FATIGUE INVESTIGATION OF BOLTED JOINT USING NONLINEAR STRUCTURE AND EXPERIMENTAL ANALYSIS

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Abstract*- Fastener are subjected to tensile compressive and shear loads in various application such as automotive, aerospace etc. Shear load are prominent for failure of bolt along shank lengths. In a study, shear load will be applied at a constant amplitude load cycle using pneumatic cylinder. Arduino program will be done for controlling frequency of application of load at shank area of bolt. Number of cycles will be measured for fatigue. static structure analysis will be done using ANSYS 19 software for calculating require stress at various shear force value. Experimental setup will be manufacture for validation purpose. fatigue life will be stated using analysis workbench. ANSYS software also help in calculation FOS and damage. Result and discussion will be evaluated from simulation and experimented result. Suitable future scope will be suggested.*

Keyword - Bolted joints, Bolt loosening, FEA, FFT analyzer

I. INTRODUCTION

Fatigue stacking is a typical reason for failure in the securing joints. So as to comprehend the failure instruments and the impact of parameters, the fatigue conduct investigation of the affixing joints of sheet materials has been the subjects of a lot of exploratory and numerical examinations. The expanding complex joint geometry and its three-dimensional nature consolidate to build the trouble of getting a general arrangement of overseeing conditions for anticipating the fatigue properties of the affixing joints. Cross breed joints unite the benefits of various securing procedures. Bolted or bolted joints are broadly utilized in airplane structures since they can be handily disassembled, fixed or supplanted after any imperfection or administration life. In such strategies, either pressure or tractable circumferential leftover or pre-stress are presented around the latch opening or an opposition frictional power is made against applied remote load and furthermore exhaustion split development in reached surfaces introduced in catapulted examples. The mechanical conduct of the bolted joint structure under vibration has for quite some time been described and concentrated with regards to designing apparatus, including displaying and explores techniques. The nonlinear attributes of bolted joint interface are of incredible intrigue in light of their effect on auxiliary vibration, which can even be unfavorable to in general elements. Bolted joint gives confined high worry during attaching, which brings more contemplations for displaying works and structure. Strain part association and graft. It subjects the jolts to powers that will in general shear the shank. It subjects the jolts to powers that will in general shear the shank. The holder association places the jolts in pressure. Basic association in which the line of activity of the power following up on the association goes through the focal point of gravity of the association, at that point each jolt can be accepted to oppose an equivalent portion of the heap. The quality of the straightforward association will be equivalent to the aggregate of the qualities of the individual darts in the association. Associations represent the greater part the expense of auxiliary steelwork thus their plan and enumerating are of essential significance for the economy of the structure. The sort of association planned has an effect on part configuration thus should be chosen even before the plan of the basic framework and structure of individuals. Take for instance, the association of a pivotally stacked bracket part at a joint. In the event that the bracket is thought to be pin jointed, at that point the part ought to preferably be associated by methods for a solitary pin or jolt. Notwithstanding, by and by, if the pin or jolt measurement works out to be bigger than that conceivable, more than one jolt will be utilized. The support would then be able to be viewed as pin-jointed just if the bowing because of self-weight or other superimposed loads is irrelevant. Note that the association conduct will likewise impact the computation of the powerful length for the clasping examination of swaggers. Welded associations have the bit of leeway that no openings should be penetrated in the part and thusly have higher efficiencies. Welded associations are additionally vulnerable to failure by splitting under rehashed cyclic loads because of exhaustion which might be because of working loads, for example, prepares disregarding an extension (high-cycle fatigue) or quakes (low-cycle fatigue). A unique kind of catapulted association utilizing High Strength Friction Grip (HSFG) jolts has been found to perform preferable under such conditions over the regular dark jolts used to oppose dominatingly static stacking. Darted associations are additionally simple to review and supplant.

II. LITERATURE REVIEW

Xiaocong et al. [1] presented the fatigue conduct of such attaching joints and FEA examination. Pretty much every mechanical structure requires segment individuals to be jointed. Some relative new affixing procedures, for example, SPR, mechanical securing and auxiliary cement holding are proficient joining strategies which are appropriate for joining propelled lightweight sheet materials that are difficult to weld; particularly SPR, mechanical securing, basic glue holding, and their blends are broadly utilized in lightweight vehicle industry late years for joining different materials in the get together of segments and structures. Adhesively holding is typically used to build the quality of mechanical joints and make the watertight. It is regularly comprehended that the expansion of cement in SPR or secured joints is valuable. Thus, satisfactory comprehension of fatigue conduct of the affixing joints is important to guarantee productivity, wellbeing, and unwavering quality of such joints. FEA of fatigue conduct of the affixing joints will permit a wide range of fatigue failure procedures to be reproduced so as to play out a choice of various parameters before testing, which would be very tedious or restrictively costly practically speaking. The primary techniques utilized in FEA of fatigue conduct of the securing joints, for example, parameters determination, materials displaying, and coinciding methodology are to be well understood.

