STRUCTURAL ANALYSIS OF A MULTI TARGETING RADAR

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Abstract: Our Indian navy is doing a tremendous job protecting our country from dangerous enemies, so having the best-in-class equipment is essential, Radars are such equipment. RADAR is a classic example of an electronic engineering system that utilizes Waveform Design, Electromagnetic Scattering, Antennas. Radars play an important role to help the Navy in identifying any threats. RADARS were developed by various nations before and during Second World War. Bharat electronics has come up with a new type of radars that can identify more than one target. This new equipment is called as multi targeting radars or MTR.

Using methods like Transient, Modal and Harmonic Analysis on ANSYS software, we must come up with a new set of materials that can be used in the construction of these radars which can make them lighter and durable.

Key Words: Radar, Ansys, Structures.

I. INTRODUCTION

Introduction to BHARAT ELCTRONICS limited

- Bharat Electronics Limited is an Indian state-owned aerospace and defense company with about nine factories, and several regional offices in India. Bharat electronics was started in the year 1954 as a manufacturer of a few communications equipment.
- Bharat Electronics Limited is engaged in design, manufacture, and supply of electronics products/systems for the defense requirements, as well as for non-defense markets.
- The Company's principal products/services include weapon systems, radar and fire control systems, and communication.
- BEL designs, develops, and manufactures a range of products in the following fields:

i. Electronic voting machines
ii. Voter-verified paper audit trail
iii. Traffic signals
iv. Radars
v. Telecommunications

What is a Radar System?

- RADAR stands for Radio Detection and Ranging System. It is basically an electromagnetic system used to detect the location and distance of an object from the point where the RADAR is placed.

Bharat Electronics Limited is specialized in all sorts of radars used in military; like

I. Battlefield Surveillance Radar (3D Surveillance Radar Rohini)
II. Fire Control Radars
III. Weapon Locating Radars
IV. Secondary Surveillance Radars

Electronic Warfare

Electronic warfare (EW) can be defined as any possible action that is possible with the use of the electromagnetic spectrum or directed energy to control the spectrum, attack an opponent, or obstruct enemy assaults via the spectrum. The main purpose of electronic warfare is to deny opponent attacks and ensure friendly unrestrained access to the electromagnetic spectrum. Electronic warfare applications can be seen in air, sea, land, and space applications for both manned and unmanned systems as illustrated in Figure. Targets of the applications can be humans, communications, radar, or other assets. In military applications, electronic warfare is used to support military operations by means of detection, denial, deception, disruption, degradation, protection, and destruction.

Electronic warfare can be divided into three main subdivisions, namely, electronic attack, electronic protection, and electronic support. Electronic attack (EA) applications are performed by active and passive ways. Active ways are jamming, deception and active cancellation; passive ways are chaff, towed decoys, radar reflectors and stealth. Electronic protection (EP) is also applied in active and passive ways. As technical modification to radio equipment is an active way; education of operators, enforcing strict discipline and modified battlefield tactics or operations are passive ways of electronic protection. Electronic support (ES) can be defined as an action of searching, interception, identification, and detection the location of radiated electromagnetic energy sources for the purpose of immediate threat recognition. Signals Intelligence (SIGINT), Communications Intelligence (COMINT) and Electronics Intelligence (ELINT) are three subgroups of electronic support applications.

- Purpose of SIGINT is to collect and analyse of information from radar and radio signals.
- Purpose of COMINT is to listen into, analyse and decode the military radio-traffic, teletype, and fax signals.
- Purpose of ELINT is to collect and analyse the radar, Identification Friend and Foe (IFF), datalink, and missile firing signals. Radar Warning Receivers (RWR) is one of the examples of these types of applications.

Apart from these classifications, radar technologies are another subgroup of electronic warfare. The use of radar technologies is basically air-defense systems, antimissile systems; marine radars to locate enemy ship, ocean surveillance systems, outer space surveillance and rendezvous systems, guided missile target locating systems so on.
For all these electronic warfare applications, antennas, receivers, transmitters, power unit, data collection and processing units, user interfaces and other residual components are gathered up for the complete operation quality and performance.

