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Finite Element Analysis of Vibrating Grizzly Feeder

[1]Prof. A. P. Bhavsar, [2]Prof. N. R. Prajapati, [3]Prof. H. N. Pandya

[1]Assistant Professor, [2] Assistant Professor, [3] Assistant Professor

[1]Mechanical Engineering Department,

[1]Dharmsinh Desai University, Nadiad, India

Abstract: The project involved in this paper is a Vibrating Grizzly Feeder, 1200 TPH capacity designed by ELECON Engineering Pvt. Ltd. As this type of feeder conveys the material by the application of vibration so its Modal Analysis is been done previously to check the resonance occurs or not. In this paper based on structural design and finite element model, the 3D model of VGF is made on Pro-E and analyzed on ANSYS Workbench 14. The VGF is designed based on empirical design. So different loading conditions are assumed to act on VGF and different boundary conditions are applied in FE Model. Von Mises stresses are found out for different loading conditions and checked for failure.

I. Introduction

Material handling equipments are industrial devices that are used to move, transport, store, protect, handle and/or dispose goods, products and materials. This equipment is generally used in large industries such as shipping and logistics, warehousing, pharmaceuticals, food industry, construction and manufacturing. Small and medium industries also used material handling equipment that is intended for smaller workload and applications. The feeder is a material handling equipment used to regulate the flow of a bulk material from a bin or hopper. A feeder is essentially a conveyor used for short distances where a constant rate of dispersal is required. There are many types of feeders to suit many different industries; ranging from mining, to pharmaceuticals, to agriculture. Feeders are often used in conjunction with other types of material handling equipment, like conveyors, crushers, dryers, grinders, blenders, and mixers.

Vibrating Grizzly Feeder works on the phenomena of Vibration. Here vibration means "to move back and forth rapidly." On a vibratory feeder, material is "thrown" up and forward so that it drops to the surface at a point further down the tray. This is the feeder's amplitude. The number of times per minute that it repeats is the frequency. A third variable is the angle of deflection, meaning how high the product is thrown as compared to its horizontal movement.

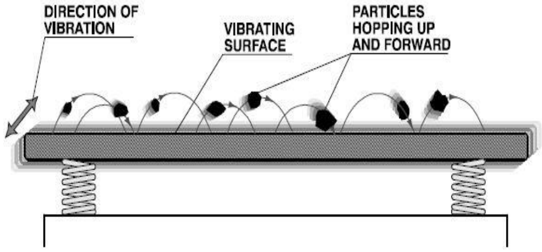


Fig 1 Working principle of VGF

Vibrating Grizzly Feeders are used in the mining and construction industries to separate large rocks from fine material. Grizzly feeders are powered by an off-balance electric motor, which causes the unit to vibrate. They operate by conveying ore over a series of steel beams, which prevents large rocks from passing. The mixture that falls through is entirely fine.

II. LITERATURE REVIEW

The earlier conveyors were crank driven at low frequencies, which move materials forward by altering "stick" and "slip" phases during each cycle [1,2]. As the material slides on trough, it leads to wear and increases power requirements. In the region of 1926, conveyor with high frequency and small amplitude were introduced [3]. Vibrating Feeders can be differentiated by the type of spring mass systems or by the drive used for the excitation. Trough of Vibrating Feeder can be suspended freely or constrained to move in one direction only [3,4]. G.H.Lim in his studies represented the dynamic analysis of Vibrating Feeder. He created model who incorporates various system and operating parameters like slope of trough, amplitude of vibration, frequency and coefficient of friction. He concluded that conveying velocity of feeder body is particularly sensitive to variations in coefficient of friction and inclination angle of track of feeder with horizontal [5]. G.H.Lim in his another paper done comparison of practical model of Vibrating Feeder with theoretical model created on Turbo C++. He concluded the parameters he has considered for Turbo C++

program were working identical to the actual one [6]. Ganapathy et al represented unbalanced mass driven vibrating conveyor with a small damping have a risk of "stalling" at resonance or crossing resonance with large amplitude of vibration. He advised to start feeder with "load" rather than empty [7]. Bhattacharya et al worked on anti-loosing characteristics of different fasteners and found nylon and aerotight nut showed best anti-loosening characteristics against vibrations [8]. Bhavsar et.al. done analysis of Vibrating Grizzly Feeder of particular capacity on ANSYS to check "resonance", as it is much needed for vibratory system. He suggested that use of CAD software is much time and cost saving [9]

III. OBJECTIVE AND SOLID MODELING

The objective of the paper is to do FE Analysis of VGF of given capacity to check whether it fails or not in any of the actual loading condition.

