DEDICATION

To all our parents who taught us since childhood and watched us nights. We would like to dedicate this project to you, where you can see with your own eyes the merit of this hard work that you worked for us, which made our character and led us to become real engineers

Signed: ________________________

Date:

Signed (repeat for all students) :

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Acknowledgment

First, we would like to express our deepest gratitude and appreciation to our parents for their unwavering love, support, and guidance throughout our life. Their constant encouragement and motivation have been a driving force behind our achievements and successes.

And also, we would like to express our heartfelt appreciation to our advisors, for their unwavering support of our study and research, as well as their patience, encouragement, inspiration, and vast knowledge. Their advice was invaluable throughout the research and writing of this thesis. We could not have asked for better advisors and mentors for our project. Finally, we would like to show our special thanks to the department's head, Prof. Dr. Bahaa Eldin.

Abstract

This unidirectional shake table test delves into the seismic performance of a specimen type under simulated earthquake motions. Secured on the platform, the specimen faces a meticulously curated sequence of ground motions mimicking diverse earthquake scenarios. Throughout the tremors, its acceleration, displacement, and strain responses are meticulously monitored and captured. A thorough data analysis then dissects its dynamic properties, earthquake-resistant capacity, and overall resilience. This unveils valuable insights into its seismic behavior, validates numerical models for enhanced accuracy, and ultimately informs the development of robust earthquake-resistant design strategies.

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تحية طيبة

الموضوع/ تعاون في تنفيذ مشروع تخرج 2023-2024 Uni-axial Shaking Table

بالاشارة إلى الموضوع أعلاه , حيث يقوموا طلاب هندسة الميكاترونيات مجموعة(8) بتنفيذ المشروع بالموصفات التالية:

Specifications of System Design	Value of Specification
Shaking direction	Uni-axial horizontal motion
Dimension of shake table	60× 40cm
Dimension of shake table	10cm
Maximum load weight	10kg
Amplitude range	1-80 mm
Control system	dedicated software running under a PC
Engine	Stepper motor

وعليه فإن الزملاء طلاب هندسة التشيد يقوموا بتنفيذ نماذج هياكل الاختبار. ومن ثم نقوم معا(طلاب هندسة الميكاترونيات و طلاب هندسة التشيد) بإجراء الاختبارات على المشروع ومقرنتها بالوقع خلال شهر ابريل 2024

ولكم جزيل الشكر والتقدير

رئيس قسم هندسة الميكاترونيات

رئيس قسم هندسة التشيد

Ahmed Sayed

Chapter 1
Introduction

1.1 Introduction

Earthquakes

The Earth, often perceived as a stable platform, occasionally unleashes its raw power through earthquakes – sudden and violent shaking of the ground that can leave a trail of destruction in its wake. These events, a stark reminder of Earth's dynamic nature, have captivated and terrified humanity for centuries.[1]

The Trembling Earth:

Sudden Ground Motion: Earthquakes are not mere tremors, but violent shaking of the Earth's surface caused by the movement of tectonic plates, Earth's colossal puzzle pieces constantly shifting beneath our feet.

Widespread Devastation: The consequences of earthquakes can be far-reaching, causing widespread damage to infrastructure, triggering landslides and tsunamis, and even altering landscapes.

Magnitude Matters: The severity of earthquakes is measured on the Richter magnitude scale, a logarithmic scale ranging from 1 (barely perceptible) to 10 (capable of reshaping entire regions).

Plate Tectonics: The Earth's outermost layer, the lithosphere, is not a monolithic shell but a fragmented mosaic of massive, rigid plates constantly in motion due to the convection currents within the Earth's mantle.

Friction and Release: These plates grind against each other, slide past, or occasionally collide, building up immense frictional forces. When this tension reaches a critical point, it releases energy in the form of seismic waves, causing the ground to shake.

Seismic Waves: The energy released during an earthquake travel through the Earth's interior as seismic waves, causing the ground to vibrate sometimes for hundreds of miles around the epicenter, the point on the surface directly above the rupture.

