TRANSIENT ANALYSIS OF TWIN SPOOL AERO-GAS TURBINE ENGINE

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Abstract - *Twin spool Aero-gas turbine engine is rotating equipment having two rotors called low pressure Spool and high pressure Spool. The rotors are designed to rotate at wide range of rotational speeds to meet the operational requirement. Twin spool engine consists of a low pressure compressor a high pressure compressor connected by shaft with a low pressure turbine and high pressure turbine. The rotors are axial flow compressor and axial flow turbine connected by shaft. Due to high speed of rotors, the mechanical behavior is critical and creates vibration. In transient behavior the vibration acts for a short period of time and die down before the occurrence of the next disturbance. The transient analysis is used to calculate the response of a structure to arbitrary time varying loads. Here in this project work we are using the transient analysis to analyze the time varying stresses of the twin spool aero gas turbine engine and also the stresses in the rotor system for a given input force is computed. The analysis is mainly carried out to find out that these stresses are lesser than the yield point values of the materials used in aero gas turbine engine. And the analysis is carried out using ansys software.*

***Key Words*: Twin spool engine, compressor, turbine, yield point, transient state**

1. INTRODUCTION

One of the most important characteristics of a jet engine is represented by its behavior during transient working conditions. The acceleration response rate, the possibility and the necessity of working in the stable zones of the components, the need to avoid excessive thermal and mechanical stresses, especially for conditions on the border of the flight envelope influence the design choices.

All the previous requirements and related problems become even more important for modern military air-craft engines. In fact, narrow stall limits, resulting from the high stage compressor ratios, slam accelerations from idle to maximum rotational speed and higher performance are quite common in the marketing specifications. These items represent the main goals of the design of the apparatus that may be considered as the brain of the engine: the control system. In fact, the not so easy task of matching the required high performance and the safety margins for every flight condition is the responsibility of the control system.

Moreover, when the complexity of the engine increases and there are variable geometries, i.e., Inlet Guide Vanes, exhaust nozzles, and in the near future, turbine stators, the tasks and the harmonizing requirements of the control system rise rapidly. That's why the possibility to have physical-mathematical models allowing the simulation of the engine behavior during transient working conditions and permitting the performance computation for the same conditions represents a powerful tool for the design, the development and maintenance activities of the engine and of its control system.

Transient vibration is defined as a temporarily sustained vibration of a mechanical system. It may consist of forced or free vibrations, or both. Transient loading, also known as impact, or mechanical shock, is a no periodic excitation, which is characterized by a sudden and severe application.

1.1 BASIC CONCEPTS OF VIBRATION

A vibratory system, in general, includes a means for storing potential energy (spring or elasticity), a means for storing kinetic energy (mass or inertia), and a means by which energy is gradually lost (damper). The vibration of a system involves the transfer of its potential energy to kinetic energy and kinetic energy to potential energy and alternatively.

If the system is damped, some energy is dissipated in each cycle of vibration and must be replaced by an external source if a state of steady vibration is to be maintained.

Vibration can be classified in several ways. Some of the important classifications are as follows:

• Free vibration: If a system, after an initial disturbance, is left to vibrate on its own, the ensuing vibration is known as free vibration. No external force acts on the system. The oscillation of a simple pendulum is an example of free vibration.

• Forced vibration: if a system is subjected to an external force (often, a repeating type of force), the resulting vibration is known as forced vibration. The oscillation that arises in machines such as diesel engines is an example of forced vibrations.

If the frequency of the external force coincides with one of the natural frequencies of the system, a condition known as resonance occurs, and the system undergoes dangerously large oscillations.

• Undamped vibration: If no energy is lost or dissipated in friction or other resistance during oscillation, the vibration is known as undamped vibration.
• Damped vibration: If any energy is lost due to friction or any other resistance during oscillation, it is called damped vibration.
• Linear vibration: If all the basic components of a vibratory system; the mass, the spring, and the damper behave linearly, the resulting vibration is known as linear vibration.

