"DESIGN, SIMULATION AND ANALYSIS OF HOLLW BOLT FASTNER"

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Abstract – *This project will focus the whole concept on fatigue analysis of threaded portion of the power screw or bolt. For the analysis and experimental purpose M10 bolt will be selected and it will be modelled for different helix angle. Moreover, moment of inertia will be changed to check the effect of "I" on stress value and life. So, to sum up effect of moment of inertia and helix angle will be investigated to have the value for factor of safety and maximum stress.*

***Key Words*: Bolt, Dynamic Analysis, FEA Analysis, Harmonic Analysis, power screw, simulation, V-Thread**

1. INTRODUCTION

1.1 TYPES OF THREADS

A. **Square Thread:** The efficiency of square threads is more than that of trapezoidal threads. There is no radial pressure or side thrust on the nut. This radial pressure is called 'bursting' pressure on the nut. Since there is no side thrust, the motion of the nut is also increased.

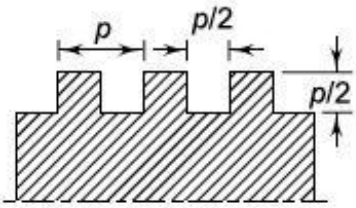


Fig 1:Square thread

B. **Acme Thread**: The Acme thread form has a 29° thread angles with a thread height half of the pitch. The apex and valley are flat. This shape is easier to machine than is a square thread. The tooth shape also has a wider base, which means it is stronger than a similarly sized square thread. This thread form also allows for the use of a split nut, which can compensate for nut wear.

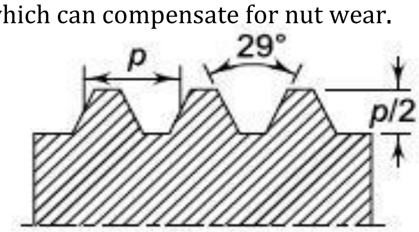


Fig 2: Acme Thread

C. **Buttress Thread**: In machinery, the buttress thread form is designed to handle extremely high axial thrust in one direction. The load-bearing thread face is perpendicular to the screw axis or at a slight slant (usually not greater than 7°) the other face is slanted at 45°. Great strength. Only unidirectional loading.

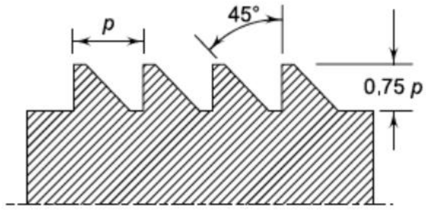


Fig 3: Buttress Thread

1.2 BASIC TYPES OF SCREW FASTENING

A. **Through Bolt**: A through bolt is simply called a'bolt' or a 'bolt and nut'. It is shown in fig .The bolt consists of a cylindrical rod with head at one end and threads at the other**.** The head of the bolt and the nut are either hexagonal or square. Hexagonal head bolt and nut are popular in the machine building industry. Square head and nut are used mostly with rough type of bolts in construction work.

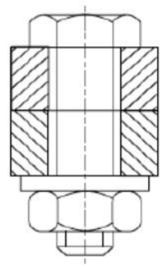


Fig 4: Through Bolt

B. **Tap Bolts and Cap Screws:** There is a basic difference between through bolt and tap bolt. The tap bolt is turned into a threaded (tapped) hole in one of the parts being connected and not into a nut. On the other hand, the through bolt is turned into the nut.

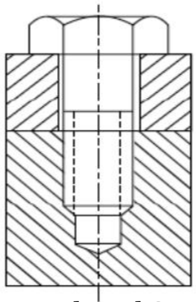


Fig 5: Tap Bolt and Cap Screws

C. Studs: A stud is a cylindrical rod threaded at both ends one end of the stud is screwed into the tapped hole in one of the connecting parts. The other end of the stud receives a nut.

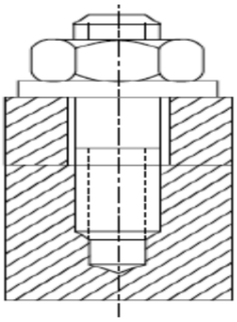


Fig 6: Studs

2. OBJECTIVES

- This project will focus the whole concept on fatigue analysis of threaded portion of the power screw or bolt. For the analysis and experimental purpose M10 bolt will be selected and it will be modelled moment for different helix angle. Moreover, moment of inertia will be changed to check the effect of "I" on stress value and life. So, to sum up effect of moment of inertia and helix angle will be investigated to have the value for factor of safety and maximum stress.

- In this project is to check the fatigue life of M10 bolt by changing geometrical dimensions.

- Validate by checking static condition on universal testing Machine.

- Validate by checking fatigue condition by NDT testing or by comparing the analysis data with other pre-existing technical papers.

3. PROBLEM DEFINATION

In industries everywhere threaded components are used in the form of screws, bolts or power screws. So by having the standard components, sometimes factor of safety is concerned when working stress reached it's more than define value. So, permanent solution for the same size of the components should be adopted and changing the geometrical dimensions of the component does it. So, here helix angle and hollowness of the M10 bolt will be changed for obtaining the better solution.

4. DESIGNS AND SIMULATION

4.1 SIMULATION

In simulation and optimization section many process like pre-process, post-process optimization etc. are adopted for having result of component here, boundary condition, loading condition, matric data, simulation aspects is define by company's design aspects and it is mentioned in there.

4.2 MATERIAL DATA OF COMPONENT

Aluminum alloy 6082 is an alloy in the wrought aluminum –magnesium-silicon family. It is a medium strength alloy with excellent corrosion resistance .It has the highest strength of the 6000 series alloy it also, known as structure alloy the addition of a amount of manganese control the grain structure which in turn result in a string alloy.

Sr.	PROPERTIES	VALUE
1	Young modulus (Mpa)	69900
2	Poisson ratio	0.33
3	Bulk modulus (Mpa)	66700
4	Shear modulus (Mpa)	26000
5	Density (kg/m^3)	2700
6	Thermal conductivity (w/m*k)	162
7	Coefficient of thermal expansion	0.000227
8	Yield strength (Mpa) (tension)	243
9	Yield strength (Mpa) (ultimate)	305

Table 1: Material Properties

As per Table Stress and number of cycle curve data maximum life can get if amplitude-stress generation remain below 80.5 MPa. If stress generation is shown above this value, it will be considered as a finite life component.

ALTERNATING STRESS (Pa)	ALTERNATING STRESS (MPa)	CYCLES
4817000000	4817	10
2798000000	2798	20
1828000000	1828	50
1410000000	1410	100
1058000000	1058	200
447100000	447	2000
263900000	264	10000
209200000	209	20000
134800000	135	100000
110000000	110	200000
80500000	81	1000000

Table 2 : Stress And Number Of cycle

4.3 SIMULATION CASE STUDY

A .Boundary Condition: In defending the component the M10 bolt the head of the bolt was fixed. When the body vibrated the internal thread and bolt thread are vibrating and the fatigued load apply on bolt thread portion when we fixed head of bolt then the thread part of bolt was applicable to apply the load profile.