The crust can move vertically or horizontally because of fault movements.

If the crust moves vertically, scientists say it has been uplifted. Vertical movements create a sharp edge called a fault scarp. If the crust moves horizontally we say it has been offset or displaced .

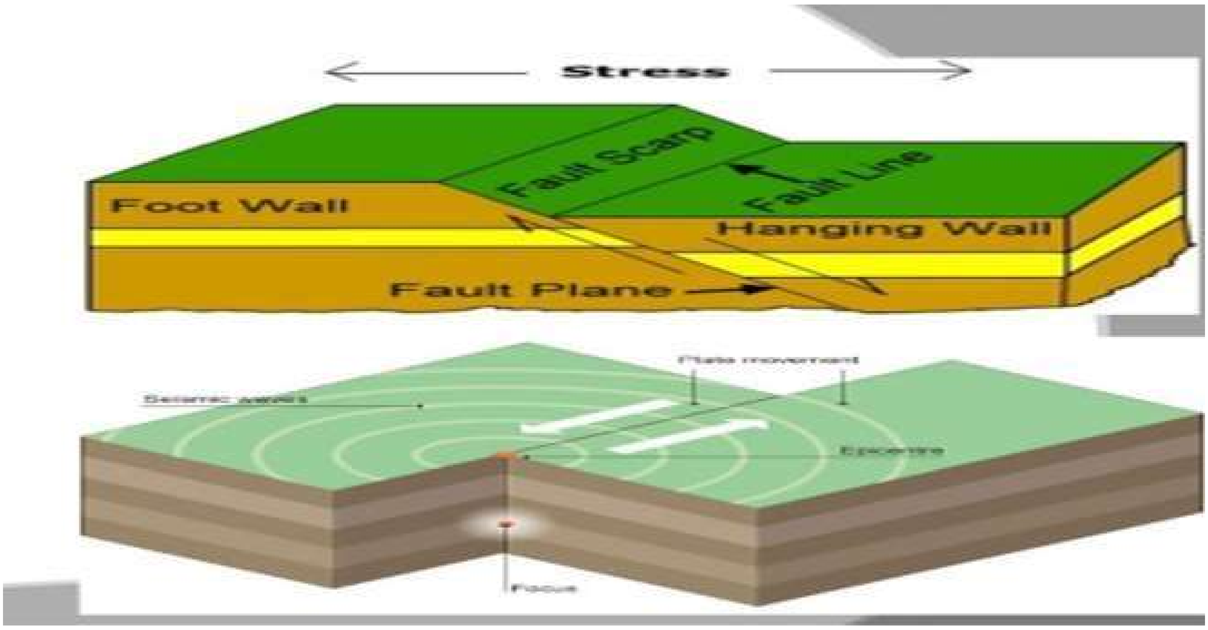


fig 1.1 s-wave, p-wave direction

to the direction of particle motion. Vertically and horizontally polarized S-waves are known as SV-wave and SH-wave, respectively. They are sometimes called secondary waves because they travel more slowly than P-waves in the same material. S-waves do not change the instantaneous.