Mechanical Shock

Mechanical shock is defined as a non-periodic excitation of a mechanical system. It is characterized by severity and suddenness that disrupts the equilibrium of the system usually causing significant relative displacements. These non-periodic excitations can be caused by suddenly applied forces or by sudden changes in magnitude or direction of velocity. Mechanical shock is usually expressed as a single input pulse like half sine, saw-tooth, versed sine, triangular, rectangular, and other possible forms with peak amplitude (in acceleration or velocity) and duration of the pulse. The duration of a shock pulse is the time required for the acceleration of the pulse to rise from some stated fraction of the maximum amplitude and to decay to this value. TE is the "shock duration" which can be defined as the minimum length of time containing all time history magnitudes more than absolute value which is one-third of the shock peak magnitude absolute value, Ap. On the other hand, Te is the "effective shock duration" which can be defined as the minimum length of continuous time that contains the root-mean-square (RMS) time history amplitudes more than the value which is one tenth of the peak RMS amplitude related to the shock event and the averaging time for the unweighted RMS computation is assumed to be between one tenth and one fifth of Te.

Shock testing is very important to simulate the shock environment in laboratory conditions in proper and reliable manner. For different shock environment, 11 different test methods should be selected. Determining factors of these methods are shock amplitude, shock duration and the dimensions of to-be-tested part. Shock testing methods can be classified as following.

I. Simple Shock Pulse Machines:
- Drop Tables
- Air Guns
- Vibration Machines

II. Complex Shock Pulse Machines:
- High-Impact Shock Machines

1. Lightweight Machines
2. Medium-Weight Machines
3. Heavy-Weight Machines

- Hopkinson Bar

i. Multiple Impact Shock Machines
ii. Rotary Accelerator

Ship Shock and Underwater Explosion

- Following years, especially after the World War II, navies studied on to understand the phenomena of underwater explosion and develop design methodologies to reinforce ships against the threat.
- The effects of such explosions may collapse the whole structure of ships and submarines, or may cause severe damages to electronic equipment, warfare technologies or structural parts.
- The Machinery and equipment for naval application must be designed to operate under these severe conditions.
- The shock conditions for naval applications are more severe than most of the other military operations like tanks and airplanes. Therefore, shock competitive ship/submarine design, component survival precautions and shipboard design improvements have become primary issues for underwater explosion survival.
- In the scope of this thesis, shock analysis of the antenna structure subjected to underwater explosions is performed. Complete shock analysis consists of determination of underwater shock characteristics, analytical solution of shock phenomenon, finite element model solutions of shock phenomenon, shock testing and shock isolation of the antenna structure with the platform.
- Design specifications of naval electronic warfare applications for foreign customers contain harsh naval shock survival criterion. Therefore, mechanical structures of those systems should withstand and pass laboratory test for naval shock. Preliminary design considerations should be taken, and further actions should be carried with those shock analysis and tests beforehand. Thus, underwater explosion shock (UNDEX) should be analyzed analytically and should be qualified with finite element models and experiments.

2 PROBLEM STATEMENT

1. The main intention of this project is to come up with new set of that can be replaced with the current materials being used by Bharat Electronics.
2. The new materials should be able to withstand all the given condition of the sea.
3. The new material should be lighter and more durable compared to the previous set of materials.

3 OBJECTIVES

The main objectives of this projects are.

1. Using ANSYS we are performing the structural analysis on antenna to find out the total deformation, natural frequency, shock test, and vibration on the antenna due to sea behaviour and sea weather.
2. To determine whether the current materials used by Bharat Electronics i.e., Aluminium Alloy can be replaced by any other suitable materials.
3. Using methods like Transient, Modal and Harmonic Analysis on ANSYS software, we must come up with a new set of materials that can be used in the construction of these radars which can make them lighter and durable.

4 MATERIALS AND METHODS

Iteration 1 materials

- Aluminium - palette.
- Structural steel - hinges.
- Epoxy E-glass UD - radome.

Iteration 2 materials

1. • Magnesium alloy (AZ91D) - palette.
2. • Structural steel - hinges.
3. • Epoxy E-glass UD - radome.

Introduction

In this chapter, transient response analysis of antenna structure subjected to underwater shock explosions is performed by means of Finite Element Analysis (FEA). In the scope of this chapter, modal and transient analyses are performed by means of finite element software package ANSYS®. Antenna geometry created on computer aided drawing software program is imported to ANSYS® Workbench. Material properties are introduced to the engineering data library. FEA modelling option is to be proposed as an alternative to mathematical model to perform shock analysis from simple to complex antenna structures.

