# "STATIC STRUCTURAL AND MODAL ANALYSIS OF SECONDARY AIR FLOW SYSTEM"

**Akash Shindolkar[1], Sachin Patil[1], Yogesh Hangirgekar[1], Nikhil Patil[1], Revanasiddappa Havaragi[2]**

[1] Student Dept. of Mechanical Engineering, MMEC, Belagavi, Karnatak, INDIA

[2] Assistance Prof. Dept. of Mechanical Engineering, MMEC, Belagavi, Karnatak, INDIA

---

***Abstract* - Secondary air flow system play a significant role in turbine engine to accomplish reliable operation of the individual modules as well as the whole engine. Main functions of secondary air flow system are to provide cooling flow to engine components, to seal bearing chamber and to control bearing axial loads. Being a functional discipline, secondary air flow system owns the air flow that is essentially not the primary flowpath. In this study, solid modelling of Secondary air flow system having trapezoidal cross-section referring to one of its existing design is done using CATIA V5. Further, analyses are carried out in ANSYS Workbench. Further, Modal analysis is carried out to determine the vibration characteristics such as natural frequencies and mode shapes. The combination of frequency and amplitude is found to be efficient method for reducing or controlling applied forces which generate stress.***

***Keywords— Secondary air flow system, Static Analysis, Modal Analysis, Ansys 18.1***

## 1. INTRODUCTION

An aircraft engine is the component of the propulsion system for an aircraft that generates mechanical power. Internal heat gain due to electrical and mechanical equipment used in engine and the blade will try to grow radially and there is possibility to expand and touch the casing of aero plane engine which causes catastrophic failure. To avoid this failure, we need to cool the engine blade by providing less hot air from the compressor. To provide this less hot air one tubing structure will be present inside the engine which is known as **"Secondary Air Flow System"**. This system is connected to engine casing (very stiff) by L- bracket and flange. This structure is situated between 4th stage of High Pressure Compressor (HPC) and the engine blade side casing.

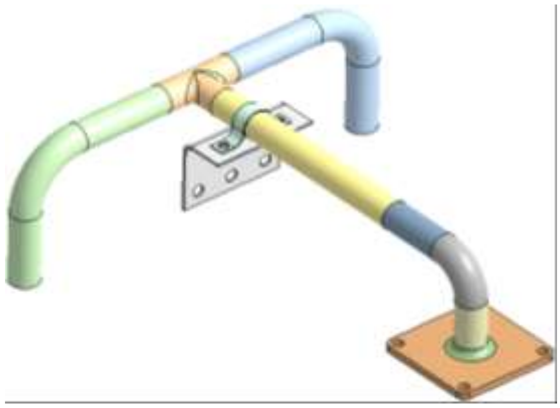


Fig 1.0 Secondary air flow system

### 1.1 Literature Survey

Following literatures are studied,

**Airflow control system for supersonic inlets". Mitchell, G.A.**
In this paper they have done an invention to provide a new and controllable air bleed system for the inlet of supersonic air craft engine. Yet another object of the invention is to provide a controllable air bleed system which responsive to a substantially constant bleed pressure characteristics control device. An additional object of the invention is to provide a controllable air bleed system for supersonic inlets where in massive amount of air may be bypassed from the throat of a supersonic inlet.

**"Heat Transfer inside Compressor Rotors: Overview of Theoretical Models"**
**J. Michael Owen, Hui Tang and Gary D. Lock**
Increasing pressures in gas-turbine compressors, particularly in aero engines where the Pressure ratios can be above 50:1, require smaller compressor blades and an increasing focus on Blade clearance control. The blade clearance depends on the radial growth of the compressor discs, which in turn depends on the temperature and stress in the discs. As the flow inside the disc cavities is buoyancy-driven, calculation of the disc temperature is a conjugate problem: the heat transfer from the disc is coupled with the air temperature inside the cavity. The flow inside the cavity is three-dimensional, unsteady and unstable, so computational fluid dynamics is not only expensive and time-consuming, it is also unable to achieve accurate solutions at the high Grash of numbers found in modern compressors. Many designers rely on empirical equations based on inappropriate physical models, and recently the authors have produced a series of papers on physically-based theoretical modeling of buoyancy-induced heat transfer in the rotating

cavities found inside compressor rotors. Predictions from these models, all of which are for laminar flow, have been validated using measurements made in open and closed compressor rigs for a range of flow parameters representative of those found inside compressor rotors.