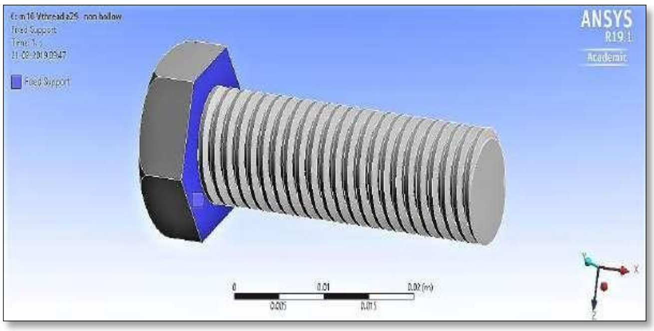


Fig 7: Boundary Condition

B. Loading Condition: When the bolt was tight in body which have internal thread the fatigued load was apply only in bolt trade portion which very with amplitude of vibration for simulation when we fixed the head of bolt the fatigue load apply on thread portion of bolt that the maximum force apply on thread portion of bolt was 1000 N.

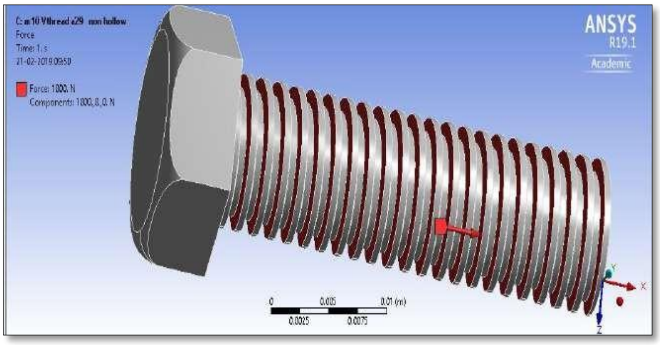


Fig 8: Loading Condition

4.3.1 CASE 1: M10 VTHREAD A29 NON-HOLLOW

A) 3-D Modal:

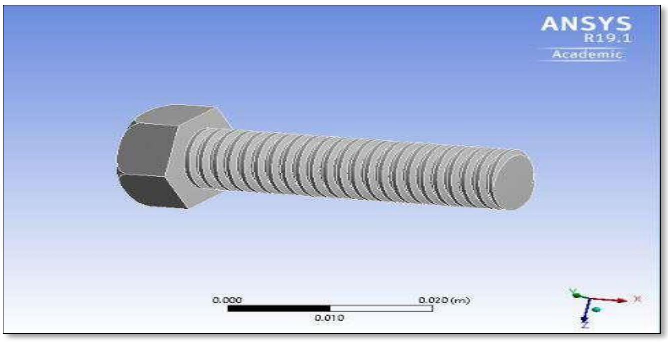


Fig 9: 3-D Modal

B) Equivalent Stress And Total Deformation:

i) Equivalent Stress:

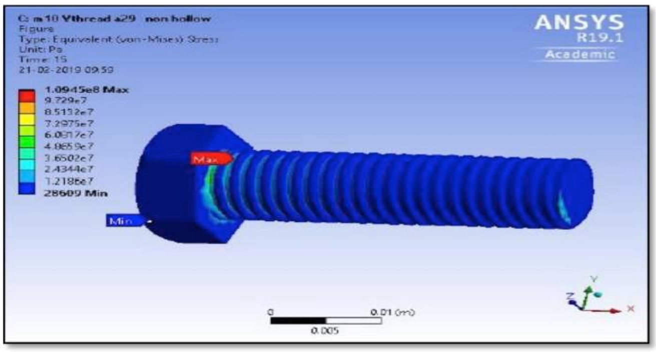


Fig 10: Equivalent Stress

In non-hollow fastener when applied 1000 N force on thread portion towards the shank end, then the maximum equivalent stress was 109.45 Mpa at root thread and minimum 28.6 Mpa at bolt head.

ii) Total Deformation: The total maximum deformation 0.0003 mm on fastener at the end of the bolt or shank end and minimum deformation 0.00007 mm at bolt head.

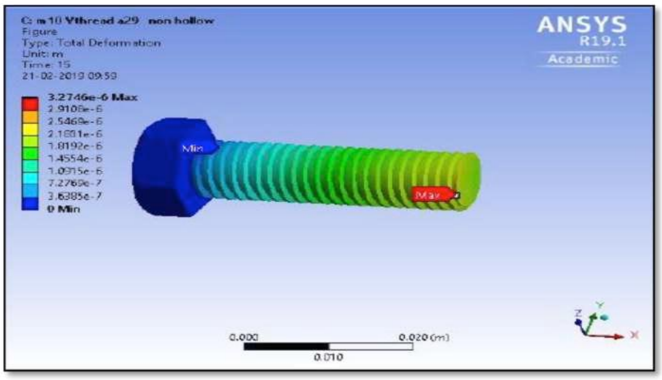


Fig 11: Total Deformation

C) Life and Damage Parameter:

i) Life: The maximum life 1000000 and minimum life were 205260 cycles. This minimum cycle at thread root, the 1000000 cycles was predefine that the area was not critical region and 205260 cycles indicated area that was first start damage.

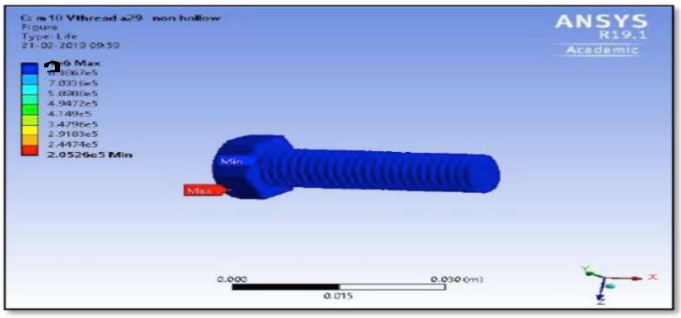


Fig 12: Life

ii) Damage: The damage was maximum 4871.9 and minimum 1000. In ansys 1000 damage was predefine that there was not damaged. When we are comparing life and damage we saw that where life was minimum their damage was high and where life was higher damage was minimized.

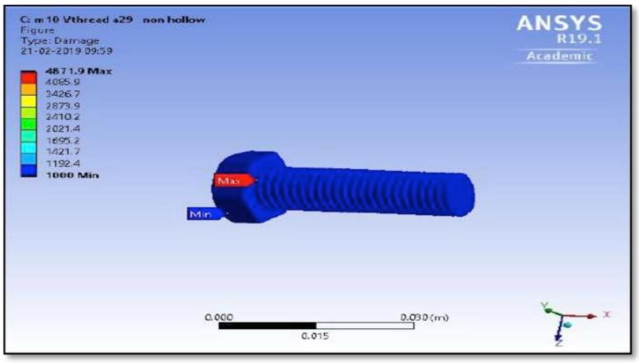


Fig 13: Damage

D) Safety Factor Parameter: The safety factor was high in that area where the damages were high and minimum where the damages were minimum.

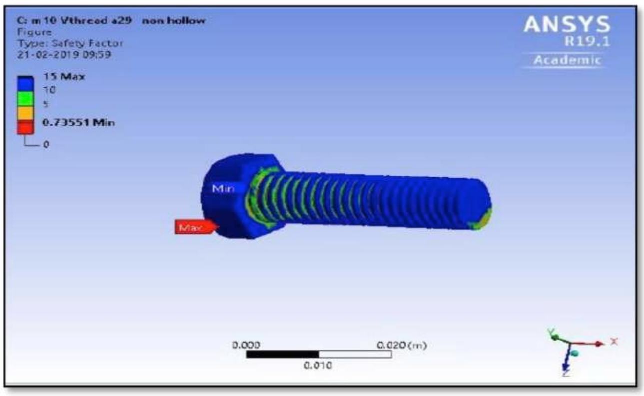


Fig 14: Safety Factor Parameter

E) Stress Sensitivity Curve: When the load factor 1 means when load 1000n then available life was 205260 cycles when we reduced load 25% or load value 0.75 times, then available life was 885000 and reduced 50%, then available life was 1000000 if when the load was increased 1.25 times then life was very low.