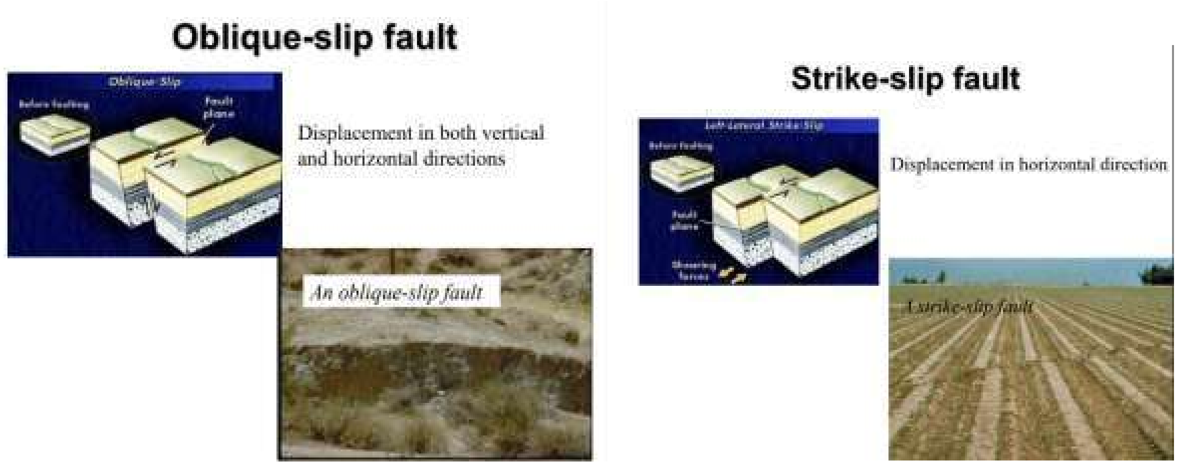
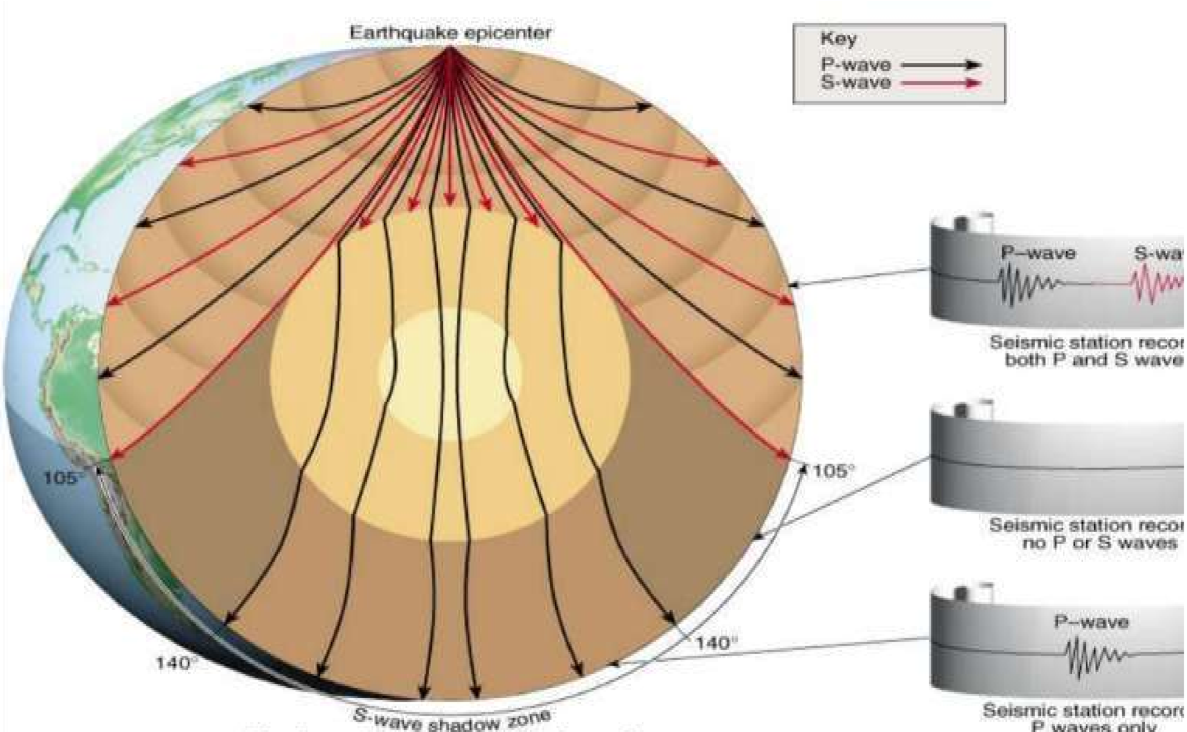


