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Analysis of joints with V band and T bolts

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ABSTRACT

ANALYSIS OF JOINTS WITH V BAND AND T BOLTS

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T bolts with V bands are used to hold two sections of pipe together with each section of pipe having a flared flange at the ends. Though they are quite popular in various industries including heavy duty diesel engines, analysis involving these joints is not available. This thesis would involve static and dynamic behavior of the joints. Behavior of these joints in comparison with bolted joints are also provided.

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ANALYSIS OF JOINTS WITH V BAND AND T BOLTS

BY

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DEDICATION

To my parents, brother and sisters, with love and gratitude.

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CHAPTER 1

INTRODUCTION

1.1 Clamp History

In present generation clamping tasks are versatile and numerous in industries like manufacturing, automotive, agricultural. The systems or elements which are supported by using clamps will gain lot of importance in future. The word clamp is originated probably from Dutch or Low German origin. DE-STA-CO, a Dover Company, was founded in 1915[14], manufactured the first manual toggle clamp in 1936. DE-STA-CO offers a wide variety of manual toggle clamps from hold down clamps (vertical or horizontal handle) to latch clamps and straight action or squeeze-action clamps [15]. First original Toggle clamp [1] is shown in Figure 1.

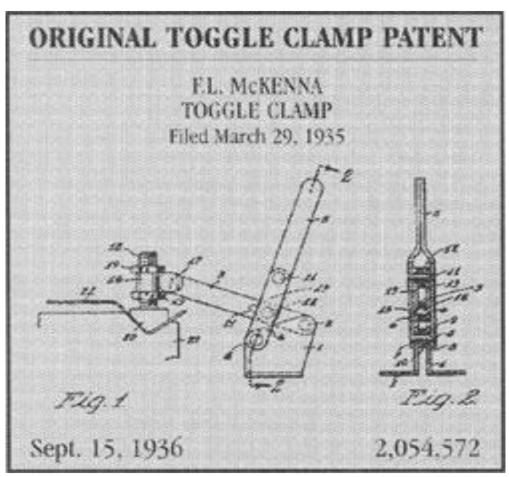


Figure 1 First Manual Toggle Clamp

A clamp is a device that used to hold or secure objects together rigidly, in order to prevent movement between the parts which are clamped or separation between the parts by the application of inward pressure. Figure 2 is taken from [2]

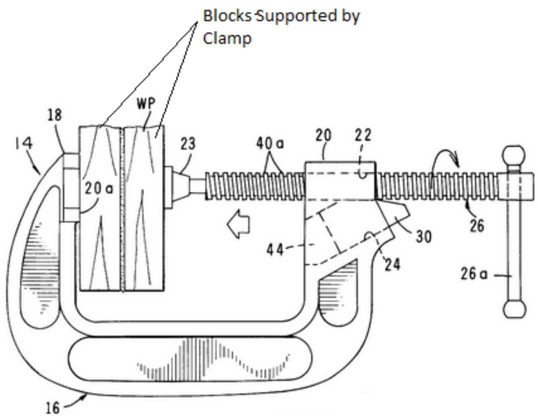


Figure 2 Clamp

Clamps are used in marine industries, which can withstand the corrosive nature of the marine and designed to withstand the shipboard environments. They also found application in automotive industries, the clamps that are used in automotive can withstand high temperatures and also they can withstand high stresses associated with automotive components. Clamps which are used in agricultural industries will be strong and durable. They also are used in medical field, in order to restrict the movement of different tissues or bones when operated.

1.1.1 Characteristics for Selecting Clamps

Clamp need to have high clamping forces, low actuation torques , large path of operation, high operational safety, control on clamping force, easy to install, economical clamping technology, more humane workplace, reduced risk of accidents simple , manual operation or automatic mode ,versatile application through compact and flexible design. These are few characteristics which need to be considered while selecting a clamp [3].

1.2 Types of Clamps

Clamps come in many sizes and shapes. Some can be used for many situations and some can be used for specific requirement. Some clamps may be expensive and some can be improvised. Different types of clamps are available in market depending upon their requirement. Some of them are

a.) Bar Clamps
b.) Pipe Clamps
c.) C Clamps
d.) Spring Clamps
e.) Band Clamps

Another method of clamping includes hand screws, bench vices, bench hold downs and vacuum clamps.

a.) **Steel Bar Clamp:** These type of clamps are usually used in assembling cabinets or furniture's. It is mostly used when it need to be glued edge to edge. Generally Work piece is placed in between the two jaws. Clamp height range is 2 to 9 feet. Movable jaw of the clamp has a friction to hold the work piece in desired position, other end of the clamp is used to apply pressure. For lighter duty applications the friction catch and tightening screw will be on same jaw. These type of clamps can damage the surfaces and finished surfaces, so they need to be protected by scrap placed between jaws of the clamp [4].

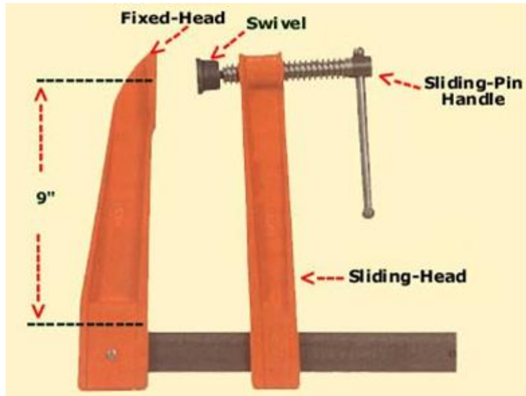


Figure 3 Steel Bar Clamp

b.) **Pipe Clamps**: These are similar to bar clamps except that round shafts are used in place of the flat bar that holds the jaw. These are less expensive when compared to bar clamps. They almost find the same application as of Bar clamps [4].

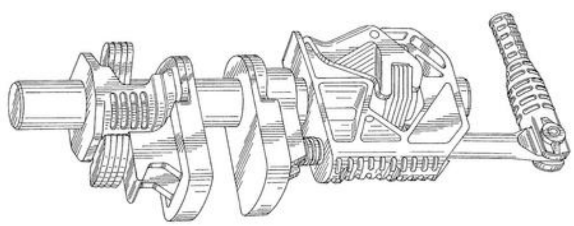


Figure 4 Pipe Clamp

c.) **C- Clamps**: These clamps are also recognized by other names such as carriage clamps or G clamps as they appear in the shape of "G". Most versatile and widely used clamps now a days. The distance between both jaws varies in between 1inch over 8 inches. They have got a machine screw, by tightening it clamping action is generated. Swiveling foot right at the end of the screw that will move to allow tight clamping pressure, against a slanting surface or an irregularly shaped piece. There is chance of surface getting damaged by these clamps, so work piece need to be protected by using scrap between two jaws[4]. C – Clamps is shown in Figure 2.

d.) **Spring Clamp**: In this type of clamping, pressure remains constant depending on tension of spring. Serrated teeth is used to grip the work piece held at irregular angles, they may also have soft plastic ends to prevent from spoiling the work piece [4].

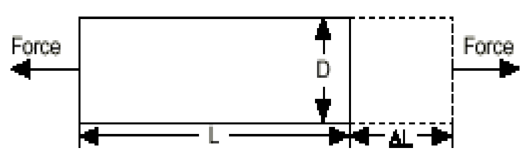
Figure 5 Spring Clamp

e.) **Band Clamps**: In this type of clamp, the screw or ratchet mechanism applies clamping pressure by which band gets tightened. When surface are not parallel to each other, these type of clamps comes into play or when from multiple directions, the pressure is needed at once. These type of clamps provide high strength capability [4].

Figure 6 Band Clamps

1.3 Resistance Strain Gauges

Strain is the deformation in a body due to external force. It is measured as Change in length by Original Length. It is dimensionless quantity.



$$\varepsilon = \frac{\nabla L}{L}$$

To measure deformation (strain) in an object we can use several ways like pneumatic, mechanical, optical etc.; at first extension meter (extensometer) is used to measure strain in a body. Apart from the fact that the strain gauges are huge and complicated to use, it also gives us low resolutions. Later, capacitance and inductance-based strain gauges are introduced .These devices are used for purposes like sensitivity. The object whose deformation is to be measured is tightly bonded, so that the sensing element (metallic resistive foil) may expands or contract according to the strain borne by the measuring object.

They are available commercially with nominal resistance values from 30 to 3,000 Ω. Most commonly used are 120, 350 and 1000 Ω. Different types of strain gauges are available depending upon the requirement [5].

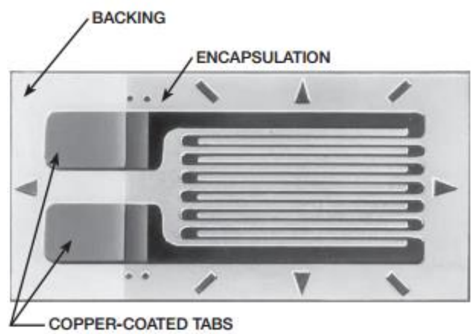


Figure 7 Strain Gauge

1.4 Literature Review

Zhengui Zhang et al [6], built a model of V-band clamp to determine the contact pressures generated between the piping systems, in particular, bellow and manifold. The approaches for this analysis include theoretical modeling, finite element analysis (FEA) using COMSOL multi-physicals, and experimental validations. The analytical results are utilized to optimize the design of V-band clamp for releasing the peak stress trunnion and eliminating its nearby warping effect.

Shoghi et al [7], explained the theory that was developed to allow the stress distribution to be calculated in terms of applied torque and displacement. The developed theory was validated with experimental data for both non-contact and contact with friction stages of operation, giving a knowledge base for the rational design of V-section band clamps.

Z.Y. Qin et al [8], proposed a model that can represent the nonlinearity of the clamp band joint and be used conveniently to investigate the effects of the structural and loading parameters on the dynamic characteristics of clamp type of joint system.

S M Barrans et al [9], provided an understanding of how a model should be set up to investigate the ultimate axial load capacity of V-section band clamps. In future work, it was proposed that the model will be improved to predict the interplay of elastic and plastic deformation mode, taking into account the influence of several V-band diameters.

1.5 Objective

My main objective of this thesis is to provide a validation report by comparing the Static and dynamic behavior of joints supported by V band clamp with T bolt and supported by nut and bolt. Static testing and Dynamic Testing is performed experimentally and Computational analysis has been done.