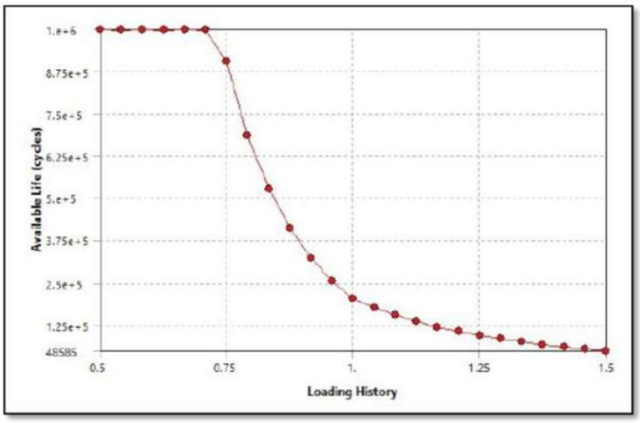


Chart-1: Stress Sensitivity Curve

4.3.2 CASE 2: M10 VTHREAD A29 UP TO SHANK HOLLOW (34 MM)

A) 3-D Modal:

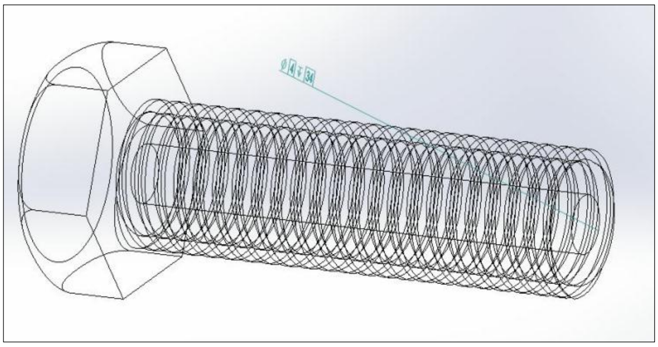


Fig 15: 3-D Modal

B) Equivalent Stress and Total Deformation:

i) Equivalent Stress: In non-hollow fastener when applied 1000 N force on thread portion towards the Shank end, then the maximum equivalent stress was 88.91 Mpa at root thread and minimum 0.418 Mpa at bolt head.

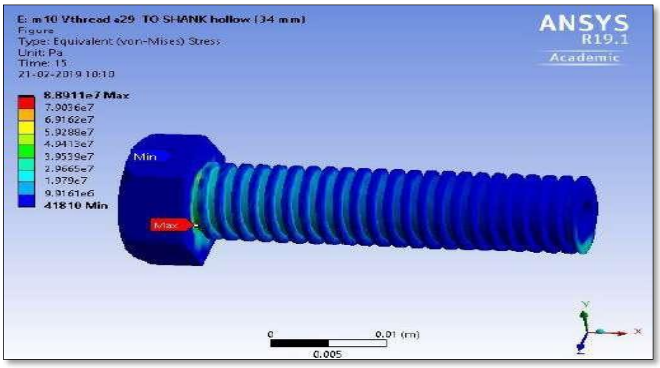


Fig 16: Equivalent Stress

ii) Total Deformation: The total maximum deformation 0.000407 mm on fastener at the end of the bole or Shank end and minimum deformation 0.000045 mm at bolt head.

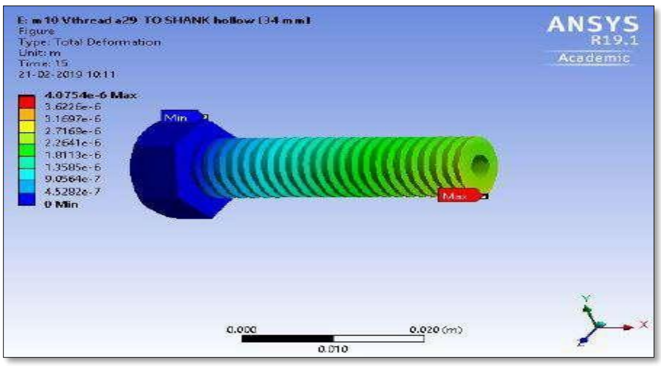


Fig 17: Total Deformation

C) Life and Damage Parameter:

i) Life: The maximum life 1000000 and minimum life were 599150 cycles. This minimum Cycle at thread root, the 1000000 cycle was predefine that the area was not critical region and 599150 cycles indicated area that was first start damage.

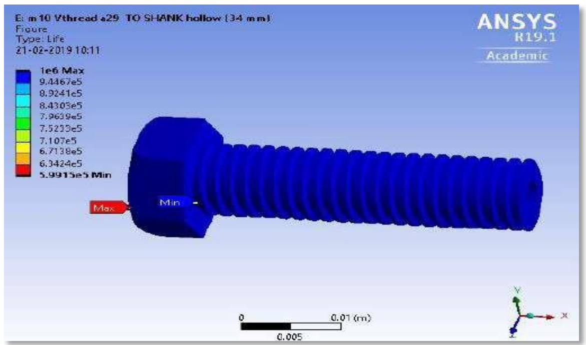


Fig 18: Life

ii) Damage: The damage was maximum 1669 and minimum 1000. In Ansys 1000 damage was Predefine that there was not damaged. When we are comparing life and damage we Saw that where life was minimum their damage was high and where life was higher damage was minimized.

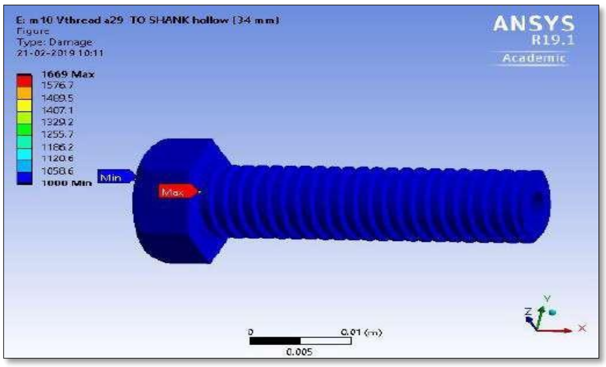


Fig 19: Damage

D) Safety Factor Parameter:

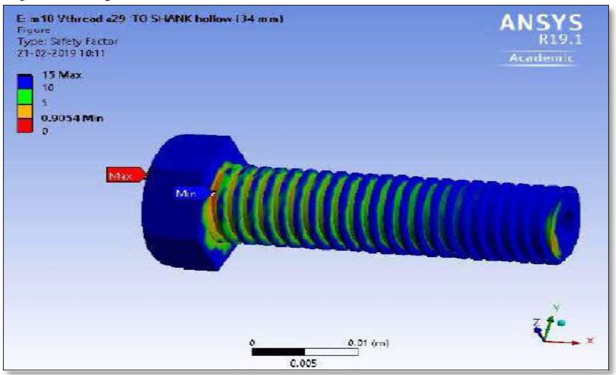


Fig 20: Safety Factor Parameter

E) Stress Sensitivity curve: When the load factor 1 means when load 1000n then available life was 5999150 cycles when we reduced load 25% or load value 0.75 times, then available life was 1000000 and reduced 50%, then available life was 1000000 if when the load was increased 1.25 times then life was very low176500.