Fig1.2 type fault



Shadow Zone - no earthquake waves

1.2 Shake table introduction.

Comparing theoretical results to the dynamic behavior of structures using scaled structure models is a preferred research method in civil engineering. To facilitate this, a shake table equipped with Arduino microcontroller boards, has been developed for earthquake simulations. The horizontal components of the acceleration records obtained from past earthquakes are scaled and transferred to the shake table using software programs developed with an Arduino board. The seismic ground motion along the horizontal axis is transferred to the shake table via a linear actuator system built with a ball screw assembly, linear bearings, and a DC motor. In the advanced uniaxial vibration mechanical system of the shake table table, precision linear ball bearings and a slide assembly are used to reduce friction on the slides on which the 16mm crow balls move. The base of the table measures 62mm by 40mm, while the top measures 35mm by 35mm. The slats are fixed with suitable supports, and in the prototype stage, the top and bottom panels are manufactured from 18 mm thick MDF board using CNC machining.

The linear actuator assembly used for driving the single-phase displacement-controlled vibration table is constructed from a two-phase DC motor. Arduino transmits control signals. The presented SARSAR shaking table can perform simple single and damped harmonic motions of different amplitudes and frequencies and simulate seismic ground motion using developed Arduino software. The shaking table is calibrated with different amplitude and frequency responses for simple harmonic motion, with channel measurements at 200 Hz for six-channel measurements, which is sufficient to observe the dynamic behavior of the shake table. The Arduino code for the data acquisition part of the control unit is provided in the online resource.

Fig1.5 shaking table

1.3 data acquisition using PLX DAQ v2.

PLX DAQ v2 is a program used to establish an easy communication.

between Microsoft Excel on a Windows Computer and any device that supports serial port protocol. It was intentionally written to allow communication. between Arduino and Excel.
you can, for example, measure temperature data with your Arduino, send the results to Excel every 10 seconds, print the data on a sheet and draw a graph with all information.

All communication will be done by **Serial.println** commands just like the commands you use to send from Arduino to monitor in your Arduino IDE Serial Monitor.

