Modeling And Analysis Of Gas Turbine Rotor Blade By Using Fem

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Abstract: A Gas Turbine is an internal combustion engine that uses air as the working fluid. in the design of the blades is to find the frequency at which the resonance exists. Prototype building and testing of the blades is highly expensive and is a time-consuming process. Remedy to avoid prototype building is the Finite Element Analysis. But Finite Element Analysis throws a challenge in terms of the size of the model and analysis time. To build a 360-degree Rotor blade model in Finite Element Analysis with the required degree of accuracy and analysis is very difficult as it involves high configuration systems. Moreover, the time consumption for the analysis of a 360-degree model is high. To overcome this, in the present analysis, a concept called as "Cyclic symmetry Analysis " is utilized. The advantage of cyclic symmetry can be utilized only in the case of models which possess symmetry in terms of the axis. In the initial phase, Cyclic Symmetry Analysis Validation is performed with coarse mesh on the 360-degree model. The pre-stress Modal analysis is also one another concept utilized in the present analysis to find out the frequency of the blade under various conditions of angular velocity. In Pre-stress modal analysis initially, the model is stressed under the speed of the rotor wheel and the model is then vibrated to find its natural frequency under the stressed condition. Campbell diagrams are then constructed for the various nodal diameters to find the interference margins of the fundamental modes frequency like 1st bending, 1st Torsion, 2nd bending and 2nd Torsion.

1. INTRODUCTION:

The gas turbine is an internal combustion engine which uses the atmosphere as the operating liquid. The engine focuses the synthetic strength of the gas and transforms it into mechanical vitality using the vaporous vitality of the operating fluid (oxygen) to power the engine and the propeller, thus moving the aircraft[1,2]. The gas turbine's vital operation is very much like the steam power plant, apart from using air instead of water. Crisp air wind flows that carry it to the greater weight through blower. Then vitality will be included by showering fuel into the air but also illuminating it with the aim of creating an elevated-temperature stream by burning. This heavy-temperature, high-weight fuel reaches a turbine where it breaks down to the weight of the fumes, yielding a full-time pole job. The job on the turbine blade is used to power, for instance, the blower and various gadgets, an electrical system that could be attached to the base. The vitality not used for duct job is shown in the gasses of the fumes, so they either have a elevated temperature or a low velocity. The gas turbine's cause chooses the scheme with the objective of boosting the most appealing composition of vitality. To regulate driving machines, aircraft, boats, electrical generators, or even reservoirs, gas turbines are used[5,6].

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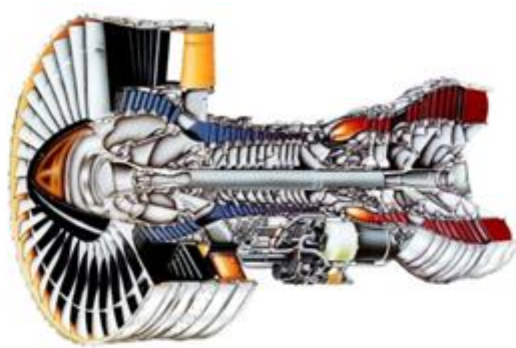

Figure 1: *A Typical Cross Section of PW4000-94 Inch Engine*

The "Brayton Cycle or Joule Cycle" is the main thermodynamic cycle on which gas turbine engines are centered. A temperature-entropy graph has been shown in Figure 1 for this ideal process as well as its implementation as a shut-off system gas turbine[3,4]. The process includes an isentropic gas pressure from state 1 to state 2; a continuous growth of weight heat to state Isotropic growth to state 4 in which research is carried out; and isobaric completion of process home to state 1. a pivoting pole links a blower to a turbine. The base communicates the energy that is essential to drive the blower as well as, for instance, an electrical generator transmits the equalization to a force. The radiator is a heater in the shut-off mode gas turbine in which cooking gasses or a nuclear origin pass warmth through thermally guiding cylinders to the operating liquid[7,8]. It is useful to understand indoor also outdoor ignition motors from time to time, irrespective of whether burning occurs in the operating liquid or in a territory separated from either the working liquid, yet in warm interaction with it. The combustion heated, shut-off mode gas turbine is a model of an external ignition engine, comparable to the steam power plant. For instance, vehicle engines, in which combustion occurs in the operating liquid flunked by a room and a cylinder, and open-cycle gas turbines, instead of indoor ignition engines[9,10].