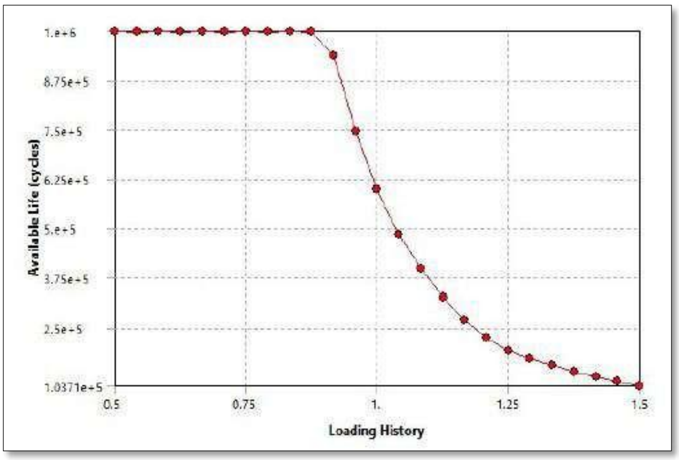


Chart- 2: Stress Sensitivity curve

4.3.3 CASE 3: M10 VTHREAD A29 3.5 HOLLOW UP TO SHANK

A) Equivalent Stress and Total Deformation:

i) Equivalent Stress: In non-hollow fastener when applied 1000 N force on thread portion towards the shank end, then the maximum equivalent stress was 82.913 Mpa at root thread and minimum 0.0345 Mpa at bolt head.

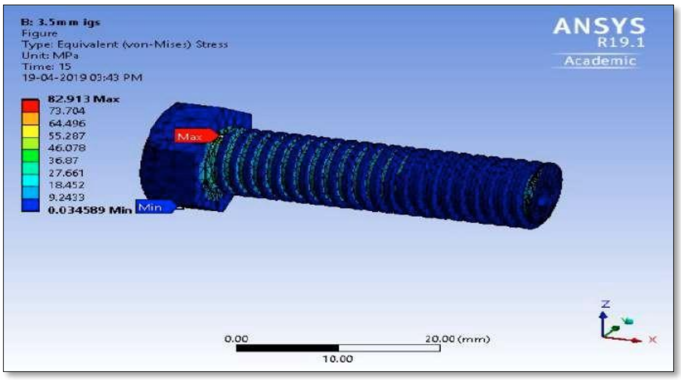


Fig 21: Equivalent Stress

ii) Total Deformation: The total maximum deformation 0.00033 mm on fastener at the end of the bole or shank end and minimum deformation 0.0004 mm at bolt head.

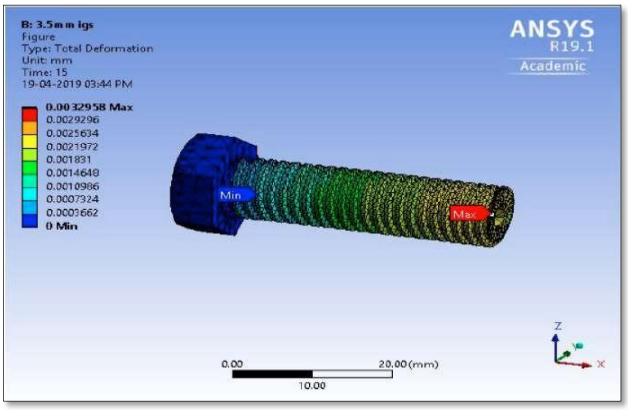


Fig 22: Total Deformation

B) Life and Damage Parameter:

i) Life: The maximum life 1000000 and minimum life were 1.E+06 cycles. This minimum cycle at thread root, the 1000000 cycle was predefine that the area was not critical region and 858770 cycles indicated area that was first start damage.

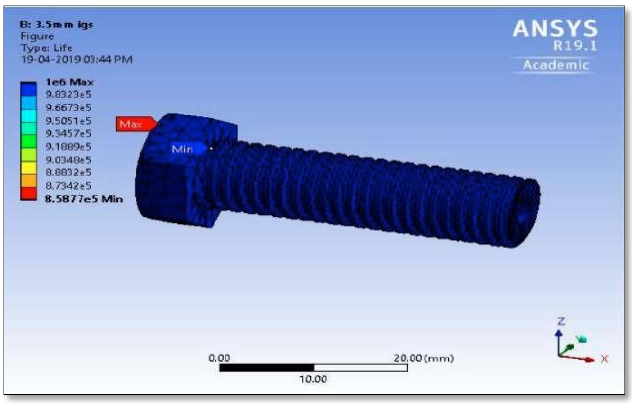


Fig 23: Life

ii) Damage: The damage was maximum 1164.5 and minimum 1000. In ansys 1000 damage was predefine that there was not damaged. When we are comparing life and damage we saw that where life was minimum their damage was high and where life was higher damage was minimized.

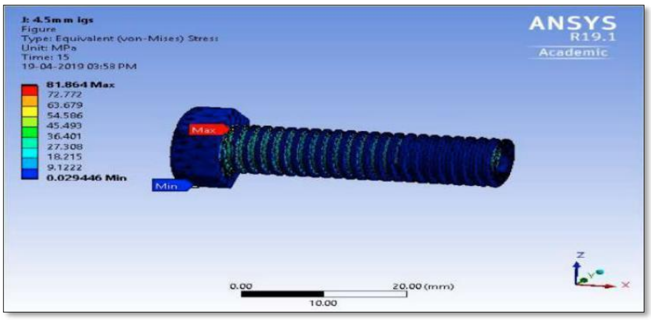


Fig 24: Damage

C) Safety Factor Parameter:

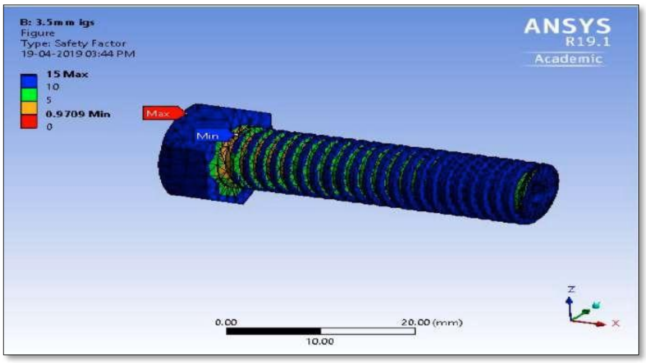


Fig 25: Safety Factor Parameter

D) Stress Sensitivity curve: When the load factor 1 means when load 1000n then available life was 858770 cycles when we reduced load 25% or load value 0.75 times, then available life was 1000000 and reduced 50%, then available life was 1000000 if when the load was increased 1.25 times then life was very 260000.

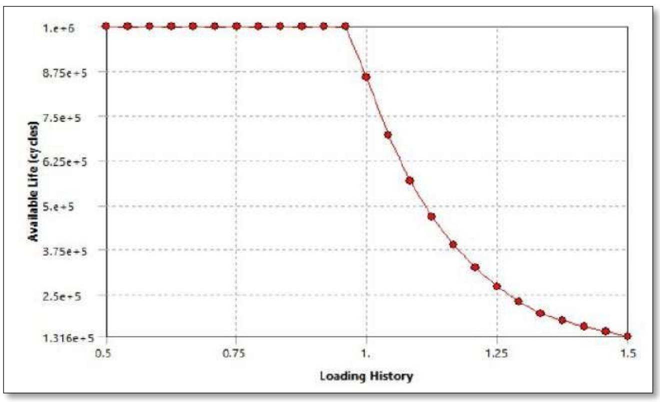


Chart-3: Stress Sensitivity curve

4.3.4 CASE 4: M10 VTHREAD A29 4.5 HOLLOW UP TO SHANK

A) Equivalent Stress and Total Deformation:

i) Equivalent Stress: In non-hollow fastener when applied 1000 N force on thread portion towards the shank end, then the maximum equivalent stress was 81.864 Mpa at root thread and minimum 0.0294 Mpa at bolt head.