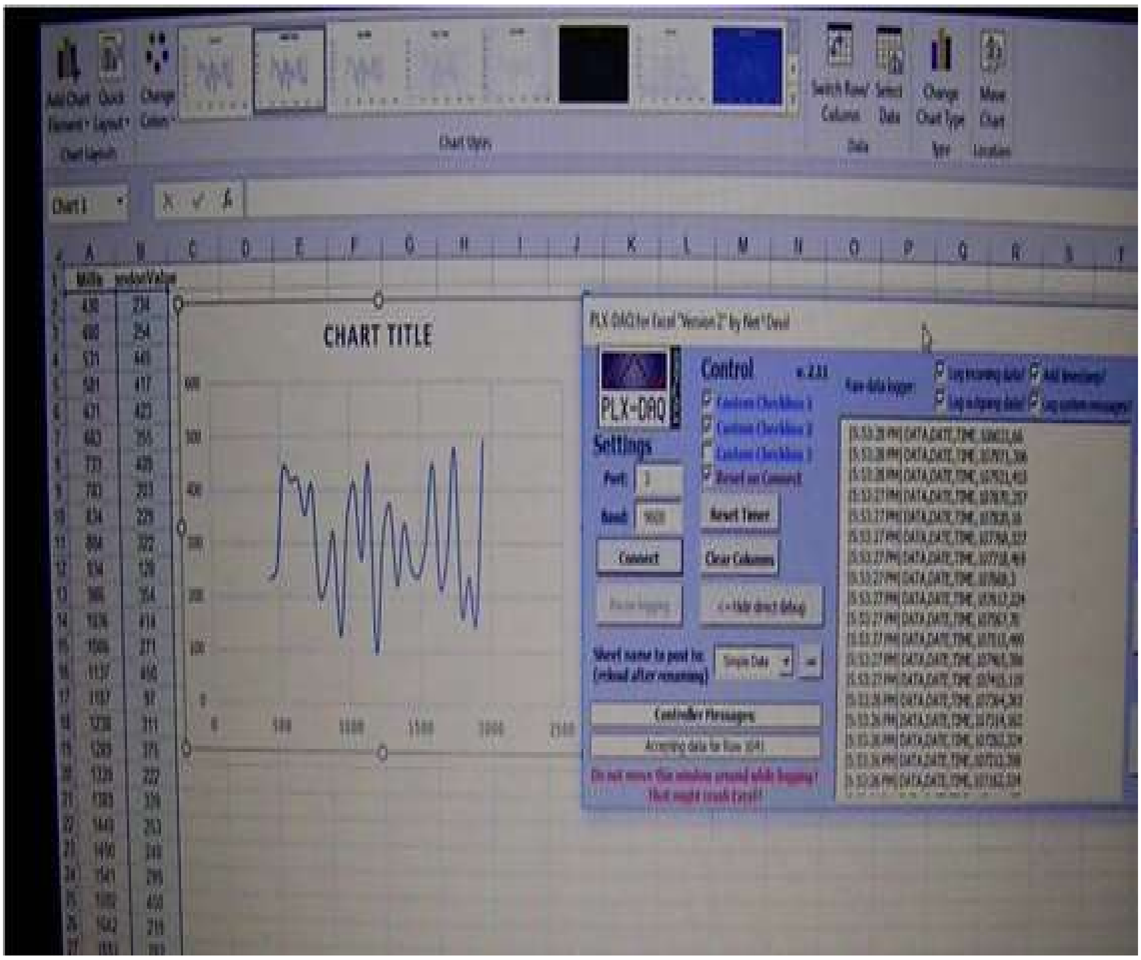


Fig1.6 data acquisition

1.3 Liquefaction Using Shake Table Test

One of the major causes of destruction during an earthquake is the failure of the ground structure. The ground may fail due to fissures, abnormal or unequal movement or loss of strength. The loss of strength may take place in sandy soils due to increase in pore pressure. This phenomenon is termed as liquefaction. The increase in pore pressure is due to shaking of ground.[2]

Naturally occurring earthquakes are a major source of vibration of ground soil. The waves produced during an earthquake are random in nature which are responsible for liquefaction. Thus earthquake induced liquefaction leads to detrimental effects to a larger extent and thus is to be assessed. The hazards caused due to liquefaction could be of various types such as flow failure, lateral spreads, development of fissure and cracks, loss of strength, increased lateral pressure on retaining walls etc.[2]

1.3.1 Test Procedure

The specific values of frequency and amplitude are set on the shake table apparatus. Then the box model 300mm x 200mm x 150mm is fixed to the base plate of the equipment. for the convenience of specimen preparation. The calculated amount of sand and water are weighted accurately. and the soil model filled in layers. The care is taken to achieve required density, corresponding to a particular relative density.

Fig1.7 the box model test

Amplitude is then set on the instrument and frequency is adjusted digitally on the display shows Thereafter, the equipment is switched on which starts shaking the soil in the model at the required acceleration. The data of acceleration versus time is recorded through data acquisition system.

Fig1.8 shaking the soil in the model

1.3.2 **Results**

Results showed that sand soils have a liquefaction potential. In addition, acceleration and relative density has a great effect on the dynamic behavior of the soils