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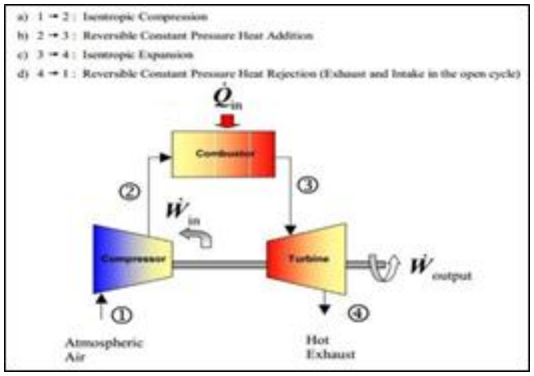

Figure 2: *Closed-Cycle Gas Turbine*

WORKING:
Turbofan motors are establishing on business aircraft about the globe also contain upset the manner in which we travel. The turbofan motor capacities by method for a thermodynamic cycle where the air is infused into the motor, packed, combusted, extended, also depleted commencing the motor making a push to move the vehicle. These five stages are done by five noteworthy motor segments: the fan, blower (low as well as high weight), combustor (or burning chamber), turbine (in elevation and low weight), and fumes spout. Figure 3 below is a drawing of a cross-area turbofan[11,12]. The sections or lines were counted in this hand perspective. From start to correct, the water passes via the engine, starting at the engine (figure number 1) as well as moving towards the fumes spout Below are detailed descriptions of the sections and what occurs at each facility. The LPC is legally connected by the low-weight rotor with the motor and the low-weight turbine (LPT)[13,14]. The LPC has rotating edge pillars that force the water into the engine once again. As the wind rearward is restricted, the cross-sectional region of the LPC decreases, causing the water quantity to decrease. This indicates that the atmosphere is going to be pressurized as well as the heat is growing from the perfect gas law. It reaches the elevated-weight blower after the wind passes through the LPC[15]. The combustion takes place within the combustor, a continuous room inside the center of the engine, which in Figure:5 is unit 3. The combustor is legally downstream of the HPC and directly upstream of the large-weight turbine. The justification for the combustor is by technique for the warmth alternative to contribute much more vitality to the wind stream. Fuel is mixed and mixed with greenhouse effect within the combustor. This fuel-air mixture is then lightened, causing an unusual temperature to increase and boosting the stream, pressing it backwards toward the high-weight turbine.

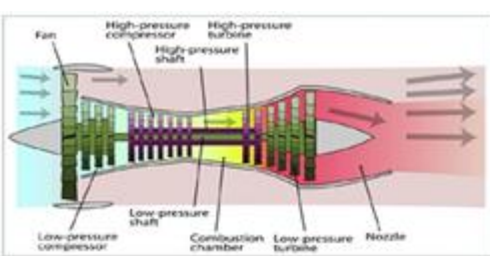

Figure 3: *Components of a Turbofan engine*

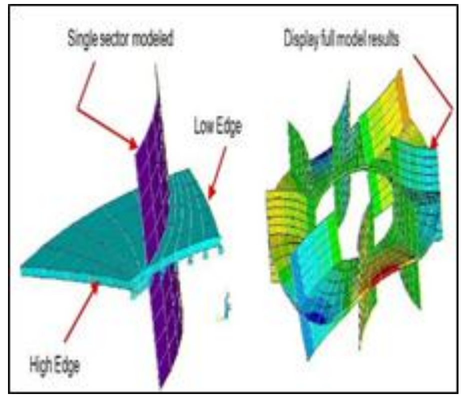

Figure 4: *CYCLIC SYMMETRY DEFINITIONS*

CYCLIC SYMMETRY ANALYSIS:

Numerous auxiliary segments have geometric qualities which are rehashed about a hub of symmetry (for example circles, gears, impellers). We container characterize the arrangement in wording of an essential fragment which is rehashed at similarly dispersed interims around the symmetry hub. On the off chance that the removal BC's of all sections are indistinguishable regarding the pivot of symmetry, we container investigate the whole structure as far as the mass also solidness attributes of a solitary portion. This strategy is designated "cyclic symmetry". Its essential bit of leeway is huge reserve funds in CPU/slipped by time and PC assets. An appropriate part speaks to an example that, whenever rehashed n times in a tube shaped organize framework, would yield the total structure. By utilizing the ANSYS Modal Cyclic Symmetry capacity we canister acquire the regular frequencies also mode states of the whole arrangement for a client endorsed scope of nodal measurements utilizing the model of a solitary segment. Using this technique, we can also conduct linear clasping examination. In ANSYS, cyclic symmetry is updated by characterizing imperative associations between the vital segment's elevated and low edges. The vital component is used repeatedly to satisfy the necessary connection of restriction. The significance of the essential circumstances is based on the determined "vowel sequence." For a model comprised of n sectors, the connection among harmonic index, k, and nodal diameter, d.