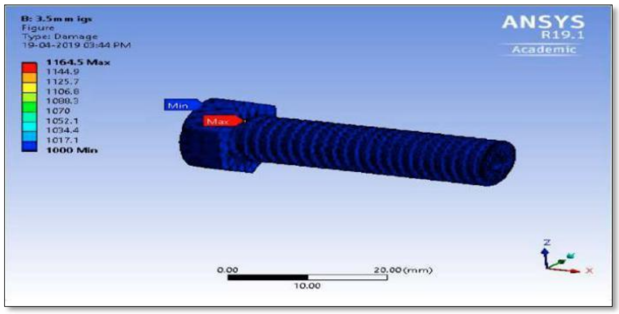


Fig 26: Equivalent Stress

ii) Total Deformation: The total maximum deformation 0.0036 mm on fastener at the end of the bole or Shank end and minimum deformation 0.0004 mm at bolt head.

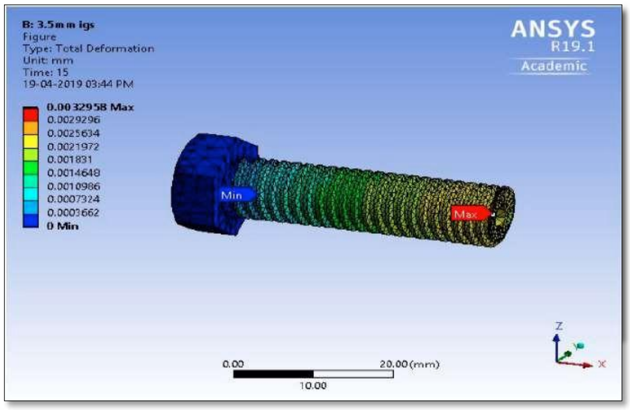


Fig 27: Total Deformation

B) Life and Damage Parameter:

i) Life: The maximum life 1000000 and minimum life were 917000 cycles. This minimum cycle at thread root, the 1000000 cycle was predefine that the area was not critical region and 917000 cycles indicated area that was first start damage.

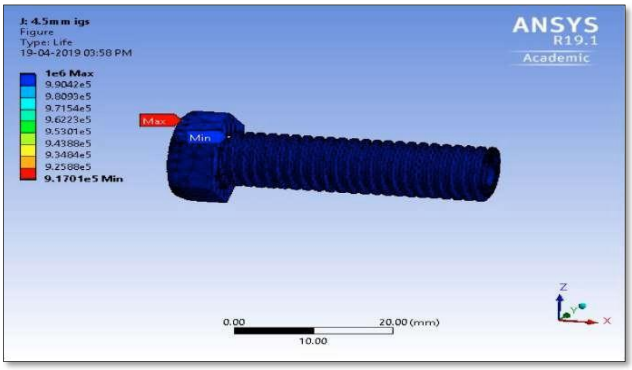


Fig 28: Life

ii) Damage:

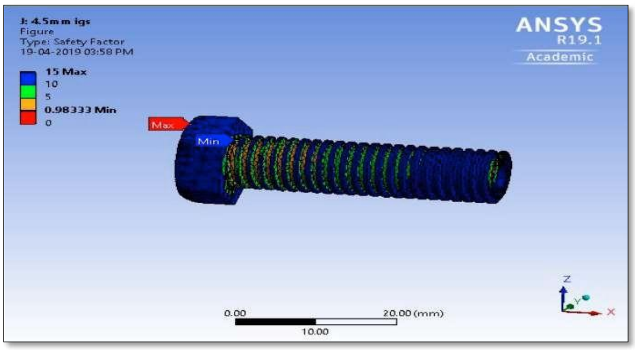


Fig 29: Damage

The damage was maximum 1090.5 and minimum 1000. In ansys 1000 damage was predefine that there was not damaged. When we are comparing life and damage we saw that where life was minimum their damage was high and where life was higher damage was minimized.

C) Safety Factor Parameter:

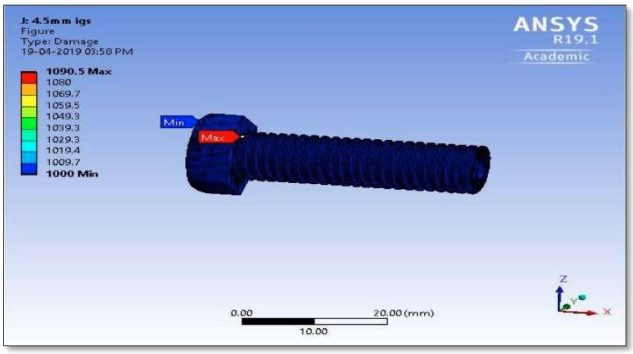


Fig 30: Safety Factor Parameter

D) Stress Sensitivity curve: When the load factor 1 means when load 1000n then available life was 885000 cycles when we reduced load 25% or load value 0.75 times, then available life was 1000000 and reduced 50%, then available life was 1000000 if when the load was increased 1.25 times then life was very low 245000.

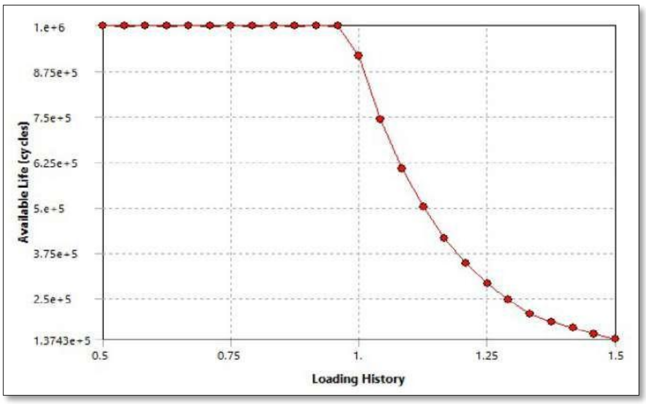


Chart-4: Stress Sensitivity curve

4.4 HARMONIC ANALISYS

4.4.1 Harmonic analisys of m10 bolt 4.5 mm hollow:

A) Modal Analysis:

Mode	Frequency [Hz]
1	4868.9
2	4899.9
3	19710
4	24278
5	24430

Table 3: Modal Analysis

B) Total Deformation at 4868.9 frequency:

Maximum Deformation at 4868.9 frequency at 529.51 mm.

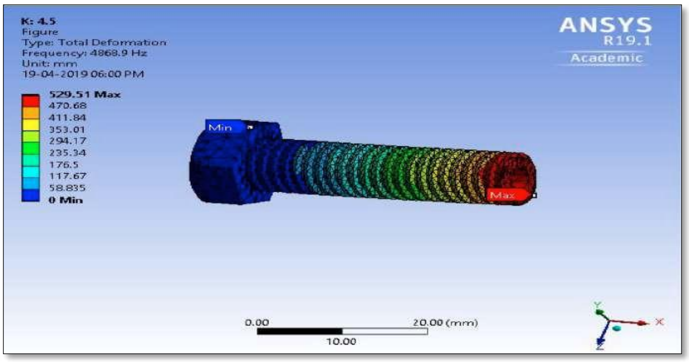


Fig 31: Total Deformation at 4868.9 frequency

C) Total Deformation at 4899.9 frequency: Maximum Deformation at 4899.9 frequency at 531.28 mm.

