INVESTIGATION OF STRESSES IN TURBINE ENGINE DISC

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ABSTRACT

In this paper, the failure analysis of the air engine's turbine disk has been established in a certain type of aircraft. From the visual examination of the surface of the fracture, the signs of the beach could be inspected, general of fatigue failure. In operating conditions, a non-linear finite element was used to determine the stress position of the disk / blade segment. High stress areas were found in the area of lower fur-tree slots, where the failure occurred. A calculation was also done at a very rotational pace. The focus of this study is devoted to the mechanism of damage to turbine discs and significant high stress areas. Residual stresses that after removing the root cause of stress, it remains in solid content. Under residual stress engineering environmental and aircraft load challenges, increasingly important aspects of design and construction of monolithic wind farms are becoming increasingly important. Residual force does not affect structural performance only during the life cycle of the service, but they also affect the quality of the part during manufacturing and assembly. Residual stress can be desirable or undesirable, during most of the manufacturing processes related to physical deformation, heat treatment, machining or processing operation, residual stress occurs, which change the size or properties of the material. They have originated from many sources and can be present in unused raw materials produced during production or manufacture by in-service shipment.

Keywords : Turbine disc, Failure analysis, Fatigue, Turbine engine, Residual stresses.

1. INTRODUCTION

Turbo-Machinery Discs are heavy, highly stressed, whose main factors are the speed and components used in the gas turbine to exceed the operating temperature. Experimental burst testing is always time-consuming and overpriced. In theoretical investigations of stress in rotating solid and annular discs at high speeds, extensive attention is being received due to a large number of applications in engineering such as turbine discs, fly wheel etc. Gas turbines work in the hot flow of disc device (650°C) and it is one of the most expensive parts. All these conditions inspire stress in excess of 100 MPa in the rim facility. Then, the disk's mechanical design includes the evaluation of centrifugal and thermal stress. Non linearities (i) objects behaviour in dissimilar temperatures, generated from (ii) geometric changes are responsible for the construction of stress. These results have been used in Ahmet, Mohammed etc al. which explains that burst occurs when the mean circle stress on a disc block becomes equivalent to determining the nominal tensile strength of the material, from an axial tensile stress. This condition of rings shows high-quality relationship with rotating experimental results, but this criterion gives a specific approximation of the maximum angular velocity for a solid or bored disk Nie and Batra surprises, and Manavi bursts into a burst the use of factor recommendation is further mentioned stress between the two.
2. LITERATURE SURVEY

Rejijon, James M. Larsen Dennis Jay. Buchanan, Noël E Asbog[1] components are used for non-destructive inspection technology to test location-specific cleft size. The crack length is believed to be based on the behavioural behaviour of crack-thermal-mechanical load conditions and materials expected to predict against the bicycle behaviour in crucial locations. Using the throwing of shot is to reduce crack growth in key locations. The introduction is tense of 150-200 micrometers. The benefits of this stress fatigue are a breakdown of growth to improve life. Bonus element of safety T-6 Al-2Sn-4Zr-6Mo components are used in Shot Paning. Kreswas set the surface length of the surface in the formation of the weight pressure intensity side length semi-oval surface.

C. AyyappanRajshekar, P. Ramesh, Rajiv Jain [2] is the forerunner of the development of the flight test rating (PERT) and the rest of the quality examination (QT) as part of the certification report. In order to increase the fatigue life of the hole in the work of expanding the automobile engine and components, it is believed that the rest of this pressure. In the case of thermal hot disks, this phenomenon becomes more complex. The only solution to the complex problem of evaluating the development of such a residual element of strategy is limited to possible. Surface and internal cracks Using the technique of ultrasound inspection, a high speed disc is tested in this test facility tests, discs are made of heavy machinery. ABAQUSTM of the disc was held to predict similar thickness finite element solutions using residual stress and deformation non-linear finite element analysis.

Kwai, S. Chan, Michael P. Eryit, Patrick J. Goulden, Sameer Naboli, Ramesh Chandra, Alan C. Pentages [3] They say that high cycle fatigue is the argument that the most expensive source of in-service damage in the army is the aircraft engine can cause the turbine blade and the risk of the HCF engine of the disc because fatigue failure is less than resonant vibratory stress Can be continuous in time. Tired fatigue is due to the loading of the HCF gas turbine engine component at the fracture risk. This data shows that fatigue can contribute to the construction of tiredness turbine discs before time of fatigue cracks in the exhaustion. In order to simplify the aerodynamic loading model was provided by NAVAIR, in particular, the structural analysis of the disk assembly was done by FEM method to calculate the stable and dynamic contact stresses. In the LCF and HCF load history, the combination of LCF and HCF in the engine disk was used in the life prediction method to assess fatigue crack increase.