## 2. Material Properties

Materials selected for Secondary air flow system are inconel-625 and inconel-718 Alloy the properties of materials are given below in Table 2.1

| Property/Material | Inconel-625 | Inconel-718 |
|---|---|---|
| Young's Modulus (Mpa) | 2.08E+05 | 2.00E+05 |
| Poisson's Ratio | 0.278 | 0.294 |
| Yield Strength(Mpa) | 1034 | 517 |
| Ultimate Strength (Mpa) | 1241 | 965 |

Table 2.1 Material properties

## 3. Modeling of secondary air flow system

The Secondary air flow system is modeled using CATIA V5 as shown in below fig.

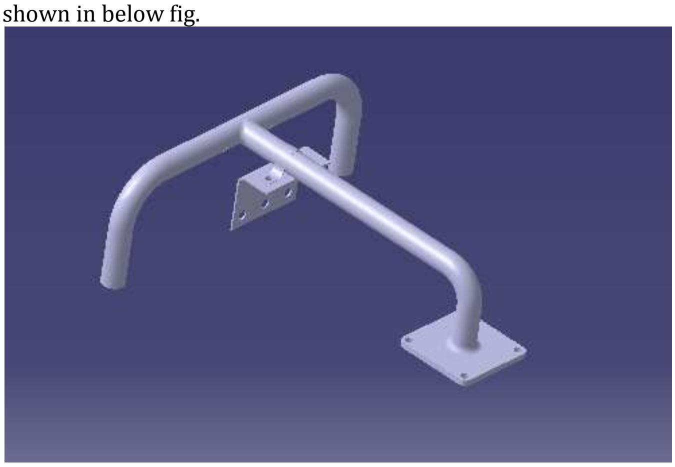


Fig. 3.1 3-D solid model

## 4. Finite Element Analysis using Ansys

The finite element analysis (FEA) is a numerical technique for solving problems which are described by partial differential equations or can be formulated as functional minimization.