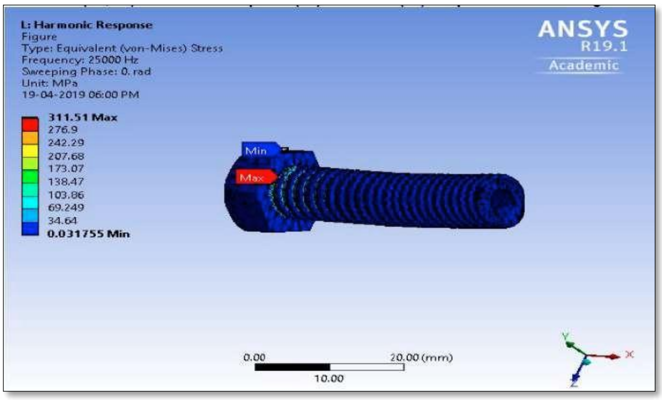


Fig 32: Total Deformation at 4899.9 frequency

D) **Total Deformation at 19710 frequency:** Maximum Deformation at 19710 frequency at 525.2 mm.

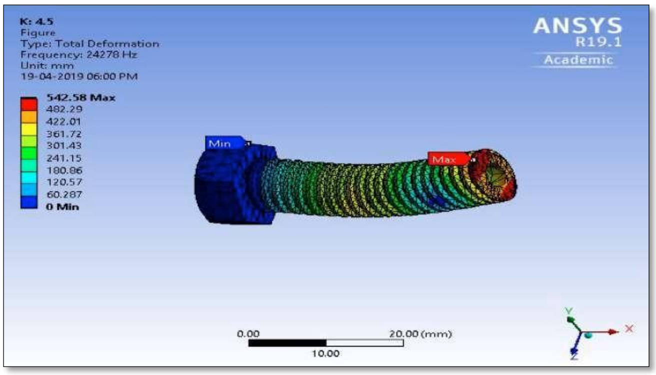


Fig 33: Total Deformation at 19710 frequency

E) Total Deformation at 24278 frequency: Maximum Deformation at 24278 frequency at 542.58 mm.

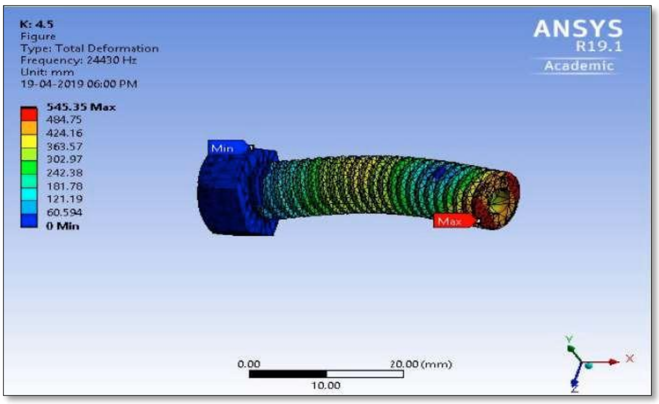
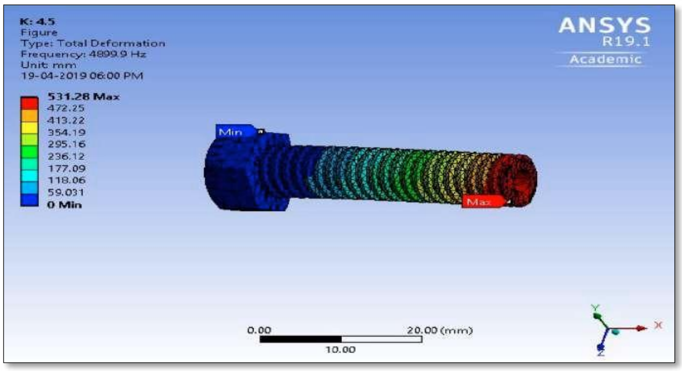


Fig 34: Total Deformation at 24278 frequency

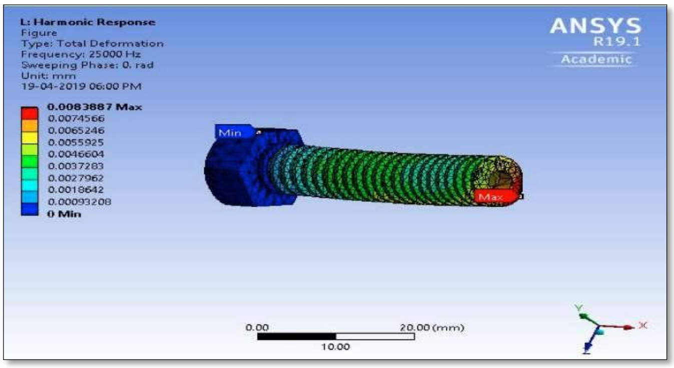
F)**Total Deformation at 24430 frequency:** Maximum Deformation at 24430 frequency at 545.35mm.

Fig 35: Total Deformation at 24430 frequency



G) Harmonic Response Equivalent Stress: Maximum Equivalent (Von-Mises) Stress at 25000 Hz was 311.51 Mpa and minimum 31.755 Gpa.

Fig 36: Harmonic Response Equivalent Stress



H) Harmonic Response Total Deformation: Total Maximum Deformation (mm) At 25000 Hz was 0.008388 mm.

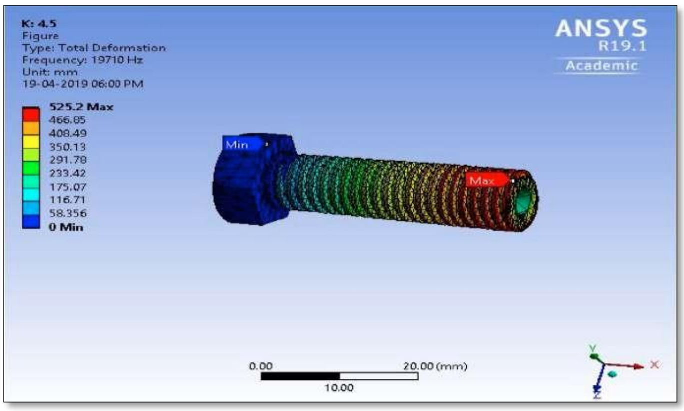


Fig 37: Harmonic Response Total Deformation

I) Amplitude (Mpa) vs Frequency(Hz): This curve was amplitude (Mpa) verses frequency. When frequency was increase then amplitude (Mpa) increase.