Babak Abazadeh et al. [2] had studied the absolute fatigue life of twofold lap shot aluminum 2024-T3 joints with impedance fitted openings. The examples are obstruction fitted with two degrees of 1.5% and 4.7% and bolt braced applying two fixing torques of 2 and 4 Nm. Likewise, the fatigue tests were conveyed out at steady abundancy, sinusoidal stacking at a load frequency of 15 Hz and a load proportion of zero with load runs somewhere in the range of 10 and 18 kN. The fatigue life estimation is completed in two pieces of fatigue break inception and fatigue split development lives. At the point when both impedance fitting and bolt clasping cold works are applied to a joint gap, pre-stresses are made around the gap. At the point when the joint is exposed to a cyclic longitudinal remote pressure, multiaxial stress (and strain) state is made around the opening from which fatigue breaks can start and spread. In any case, in this sort of examples, when the applied fixing torque builds, the frictional safe shear worry between reached plates increment as well. Additionally, as the correlation of the trial fatigue test results and evaluated all out-fatigue life appear, in high cycle fatigue life (low Load run) examples the standards overestimation the fatigue life that could be identified with the event of worrying in the joints.

Meifal Rusli et al. [3] experimented a straightforward method to watch the dynamic normal for a without fixed beam that comprises of two bars that associated by a solitary and twofold bolt. The fixing torque of the bolt is shifted from releasing condition, 2.5 Nm, 5 Nm, 7.5 Nm, and 10 Nm. It is discovered that the releasing condition or lower fixing torque will move the regular frequency of the structure. Noteworthy change will be seen at the higher frequency. In addition, the damping trademark is additionally influenced by changing the fixing torque. The effect force is applied in the vertical course to energize twisting vibration of the beam. The different fixing torques are applied to the bolt joint, from the slackening condition to a greatest of 10 Nm torque. It is discovered the slackening condition or lower fixing torque will move the normal frequency of the structure. In addition, the damping proportion will increment by diminishing the cinching force, particularly when slackening condition, the damping proportion turns out to be a lot higher than the fixing one. By this condition, this effect testing estimation could be applied as a basic method to screen or identify the condition of bolted joint in a structure. Diminishing the normal frequencies or expanding the damping proportion turned into a manifestation of the slackening or diminishing the fixing torque of a joint.

Xin Liao et al. [4] introduced the dynamic reaction qualities of a typical twofold shear lap joint structure with viscoelastic layer. The fourth order runge-kutta technique is utilized to compute the damage on reaction, where the impact of coulomb grinding and excitation levels on framework are introduced. The outcomes show that the viscoelastic layer help lessen vibration at certain degree, particularly in the high frequency area of vibration, and some extreme frequencies of framework can be changed through the viscoelastic layer. The impact of coulomb rubbing and excitation levels on vibration. In the interim, a FEM model with nonlinear solidness regarding contact calculation is built up, where the nonlinear practices under the different shot preloads and viscoelastic layer thicknesses are introduced. It is concluded that the viscoelastic layer help decrease the reaction of the composite structure to vibrations, particularly altogether in the high frequency locale, and the entire structure firmness change can be accomplished by altering the thickness of the viscoelastic layer.