### Meshing

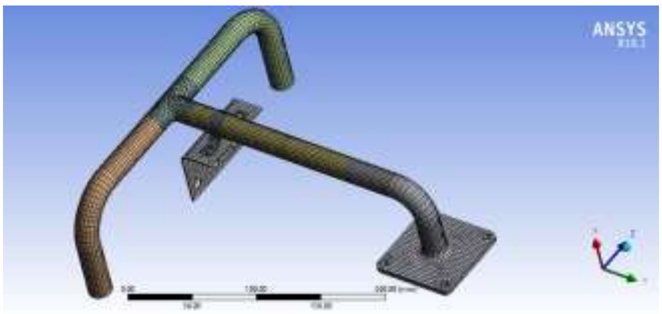



Fig 4.1 Meshed Model

### Boundary Conditions

Fixed Support 1

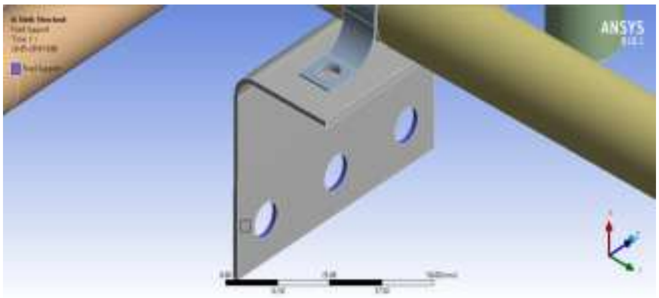



Fig 4.2 Fixed Support 1

Fixed Support 2

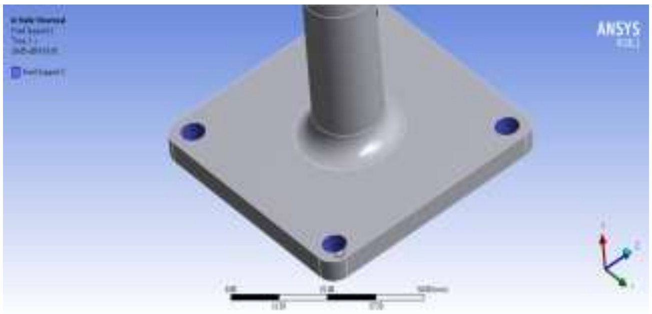



Fig 4.3 Fixed Support 2

### Loading Condition

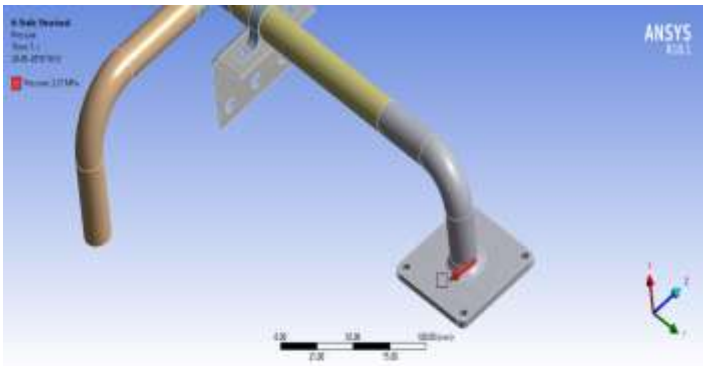
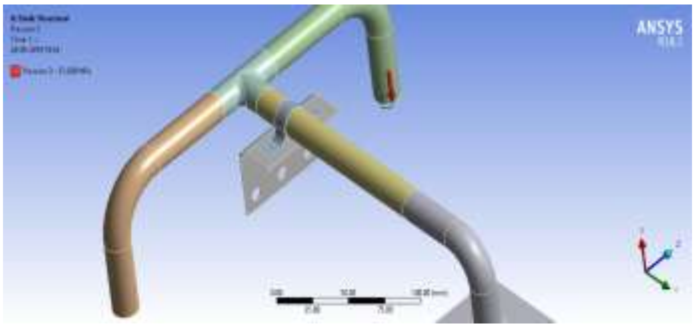



Fig 4.4 Applied pressure 1




| • Pipe | • Stress (Mpa) | |
|---|---|---|
| | • FEA | • Analytical |
| • Straight Pipe Section | 36.3 | 36.4 |
| • Bend Pipe Section | 42.4 | 43.7 |

Fig 4.5 applied pressure 2

## 5. Analytical Calculations

$\sigma$=Pd/2t

Where,

$\sigma$ = Stress in N/mm^2

P = Pressure in Mpa

d = internal diameter of pipe in mm

t = Thickness of pipe in mm

### 5.1 Normal Pressure

$\sigma$ = Pd/2t = (2.27 * 17.6)/ (2 * 0.725 ) = 27.6 Mpa

Table 5.1 Normal pressure

### 5.2 Proof Pressure

$\sigma$ = Pd/2t = (2.99 * 17.6)/ (2 * 0.725 ) = 36.4 Mpa

Table 5.2 Proof pressure

### 5.3 Burst Pressure

$\sigma$ = Pd/2t = (4.54 * 17.6)/ (2 * 0.725 ) = 55.1 Mpa

| • Pipe | • Stress (Mpa) | |
|---|---|---|
| | • FEA | • Analytical |
| • Straight Pipe Section | 55.2 | 55.1 |

| • Pipe | • Stress (Mpa) | |
|---|---|---|
| | • FEA | • Analytical |
| • Straight Pipe Section | 27.2 | 27.6 |
| • Bend Pipe Section | 32.1 | 33.1 |
| • Bend Pipe Section | 64.5 | 66.1 |