3. OBJECTIVES AND METHODOLOGY

The current goal of the job

- Identify disc-critical zones in blended, and optimize the disk.
- The disc program of the disc is insistent on the disc, which is subject to the uniform disk and spin loading.
- Diagnostic equations and disc spin weight recognition flourished with the help of limited element technologies.
- Through the linear analysis of techniques not by line analysis to test disk efficiency.
- Fast evaluation and burst margin range gas turbine disk macro development under spin loading.
- Due to the high speed of device drive fatigue study of life.
- Inspired burst marine investigate the effect of residual stress.

4. MODELLING AND SIMULATION

4.1 Geometry

CATIA is multiplatform for CAD/CAM/CAE, which is developed by a popular French company called Dassault system. The user friendly tool helps easily to generate model of the car hood accurately with ease. Initially the dimensions of the car hood are collected as per that dimensions a 3D model is created.
4.2 Meshing

The main goal of the meshing software is to provide robust, user friendly and easy handling tools simplify the mesh generation process. For the ease of work initially model is divided into number of small pieces called finite elements. Hypermesh tool is the software used to mesh the turbine engine disc.
4.3 Material Properties

Material and its properties play a vital role for the analysis of any component. Material properties are the specifications of the material.

**Table 6.1: Mechanical and Thermal Properties of INCONEL 718 considered for FE formation for prediction over speed and burst margin**

| Property                  | 20°C | 100°C | 400°C | 500°C | 600°C | 700°C |
|---------------------------|------|-------|-------|-------|-------|-------|
| Young’s Modulus N/mm²     | 20900| 19600 | 183100| 178400| 170300| 157300|
| Coefficient of Linear expansion (10⁻⁵/°C) | 12.2 | 12.8 | 13.9 | 14.0 | 14.5 | 15.0 |
| Thermal Conductivity (10³ W/mm °C) | 11.11| 12.41| 17.95| 19.48| 21.21| 23.09|

5. ANALYTICAL MODEL FOR BURST ENGINE

1. Consideration of centrifugal reaction
2. Thermal correction
3. Speed correction
4. Modification of burst margin equation
5. Bursting speed computed by analytical method

6. RESULTS

![Fig.6.1 Equivalent von-mise stress](image1)

![Fig.6.2 Total deformation](image2)
Fig. 6.3 Equivalent elastic strain

Table 6.1  Life prediction results of blades for fatigue interface at different speeds and loads

| Speed (rpm) | Force (kN) | Hoop stress (MPa) | Radial stress (MPa) | von-Mises Stress (MPa) | Deflection (mm) | EPTOEQ* | EPELEQV | LCF |
|-------------|------------|-------------------|--------------------|-----------------------|-----------------|----------|---------|-----|
| 10000       | 90.13      | 675.76            | 595.77             | 834.69                | 1.84            | 0.007372 | 0.0047582 | 5780 |
| 11000       | 190.05     | 754.75            | 478.58             | 859.77                | 1.92            | 0.007487 | 0.0047792 | 5450 |
| 12000       | 129.78     | 821.06            | 483.60             | 868.68                | 2.00            | 0.007705 | 0.0048195 | 4865 |
| 13000       | 152.31     | 881.81            | 541.79             | 881.84                | 2.11            | 0.008086 | 0.0048817 | 4050 |
| 14000       | 176.65     | 955.90            | 600.33             | 896.63                | 2.24            | 0.008649 | 0.0049335 | 3200 |
| 15000       | 202.79     | 953.95            | 649.98             | 919.98                | 2.44            | 0.009600 | 0.005074 | 2300 |
| 16000       | 230.73     | 997.84            | 692.22             | 943.92                | 2.74            | 0.011212 | 0.0052027 | 1500 |
| 17000       | 260.47     | 1106.13           | 746.58             | 946.66                | 3.65            | 0.016347 | 0.0053392 | 570  |

Table 6.2 Life prediction results of blades for fatigue interaction at different temperature range at constant centrifugal load.

| Temperature in °C | Speed (rpm) | Force (kN) | Hoop Stress (MPa) | Radial Stress (MPa) | Von-Mises Stress (MPa) | Deflection (mm) | EPTOEQ* | EPELEQV | LCF |
|-------------------|-------------|------------|-------------------|--------------------|-----------------------|-----------------|----------|---------|-----|
| 350-500           | 10000       | 90.13      | 650.6             | 406.82             | 806.02                | 1.52            | 0.005589 | 18600 |
| 400-550           | 10000       | 90.13      | 664.5             | 460.88             | 832.08                | 1.68            | 0.006444 | 9840  |
| 450-600           | 10000       | 90.13      | 675.7             | 505.77             | 854.69                | 1.84            | 0.007372 | 5780  |
| 500-650           | 10000       | 90.13      | 690.0             | 542.63             | 875.04                | 2.02            | 0.008363 | 3685  |
| 550-700           | 10000       | 90.13      | 708.1             | 594.44             | 900.52                | 2.20            | 0.009725 | 2260  |