TABLE 1: *Solid Blade Creation*

Point No	x	y	z
1	0.00	11.22	0.00
2	2.45	11.37	0.00
3	4.90	12.50	0.00
4	7.35	13.48	0.00
5	9.80	14.26	0.00
6	12.25	14.80	0.00
7	14.70	14.99	0.00
8	17.15	15.09	0.00
9	19.60	15.04	0.00
10	22.05	14.80	0.00
11	24.50	14.50	0.00
12	26.95	14.01	0.00
13	29.40	13.48	0.00
14	31.85	12.69	0.00
15	34.30	11.66	0.00
16	36.75	10.39	0.00
17	39.20	8.92	0.00
18	41.65	6.91	0.00
19	44.10	4.66	0.00
20	46.55	1.86	0.00
21	49.00	0.00	0.00
22	0.00	11.22	0.00
23	2.45	18.77	0.00
24	4.90	21.41	0.00
25	7.35	23.28	0.00

Point No	x	y	z
26	9.80	24.70	0.00
27	12.25	25.77	0.00
28	14.70	26.51	0.00
29	17.15	26.90	0.00
30	19.60	27.05	0.00
31	22.05	26.90	0.00
32	24.50	26.41	0.00
33	26.95	25.63	0.00
34	29.40	24.55	0.00
35	31.85	23.08	0.00
36	34.30	21.07	0.00
37	36.75	18.57	0.00
38	39.20	15.58	0.00
39	41.65	12.20	0.00
40	44.10	8.67	0.00
41	46.55	5.00	0.00
42	49.00	0.00	0.00
43	0.00	11.22	0.00
44	19.80	15.03	0.00
45	0.00	13.26	0.00
46	18.29	27.00	0.00
47	29.20	13.53	0.00
48	48.77	0.00	0.00
49	29.20	24.65	0.00
50	49.00	0.34	0.00
51	21.07	27.00	0.00

DESIGN AND ANALYSIS OF BLADE

Airfoil profile is based on the performance of the compressor. Information focuses are accommodated the cross-area of the Airfoil. Information focuses are then associated by utilizing the splines and after that joined to shape the zones in Ansys. Following are the data points considered for the airfoil profile.

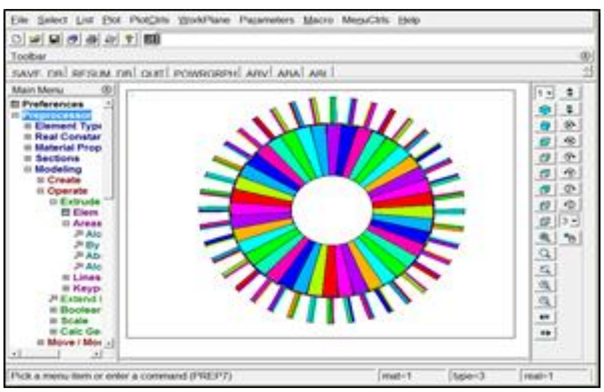

Figure 5: *Solid Blade Creation*

Base of the Airfoil is then extruded in the other direction to create rotor wheel so that a cyclic symmetry sector with aa sector angle of 9 degree. Cyclic sector is then copied 40 times to form a complete stage of Rotor as shown in the below figure