Non Linear vibration: If, any of the basic components of response of the system behave non linearly the vibration is called non-linear vibration.

1.2 TRANSIENT VIBRATION

The response of a vibratory system to sudden blows or impacts is known as transient vibration. Impact and transient loading will be synonymous. In transient vibration, the concept of impact gives rise to analytical methods for predicting the response of a system to a wide variety of forcing functions. The general solution for periodic forcing can be expressed in terms of the solution for harmonic forcing.

If the impacting mass is large compared to the mass of the system, the two may cling together and move as one. Adherence may result regardless of size, if the surfaces are sufficiently inelastic. Conversely, if the dropped mass is small compared with the mass may rebound immediately after it strikes. These two extreme cases are quite simple to handle. But between these interactions lie a broad range of interactions where the elasticity or inelasticity of the impacting bodies must be taken into account along with other phenomena.

2. STEPS INVOLVED IN VIBRATION ANALYSIS

A vibratory system is a dynamic system for which the variable such as the excitations (inputs) and responses (outputs) are time dependent. The response of a vibrating system generally depends on the initial conditions as well as the external excitations. Most practical vibrating systems are very complex, and it is impossible to consider all the details for a mathematical analysis.

Only the most important features are considered in the analysis to predict the behavior of the system under specified input conditions. Often the overall behavior of the system can be determined by considering even a single model of the complex physical system.

Thus the analysis of a vibrating system usually involves mathematical modeling, derivation of the governing equations, solution of the equations and interpretation of the results.

2.1 MATHEMATICAL MODELING

The purpose of the mathematical modeling is to represent all the important features of the system for the purpose of deriving the mathematical (or analytical) equations governing the system's behavior. The mathematical model should include enough details should be able to describe the system in terms of equations without making it too complex.
The mathematical model may be linear or non-linear depending on the behavior of the system's components. Linear models permit quick solutions and are simple to handle; however, non-linear model sometimes reveals certain characteristics of the system that cannot be predicted using linear models. Thus a great deal of engineering judgment is needed to come up with a suitable mathematical model of a vibrating system.

2.2 DERIVATION OF GOVERNING EQUATIONS

Once the mathematical model is available, we use the principles of dynamics and derive the equations that describe the vibration of the system. The equations of motion can be derived conveniently by drawing the free body diagrams of all the masses involved. The free body diagram of a mass can be obtained by isolating the mass and indicating all externally applied forces, the reactive forces, and the inertia forces.

The equations of motion of a vibrating system are usually the form of a set of ordinary differential equations for a discrete system and partial differential equations for a continuous system. The equations may be linear or non-linear, depending on the behavior of the components of the system. Several approaches are commonly used to derive the governing equations. Among them are Newton's Second Law of Motion, D'Alembert's principle, and the principle of conservation of energy.

2.3 SOLUTION OF THE GOVERNING EQUATIONS

The equations of the motion must be solved to find the response of the vibrating system. Depending on the nature of the problem, we can use one of the following techniques for finding the solution; standard methods of solving differential equations, Laplace Transform methods, Matrix methods and Numerical methods.

If the governing equations are non-linear, they can seldom be solved in closed form. Furthermore, the solution of partial differential equations is far more involved than that of ordinary differential equations.

Numerical methods involving computers can be used to solve the equations.

However, it will be difficult to draw general conclusions above the behavior of the system using computer results.

2.4 INTERPRETATION OF RESULTS

The solution of the governing equations gives the displacements, velocities and accelerations of the various masses of the system. The results must be interpreted with a clear view of the purpose of the analysis and possible design implications of the results.

3. PERFORMING THE TRANSIENT ANALYSIS

The transient analysis is used to calculate the response of a structure to arbitrary time varying loads (impulse load).You can get time varying displacements, stresses, strains, and forces a structure or in a component using the transient analysis. In transient analysis, the inertia and damping effects are important.