For the blade, LCF simulation material employs a centrifugal weight wave similar to samples, whose peak value is the rated weight and the valleys are almost zero. Shipment occurrence is 300 cycles per 100 hrs. The temperature of the calculation is distinct as 350-500 °C in different sections, so that the consequences of predicting life can be safe. Centrifugal stress is always positive and is very large due to other loads, which suggests that tissue stress is present near hysteresis loops. In the reference, the result shows that the steam turbine represents the centrifugal stress-stress response feature of the blade, in which the wave of loading is similar to the previous research work.
6.1 Induced residual stress due to over speed

Residual stress can vary in the internal radius, to know that the outer radius on the line between the thickness of the disk is considered. Table 8.1(A) shows the results of elastic plastic analysis at 18,000 rpm with the inner radius, along the path of the outer radius. Speed 18,000 rpm is chosen because it is plasticization start and plasticization and velocity. Table 8.1 (B) shows the results of pure elastic analysis at 18,000 rpm, with the inner radius in the centre of the thickness of the disk along the path of the outer radius. Both elastic and elastic plastic analysis were done with angular velocity ω and blade load.

Table 6.3 Hoop stress, Radial stress, Von-Mises stress components of stress at 18000 rpm

| Radial Distance (mm) | a. Elastic-plastic analysis | b. Pure elastic analysis | c. Residual stresses |
|----------------------|-----------------------------|-------------------------|---------------------|
|                      | Hoop Stress (MPa) | Radial Stress (MPa) | Von Mises Stress (MPa) | Hoop Stress (MPa) | Radial Stress (MPa) | Von Mises Stress (MPa) | Hoop Stress (MPa) | Radial Stress (MPa) | Von Mises Stress (MPa) |
| 105                  | 1120          | 10                | 1181                | 1267          | 9              | 1344               | -146.1         | 0.6974            | -163.1               |
| 110                  | 1153          | 48                | 1172                | 1229          | 55             | 1247               | -74.7           | -7.055             | -74.9                |
| 115                  | 1191          | 112               | 1163                | 1209          | 123            | 1165               | -8.9            | -11.45             | -1.8                 |
| 119                  | 1207          | 173               | 1156                | 1175          | 191            | 1093               | 32.7            | -17.67             | 43.6                 |
| 124                  | 1196          | 259               | 1066                | 1162          | 274            | 1027               | 33.7            | -15.36             | 38.8                 |
| 129                  | 1187          | 354               | 1010                | 1155          | 369            | 976                | 31.9            | -14.86             | 34.58                |
| 134                  | 1168          | 434               | 988                 | 1139          | 448            | 957                | 29.6            | -14.25             | 30.67                |
| 138                  | 1140          | 480               | 984                 | 1112          | 494            | 957                | 28              | -13.99             | 26.73                |
| 143                  | 1110          | 486               | 965                 | 1083          | 499            | 941                | 26.6            | -12.95             | 24.3                 |
| 148                  | 1084          | 484               | 941                 | 1059          | 495            | 918                | 25.5            | -11.44             | 23.19                |
| 153                  | 1060          | 482               | 920                 | 1036          | 492            | 98                 | 24.4            | -10.27             | 21.95                |
| 157                  | 1037          | 477               | 897                 | 1014          | 486            | 876                | 23.3            | -9.19              | 20.91                |
| 162                  | 1016          | 454               | 861                 | 994           | 461            | 840                | 22.32           | -7.88              | 20.93                |
| 167                  | 979           | 430               | 856                 | 958           | 437            | 836                | 21.87           | -7.19              | 19.66                |
| 172                  | 945           | 392               | 837                 | 925           | 397            | 818                | 21.11           | -5.51              | 19.28                |
| 176                  | 927           | 376               | 809                 | 907           | 380            | 790                | 20.41           | -4.81              | 19.02                |
| 181                  | 911           | 355               | 773                 | 892           | 359            | 754                | 19.69           | -3.9               | 19.09                |
| 186                  | 894           | 283               | 718                 | 875           | 285            | 700                | 19.05           | -2.6               | 20.08                |
| 191                  | 841           | 199               | 712                 | 823           | 201            | 636                | 18.82           | -1.67              | 19.46                |
| 195                  | 762           | 139               | 755                 | 743           | 139            | 737                | 18.82           | -0.64              | 17.8                 |
| 200                  | 697           | 116               | 848                 | 678           | 116            | 833                | 18.79           | -0.16              | 15.14                |

7. CONCLUSION

On the basis of this study, a method is obtained analytically to calculate the amount of explosion margin, fatigue life and residual stress of specific aerial engine disk blade. Some important findings from this analysis is work has been done to exhibit that revised mathematical models and FE allows automated analysis which can enable mass simulation on large scale. The hoop strain component is considered to be the maximum on the internal surface, but the lowest on the outer surface. Radial is initially emphasized to grow with radial section, so it decreases with radial distance. Increasing rotating disk with increasing speed of rotating disk
8. REFERENCES

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