Table 5.3 Burst pressure

## 6. RESULTS AND DISCUSSION

### Equivalent Stress

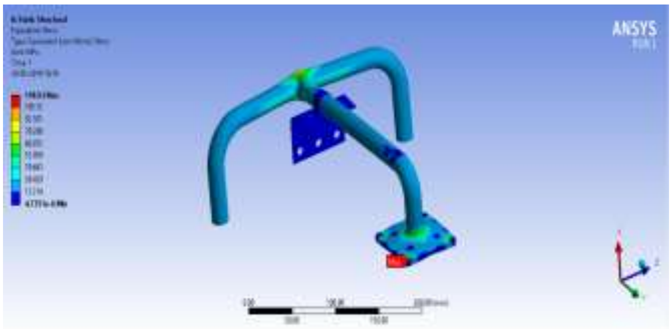



Fig 6.1 Equivalent Stress 1

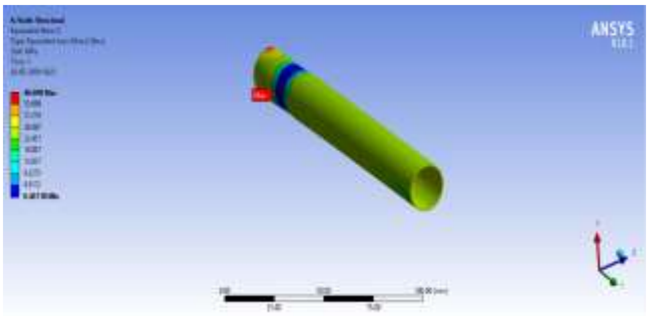



Fig 6.2 Equivalent Stress 2

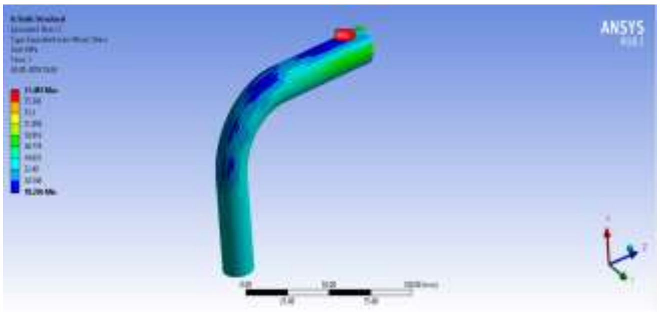


Fig 6.3 Equivalent Stress 3

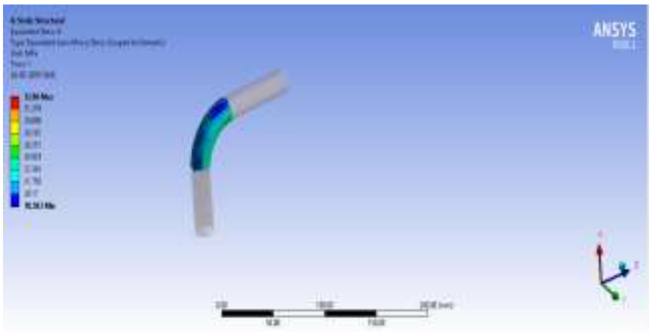


Fig 6.4 Equivalent Stress 4

**Total Deformation**

- STATIC STRUCTURAL

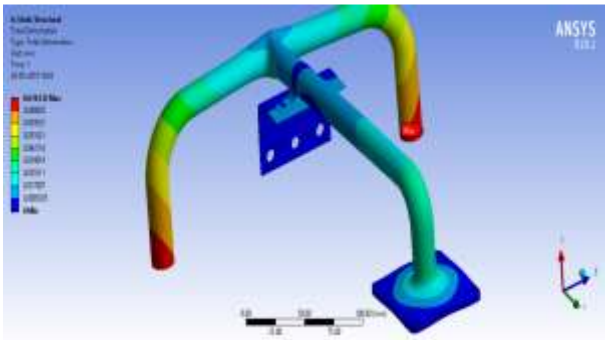


Fig 6.5 Total Deformation A (SS)