Transient Response Structure of Antenna System

Mathematical model of the antenna structure is built based on modal analysis by means of continuous modelling with classical approach using Euler-Bernoulli Beam Theory. In this chapter, transient response analysis is performed by these models. Following the road map of analysis procedure, first, MDOF transient response analysis which is the main purpose of the study is performed by RFR method. Modal analysis outputs such as natural frequencies, mode shapes and participation factors are used as inputs for RFR transient analysis. Therefore, this analysis can also be called as Modal Transient Analysis because of the use of modal matrices built in continuous modelling. Shock profiles simulating underwater explosions obtained in Chapter 3 are also used as acceleration inputs. The output of analysis includes displacement, acceleration and velocity shock responses obtained at any point on the antenna structure. Critical displacement and acceleration response ranges are investigated with Phase Portrait plots. Histograms also present the reluctance of antenna structure to failure or electromagnetic malfunctions.

Secondly, simplified methods are presented involving three different methods presented. Maximum absolute acceleration and relative displacements are estimated by means of these methods. A comparative evaluation of results is carried to understand the efficiency of these simplified models in predicting the antenna response to shock input as described. Meshing is defined with normal element sizes since structure is not complex and it does not have irregular surfaces.

Modal Analysis of Antenna Structure

ANSYS® Workbench is used to perform modal analysis. From workbench selections, “Modal (ANSYS)” is selected and dragged from Workbench to the standalone project created. First, geometry should be created on Design Modeler in ANSYS® Workbench or on any computer aided drawing software and then imported to “Modal”. In the analysis, antenna geometry is imported to ANSYS® as a pre-designed part file created by means of solid works ANSYS® are working interactively, it is the best and easiest way to create and update models to be analysed on ANSYS® platform. As the antenna material, mechanical properties are imported to “Engineering Data Sources” of ANSYS®. After geometrical and mechanical properties are introduced, modal analysis properties are defined one by one. Boundary conditions are introduced as a fixed support at one end of antenna structure and free otherwise, and all initial conditions are defined as zero.

Material List

Figure shows the list of materials that are used for first iteration. The material used are Aluminum alloy, Epoxy E glass and Stainless steel. The properties of these materials are also listed in the fig. Epoxy E glass is used in the radome and the Stainless steel is used in hinges and other moveable parts and the rest is made of aluminum.

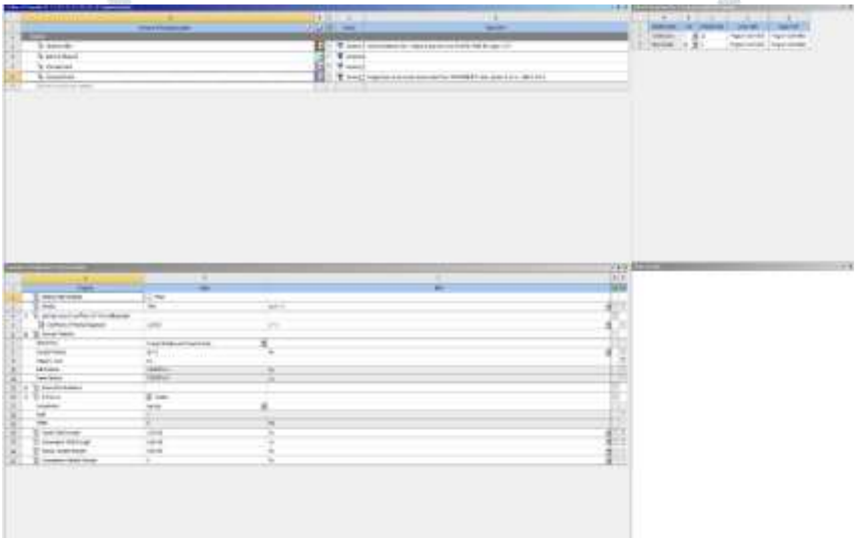

Fig 1 Materials List for 1st Iteration

MESHING

What is meshing?

Meshing is the process in which the continuous geometric space of an object is broken down into thousands or more of shapes to properly define the physical shape of the object. The more detailed a mesh is, the more accurate the 3D CAD model will be, allowing for high fidelity simulations.