Yanzhi Liu et al. [5] proposed a trial examination on the fatigue execution of a visually impaired bolt under pivotal strain cyclic loads. It is discovered that S–N bends follow a force work with negative example, and show comparative S–N bends to standard rushes under higher load proportion. The failure modes of the standard rushes under static and fatigue loadings were shank break, while sleeve crack was watched for dazzle bolts exposed to static strain. Significantly, the failure designs of most visually impaired darts under consistent adequacy and variable-sufficiency fatigue loadings was shank break; in any case, a few examples fizzled by sleeve crack under outrageous pinnacle loads. It was discovered that the load abundancy cycle relationship of the tried bolts seemed to comply with a force work with a negative example, and that the fatigue life of visually impaired bolts was altogether affected by the load plentifulness and load top. S–N bends of the test darts under a steady adequacy fatigue stacking were gotten by relapse investigation. Then, the total damage esteems for the visually impaired dashes under factor plentifulness fatigue stacking were determined dependent on the Miner straight combined damage hypothesis, while an equal consistent adequacy stress was presented to consider the presentation of visually impaired dashes under factor abundancy fatigue stacking. It was discovered that the fatigue quality of Grade 10.9 visually impaired bolts was higher than that of Grade 8.8; be that as it may, both fatigue life esteems were almost the equivalent. It was discovered that most visually impaired bolt tests were over the predefined configuration bends given by the codes of training (EC 3, BS 7608, and AISC-LRFD), which demonstrates that the fatigue execution of visually impaired bolts could be moderately evaluated by the relating plan determinations for situations where the applied pinnacle load was lower than 100 KN.

III. PROBLEM STATEMENT

Bolted connections are utilized in an enormous number of auxiliary individuals. These connections may look basic on a superficial level, however are unpredictable collects with shifting geometric and fatigue properties which should be appropriately represented so as to give an away from of their helpful life in administration. A presentation into fatigue and strategies by which fatigue strength can be evaluated are analyzed. Additionally, introduced are the guidelines at present used to oversee plan, establishment and operational existence of bolted connections.

OBJECTIVES

- Modelling of bolted joint specimen of in CATIA V5 software.
- To perform static structural analysis of bolted joint specimen by using ANSYS 19 software.
- To perform fatigue analysis of bolted joint specimen to find out fatigue behavior.
- To calculate number of life cycle of bolted joint specimen.
- Experimental testing and correlating results.

METHODOLOGY-

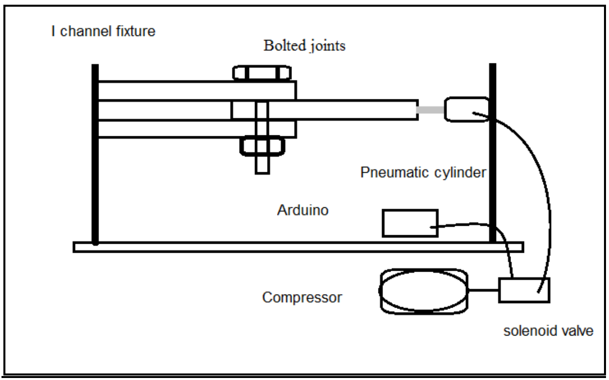
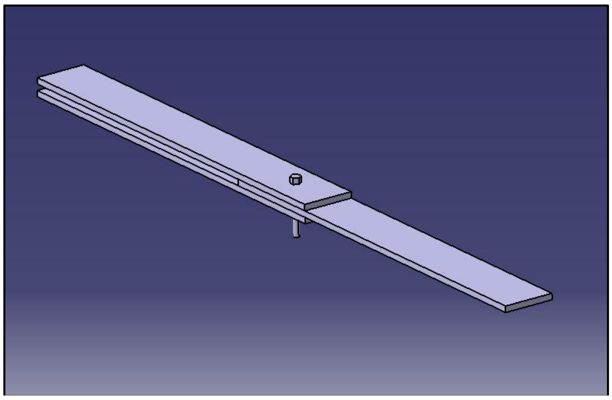


Fig.1: Schematic layout of setup

PROJECT STAGE 1

- Initially research paper relevant to the topic is gathered and after going through research papers, fatigue of bolt setup is examined.
- A 3-D CAD model will be prepared by studying the conventional design of mini setup for bolt fatigue setup.
- Prepared 3-D model will be transferred to ANSYS software and proper meshing will be created on the model for further analysis.
- To perform static analysis in ANSYS software to determine yield and fatigue life of bolt.
- A prototype of the model will be manufactured.
- Experimental analysis will be performed on the fatigue bolt setup to determine the bolt loosening parameter.
- Validation of experimental and numerical results.