Detailed drawing of Vibrating Grizzly Feeder is taken out from ELECON Engineering Pvt. Ltd., which is further examined under different loading condition. To make solid model Pro-E wildfire 5.0 software is used. It is user friendly and we can make different parts and can assemble on it. Here in this paper Vibrating Grizzly Feeder of 1200 TPH capacity is containing six nos. of beams. These beams are located at the position as defined in drawing (fig 2).

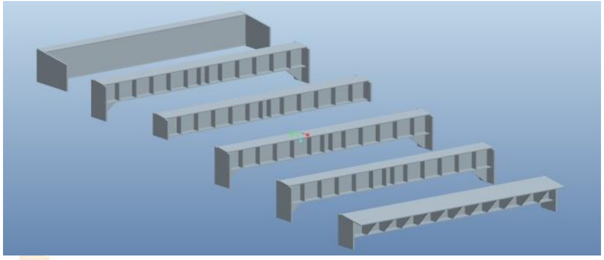


Fig 2 Beam position

Each beam contains various nos. of parts which are assembled to make a beam as shown in fig 3.

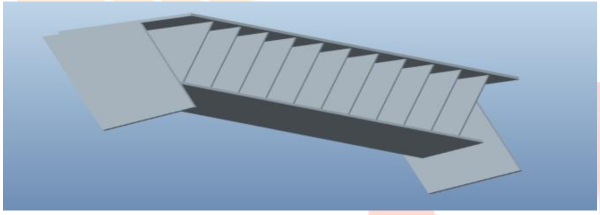


Fig 3 Beam assembly

After positioning all the beams on desired location, plates are fixed to the beam, which is shown in figure [fig 4]. Plates are mainly three types, deck plate, screen plate and end plate. Total four nos. of deck plates are fixed in a row. On which material falls initially. The other rows contain screen plates; the total rows of screen plates are four and each row contains four screen plates. The size of deck plate and screen plate are same but the difference is that the screen plates contains aperture to screen the material, to pass the material. The solid model of each beam and their combine assembly with deck and screen plates as shown in below figures. Total numbers of parts are 187.

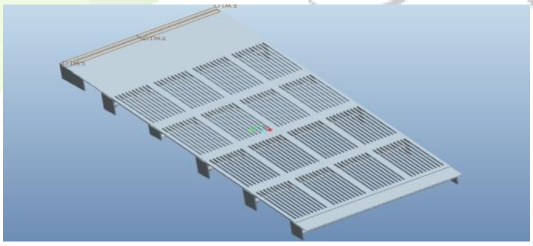


Fig 4 Solid modeling of entire VGF assembly

Table 1 Dimensions of Deck plate and screen plates are given below:

Description	Unit	Value
Deck plate length	mm	1010
Deck plate width	mm	610
Deck plate thickness	mm	16
Screen plate length	mm	1010
Screen plate width	mm	610
Screen plate thickness	mm	16

Each screen is having 10 nos of aperture of length 850 mm * 25 mm.
Total No. of deck plate: 4
Total No. of screen plate: 16
During this Solid Modeling some assumptions have been made:

(1) All beam members are actually fabricated, but in drawing they are fixed to each other. Welded joint is not considered.
(2) Chamfering at all places not accounted.

(3) Holes for plate fix up has not provided in Solid Modeling.