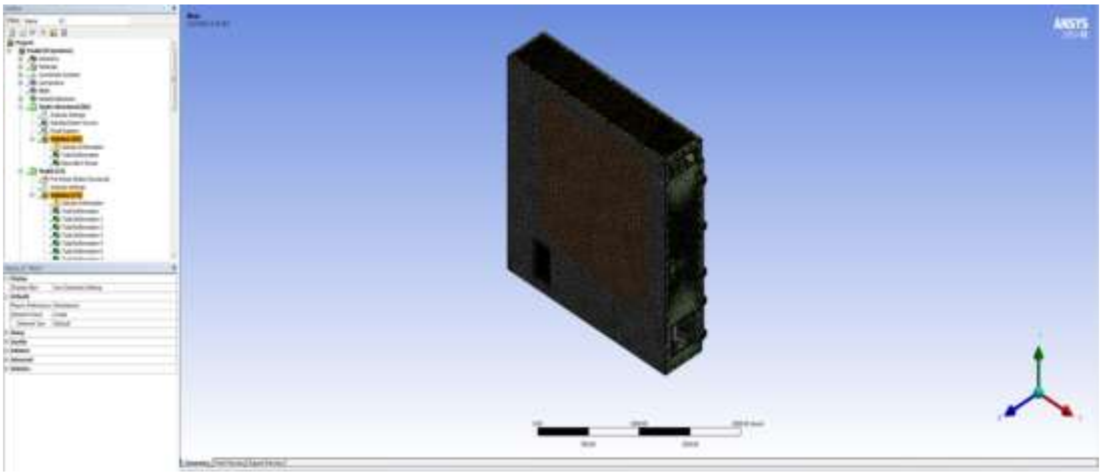

Fig 2 Meshing for 1st iteration

Ansys meshing capabilities help reduce the amount of time and effort spent to get to accurate results. Since meshing typically consumes a significant portion of the time it takes to get simulation results

STATIC STRUCTURAL

What is static structural analysis?

Structural analysis is the determination of the effects of loads on physical structures and their components. ... The results of the analysis are used to verify a structure's fitness for use, often precluding physical tests. Structural analysis is thus a key part of the engineering design of structures.

What is the use of static analysis?

The structural analysis helps to determine the cause of a structural failure. The purpose of the structural analysis is to design a structure that has the proper strength, safety, and rigidity.

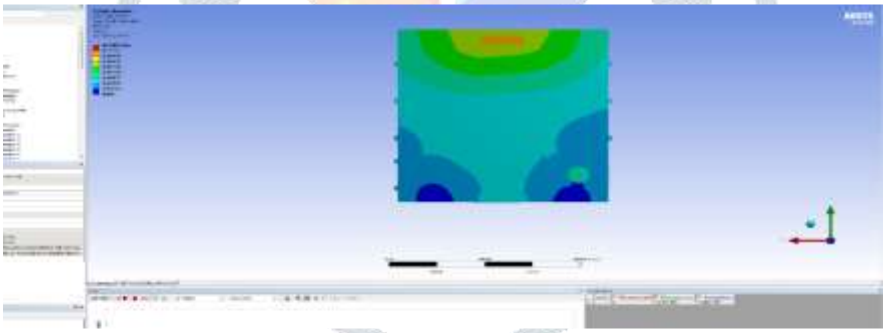

Fig 3 Total Deformation

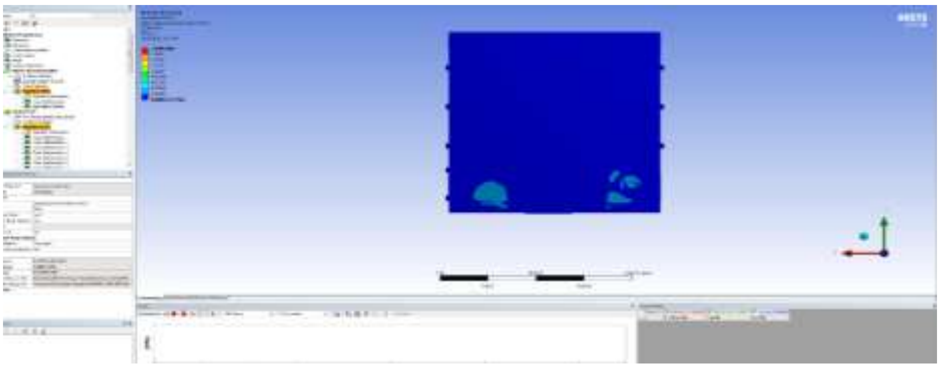

Fig 4 Equivalent Stresses

Figure (3) shows the total deformation of meshed antenna that is found to be 0.012097 mm and the figure (4) shows the equivalent stress that is found to be 1.8405 Mpa. In fig (3) red indicates maximum deformation and blue indicates minimum deformation. In fig (4) red indicates maximum stress and blue indicates minimum stress.