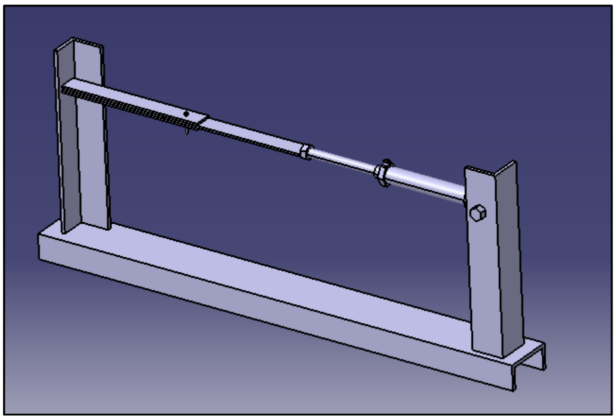


Fig. 2 : CATIA model

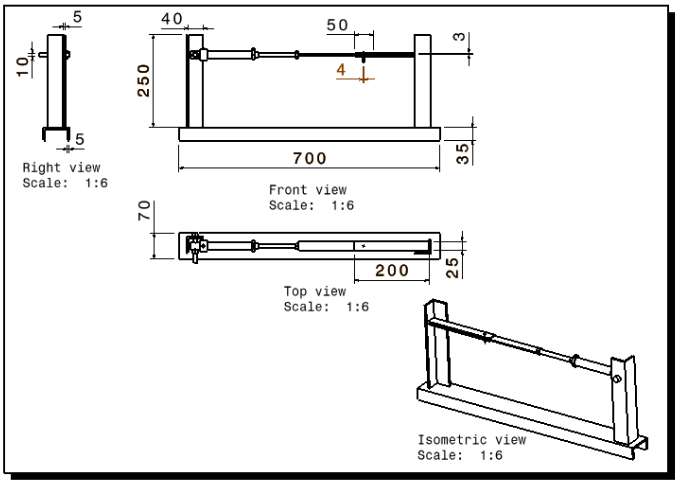


Fig. 3: Drafting of model

FEA ANALYSIS

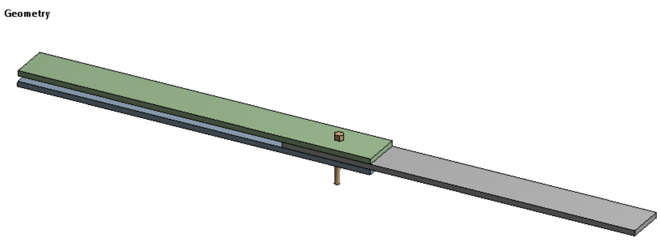


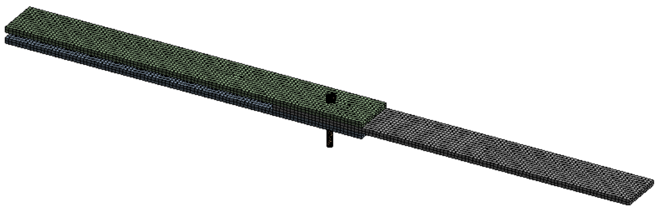
Fig.4: Geometry imported in ANSYS

Properties of Outline Row 4: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and Poisson's R...	
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa

MESH

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Multiphysics solutions. In ANSYS after importing geometry in module meshing is performed also known as discretization process. In meshing whole component is breakdown or discretized into small elements to solve finite element equation at nodes. In present hexahedral mesh is used for analysis. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model.

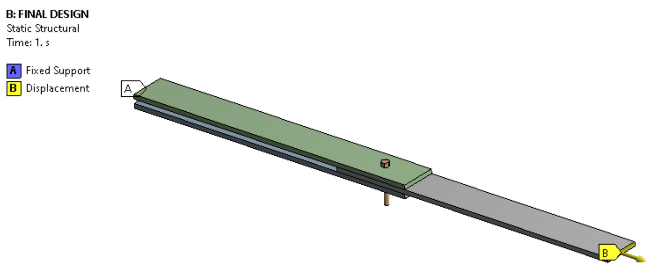


Statistics	
Nodes	48452
Elements	9557

Fig.5: Details of meshing

Boundary Condition

In present displacement of approximately in the range 0 to 1 mm is applied as per time step of 1 sec increment with fixed support at one end. A boundary condition for the model is that the setting of a well-known value for a displacement or an associated load. For a specific node you'll be able to set either the load or the displacement but not each. The main kinds of loading obtainable in FEA include force, stress and temperature. These may be applied to points, surfaces, edges, nodes and components or remotely offset from a feature.



Tabular Data

	Steps	Time [s]	Z [mm]
1	1	0.	0.
2	1	1.	-0.2
3	2	2.	-0.4
4	3	3.	-0.6
5	4	4.	-0.8
6	5	5.	-1.