IV. ANALYSIS OF VIBRATING GRIZZLY FEEDER USING ANSYS 14 WORKBENCH:

The FEM analysis of Vibrating Grizzly feeder is carried out in well-known FEA software ANSYS 14 Workbench. Here all the analysis carried out is Static structural analysis. At any instant effect of different loads on the structure is examined. The failure criterion is based on Equivalent von Mises stresses. Equivalent von Mises stress is compared with allowable stress. Following cases are checked out for analysis of Vibrating Grizzly feeder, which resembles the actual loading conditions.

Load cases:

(1) No Load condition.
(2) Initial loading condition.
  (i) If the material initially directly falls on middle two deck plates.
  (ii) If the material initially directly falls on deck plates of two sides.
  (iii) If the material initially falls on all four deck plates.
(3) Full load condition.

As the Vibrating Grizzly feeder is working based on creation of vibration, Modal analysis of Vibrating feeder is been carried out to find the natural frequency of the system. Working frequency of the system is 25 Hz and the first modal frequency achieve is 132.06 Hz [9], which is far different then the frequency of system, so there are no chances of "Resonance".

Static structural Analysis:

Structural analysis is probably the most common application of the finite element method. The term structural implies not only civil engineering structures, but also naval, aeronautical and mechanical structures.

There are seven types of structural analyses available in the ANSYS family of products. We are going to do static structural analysis. It is used to determined displacements, stresses etc. under static loading conditions.

ANSYS consist three basic parts, (i) pre-processing, (ii) Solution. (iii) post processing.

In pre-processing we define different loading conditions, boundary conditions, constrains resemble to actual loading condition.

(i) Constrains: The side plates of each beam are fixed up with other two side plates; which is not a part of our model. So, The Vibrating Grizzly Feeder is fixed at side plates as shown in figure 4 by blue colour. This constrain will remain same for all loading condition, only load will vary.

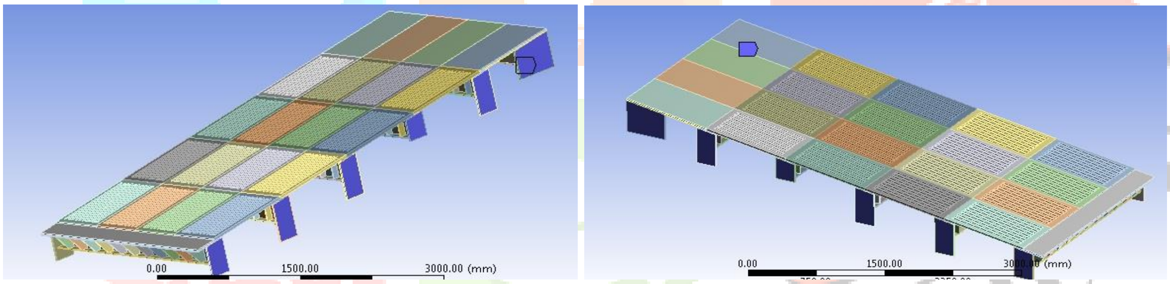


Fig 4 Boundary constrains (Fixed displacement)

(ii) Material:

The material used to make vibrating Grizzly Feeder is st-42 (E250), which is structural steel. Properties of it are given below:

Material	St 42 (E250)
Poisson's ratio (v)	0.3
Young's modulus (E)	210000 MPa
Density (ρ)	7850 kg/m^3
Yield stress (Sys)	250 MPa
Ultimate Tensile stress (Sut)	500 MPa
Elongation (%)	23%

Above material is been selected from Engineering data of ANSYS and assign to model.

(iii) Meshing:

The whole VGF is meshed very finely, especially the screen area by 15 mm elemental size for meshing. After meshing, 771299 nodes representing 187 bodies' active components are found. Total elements created are 116174. Four nodal quadrilateral elements selected for meshing.