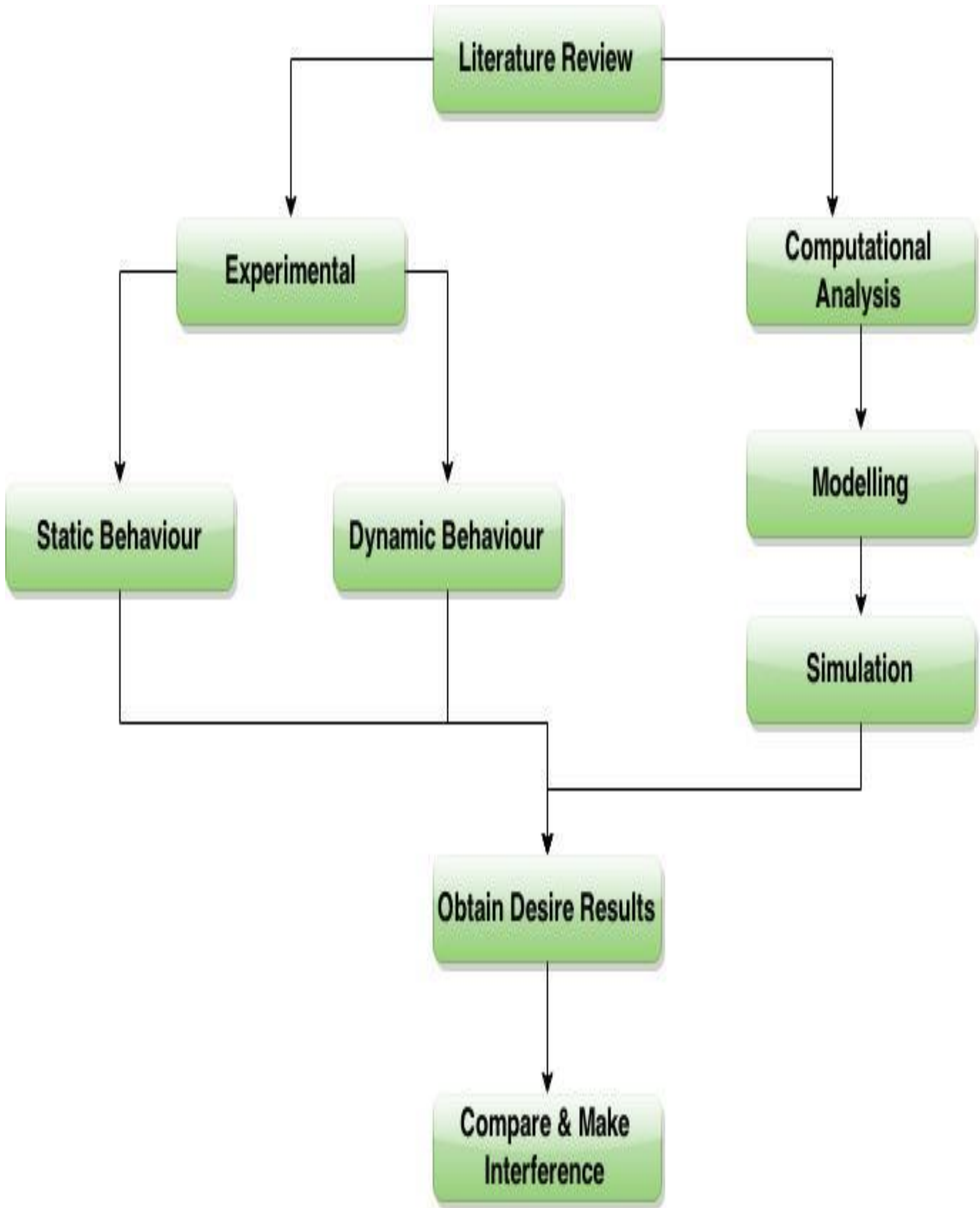


Figure 8 Objectives of My Thesis

CHAPTER 2

CONCEPTS OF DESIGN

2.1 V Band Clamp

Inventor Herbert "Zeppo" Marx, the youngest of the Marx brothers, he was the one who established Marman Products Company, Inc. of Inglewood, California. In 1941 he found Marman Company, whose products are clamping devices. V - Section band clamps are used in wide range of application in aerospace and automotive industries. They were invented during the Second World War by the Marmon Corporation and are nowadays used to connect the housings of diesel engine turbochargers and also to assemble satellites to their launching device [9].

V band clamps are one of the most popular bands used in automotive exhaust. They can be used to hold any flanged joints together. They found their application from light duty to the most demanding purpose. These types of clamps are produced in wide range of materials for application that requires a leak-free, easy to use restraint device [10].

Figure 9 V Band Clamp with T bolt

2.1.1 Working Principle of V Band Clamp

By tightening of the clamp nut results in the application of a radial force due to the increase in tension in the band. The wedging action of the band on the flanges then generates an axial load that can seal the joint and allow it to sustain applied rotational and bending moments. [7].

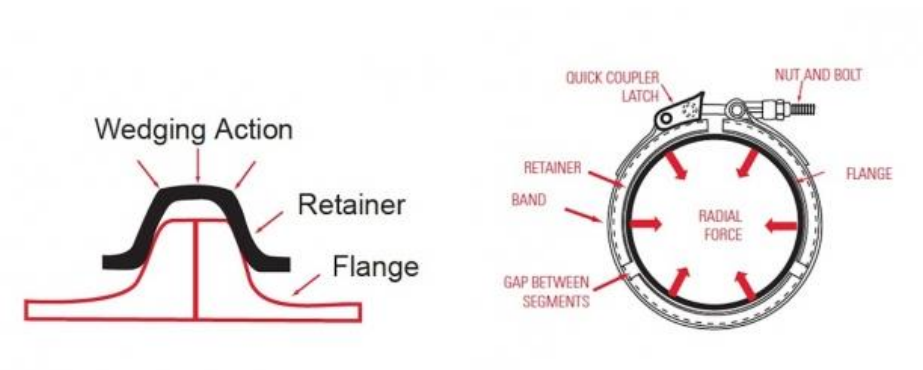


Figure 10 Working Principle of V band

"V-Band clamps are basically a positive attachment retention system for tubing and components."

– Rob Stevenson of Race part solutions [10]

2.1.2 Advantages of V band Clamp

In contrast to other bolt clamps the connections made by V-band clamps are quicker, lighter and easier to dismantle the connection. Requires less installation time and also cheaper when compared to all other clamps in terms of maintenance cost also. They provide extra strength by absorbing the load applied in circumferential direction and also applies uniform clamping force around the flanges. They got improved appearance and reduce in weight of band.

2.1.3 Applications of V band Clamp

In order to achieve good axial strength and torsional rigidity these are used in auto motives, aircrafts. V band clamps are used in diesel engines and turbochargers exhaust. V band clamp also plays a key role in holding tubes, filter vessels, pumps. In space vehicles and satellite launch these V band clamps are used in pay-load separation and launch lock applications.

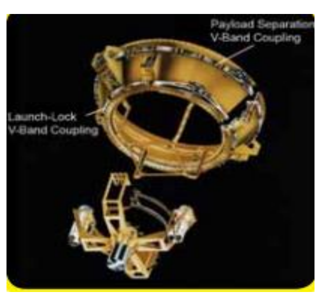


Figure 11 V band Application in Satellites

2.2 Parts of V band

The V band clamp assembly is composed of a band, three pieces pf V –shape retainers, T-bolt, trunnion and nut. The ends of the band are back bent to provide the pivoting holes for T-bolt and trunnion [6].

2.2.1 V - Shape Retainers

V Retainers are mainly used to wedge onto and hold the flanges. V retainers are available in market in different segments. More the segments more is the flexibility. Retainer with single segment is least flexible and if its needed in application of holding small diameter's they are not the correct choice. One of the most popular device is retainer with three segments .The main advantage of this it provide uniform clamping force. It can used for smaller as well as larger diameter.

Designers should have clear picture about the loads and operating temperature of V retainer's application. Coupling's total load can be determined by the following factors [11]

$$N_p = \frac{pD_s^2}{4D}$$

$$N_B = \frac{4M}{pD^2}$$

$$N_A = \frac{A}{pD}$$

Material Considerations Several rules of thumb help engineers choose the right coupling material.

- 316 CRES - For salt water or other corrosive environment.
- For applications over 400 °F Aluminum cannot be used.
- For applications over 600 °F Titanium cannot be used.
- Stainless Steel cannot be used ,if it's application is over more than 800 °F
- For applications over 1000 °F A286 cannot be used.
- For applications over 1200 °F cannot be used [12].

Figure 13 represents the V Retainer that has been model for this thesis. Material assumed is Stainless Steel AI 304, as this metal is resistant to corrosion, oxidation. It has got improved weld ability.

Figure 12 V Shape Retainer

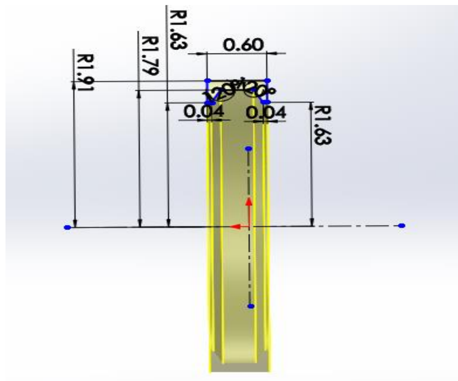


Figure 13 Dimensions of V Retainer

2.2.2 T bolt

A headed bolt with T shaped head. It is used to tighten the band. It provides more clamping force. V band clamp with T bolt are developed for Heavy Duty, Maintenance-Free, Long Life Performance.

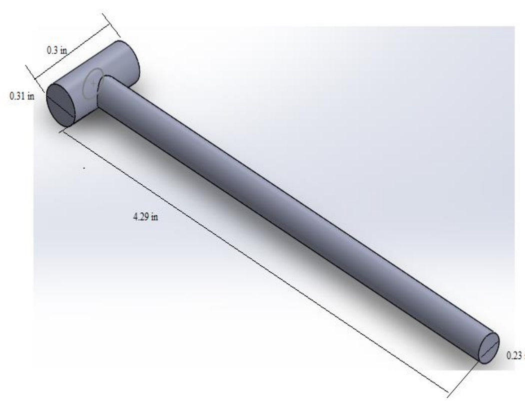


Figure 14 T- bolt

It can be used for higher torqued assemblies by creating more efficient and tightening mechanism. It has got strongest trunnions available for this type. (Stainless is standard instead of plated steel). Installing this kind of bolt is easy. It has got attention to detail (like smooth edges and quality materials).There is a chance of slight variation in allowance in hose diameter and shape by using T bolt. These are few advantages of T bolt.

Though it has got several pros, even very best t-bolt clamps won't work properly, if they aren't the perfect size. Any small error in the measurement of the diameter can make a big difference.

2.2.3 Trunnion and Nut

It is a cylindrical protrusion used as a pivoting point or mounting, it found application in canon, which are usually used military purposes.

Figure 15 Trunnion in Military

Whereas in V Band clamp it acts like cylindrical protrusion through which T- bolt passes through it, one end of a T bolt provides bearing surface for nut and other end pushes the loop towards clamp. T bolt with Trunnion is the best fit, when you don't want to remove the clamp once it is fixed. This latch is stronger than any other latches and will work on any size clamp.

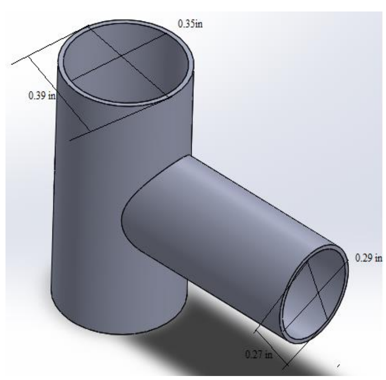


Figure 16 Dimensions of Trunnion

2.2.4 V band Assembly

V Band with T bolt latch type is used in this thesis, because it is strongest of all clamps. It can be used to support any kind of joints. It has got high reliability when compared to others. V band has been designed in SOLID WORKS software and it is imported into Finite Element Analysis Software to perform static and dynamic analysis. Solid works is one most compatible and user friendly software.

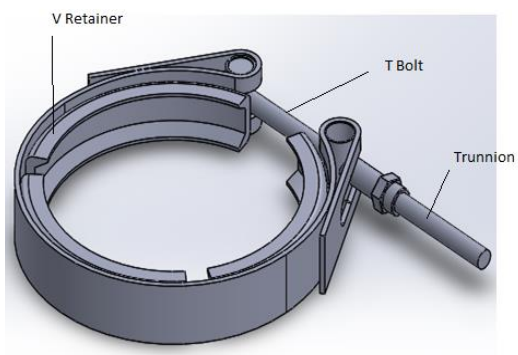


Figure 17 V band with parts

Before performing analysis few assumptions are made .They are

1. All components of clamp band joint system respond in a linear elastic manner.
2. Friction between the metal plates and the V-segments is ignored [6].

In this thesis, two kinds of support has been chosen to determine the static and dynamic behavior of the cylinder.

1. Joints supported by nut and bolt.

2 .Joints supported by V band Clamp with T bolt.

2.3 Assembly of Cylinder with Nut and Bolt

In this the two cylinder need to be supported by means of a nut and bolt. Some of the assumptions while designing and performing analysis are:

1. Length of each cylinder is 6 inch.
2. Material opted is Stainless Steel AI304
3. Nut is of type M6.

In order to design assembly the following parts need to be designed first. Cylinder of outer diameter 3.20 inch with 0.12 thickness is designed. One end of a cylinder is designed in the shape of flange whose inner diameter would be around 3.02 inch.

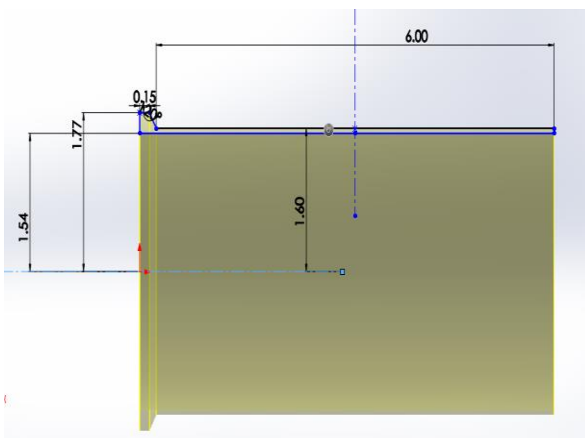


Figure 18 Dimensions of cylinder with flanges

Once cylinder with flanges designing is done, 8 holes of M6 has to be drilled on each flanges, in order to support two cylinders with nut and bolt.