Fig.6: Boundary condition

In finite element method the total deformation and directional deformation are general terms irrespective of software being used. Directional deformation may be place because the displacement of the system in a very particular axis or user defined direction. Total deformation is that the vector sum of all directional displacements of the systems.

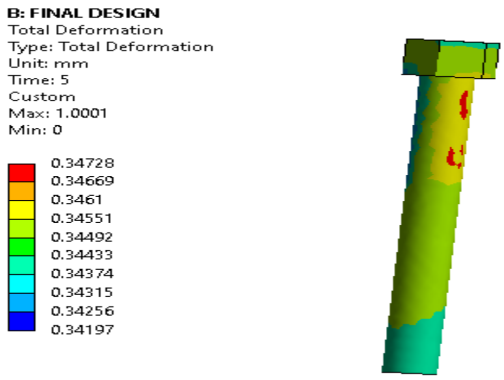


Fig.7: Total deformation of bolt

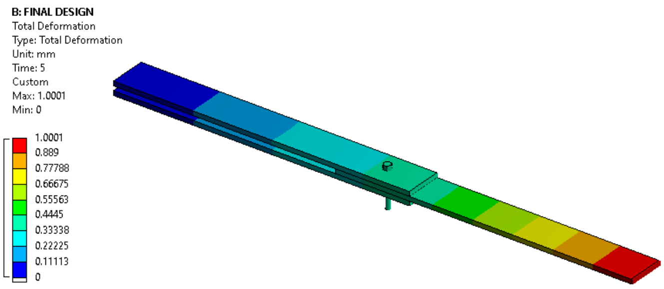


Fig.8: Deformation results of assembly

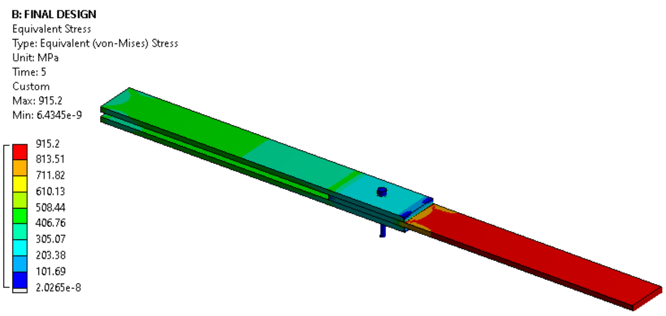


Fig. 9: Equivalent stress result of assembly

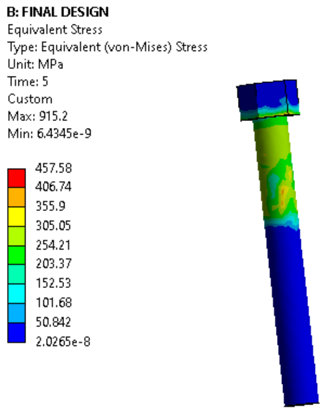


Fig.10: Equivalent stress result of bolt

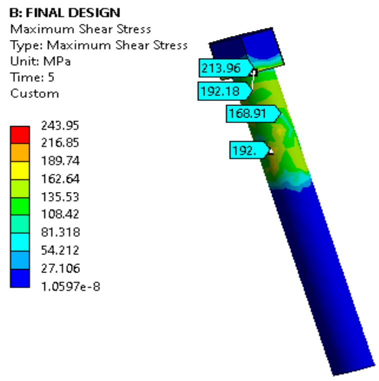


Fig.11: Shear stress result

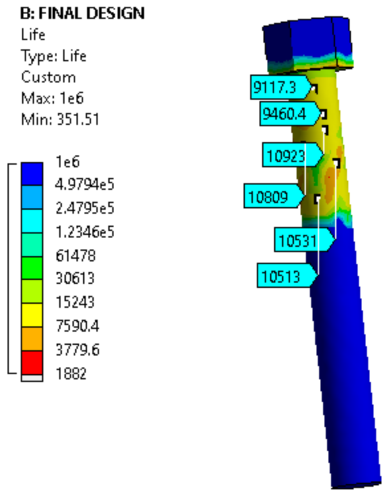


Fig.12: Fatigue life results

It is observed from FEA result number of cycles required for failure is around 10222.5 cycles with bolt crossing yield strength of stress for failure.