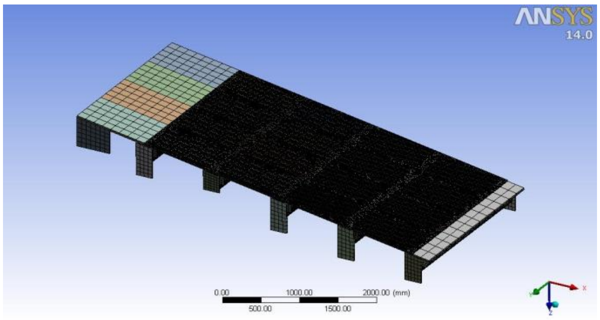


Fig 5a Meshing of whole VGF

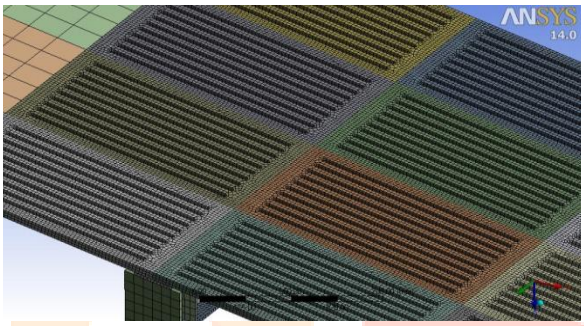


Fig 5b Meshing of screen

The all above things means material property, meshing and body constrain will remain same for all the loading conditions only force will change according to conditions.

Analysis for different loading conditions is applied as below.

(i) No Load condition

This is the condition when there is no any external load is applied on Vibrating Grizzly Feeder. Vibrating Grizzly Feeder is steady, no working condition. In this condition stresses developed due to self-weight is found out.

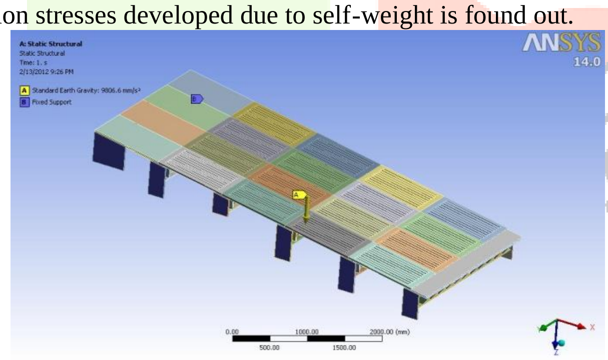


Fig 6a Boundary condition for No loading condition

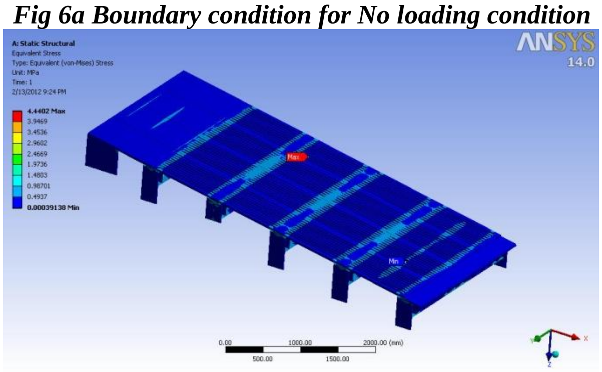


Fig 6b Equivalent von-Mises Stress under No loading condition

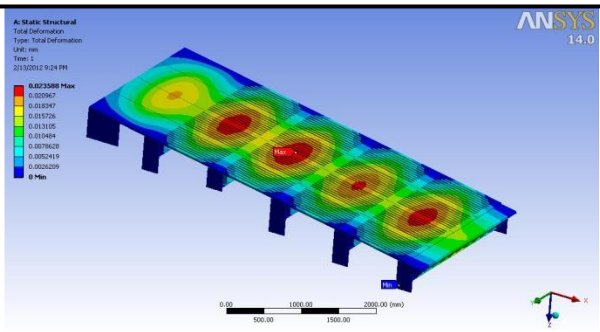


Fig 6c Total deformation under No loading condition

(ii) Initial loading condition:

In initial loading condition load applied due to falling of material. In this condition screening has not started. The effect of centrifugal force due to rotating member on feeder structure is assumed not to be act on this case. The Vibrating Grizzly Feeder is of 1200 TPH capacity, means at any instant the material fall on the feeder is 1200 tons/hour. So, 333.33 kg of material falls per second is on deck plate. Chute is provided above the feeder. Material first falls on chute and then slides on it and then fall on deck plate area. We have to analyses the feeder under worst loading condition. This condition will occur when chute is not provided and material directly falls on deck plate area. Material is coming out on deck plate via belt conveyor. Velocity of material on the belt conveyor is 3.4 m/s, which is initial velocity. The impact force on the deck plate can found as below.