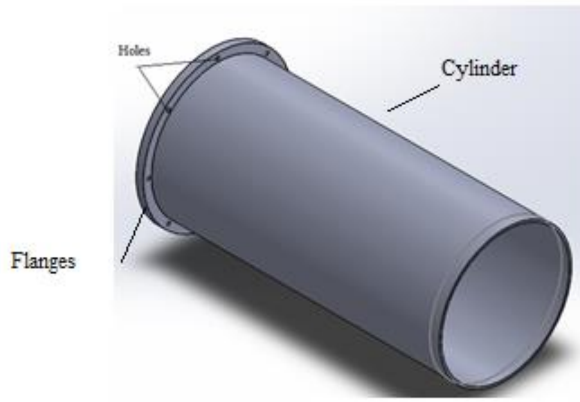


Figure 19 Cylinder with flanges and Holes

Once after you drill hole, nut and bolt need of type M6 has to be modelled in order to support the cylinder. Dimensions of nut and bolt are shown below.

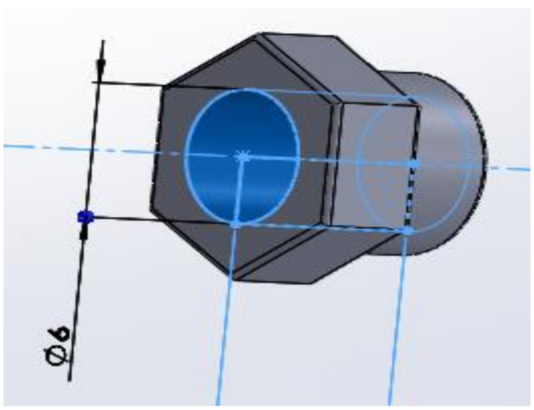


Figure 20 Nut with Dimensions

After modelling all the parts, it need to be assembled and make it ready for importing it into Finite Element Analysis Software. Figure 22 shows the final assembly of a Nut and bolt support.

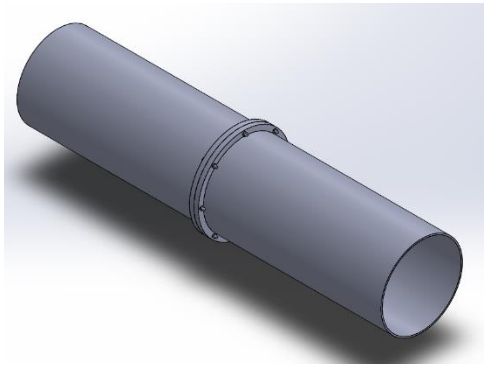


Figure 21 Final Assembly of Nut & Bolt Support

2.4 Assembly of Cylinder with V band Clamp with T Bolt

In this the two cylinder has been joined by means of a V band Clamp. Some of the assumptions while designing and performing analysis are:

1. Length of each cylinder is 6 inch.
2. Material opted is Stainless Steel AI304
3. V band is of 3 segments with T bolt latch Type.

In order to design assembly the following parts need to be designed first. Cylinder of outer diameter 3.20 inch with 0.12 thickness is designed. One end of a cylinder is designed in the shape of flange whose inner diameter would be around 3.02 inch. Same as in Nut and Bolt support. Once after modelling two cylinder with flanges of same type it need to be supported by V band clamp with T bolt which we modelled it previously i.e. in Figure 20.Figure 23 shows the final assembly of V band clamp support.

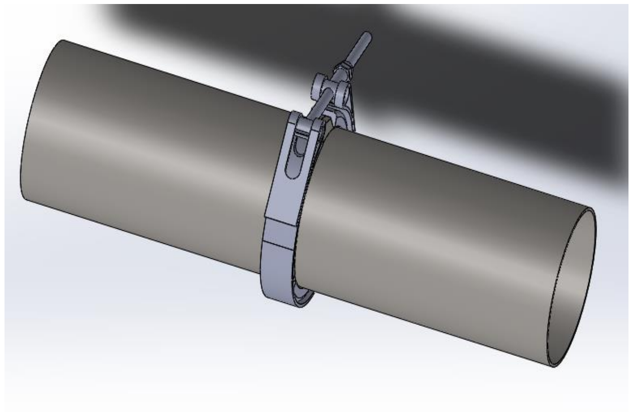


Figure 22 Final assembly of V band Clamp support

Modelling of joint supported by V band clamp and joint supported by nut and bolt has been done. Now both the joints are ready to perform Static Structural Analysis and Dynamic Analysis in ANSYS.

CHAPTER 3

STATIC AND DYNAMIC TESTING

3.1 Resistance Strain Gauge Installation

3.1.1 Cleaning Procedure on which Resistance Strain gauge need to be installed

Before installing the strain gauge, its surface need to be cleaned, no more than 30 minutes prior to installation. Surfaces need to be cleaned by sand paper of grit size 320.After cleaning, apply one or two drops of M – prep Conditioner A to cleaned area. Again clean the area with 400 grit size sandpaper to remove the stains especially paint in area where it is need to be installed. Use gauge sponges to clean the surface. Clean until no traces of stains is seen on gauge sponge. Again apply one or two drops of M-prep Neutralizer 5A and scrub the area by making a single stroke across the cleaned surface. Clean until there are no stains on gauge sponges. Pencil line can be used for proper alignment of gauge.

3.1.2 Gauge Preparation and Installation

Never ever touch the strain gauges with hands, always use tweezers to handle gauges. As they are most sensitive, so one need to handle it with proper care. Take the gauge out of Mylar tape by using tweezers. Place the strain gauge on a chemically clean surface.

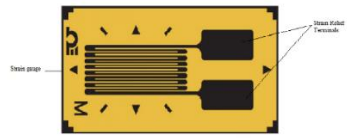


Figure 23 Strain gauge

Once after placing strain gauge on cleaned surface, align (100 mm) of M-LINE PCT-2A cellophane tape over the length of a cleaned surface. Ensure that the gauge is centered in the tape strip. Then apply some pressure on tape by wiping it, to make sure that gauge sticks to M –LINE PCT -2A cellophane tape. Take out the tape gently at an angle less than 45° to lift the gauge and terminals off the cleaned surface. Be cautious and do not over bend the tape and ruin the gauge. Place the strain gauge in the appropriate location and anchor one side of the tape to the cleaned surface. Gently apply the pressure on the tape down to place the gauge and make sure the alignment. Place the strain gauge as required.

Figure 24 Alignment of Strain gauge

Now slowly lift the tape at a shallow angle less than 45°, so that strain gauge comes along with the tape. Once that is done fold the tape under and tack it behind the gauge. After doing that apply M-bond catalyst sparingly in a uniform coat. Clean the catalyst brush, and brush the surface with single strokes that covers entire length of gauge. Make sure you cover entire length of gauge in one stroke. After applying allow it to dry for at least on minute. After allowing it to dry, apply M bond 200 adhesive at the junction of the tape and nearest to the surface. Rotate the cellophane tape towards the bonding side, now gauge will be at proper position but not in contact with surface. Immediately apply pressure on the gauge by using thumb, if any excessive adhesive leaks from side, try to clean without releasing pressure. Wait for at least 2 minutes till adhesive gets set. Remove the tape from surface carefully, so that gauge doesn't come out with tap

3.1.3 Lead Wire Attachment

First and foremost important thing before attaching lead wires is to prevent the gauge from overheating, which may damage the gauge. In order to prevent from overheating, cover the strain gauge with a drafting tape and make sure the soldering tabs are only exposed. Once it is covered the tip of soldering iron should be cleaned on the wet sponge pad, then tin the soldering tip with some solder. Place end of the solder across the solder tab and apply the iron tip onto the solder. Apply little pressure about second and remove both the solder and the iron simultaneously. Until you have a nice even mound of solder on each solder tabs repeat the above procedure. Strip and tin the wires. The wires need to be bended in such a way that there will be a small bend between the strain relief and the gauge when the wire is soldered to the gauge. Wire assembly need to be tapped by using drafting tape. While feeding a small amount of solder between the iron and the wire, the soldering iron need to be pressed onto the wire over a pad. The wire should go into the melting solder gently. Allow it for some time to cool before handling it. Repeat Above procedure for each solder tab. Leftover flux from the solder should be removed with a gauze sponge soaked in rosin solvent. Once the lead wires are connected check the resistances between leads with help of a multi meter.

3.2 Static Testing Of a Cylinder Supported By A V Band Clamp.

3.2.1 Experimental Analysis

In order to perform experimental Analysis, the following things need to be done prior to it. First get an exhaust tube of Outer diameter 3.00 inches and thickness of 0.09inches of length 2 feet which need to be cut into four equal parts i.e. 6 inches each.

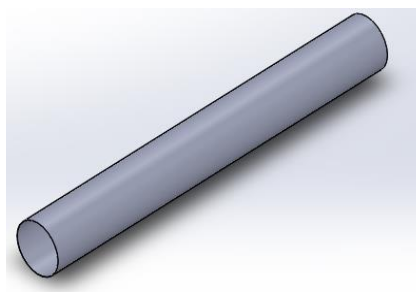


Figure 25 Exhaust Tube (i.e. Cylinder)

Once it cut into 4 pieces, take two pieces and a pair of flanges. Weld each flange to one end of a cylinder by using MIG welding. MIG welding parameters are 16.5 Volts and 235 Feed Rate. Once welding is done, support both the cylinders with the help of V band Clamp with T-Bolt. Figure 27 shows two cylinder with flanges supported by V band Clamps and torque applied on nut of V band clamp is 10lbf.

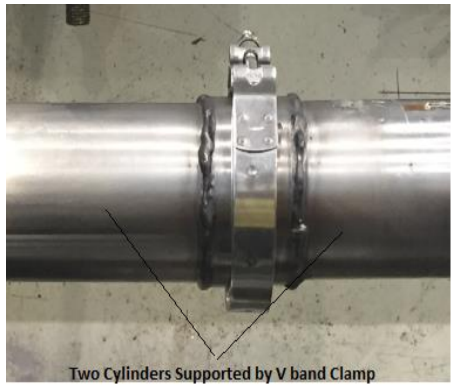


Figure 26 Cylinders supported by V band clamp

Once cylinders are supported by V Band clamp, it should be provided with cantilever support. Before that strain gauge need to be installed of type CAE-06-240UZ-120 with lead wires soldered by following the procedure in Section 3.1 .After installation cantilever support need to be provided , in order to do that one end of the cylinder is welded one of the flange using MIG welding. Figure 28 shows the strain gauge which is used for analysis and Figure 29

Shows the position of installation.

Figure 27 Strain Gauge

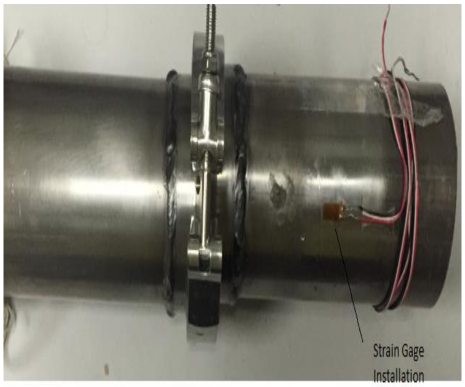


Figure 28 Strain Gauge Position

After installing strain gauge, two cylinders with V band clamp support and strain gauge installed should be supported with the help of a lathe chuck (i.e. Cantilever Support) as shown below in Figure 30.

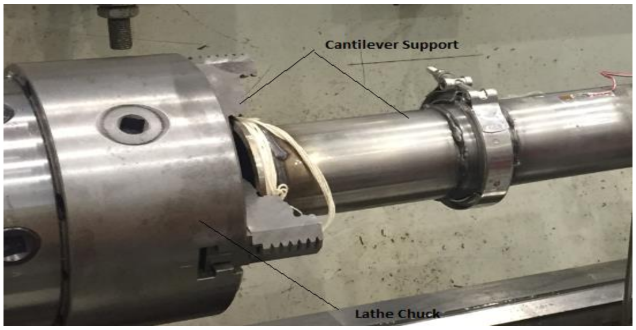


Figure 29 Cantilever Support

Strain gauge with lead wires need to be connected to strain indicator for strain measurement. It need to be connected in a quarter bridge connection, i.e. red wire goes in red terminal and white and black wire goes in black terminal.