Table. 1: Stress vs No. of cycles

	B	C
1	Cycles	Alternating Stress (Pa)
2	10	3.999E+09
3	20	2.827E+09
4	50	1.896E+09
5	100	1.413E+09
6	200	1.069E+09
7	2000	4.41E+08
8	10000	2.62E+08
9	20000	2.14E+08
10	1E+05	1.38E+08
11	2E+05	1.14E+08

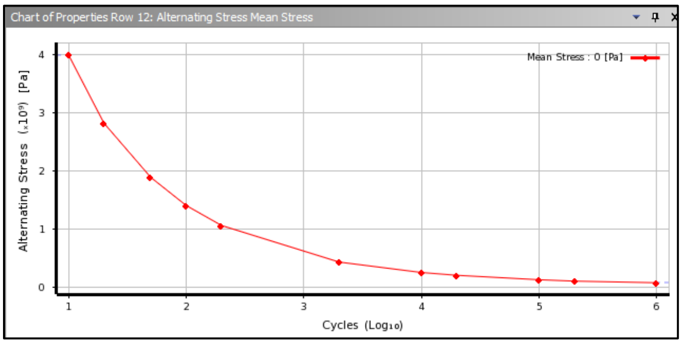


Fig. 13: Graph of stress variation with cycles

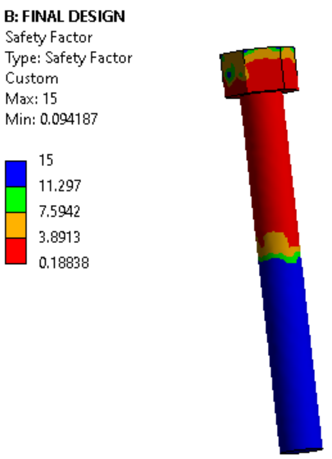
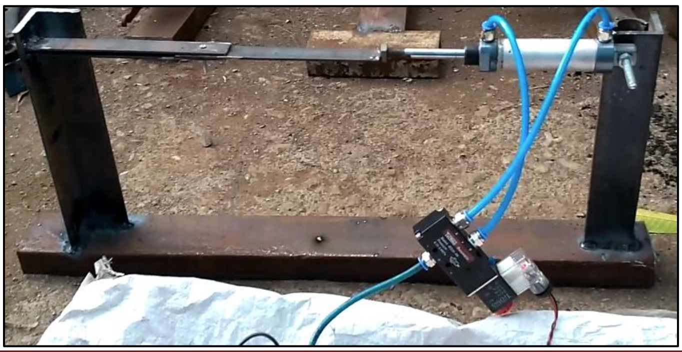


Fig.14 : Safety factor result

EXPERIMENTAL TEST



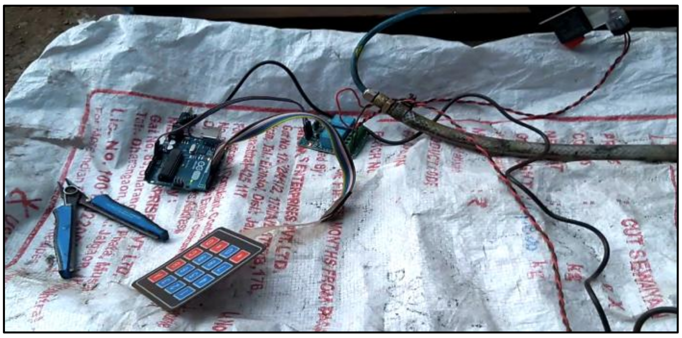


Fig. 15: Experimental setup

EXPERIMENTAL PROCEDURE

In present study in experimental setup it consists
Three rectangular plate, Base frame (C section), Support structure (L section), Pneumatic cylinder, Solenoid valve, Arduino, M4 bolt and nut, Battery
Initially certain pressure of air is supplied to pneumatic cylinder with 20 Hz frequency for excitation of fatigue bolt assembly.
Time is recorded until bolt start to rotate and due to which failure of bolt across and time is recorded.
From FEA analysis fatigue cycles is calculated.
From experimental it is observed that around 3 min (180 sec) bolt fails and start to rotate.

IV. CONCLUSION

1. In present research fatigue investigation of M4 bolt is performed with three plates sandwiched with bolt to determine von misses stress, shear stress, fatigue life.

2. In shear stress it is observed around average 191 MPa which lead to failure of bolt to determine number of cycles for sustain boundary condition.

3. From experimental results it is observed that failure cycles calculated by FEA and experimental are nearly identical.

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