RESULTS

- EQUIVALENT STRESS:1.8405MPa
- TOTAL DEFORMATION:0.012097mm

MODAL ANALYSIS

What is modal analysis?

A modal analysis is a technique used to determine the vibration characteristics of structures.

Benefits of modal analysis

1. Allows the design to avoid resonant vibrations or to vibrate at a specified frequency (speaker box, for example).
2. Gives engineers an idea of how the design will respond to different types of dynamic loads.
3. Helps in calculating solution controls (time steps, etc.) for other dynamic analyses.

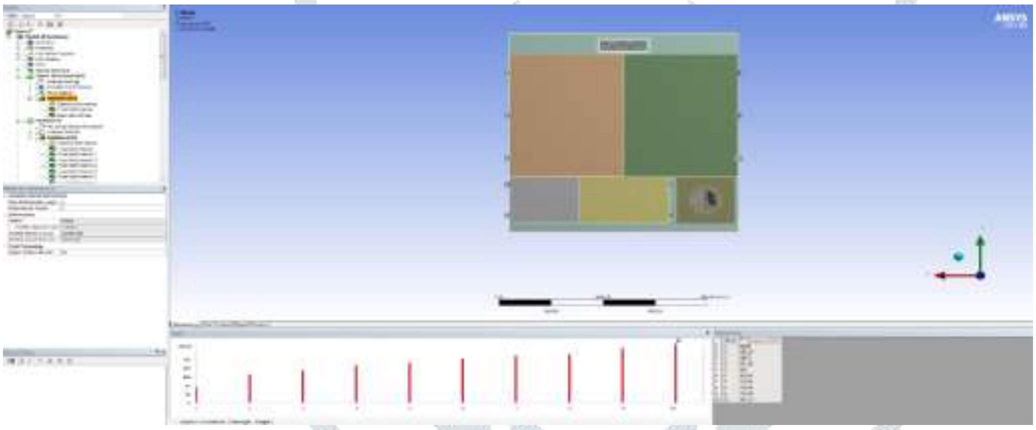

Fig 5 Modal Analysis

The total deformation that is found to be 1.4579mm in fig 6.5.

RESULT:

TOTAL DEFORMATION: 1.4579mm

TRANSIENT 1

What is transient analysis?

Transient structural analysis is also referenced as flexible dynamic analysis. It can be used to find out the dynamic response of a structure under the action of any general time-dependent loads.

What is the use of transient analysis?

Transient structural analyses are needed to evaluate the response of deform able bodies when inertial effects become significant.