Figure 30 Strain Indicator with Lead wire connections

Before performing experiment, adjust the gauge factor as listed on strain gauge package i.e. 2.10, and ensure that strain reading is zero. Check the connections properly, before starting. After that load the free end of a cylinder transversely by hanging weights in the range of 1kg -6 kg with an increment of +1. While when your loading elastic strain reading in strain indicator fluctuates, allow it for few seconds to get stable. Once it is stable make note of the strain reading. Once after remove load the strain reading need to be zero again. Figure 32 shows the experimental setup for cylinder supported by V band clamp with T bolt.

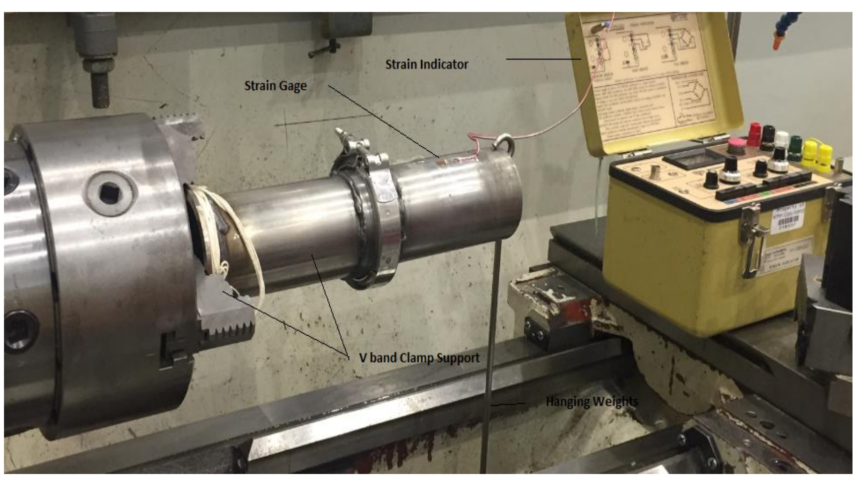


Figure 31 Experimental Setup for cylinder supported by V band Clamp with T bolt

Theoretical Stress Calculations

When thin cylinders whose thickness is far less than Outer diameter (t >> D_o) are subjected to internal pressure,

- Circumferential Stress or Hoop's Stress
- Radial Stress
- Longitudinal Stress

These three mutually perpendicular principle stresses will set up in cylinder.

Circumferential Stress or Hoop's Stress

This is the stress which is set up in resisting the bursting effect of the applied pressure and can be most conveniently treated by considering the equilibrium of the cylinder [13].

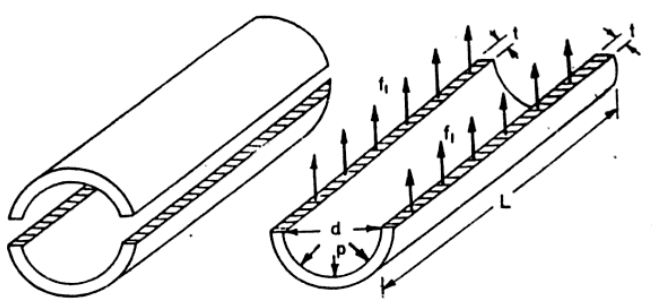


Figure 32 Hoop Stress

p = internal Pressure

t = Thickness of the wall

L = length of cylinder

d = Inside diameter.

Force Acting on the cylinder = Internal Pressure x Projected Area.

$= p \times d \times L$

$=$ pdL … …….. (1)

Resisting Force owing to hoop's Stress (□$_{H}$) set up in walls of cylinder.

$= \mathbf{2 . \sigma_H . L . t}$ --------- (2)

Because □σ_H.L.t. is the force in the one wall of the half cylinder.

Equating equations (1) & (2) we get

$$\mathbf{2 . \sigma_H . L . t = p . d . L}$$

$$\square\, \sigma_H = (p. d) / 2t$$

Circumferential Hoop's Stress is $\sigma_H = (p. d) / 2t$

3.2.2 FEA Analysis

Once designing of Assembly of cylinder supported by V band clamp is done, then it need to be imported in Ansys Software for simulation. This is it how it looks when it is imported in Ansys.

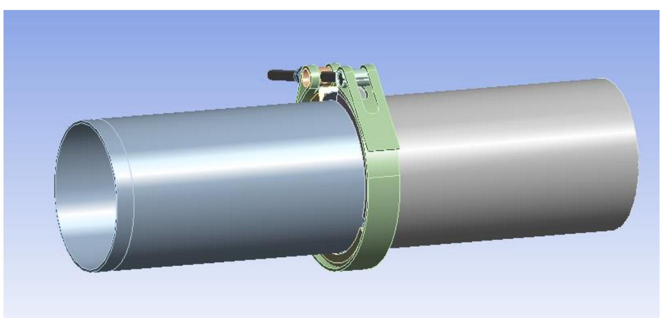


Figure 33 Model Imported into Ansys

After importing, the first and foremost step is assign material properties. Material used is Stainless Steel AI 304. Material data was taken from experimental test carried by Shoghi [7]

Young's Modulus – 227 GPA

Poison Ratio - 0.29

Density – 0.23 lb. /in3 (or) 8.03 gm/cm3

Ultimate Tensile Strength – 860-1000Mpa (857 MPA)

Yield Strength – 515 MPA

After assigning material properties proper connections need to be given for better results like no separation, bonded, frictional support, and frictionless support. Figure 35 representing frictional contact between V retainer of V band clamp and flanges of cylinder.

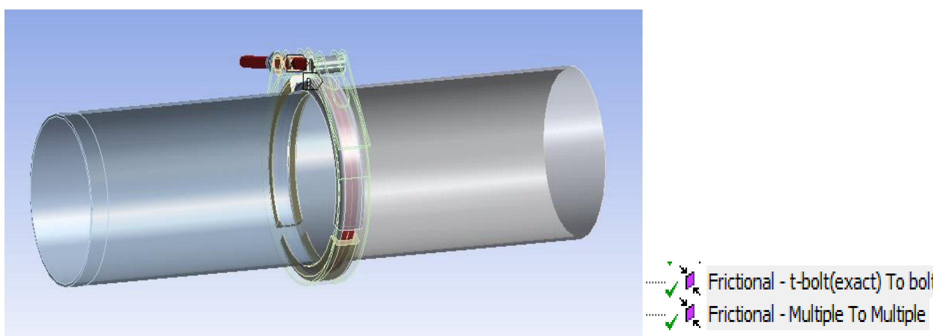


Figure 34 Frictional Contacts

Figure 36 shows non separation contact between various parts of V band Clamp with T bolt and cylinder with flanges

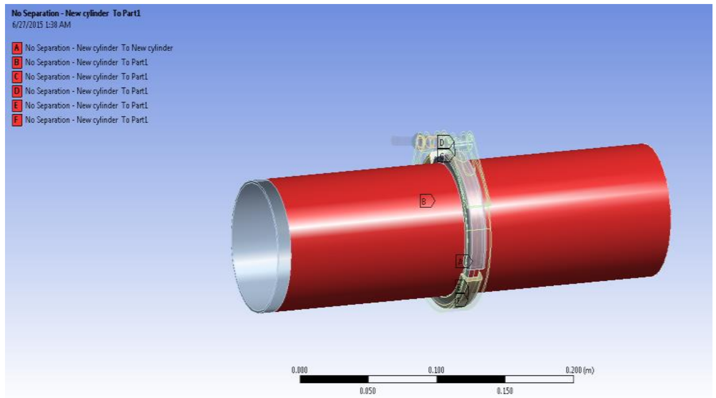


Figure 35 No Separation Contact

These are the connections which are assigned to different parts of assembly. After giving connections, next thing is to mesh the cylinder as fine as possible because we are concentrating on cylinder behavior. Method followed is Patch conforming method and type of elements is Tetrahedron.

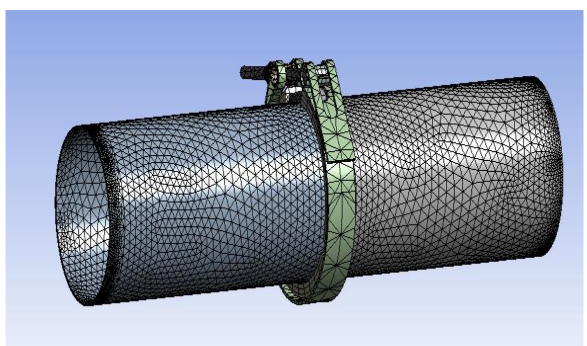


Figure 36 Meshing

These are the boundary conditions which are used in this thesis, in order to determine the static structural behavior when cylinder supported by V band Clamps. Force acting vertically downwards.

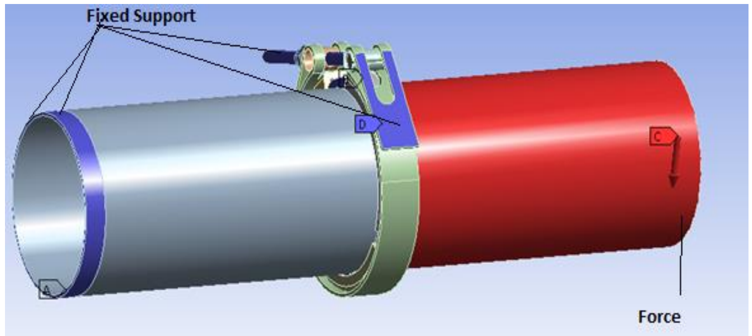


Figure 37 Boundary Conditions

Results are explained in Chapter 4 section 4.1.1

3.3 Static testing of a cylinder supported by Nut and Bolt.

3.3.1 Experimental Analysis

Follow the same procedure which is discussed in 3.2 .1(i.e. Static Testing of a cylinder supported by a V band Clamp) but instead of supporting with a V Band clamp, support it with nut and bolt by drilling 8 holes to the flanges and load the cylinder with increasing weight gradually and find out the strain readings from the strain indicator and calculate the theoretical stress values respectively. Dimensions of the holes are M6 Diameter. Nuts used to support the cylinder of Dimension 6-32 x 3/8 inch. Same amount of torque need to apply to tight the nut i.e. 10 lbf. Figure 39 shows the experimental setup of cylinder supported by nut and bolt. Results are explained in Chapter 4 section 4.2.2.

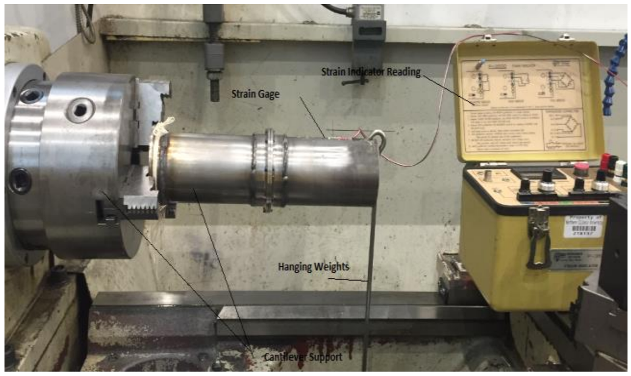


Figure 38 Experimental Setup for Cylinder supported with nut & Bolt

3.3.2 FEA Analysis

Cylinder with nut and bolt support which was already modelled in section 2.4 is imported to Ansys. Figure 40 represents cylinder supported by nut & bolt imported in Ansys

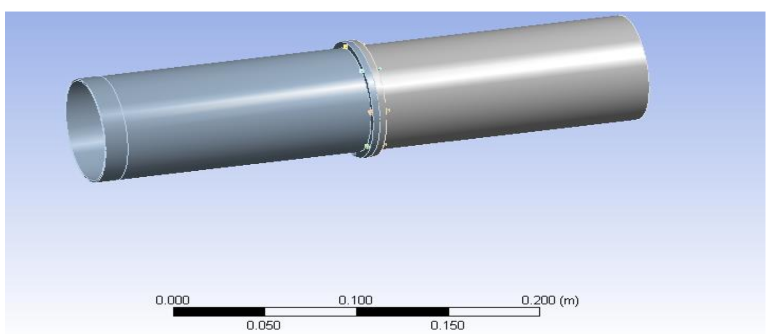


Figure 39 Model Imported into Ansys

All parts of the assembly are given bonded contact. After assigning connections, meshing is done. Method followed is patch conforming and type of elements are tetrahedron.