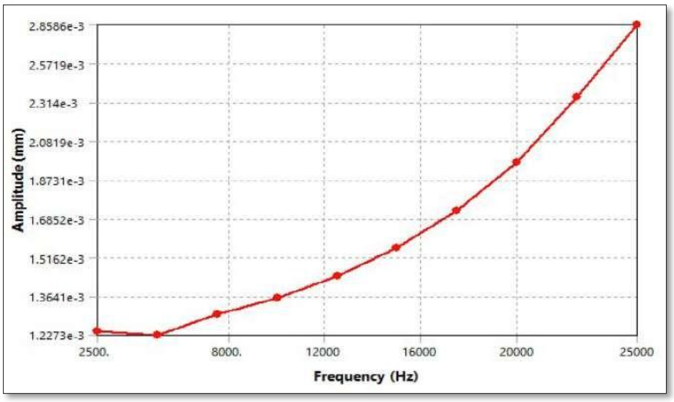
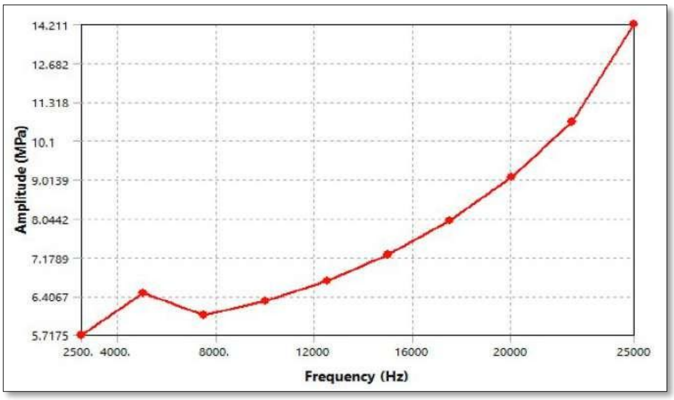


Chart -5: Amplitude(Mpa) vs Frequency

J) Amplitude (mm) vs Frequency(Hz): This curve was amplitude (mm) verses frequency. When frequency was increase then amplitude (mm) increase.

Chart -6 : Amplitude(mm) vs Frequency



5. RESULT AND DISCUSSION

5.1 All case Study Compression:

RESULT PARAMTERS	CASE:1		CASE:2	
	HA-29-NON HOLLOW		HA-29-HOLLOW	
	NA		UP TO HEAD	
MASS (gm.)	26.27		22.94	
REDUCTION IN MASS	0		12.67605634	
NODES	17440		18234	
ELEMENTS	9308		9775	
MI PL-1 (kg*mm^3)	0.44924		0.4425	
MI PL-2 (kg*mm^3)	0.4266		0.3773	
MI PL-3 (kg*mm^3)	0.4266		0.3773	
	MAX	MIN	MAX	MIN
VON MISES (Mpa)	109.45	28.6	88.91	0.024
DEFORMATIN (mm)	0.0003	0.00007	0.000407	0.000045
LIFE	1000000	205260	1000000	599150
DAMAGE	4871.9	1000	1669	1058.2
SAFETY FACTOR	15	0.73	15	0.9054
FATIGUE SENSTIVITY	0.7		0.85	

Table- 4 : Case Study1&2 Comparison

5.2 RESULT BASED PLOT GRAPH

In this section life, damage, safety factor, total equivalent stress and deformation charts are illustrated against different cases of modification. Moreover, convergence curve of optimum result is also shown for different elements.

i. Total Equivalent Stress v/s Modification:

The graph depicts the graphical representation between total equivalent stress v/s modification.

Table-5 : Case Study3&4 Comparison

RESULT PARAMTERS	CASE:3		CASE:4	
	HA-29-HOLLOW		HA-29-HOLLOW	
	3.5 mm HOLE SIZE		4.5 mm HOLE SIZE	
MASS (gm.)	23.721		22.05	
REDUCTION IN MASS	9.703083365		16.06395128	
NODES	18356		17811	
ELEMENTS	9859		9477	
MI PL-1 (kg*mm^3)	0.44258		0.4385	
MI PL-2 (kg*mm^3)	3.8937		3.6326	
MI PL-3 (kg*mm^3)	3.8937		3.6326	
	MAX	MIN	MAX	MIN
VON MISES (Mpa)	82.913	0.0345	81.864	0.02944
DEFORMATIN (mm)	0.00329	0.00036	0.0036	0.0004
LIFE	1.E+06	858770	1.E+06	917000
DAMAGE	1164.5	1017.1	1090.5	1009.7
SAFETY FACTOR	15	0.9709	15	0.983
FATIGUE SENSTIVITY	0.9		0.96	

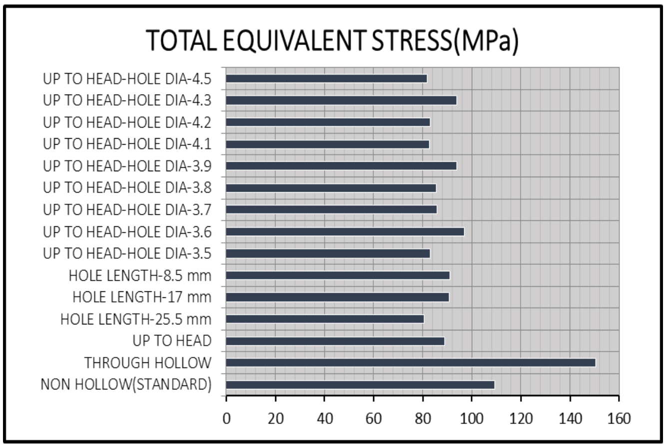


Chart-7 Total Equivalent Stress v/s Modification

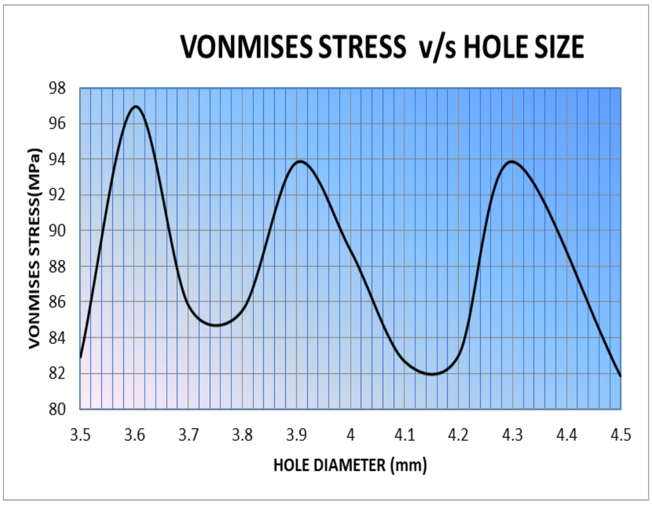


Chart-8: Total Equivalent Stress v/s Hole Size

ii. Life v/s Modification :

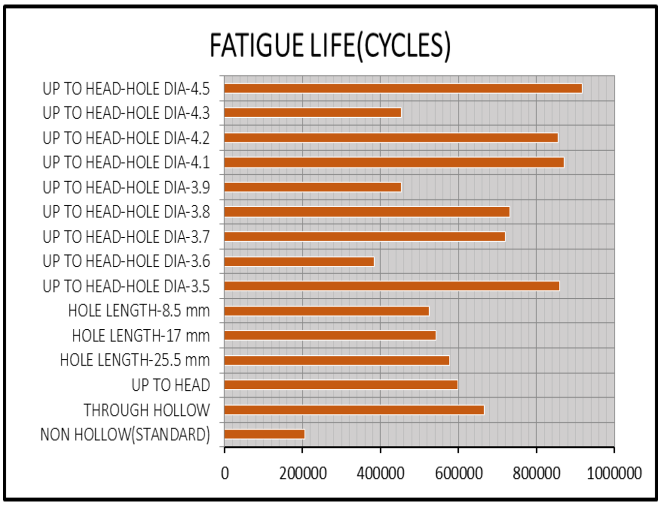


Chart-9: Life v/s Modification

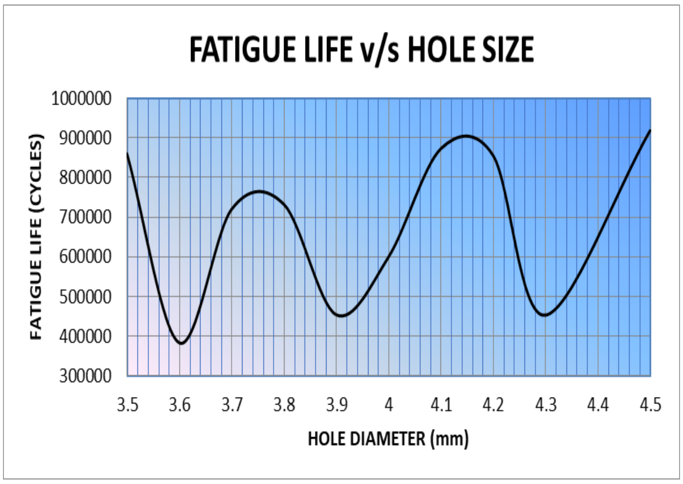


Chart-10: Life v/s Hole Size

iii. Safety factor v/s Modification :

