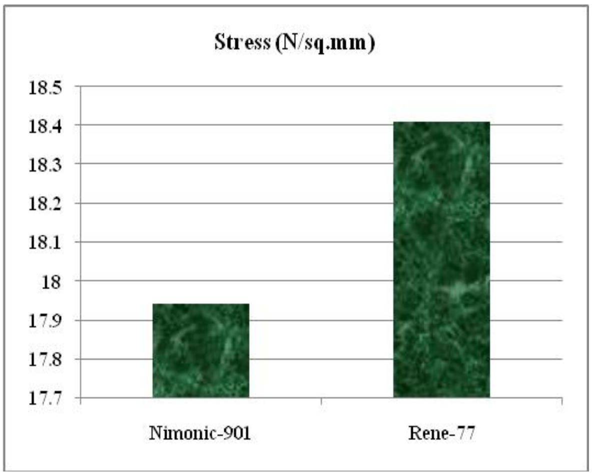


**Figure 11:** The stress of Displacement analysis

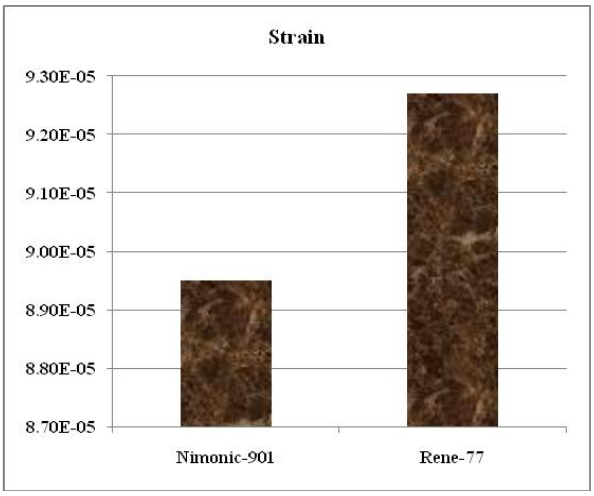


**Figure 12:** The Results of strain analysis

cooling design was investigated. The results are furnished in the Table1 and diagrammatically illustrated in Figure 10 for displacement analysis, Figure 11 for stress analysis and the Figure12 for strain analysis. According the investigated results both the materials are satisfied for the tested condition. RENE 77 made blades are little more flexible and little more stress bearing capacity also than NIMONIC-901 (Refer Figure 10 to Figure 12). The higher values of stress, strain and displacements were noticed at a right turning of cooling design and at thin sections of convex portions. The design may avoid the sharp turning and right turning for improving the stability of a avoid to forming stress concentration.

## 4. Conclusion

This research investigated the influence of materials of gas turbine fixed blades with their pre-designed shower head cooling design. The results were discussed. Both NIMONIC-901 and RENE 77 materials are satisfying the basic requirements of the gas turbine fixed blades. But for this specific cooling design and the profile of the fixed blade considered in this analysis, the RENE 77 material made fixed blades are a little more flexible as well as little extra stress bearing capacity than The NIMONIC-901 made blades. This decision may apply to the specific design of the blade, cooling type and dimensions. In future research the global deacon may be arrived with testing various blades of the same shape and cooling design.

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