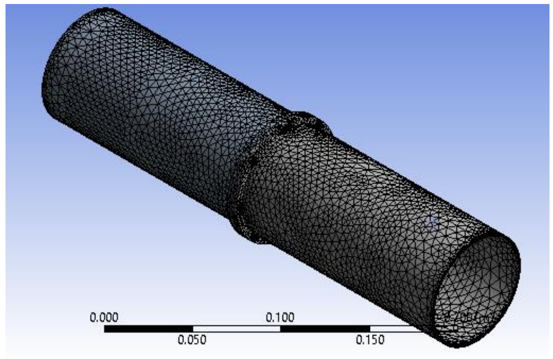


Figure 40 Meshing

These are the boundary conditions given to determine the static structural behavior of cylinder supported by nut & bolt. Blue indicates the fixed support and red color indicates plane on which force is acted and arrow indicates the place and direction where force is acted.

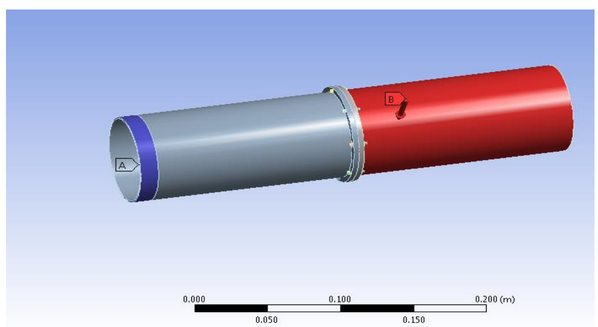


Figure 41 Boundary Conditions

Results are explained in Chapter 4 Section 4.1.2

3.4 Dynamic Testing of a cylinder supported with V band Clamp

3.4.1 Experiment Analysis

Equipment required for dynamic testing is shown in Table 1

Table 1 Equipment required for Dynamic Analysis

Quantity	Device Name	Serial Number #
1	Laptop	292345
1	Power Cord	N/A
1	NI 9234	292390
1	NI USB – 9162	3FD4A0
1	USB –B Cable	N/A
1	Unidirectional Accelerometer	39168
1	Amplifier	N/A
1	Microdot to BNC cable	N/A
1	BNC Cable	N/A
1	Beeswax	N/A
1	Tape	N/A
1	Impact Hammer	236115

Experimental Procedure (Lab View)

Open the lab view and open "Blank VI". "Save As" your VI. After opening Blank VI, click right click on Front panel go to graphs and click on wave form graph. Then create Time Domain and Frequency Domain graph. Trace the output from the DAQ Assistant in the time Domain. Perform spectral measurement on the time signal and plot that on the frequency domain graph. Click Right on block diagram window and open DAQ Assistant properties. In the channel setting box, click details. Ensure the physical channel matches where you plugged in the BNC cable and that the device type is USB – 9234. If this is wrong, then right click and change the physical channel to the correct one. Press Ok in the DAQ Assistant properties box. Open DAQ Assistant properties, adjust the number of samples such that it takes 10 seconds of data. Pull the beam downward and let's go so that it begins to vibrate. Wait for 2-3 seconds so that it reaches steady state vibration and then press run. Time domain amplitude is too low, change the gain on the amplifier. Do not let the voltage go above volts. Keep an eye on Force and accelerometer. Change the hammer tip and repeat the experiment. Observe the effect of various digital signal processing issues.

Set-Up Procedure

Take two cylinders which are supported by V band clamp and install it in the chuck of lathe. After fixing it in lathe Chuck, attach the accelerometer on the free end of cylinder. First Choose an Accelerometer. Attach the accelerometer to the top or bottom of the blocks using bees wax. The arrow on the accelerometer determines the direction that the accelerometer can measure acceleration. Ensure that this pointer is pointing either up or down. The wire of the microdot to BNC cable to the beam is to be taped, because in case the accelerometer falls off it does not get damaged. Do not pull the wire taut. Accelerometer is connected to DAQ using BNC Cable. After connecting accelerometer choose an impact hammer, and connect it to DAQ. Connect DAQ to computer using NI USB-9162.Plug Power Cord into Laptop and power outlet. Switch on Laptop open Lab view. After connecting everything in a proper way, give the impact to the cylinder with a help of impact hammer. After giving impact wait for 10 sec to analyze and graphs are generated to determine the frequency of the system. Run the experiment for 10 trials and find out natural frequency of system in each and every trial and find out the average frequency of all 10 trials compare with that FEA simulation frequency and determine percentage of error.

Equipment Required for Experiment Setup for V band clamp and Nut & Bolt Support

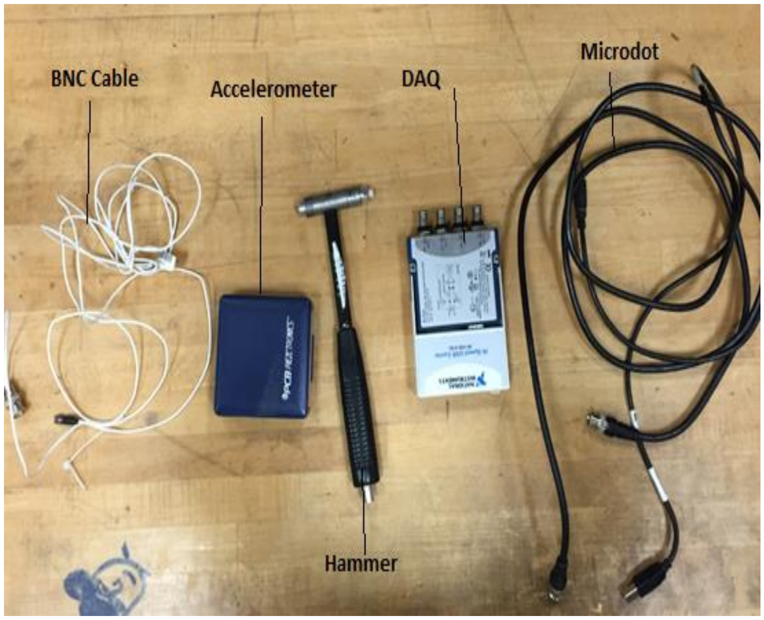


Figure 42 Equipment for experimental setup

Block Diagram of Lab VIEW

When you give impact to assembly with the help of impact hammer .it captures signals and displays in Wave Form graph and from there it goes into Spectral measurements and generates the value of frequency in waveform graph 2 of Block diagram.

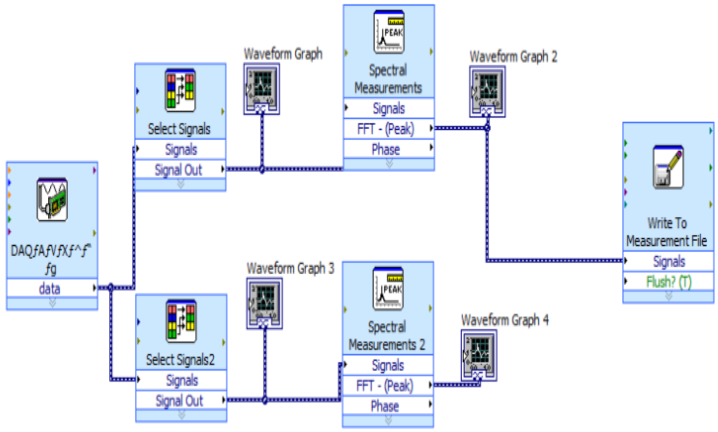


Figure 43 Block Diagram of Lab View

Figure 45 and Figure 46 shows the experimental setup for Cylinder supported with V band clamp and nut & bolt to study the dynamic behavior.

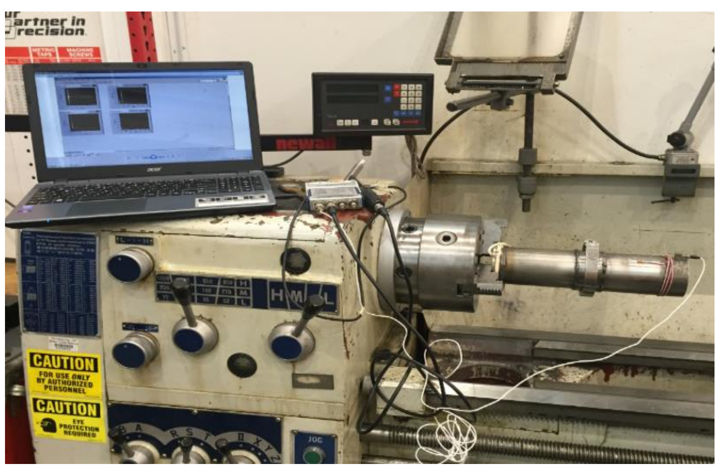


Figure 44 Experimental Setup for V band Clamp Support

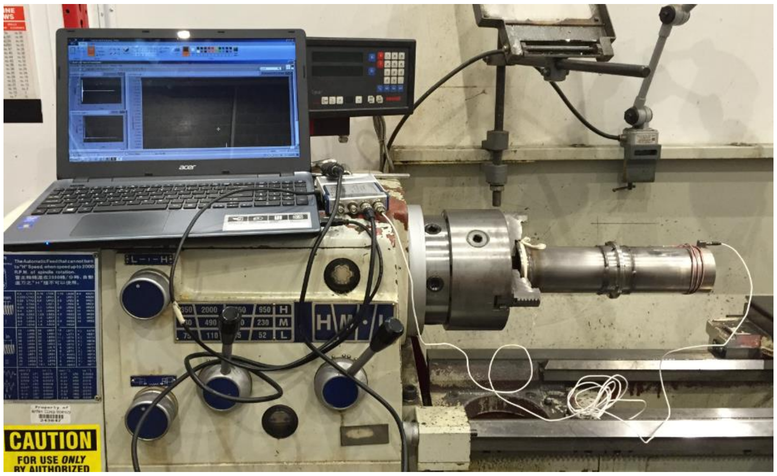


Figure 45 Experimental Setup for Nut & Bolt support

3.4.2 FEA Analysis

Once designing of Assembly of cylinder supported by V band clamp is done, then it need to be imported in Ansys Software for simulation. This is it how it looks when it is imported in Ansys.

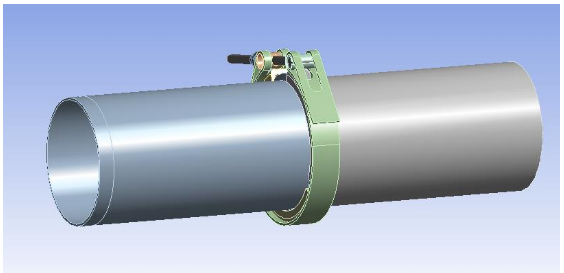


Figure 46 Model Imported into Ansys

After importing, the first and foremost step is assign material properties. Material used is Stainless Steel AI 304. Material data is same as we considered before

Young’s Modulus – 227 GPA

Poison Ratio - 0.29

Density – 0.23 lb. /in3 (or) 8.03 gm/cm3

Ultimate Tensile Strength – 860-1000Mpa (857 MPA)

Yield Strength – 515 MPA

Once you are done assigning material properties give proper connections like no separation, bonded, frictional Support, frictionless support. Figure 48 shows the contact between V retainer of V band and Flanges of cylinder and remaining contacts are assigned as no separation contacts.