Velocity of falling material at impact:

$$V_f = \sqrt{{V_0}^2 + 2gd}$$

V_f = Final velocity

V_0 = Initial velocity

g = Gravitational acceleration

d = Height of falling.

The initial velocity is taken as 3.4 m/s (data available from ELECON), gravitational acceleration is 9.81 m/s^2. Material free fall height is 2 m. By putting all the values in above equation, the final velocity achieved is 7.13 m/s.

At the impact place the Energy is due to impact or final velocity, means the impact energy is Kinetic Energy. Kinetic Energy is calculated by following equation.

Kinetic Energy = $\frac{1}{2}$ m ${V_f}^2$

m = total material falling on deck plate

So, Kinetic Energy is 8472.73 Nm.

By Work Energy principal we can find the value of force

Work = Force * Displacement

In this case the displacement is 20 mm of stoke, this value is provided by ELECON.

So, we can find the value of total force which will be applied on deck plates. The value of total force is 423217.19 N is achieved. This will be applied by three conditions:

Conditions:

(i) If the material falls only on middle two deck plates.

(ii) If the material falls only on plates of both side.

(iii) If the material falls on all four deck plates.

Condition I : If material falls only on middle two deck plates.

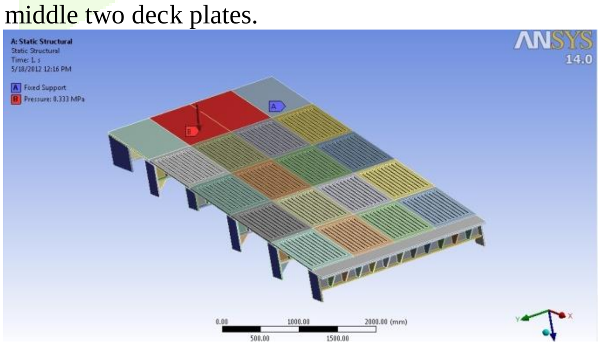


Fig 7a Boundary condition for condition I

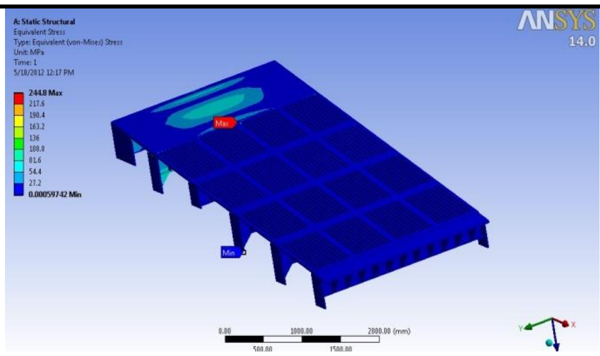


Fig 7b Equivalent von Mises stresses for condition I

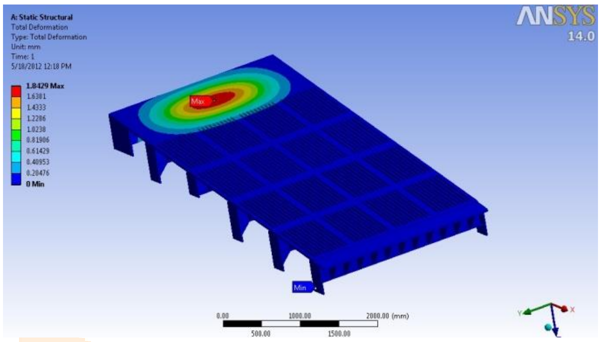


Fig 7c Total deformation for condition I

Condition II : If material falls only on deck plates of both side:

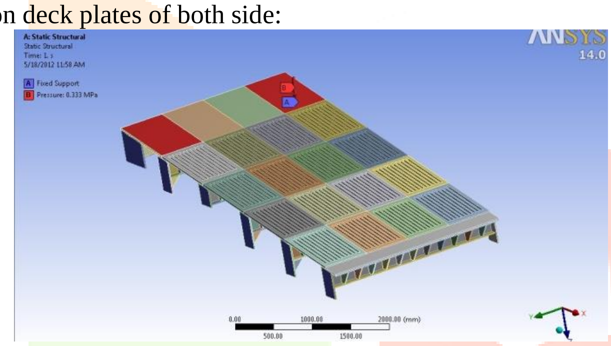


Fig 8a Boundary condition for condition II

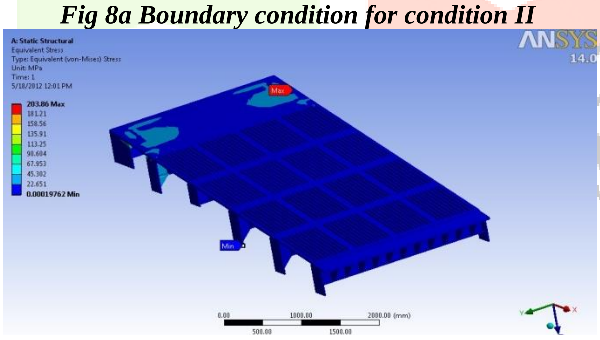


Fig 8b Equivalent von Mises stresses for condition II

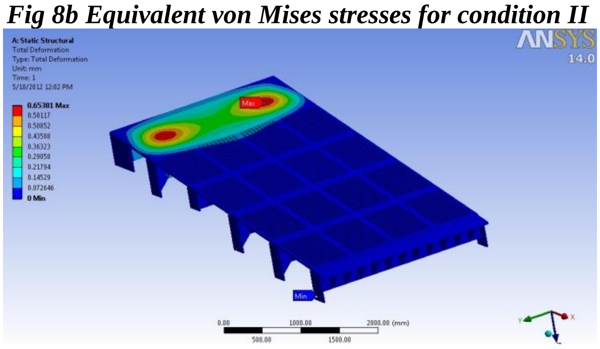


Fig 8c Total deformation for condition II

Condition III: If material falls on all four deck plates:

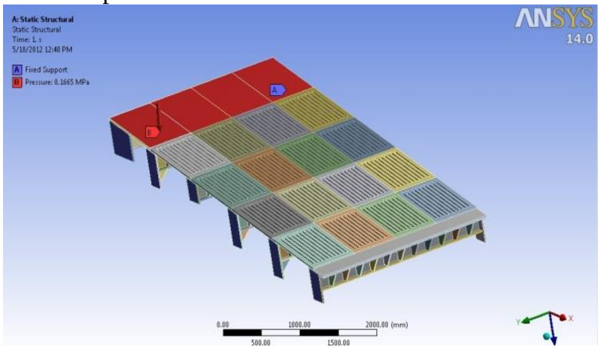


Fig 9a Boundary condition for condition III

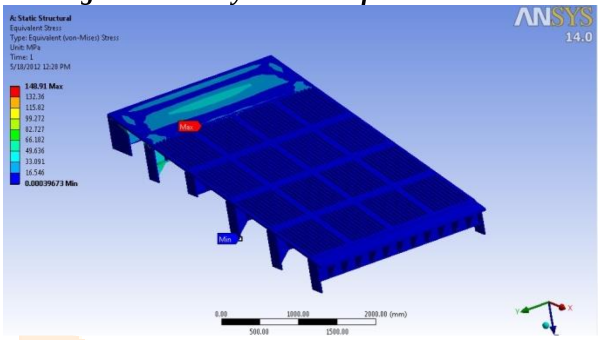


Fig 9b Equivalent von Mises stresses for condition III

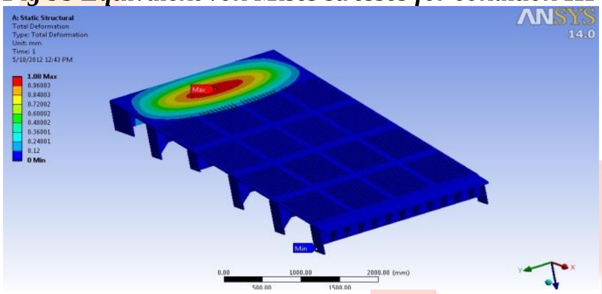


Fig 9c Total deformation for condition III

V. RESULTS AND DISCUSSION

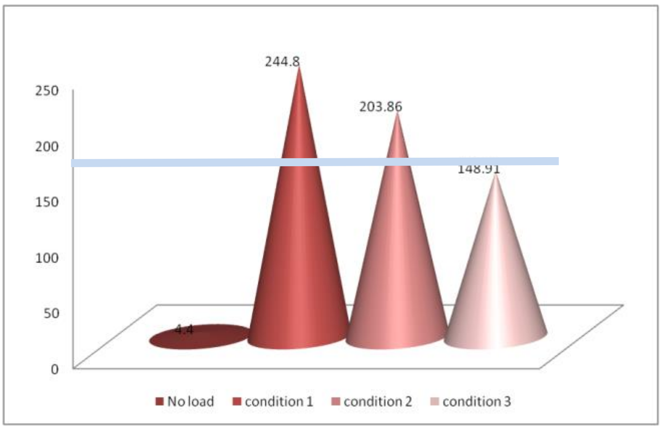
In above analysis we have considered only two main loading conditions (i) No load (ii) Initial Load. Full loading condition is not been discussed in this paper. The result is based only on the mentioned conditions.

Table 2 Results of various loading conditions

Loading condition	Von Mises Stress (MPa)	Total deformation (mm)
No load	4.44	0.023588
Condition I	244.8	1.8429
Condition II	203.86	0.6583
Condition III	148.91	1.08

The equivalent von Mises stresses and deflection of VGF in all loading conditions are taken out. The criterion of failure is taken equivalent von Mises stress. If the available equivalent von Mises stress for any loading condition will exceed the value of allowable stress then the part will not safe for that loading condition.

Vibrating Grizzly feeder involved in this thesis is made of St42 and it is having yield point stress equal to 250 MPa. The allowable stress is depending upon Yield point stress and factor of safety. The factor of safety is selected 1.4.[10]. So, the allowable stress equal to 178.57 MPa. If the von Mises stress remain within this limit the part will assumed safe.



Von Mises stress for above loading conditions compared with allowable stress is showed in graph above. Arrow represents the line of allowable stress. The X- axis of the graph shows Loading conditions. The Y- axis of the graph shows the value of von Mises stress.

From the above graph we can compare von Mises stress for given loading condition with allowable stress. Two of the all loading conditions cross the boundary of allowable stress. Means the part designed by ELECON will fail for these loading conditions. But in actual practice we can allow the stress up to a yield point stress for static loading condition and our results are below yield point stress. So, we can accept the design. But problem may create when we will design the feeder for full loading conditions because we have to consider centrifugal force also that time.

The result of Modal analysis shows that the first modal frequency comes at 132.06 Hz and second modal frequency at 136.97 Hz [9]. Our operating frequency is equal to 25 Hz. It is far less compared to the natural frequency of the system. This indicates that our system will work in sub-resonant frequency. No resonance will be created.

V. FUTURE SCOPE

We have checked the design for No loading and Initial loading condition, so future work is to check the design for full loading condition by applying appropriate formulas. In full loading condition we will apply the centrifugal force due to rotating unbalance mass on feeder in the form of static load. Force by material when it passes from deck plate to screen plate also been taken in account in full loading conditions. On bases of the results, it will be decided that the design is safe or not. If design will fail, we can suggest some modifications in beam dimensions or plate dimensions or material of the plate/beam by further analysis using same boundary and loading conditions.

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