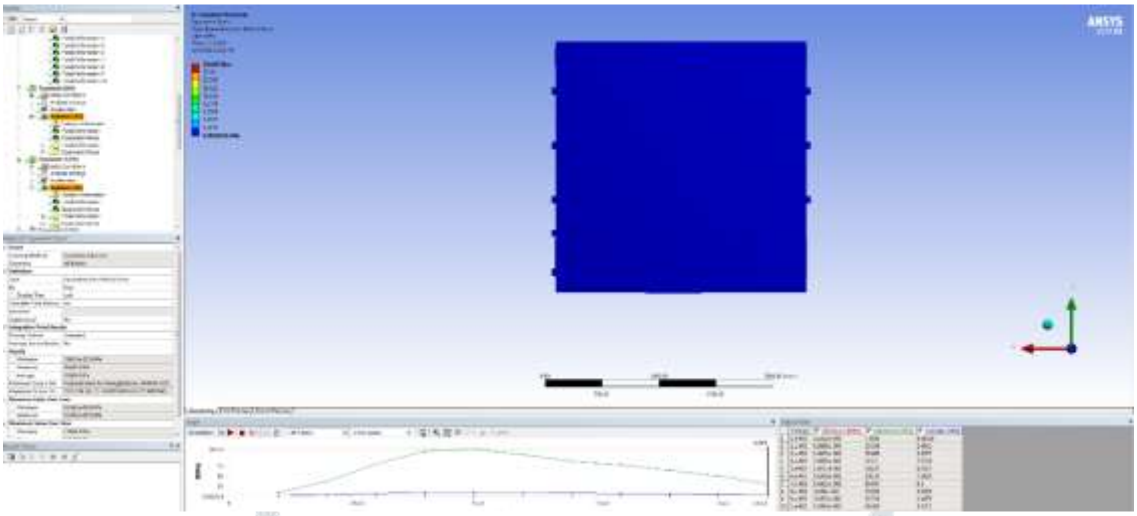

Fig 6 Total Deformation

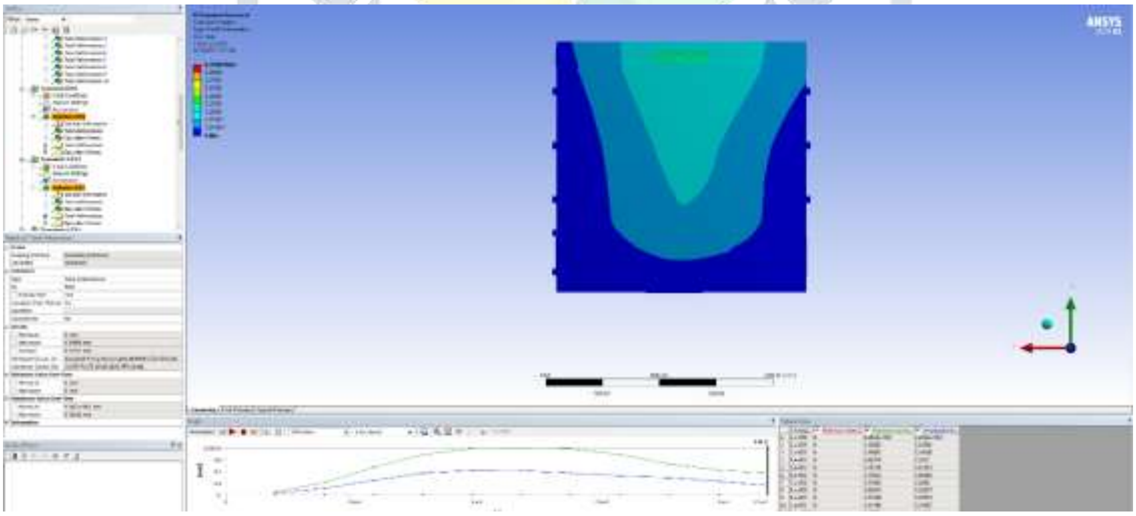

Fig 7 Equivalent Stresses

Figure (6) shows the total deformation of meshed antenna that is found to be 0.35988 mm and the figure (7) shows the equivalent stress that is found to be 28.665 Mpa. In fig (6) red indicates maximum deformation and blue indicates minimum deformation. In fig (7) the stress is distributed equally.

RESULT:

- TOTAL DEFORMATION:0.35988mm
- EQUIVALENT STRESS:28.665Mpa

7. CONCLUSION

1. By means of the proposed methodology throughout the study, multi-degree-of-freedom transient response analysis of the antenna structure is accurately performed using four modes (90% of the effective modal mass) of the structure. Transient response analysis of the similar (beam type) antenna structures with different dimensions and different field of applications can be readily applied.
2. For transient analysis of the antenna structure, RFR method is used for solution algorithm. This method is very easy to apply on shock response analysis formulation and it is very fast. Elapsed time for response obtained from this method is almost a second for both modal and transient analysis.
3. It is important to acquire reliable responses from experimental analysis if transient analysis is concerned. High coherence values at natural frequencies, spectrum content of transient response and modal updating according to experimental feedbacks assures the reliability of mathematical model and FE solution.
4. Theoretical maximum allowable stress values for structures under transient loading are so safe enough not to face with failure of antenna material. In experimental analysis stages, maximum allowable shock loading limits are exceeded, and no failure and deformation are observed. Stress values are calculated higher than yield stress of the material due to the forcing duration is very small and forcing behaviors are different than static loading cases.

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