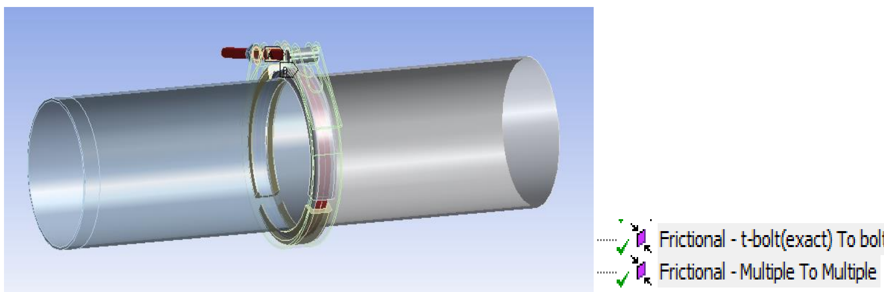


Figure 47 Frictional Contacts

Meshing need to be done, method followed is patch conforming method and type of elements is tetrahedron

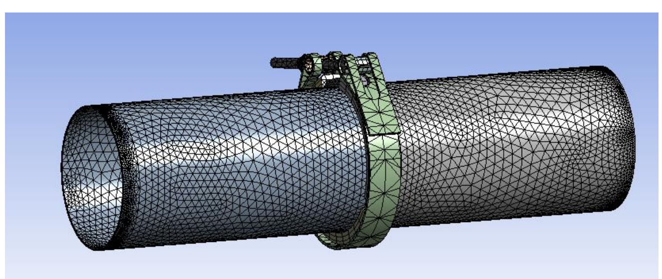


Figure 48 Meshing

Cantilever support has been given by fixing one end of cylinder to study the dynamic behavior of the model.

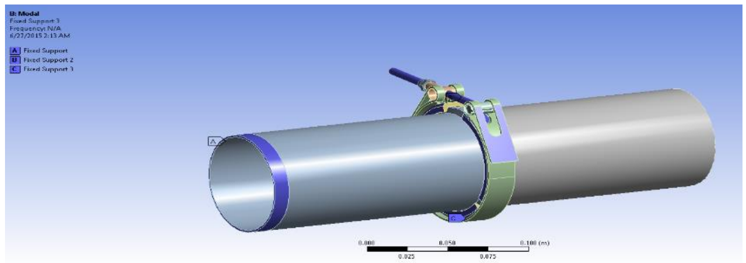


Figure 49 Boundary Conditions

Results are explained in Chapter 4 Section 4.3.1

3.5 Dynamic Testing of a cylinder supported with nut and bolt

3.5.1 Experimental Analysis

Follow the same procedure which is discussed in 3.4.1 (i.e. Dynamic Testing of a cylinder supported by a V band) but instead of supporting with a V band, support it with a nut and bolt and give impact to the cylinder with the help of impact hammer and determine the frequency of system, do this for 10 trials and find out average frequency, compare this frequency with FEA simulation and calculate the percentage error. Figure 46 shows the experimental setup of nut and bolt support.

3.5.2 FEA Analysis

Once designing of Assembly of cylinder supported by V band clamp is done i.e. in Section 2.3, then it need to be imported in Ansys Software for simulation. Figure 51 represents model imported in Ansys

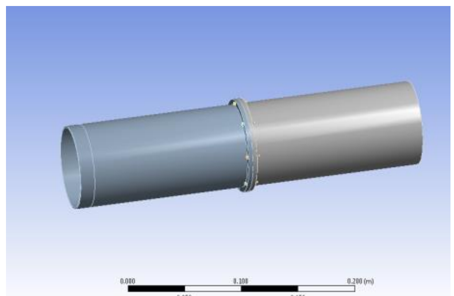


Figure 50 Model Imported to Ansys

Method followed for meshing is patch conforming method, element type is tetrahedron.

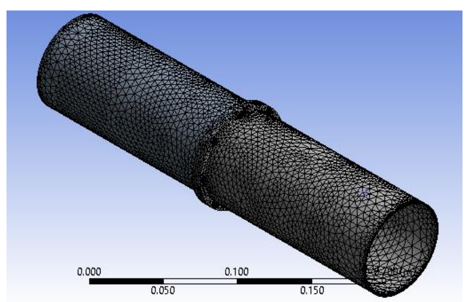


Figure 51 Meshing

Figure 53 represents the boundary conditions to determine dynamic behavior of the support.

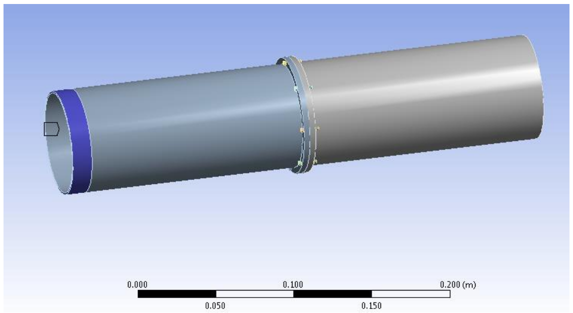


Figure 52 Boundary Condition

CHAPTER 4

RESULTS

4.1 Results from Static testing (FEA) of Cylinder Supported with V band clamp and Nut & Bolt

4.1.1 Cylinders Supported by V band Clamp

By fixing one end of the cylinder i.e. giving cantilever support and applying load transversely in gradually increasing manner run the analysis. Once analysis is completed, take note of values of equivalent strain and Von Mises Stresses. Once you obtain the respected values for all loads tabulate the values as shown below. Figure 54 and Figure 55 represents Elastic Strain and Von Mises Stress

For Load – 9.80 N

Strain

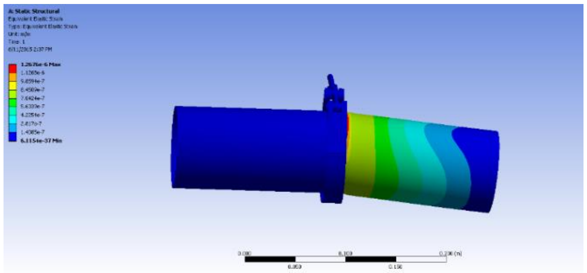


Figure 53 Elastic Strain

Von Mises Stress

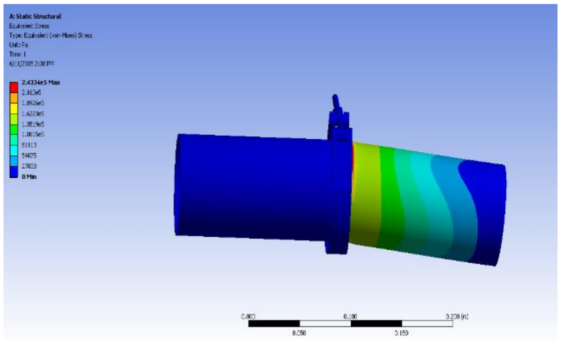


Figure 54 Von Mises Stress

FEA Analysis Results

Table 2 Static Structural Results for V band Clamp (FEA)

S. no	**Load (Kg)**	**Load (N)**	**Strain (µe)**	**Stress(N/m^2)**
1	1	9.8	1.337	2.56 x 10^5
2	2	19.61	3.45	6.62 x 10^5
3	3	29.41	5.56	10.64 x 10^5
4	4	39.22	7.04	13.51 x 10^5
5	5	49.03	8.44	16.21 x 10^5
6	6	58.83	10.91	20.95x 10^5

4.1.2 Cylinders Supported by Nut & Bolt

By fixing one end of the cylinder i.e. giving cantilever support and applying load transversely in gradually increasing manner and perform the analysis. After completing analysis take note of values of equivalent strain and Von Mises Stresses. Once you obtain the respected values tabulate the values as shown below. Blue Color indicates Fixed Support. Red Color indicates force applied on that region in downward direction

When load of 9.80 N is applied

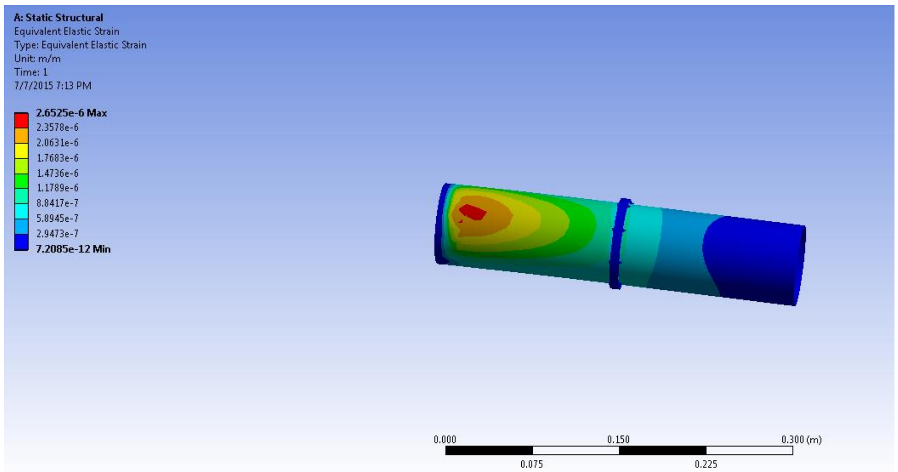


Figure 55 Elastic Strain

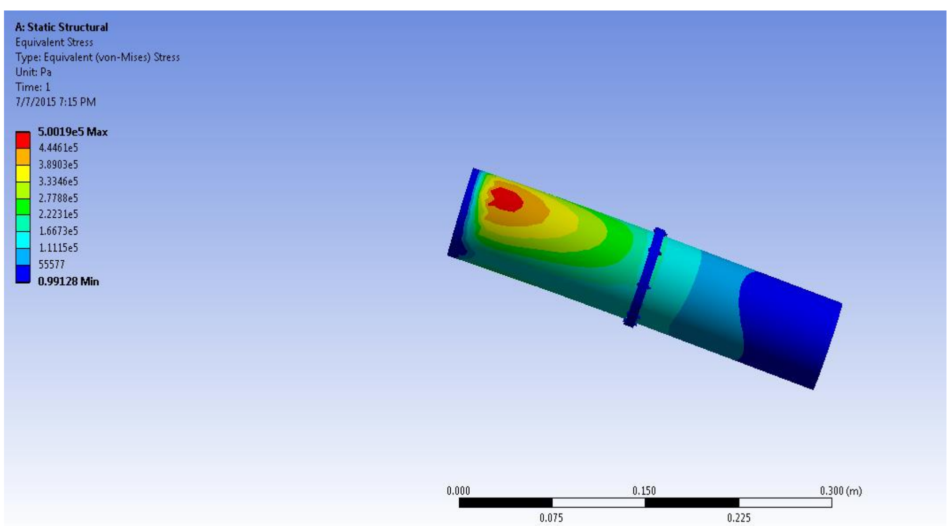


Figure 56 Von mises Stres

Table 3 Static Structural Results for Nut & Bolt Support (FEA)

S. no	Load (Kg)	Load (N)	Strain (μe)	Stress(N/m^2)
1	1	9.8	2.65	5.0×10^5
2	2	19.61	5.31	10.02×10^5
3	3	29.41	7.96	15.01×10^5
4	4	39.22	10.61	20.18×10^5
5	5	49.03	13.21	25.02×10^5
6	6	58.83	15.92	30.02×10^5

4.2 Results from Experimental Structural testing of Cylinder Supported with bolt and nut & V Band

4.2.1 Structural Testing of cylinder supported by V band clamp with T- Bolt

In this a cylinder of exactly same dimension as that of FEA analysis is chosen and strain gage need to be installed as per Chapter 3.1 instructions. Once after giving cantilever support started loading the cylinder transversely, and make note of the reading from strain indicator. As we have all input perform theoretical Stress calculations. After obtaining the required values tabulate the readings as done below.

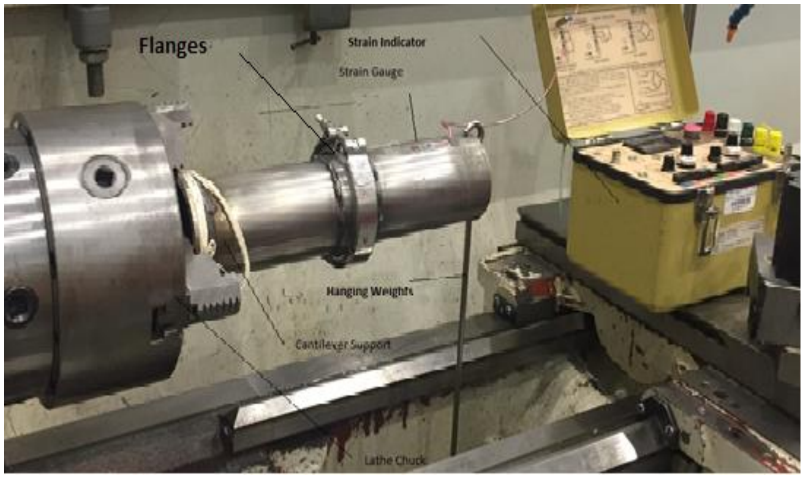


Figure 57 Experiment Procedure Setup

When load of 19.61 N, cylinder slightly deforms from its original position and it is indicated by strain indicator. Figure 58 indicates strain reading.