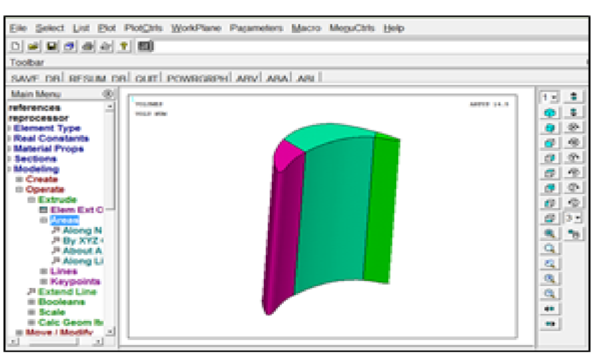

Figure 6: *Rotor Wheel with Blades*

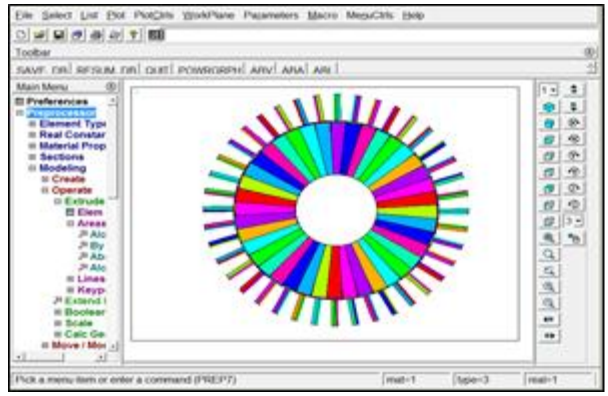

Figure 7: *Mode Shapes for Campbell*

RESULTS AND DISCUSSION

A Campbell diagram is the most traditional way of finding the interference margin between the natural frequency and the external excitation frequency. It is usually constructed by taking the Speed along the X-Axis and Frequency (Hz) on the Y-Axis. Speed lines are plotted as vertical lines on the Campbell. Mode shapes and excitation lines are plotted as the Campbell for the complete speed range. In the present analysis, Campbell diagrams are constructed for all the Nodal Diameters i.e. from 0 to 3ND, 30 ND, and 45 ND.

Table 1: *Frequency for Nodal Diameter 0- INCONEL 720*

Frequency (Hz)

RPM	Mode Frequency (Hz)			
	1B	1T	2B	2T
1000	790	2955	4708	7480
2000	792	2956	4711	7482
5000	807	2962	4731	7494
8000	830	2967	4763	7502

Interference Margin

1000 RPM	1B	1T	2B	2T
1E	4640.42%	17631.06%	28150.94%	44780.78%
2E	2270.21%	8765.93%	14025.47%	22340.39%
3E	1480.14%	5810.62%	9316.98%	14880.26%
30E	1480.14%	5810.62%	9316.98%	14880.26%
45E	5.34%	294.04%	527.80%	897.35%

2000 RPM	1B	1T	2B	2T
1E	2276.69%	8768.42%	14033.78%	22345.70%
2E	2276.69%	8768.42%	14033.78%	22345.70%
3E	692.23%	2856.14%	4611.26%	7381.90%
30E	692.23%	2856.14%	4611.26%	7381.90%
45E	-47.18%	97.08%	214.08%	398.79%

5000 RPM	1B	1T	2B	2T
1E	868.52%	3454.28%	5576.74%	8893.15%
2E	384.26%	1677.14%	2738.37%	4396.57%
3E	222.84%	1084.76%	1792.25%	2897.72%
30E	-67.72%	18.48%	89.22%	199.77%
45E	-78.48%	-21.02%	26.15%	99.85%

8000 RPM	1B	1T	2B	2T
1E	4177.13%	17000.68%	27778.96%	5526.54%
2E	211.07%	1012.54%	1686.19%	2713.27%
3E	107.38%	641.70%	1090.79%	1775.51%
30E	107.38%	641.70%	1090.79%	1775.51%
45E	-84.17%	-50.58%	-20.63%	25.08%

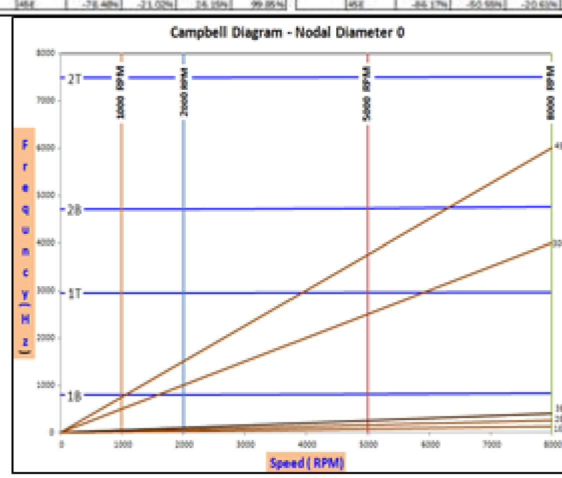

FIGURE 8: *CAMPBELL DIAGRAM FOR NODAL DIAMETER 0 - INCONEL 720*

CONCLUSION AND FUTURE WORK

From the above analysis results for the various nodal diameters, it is observed that all the fundamental modes are having good margins. 1st Bending mode is having less margin when compared to the 1st Torsion, 2nd Bending, and 2nd Torsion. Also, it is observed that both considered materials are providing good margins for all the fundamental modes. Hence any one of the materials may be considered from the vibration safety of the blade. Excitations with the difference in the upstream and downstream counts may also be considered for the Campbell's. 1st Bending mode margin may also be improved by changing the airfoil shape without losing its efficiency if required by the manufacturer. The blade may also be analyzed for any of the speeds by using the ANSYS APDL code developed. SLCF analysis may be performed on the blade by using the same cyclic symmetry model for the blade. Mesh convergence can be easily achieved with the sector model as the model size will be less when compared to the 360-degree model. Also, the pressure attentiveness factor can be creating by using the stress linearization principle. Various materials may be tested in the same sector model by developing a code which reduces the analysis time and leads to an optimized model from.

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