- Modal

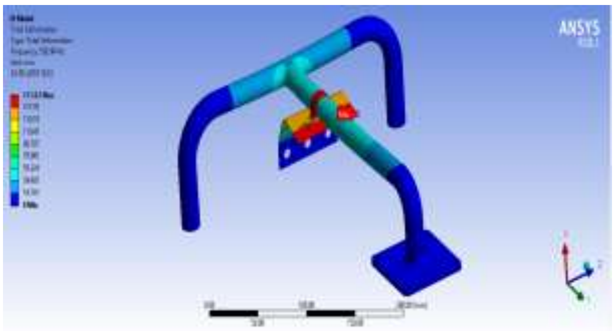


Fig 6.6 Total Deformation 1 B

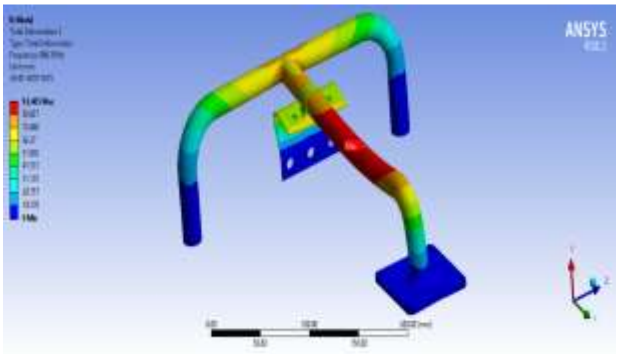


Fig 6.7 Total Deformation 2 B

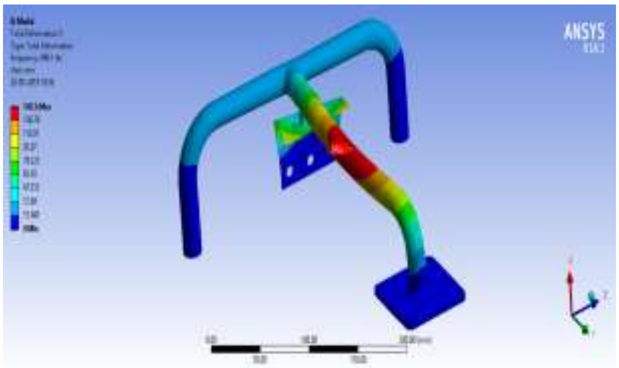


Fig 6.8 Total Deformation 3 B

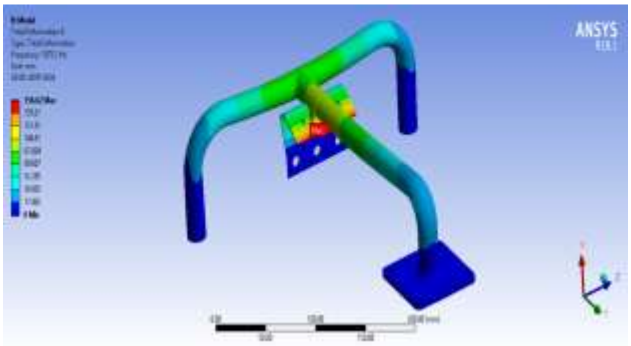


Fig 6.9 Total Deformation 4 B

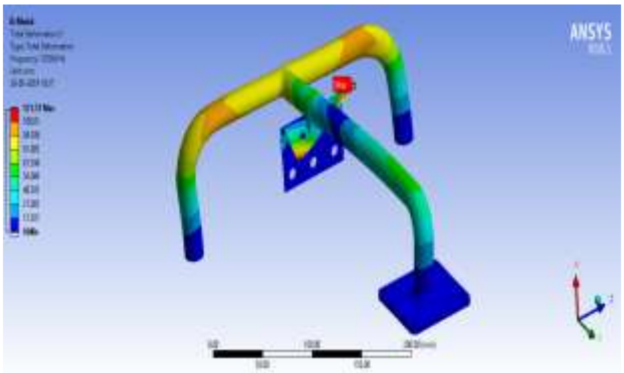
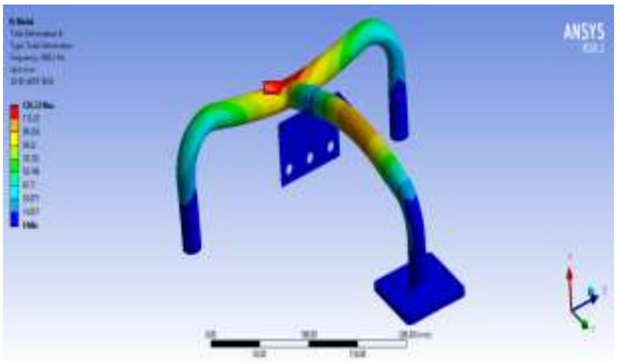


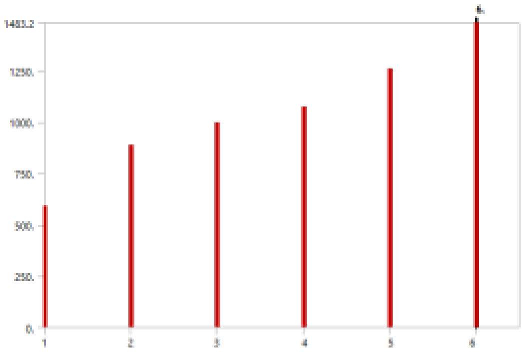
Fig 6.9 Total Deformation 5 B




Frequency (Hz)

Fig 6.10 Total Deformation 6 B

**Frequency at each calculated mode.**




Mode

Graph 6.1 Frequency at each calculated mode.

| Mode | Frequency [Hz] |
|---|---|
| 1. | 592.94 |
| 2. | 886.18 |
| 3. | 998.1 |
| 4. | 1073.3 |
| 5. | 1259.6 |
| 6. | 1483.2 |

Table 6.1 Frequency vs Mode

## 7. Conclusion

- Air flow system is meeting the design requirements for normal, proof and burst fluid pressure
- Air flow system is having factor of safety more than in all loading conditions
- Analytical results are closely matching with FEA results
- Critical frequencies and resonance condition will be checked from modal analysis.
- First fundamental frequency is observed at 576.6Hz and it is away from excitation frequency

## REFERENCES

1. "Turbojet Engine". *NASA Glenn Research Centre*. Retrieved 2009-05-06