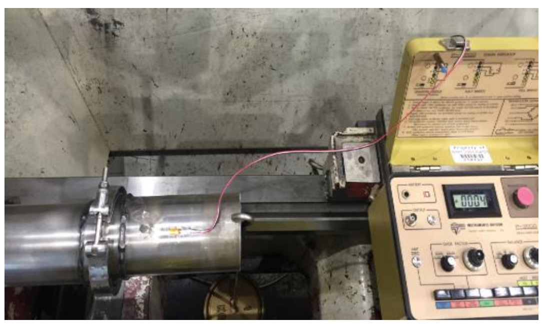


Figure 58 Strain Reading for V band Clamp Support

4.2.1.1 Experimental Strain Values

Strain results obtained by loading the cylinder in gradually increasing manner is tabulated and shown below in Table 4

Table 4 Static Structural Results for V band Clamp (Experimental)

			Strain (µe)			
S. no	**Load (Kg)**	**Load (N)**	**Trial 1**	**Trail 2**	**Trail 3**	**Average Strain**
1	1	9.8	2	1	1	1.33
2	2	19.61	4	3	3	3.33
3	3	29.41	5	6	6	5.66
4	4	39.22	6	8	8	7.33
5	5	49.03	8	9	9	8.66
6	6	58.83	10	11	12	11

4.2.1.2 Theoretical Stress Calculations

As it is a thin walled cylinder stresses acting on it will be Hoop's stress

$$\sigma = pr/t$$

R - Radius of inner diameter

p - Pressure = Force/area

Outer Diameter of tube = 3.20 inch =D

Inner Diameter of Tube = 3.08 inch =d

Thickness = 0.12 inches

Calculations

For load -9.80 N

$$\text{Area} = \frac{\pi(D2 - d2)}{4} = 0.0003739 \text{ m}^2$$

$$\text{Pressure} = \frac{Force}{Area} = \frac{9.80}{0.0003739} = 26210.216 \frac{N}{\text{m2}}$$

$$\sigma = pr/t = \frac{26210.216 \; x \; 3.08}{2 * 0.12} = 3.36 \text{ x } 10^5 \text{ Pa}$$

Similarly perform theoretical stress calculations for remaining loads and tabulate the results.

Table 5 represents theoretical stress values.

Table 5 Stress Values Theoretical

S.no	Loads	Theoretical Stress Values
1	9.8	$3.36x10^5$
2	19.613	$6.73x10^5$
3	29.41	$10.09x10^5$
4	39.22	$13.46x10^5$
5	49.033	$16.82x10^5$
6	58.83	$20.19x10^5$

4.2.2 Structural Testing of cylinder supported by Nut & Bolt

Once after giving cantilever support started loading the cylinder transversely, and make note of the reading from strain indicator. As we have all input perform theoretical Stress calculations. After obtaining the required values tabulate the readings as done below.

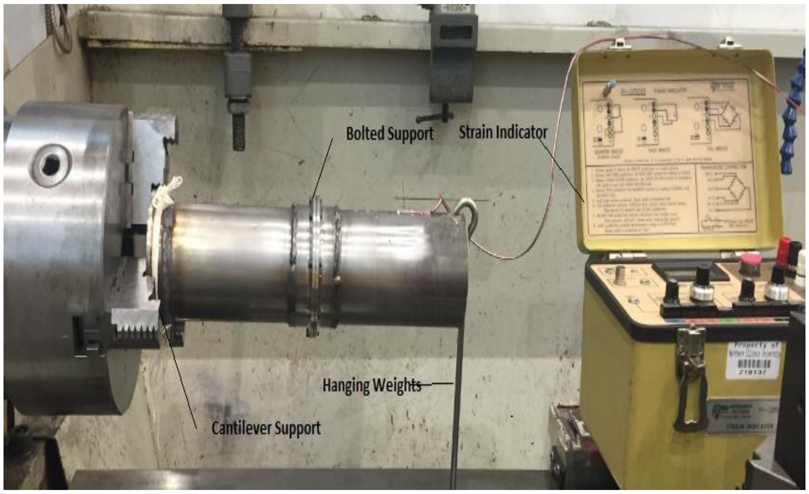


Figure 59 Experiment Setup Procedure

When load of 19.61 N, cylinder slightly deforms from its original position and it is indicated by strain indicator.

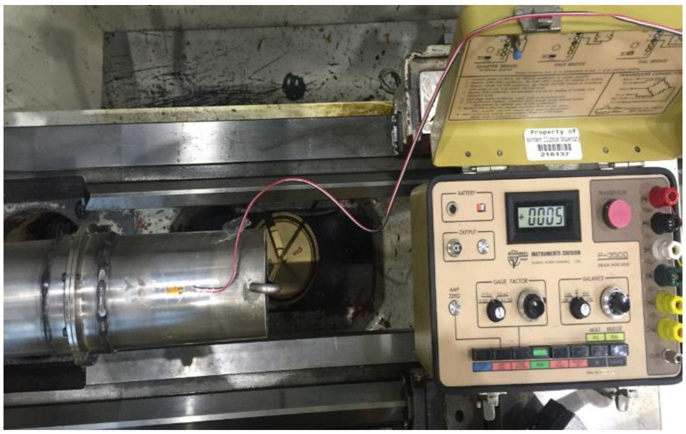


Figure 60 Strain Reading For Nut & Bolt Support

Strain results obtained by loading the cylinder in gradually increasing manner is tabulated and shown below in Table 6

Table 6 Strain Values for Nut & Bolt (Experimental)

			Strain (µe)			
S. no	**Load (Kg)**	**Load (N)**	**Trial 1**	**Trail 2**	**Trail 3**	**Average Strain**
1	1	9.8	3	2	2	2.33
2	2	19.61	4	5	5	4.66
3	3	29.41	8	9	6	7.66
4	4	39.22	11	11	12	11.33
5	5	49.03	13	13	14	13.33
6	6	58.83	15	14	17	15.33

Theoretical Stress Values

As it is a thin walled cylinder stresses acting on it will be Hoop's Stress

$$\sigma = pr/t$$

R - radius of inner diameter

t - Thickness.

p - pressure = Force/area

Outer Diameter of tube = 3 inch =D

Inner Diameter of Tube = 2.91 inch =d

Thickness = 0.09 inches

Calculations

For load -9.80 N

$$\text{Area} = \frac{\pi(D2-d2)}{4} = 0.0002988\ \text{m}^2$$

$$\text{Pressure} = \frac{Force}{Area} = \frac{9.80}{0.0002988} = 32797.858\ \frac{N}{\text{m2}}$$

$$\sigma = \text{pr/t} = \frac{26210.216\ x\ 3.08}{2*0.12} = 4.80 \times 10^5\ \text{Pa}$$

Similarly follow the same procedure for remaining loads and tabulate the results

Theoretical Stress Calculation

Table 7 Stress Values for Nut & Bolt Support

Load (N)	**Stress Values Theoretical**
9.8	$4.8\text{x}10^5$
19.613	$9.6\text{x}10^5$
29.41	$14.40\text{x}10^5$
39.22	$19.21\text{x}10^5$
49.033	$24.02\text{x}10^5$
58.83	$28.82\text{x}10^5$

4.3 Results from Dynamic Analysis (FEA) of Cylinder Supported with bolt and nut & V Band

4.3.1 Cylinder supported with V band clamp with T bolt

Import the geometry to Ansys and assign material properties as mentioned in Chapter 3, and give cantilever support by fixing at one end and determine the natural frequency of the system. Figure 61 represents the modal analysis of cylinder supported with V band clamp. We can see that the natural frequency of the V band clamp support is 1101.5 Hz. Table 8 represents mode shapes and their respective natural frequency.

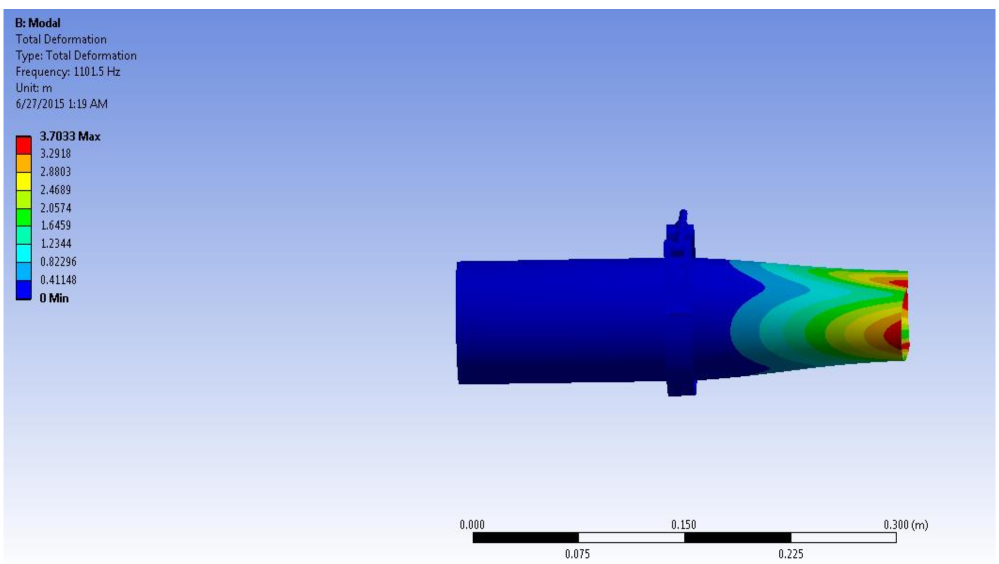


Figure 61 Modal Analysis of V band Support.

Table 8 Modal Analysis for V Band Clamp Support

S.no	**Mode Shapes**	**Natural Frequency**
1	1	1101.5
2	2	1109.2
3	3	1809.7
4	4	1811.1
5	5	2253.6
6	6	2269.9
7	7	3129.7
8	8	3159.2
9	9	3181.7

Natural frequency of a cylinder supported by V band Clamp with T bolt is 1101.5 Hz

4.3.2 Cylinder supported with Nut & Bolt.

Import the geometry to Ansys and assign material properties as mentioned in Chapter 3, and give cantilever support by fixing at one end and determine the natural frequency.

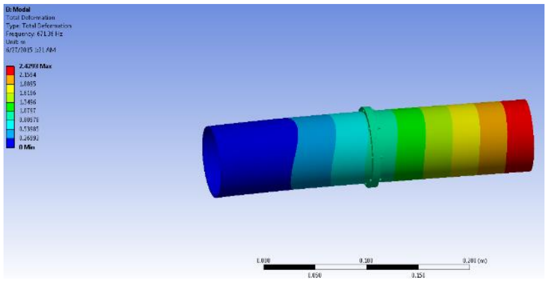


Figure 62 Modal Analysis of Nut & Bolt Support

Table 9 Modal Analysis Result for Nut & Bolt Support

S.no	**Mode Shapes**	**Frequency**
1	1	671.36
2	2	671.58
3	3	796.25
4	4	797
5	5	1818.5
6	6	1829
7	7	1835.5
8	8	1839
9	9	2411.7

Natural frequency of a cylinder supported by Nut & Bolt is 671.36 Hz

4.4 Results from Experimental Dynamic testing of Cylinder Supported with bolt and nut & V Band

4.4.1 Dynamic Testing of Cylinder supported by V band Clamp

Follow the procedure which is explained in chapter 3 about Lab View. Give proper connections to DAQ, here 1st terminal of DAQ is connected to accelerometer and 2nd terminal is connected to hammer. Fix the accelerometer at other end of cylinder which is supported by V band clamp and T bolt. When we give impact by means of impact hammer accelerometer captures signal and transfers to DAQ from there to Lab View installed laptop, signal is processed and a graph is generated between magnitude of FRF and frequency and repeat the same for few trails. Those values are tabulated in Table 10