The transient analysis takes more time to be performed. It is necessary to understand the problems for reducing the time involved in it. For example, if the problems contain nonlinearities, we need to understand how they affect the structures response by doing the static analysis first. For some problem we can ignore nonlinearities. We can also perform the modal analysis and we natural frequencies for calculating the correct integration time step.

The following steps are involved in transient analysis:

1. Create or import the solid model.
2. Define element attributes.
3. Define meshing attributes and mesh the solid model.
4. Specify the analysis type, analysis options and apply loads.
5. Obtain the solution.
6. Review results.

4. MODEL DETAILS

Total number of elements: 19
Number of disks: 4
Number of disk elements: 4
Number of bearings: 4
Number of bearing element: 4
Number of beam elements: 11

Fig-1 Model designed

The above figure shows the one dimensional view of the model (shaft of the rotor) that we analyzed and it has a total number of 19 elements. In which there are 4 bearings and one of the bearing is an intershaft bearing.

Elements from 1-8 represents the in spool and 9-14 represents the out spool. And also the model consists of disk elements and which is connected using bearings. The red line in the figure represents the bearings.

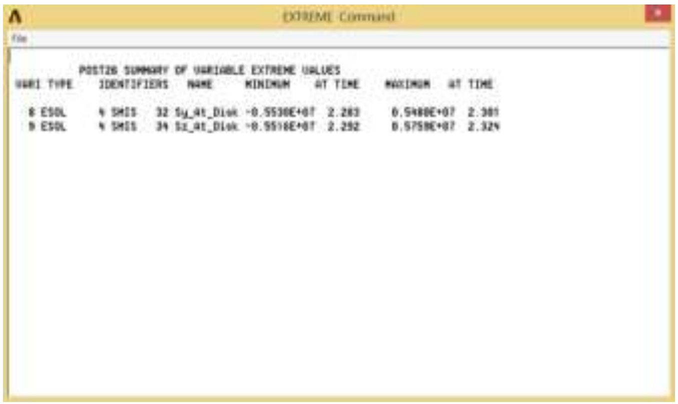

Fig-2 initial conditions

The above figure shows the initial conditions that we used in the analysis.

Fig-3 final conditions

The above figure shows the final conditions that we applied to perform the analysis.

5. RESULTS

The following are the results that are obtained in the analysis and the main results are plotted as a graph with bending stress vs. time.

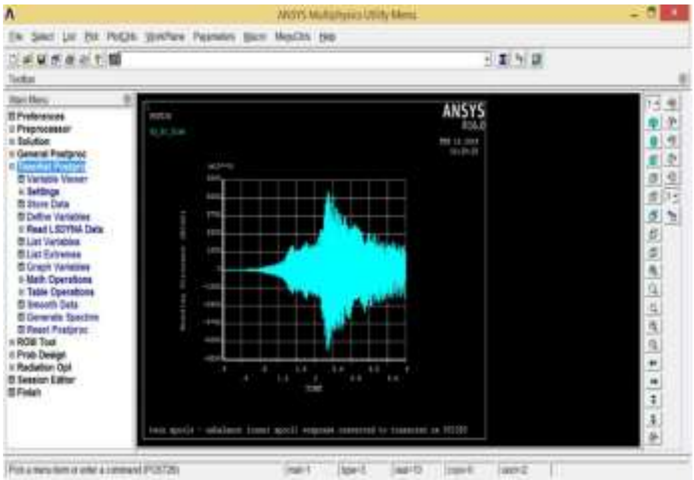

Fig-4 Graph of bending stress vs time

Here in this figure we can see that the bending stresses in the rotor system are decreasing with time.

6. CONCLUSION

The transient analysis of twin spool aero gas turbine engine was carried out using ANSYS software. Using the formulation of transient analysis, for a given transient input force the stresses in the rotor system was computed and these were found lesser than the yield point values for the materials used in aero gas turbine engine. By using transient analysis the time varying stresses of the twin spool aero gas turbine engine is analyzed.

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