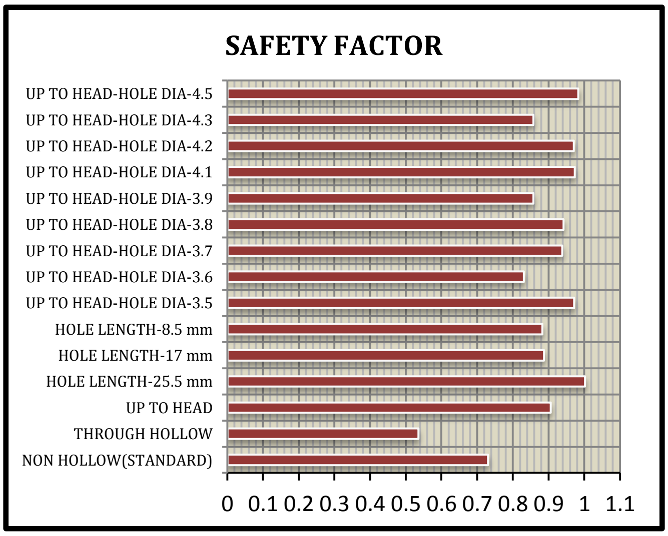


Chart-11: Safety Factor v/s Modification

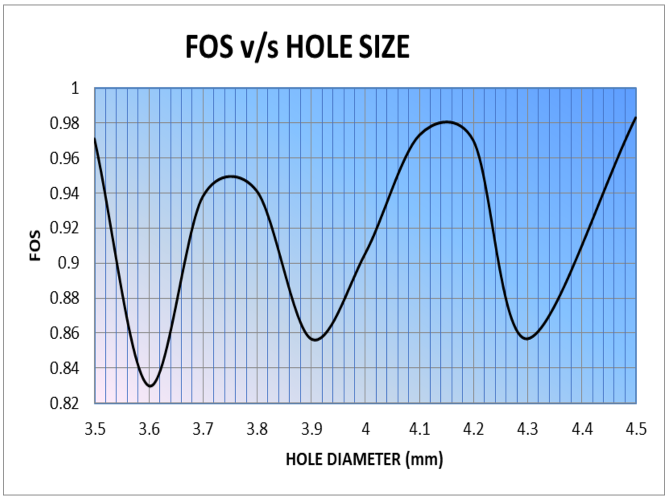


Chart-12: Safety Of Factor v/s Hole Size

5.3 HARMONIC DEFORMATION RESPONES COMPARISSION WIHT ALL CASE:

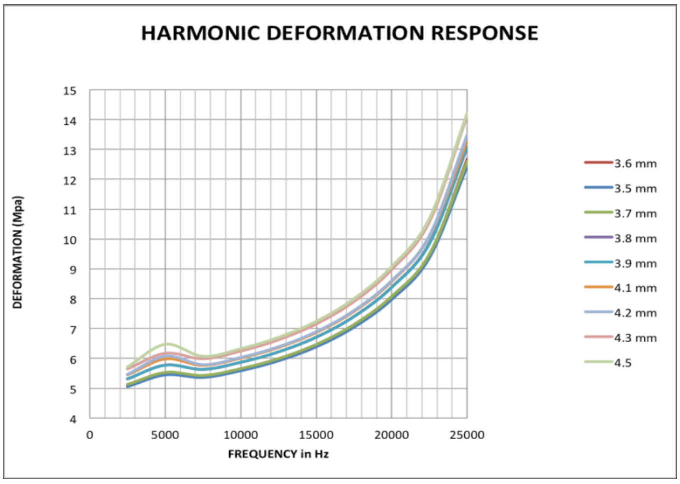


Chart-13: Deformation(MPa) v/s Frequency

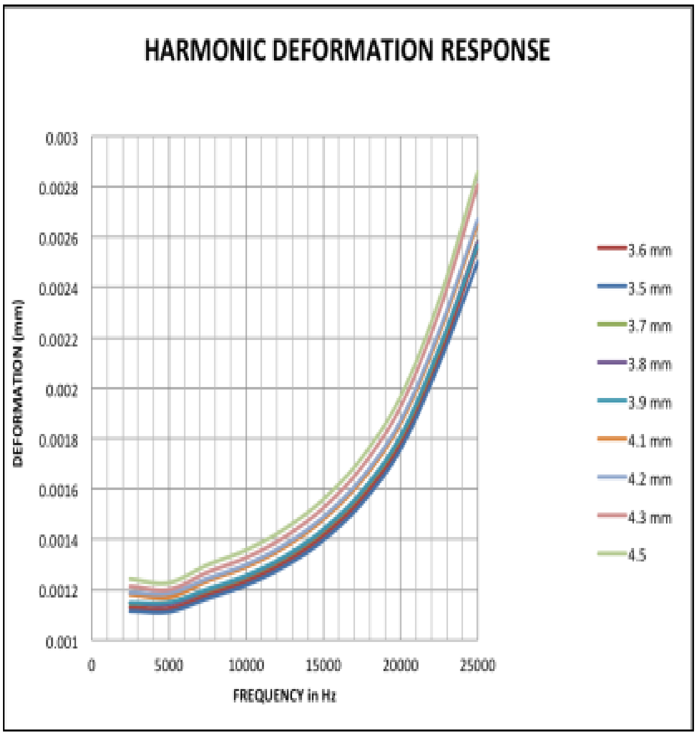


Chart-14: Deformation (MM) v/s Frequency

6. CONCLUSION:

- In finite element simulation tool, total six cases were observed with variation of hole length while keeping 4 mm diameter in M10 standard bolt. In which length up to head of bolt was identified as an optimum case which has maximum fatigue life up to 599000 cycles against 1000 N load. Now in second phase of project, different hole size was adopted from 3.5 mm to 4.5 mm for the previous optimum case and found that 4.5 mm case possessed highest fatigue life with minimum damage to the M10 bolt. In the simulation of second phase of project, it was observed that outcomes depicted from variation of holes, regular pattern of fatigue life value was shown so it need to be further study for depicting relation between hole size factor and life.

- In last phase of the project, harmonic analysis was adopted to check the stress and deflection amplitude against frequency and it was found that in each case stress generation was increasing at certain value. Moreover, while increasing hole size of M10 bolt, stress was further increased as compared to smaller size of hole. So to sum up this, I would preferred higher hole size 4.5 mm which has fatigue life around almost infinite life cycles with maximum safety factor.

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