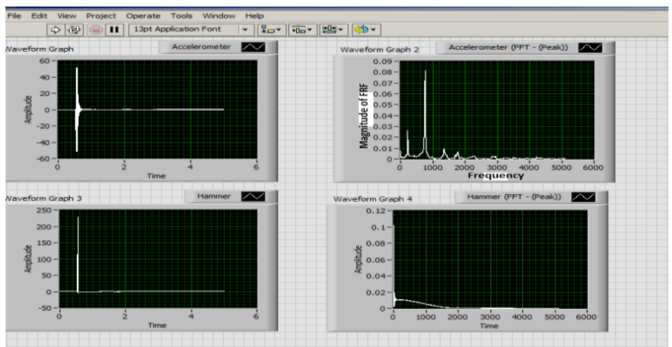


Figure 63 Dynamic Analysis Results of V band Clamp support

Table 10 Experimental Results for V band Clamp (Dynamic Analysis)

S.no	Trials	Frequency
1	1	910
2	2	890
3	3	870
4	4	870
5	5	875

Average of 5 Trials is 883 Hz

Natural frequency of cylinder supported by V band clamp with T bolt support is 883 Hz

4.4.2 Dynamic Testing of Cylinder supported with Nut & Bolt

Follow the procedure which is explained in chapter 3 about Lab View. Give proper connections to DAQ, here 1st terminal of DAQ is connected to accelerometer and 2nd terminal is connected to hammer. Fix the accelerometer at other end and give impact by means of Impact hammer and generate a graph for frequency in LabVIEW and repeat the same for few trails. Natural Frequencies are tabulated in Table 11

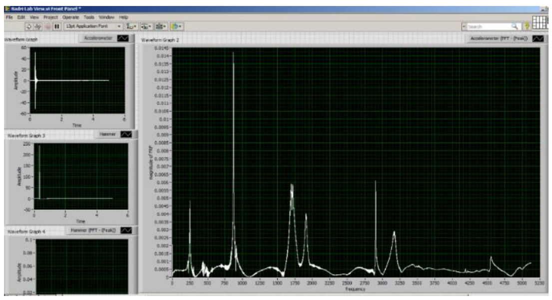


Figure 64 Dynamic Analysis Results of Nut & Bolt support

Table 11 Experimental Results for Nut & Bolt (Dynamic Analysis)

S.no	Trails	Frequency
1	1	790
2	2	780
3	3	800
4	4	790
5	5	810

Average of 5 trails is 794 Hz

Natural frequency of cylinder supported by nut and bolt support is 794 Hz

Table 12 shows Error percentage in strain and stress for a cylinder supported by V band clamp when FEA and experimental analysis is performed.

Table 12 FEA Vs Experimental Results

S.no	Load	% error in Strain	% error In Stress
1	9.80	2	2
2	19.613	3	1
3	29.41	2	2
4	39.22	3	2
5	49.033	2	1
6	58.83	1	2

Table 13 shows Error percentage in strain and stress for a cylinder supported by nut & bolt when FEA and experimental analysis is performed

Table 13 FEA Vs Experimental Results

S.no	Load	% error in Strain	% error In Stress
1	9.80	12	4
2	19.613	12	4
3	29.41	3	6
4	39.22	6	1
5	49.033	2	4
6	58.83	4	4

Table 14 V band Vs Nut & Bolt Result (FEA)

S.no	Load (N)	VBand Clamp (µe)	Nut & Bolt (µe)	V-Band Clamp (Pascal's)	Nut & Bolt (Pascal's)	Difference In Strain (µe)	Difference In Stress (Pascal's)
1	9.8	1.337	2.65	2.56×10^5	5.0×10^5	1.313	2.44×10^5
2	19.61	3.45	5.31	6.62×10^5	10.02×10^5	1.86	3.4×10^5
3	29.41	5.56	7.96	10.64×10^5	15.01×10^5	2.4	4.37×10^5
4	39.22	7.04	10.61	13.51×10^5	20.18×10^5	3.57	6.67×10^5
5	49.03	8.44	13.21	16.21×10^5	25.02×10^5	4.77	8.81×10^5
6	58.83	10.91	15.92	20.95×10^5	30.02×10^5	5.01	9.07×10^5

Strain and Stress values for both V band Clamp and Nut and Bolt Support obtained from FEA analysis compared and tabulated in Table 14. And we can see that both stress and strain values are higher for nut & bolt support. So from FEA analysis we can say V band clamp support is better but this is need to be validated by the Experimental analysis. Figure 65 and 66 represents FEA stress and strain for V band clamp and nut & bolt support.

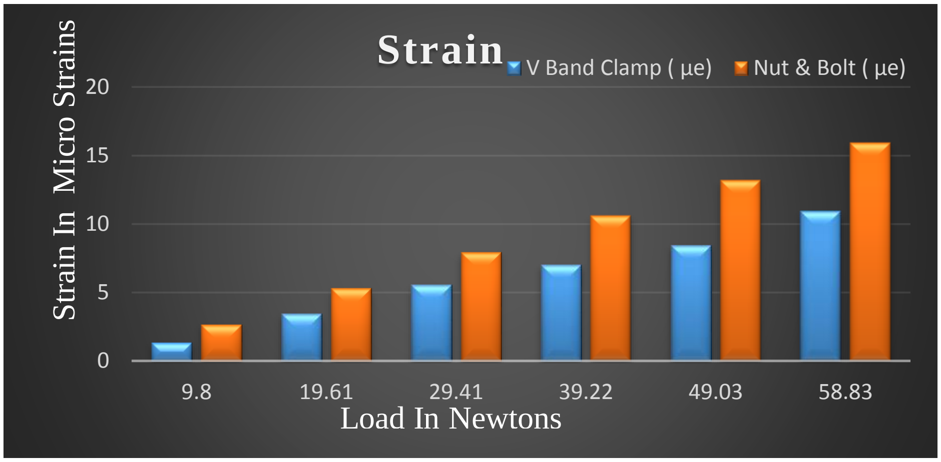


Figure 65 FEA Elastic Strain Comparison for V band clamp Support and Nut and Bolt Support

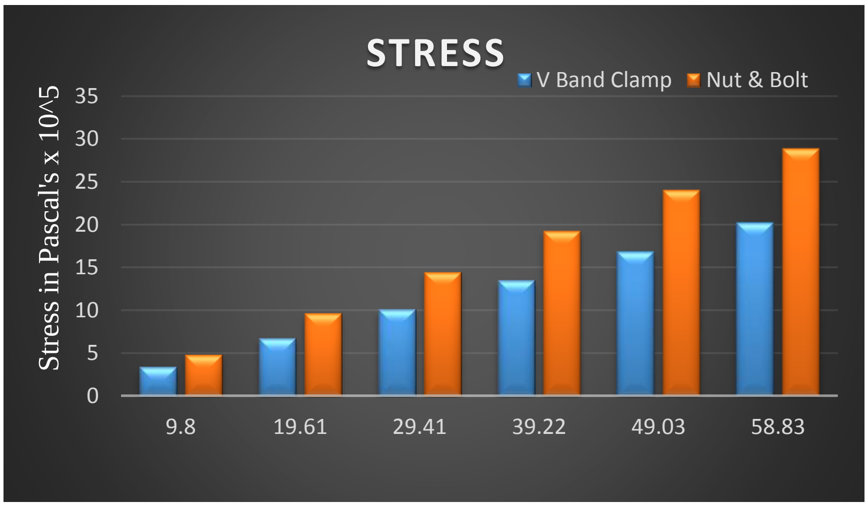


Figure 66 FEA Stress Comparison for V band clamp Support and Nut and Bolt Support

Comparing Experimental Strain & Theoretical Stress Values for V band Clamps and Nut & Bolt support

Table 15 Nut & Bolt Vs V band Clamp (Experimental)

S.no	Load (N)	V Band Clamp (με)	Nut & Bolt (με)	V-Band Clamp (Pascal's)	Nut &Bolt (Pascal's)	Difference in Strain (με)	Difference in Stress (Pascal's)
1	9.8	1.33	2.33	$3.36x10^5$	$4.8x10^5$	1	$1.44x10^5$
2	19.61	3.33	4.66	$6.73x10^5$	$9.6x10^5$	1.33	$2.87x10^5$
3	29.41	5.66	7.66	$10.09x10^5$	$14.40x10^5$	2	$4.31x10^5$
4	39.22	7.33	11.33	$13.46x10^5$	$19.21x10^5$	4	$5.75x10^5$
5	49.03	8.66	13.33	$16.82x10^5$	$24.02x10^5$	4.67	$7.2x10^5$
6	58.83	11	15.33	$20.19x10^5$	$28.82x10^5$	4.33	$8.63x10^5$

Experimental Strain and Theoretical Stress values for both V band Clamp and Nut and Bolt Support obtained from experimental analysis compared and tabulated in Table 15. And we can see that both stress and strain values are higher for nut & bolt support. So we can say V band clamp support is better.

Figure 67 and 68 represents Experimental strain and theoretical stress for V band clamp and nut & bolt support.

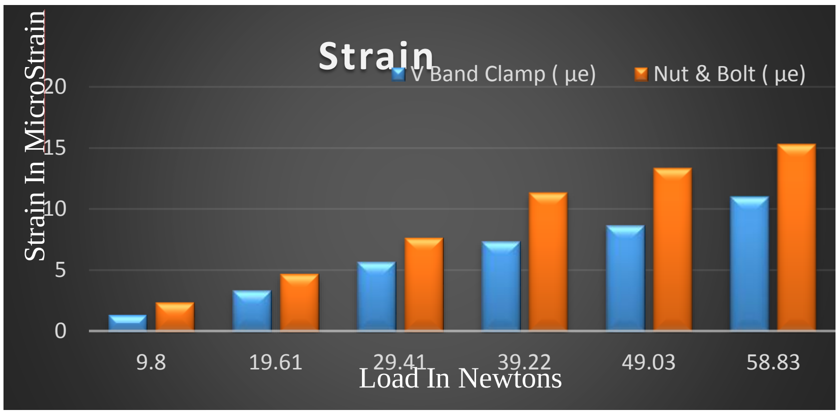


Figure 67 Experimental Strain Comparison for V band clamp Support and Nut and Bolt Support

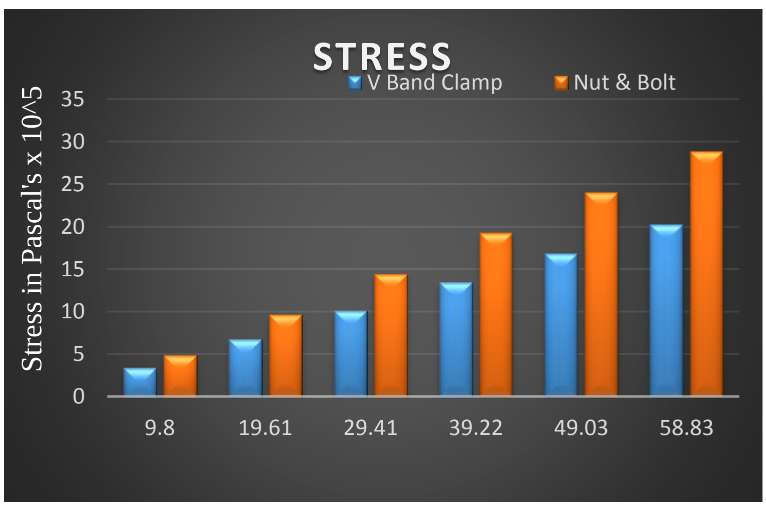


Figure 68 Theoretical Stress Comparison for V band clamp Support and Nut and Bolt Support

Comparing Natural Frequency for V band And Nut and Bolt

Experimental

V Band Clamp with T Bolt Support - 883Hz

Nut and bolt support - 802 Hz

FEA

V Band Clamp with T Bolt Support- 1101 Hz

Nut and Bolt Support -671Hz

CHAPTER 5

CONCLUSION

Static and dynamic analysis has been performed on joints supported by V band clamp with T bolt and nut & bolt .Results clearly shows (i.e. Table 14 and Table 15) that V band clamp support is best support when compared to Nut and Bolt Support. The reason for low stress and strain values is when cylinder is transversely loaded V band, is absorbing maximum amount of loading which is restricting from bending. whereas in case of nut and bolt, load is transverse through the joint which leads to high bending as a result of high stress and strain values, which can be clearly verified by FEA simulation and Experimental Analysis

In future, design a fixture and perform experimental static structural analysis to get more desired stress, strain values. Whereas as in studying dynamic behavior try to run analysis on electro dynamic shaker for getting exact natural frequency of the support.

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