2. Frank Whittle, **"Improvements relating to the propulsion of aircraft and other vehicles,"** British patent no. 347,206 (filed: 16 January 1930).
3. Dick, Erik (2015). **"Thrust Gas Turbines".** Fundamentals of Turbo machines. Dordrecht: Springer. 109.
4. **"Aircraft Gas Turbine Technology"** by Irwin E. Treager, McGraw-Hill, Glencoe Division, 1979
5. **"Gas Turbine Theory"** by H.I.H. Saravanamuttoo, G.F.C. Rogers and H. Cohen, Pearson Education, 2001
6. **"Heat Transfer inside Compressor Rotors: Overview of Theoretical Models"** J. Michael Owen, Hui Tang and Gary D. Lock

## BIOGRAPHIES

| | |
|---|---|
|  | **Mr. Akash Shindolkar** is pursuing his bachelor's degree in mechanical engineering in MMEC Belagavi, India. His area of interests is FEA field. |
|  | **Mr. Sachin Patil** is pursuing his bachelor's degree in mechanical engineering in MMEC Belagavi, India. His area of interests is FEA field. |
|  | **Mr. Yogesh Haangirgekar** is pursuing his bachelor's degree in mechanical engineering in MMEC Belagavi, India. His area of interests is FEA field. |
|  | **Mr. Nikhil Patil** is pursuing his bachelor's degree in mechanical engineering in MMEC Belagavi, India. His area of interests is FEA field. |