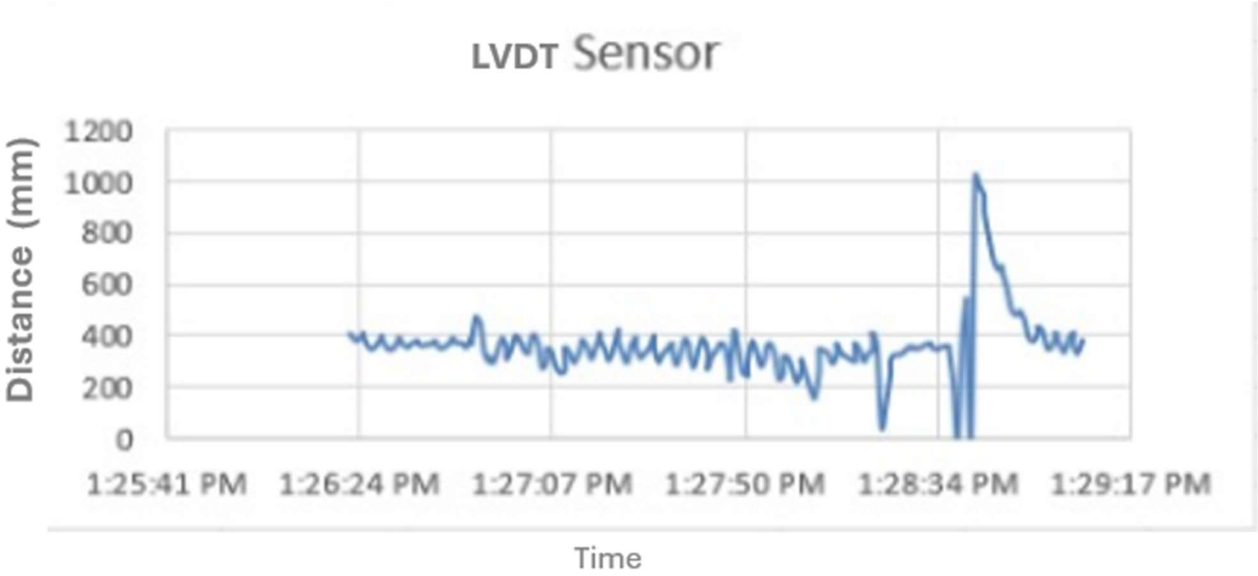


Fig 1.9 LVDT senor Results

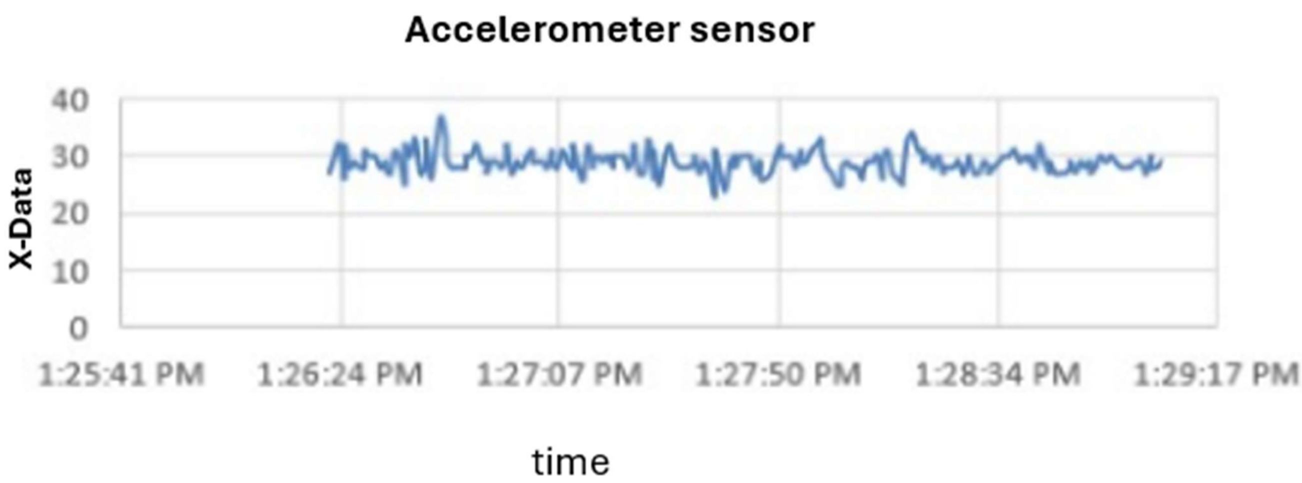


Fig1.10**Accelerometer** senor Results

Literature Review
Chapter 2

2.1_BACKGROUND: THE NEED FOR A LARGE-SCALE EARTHQUAKE TEST FACILITY

In 1995, the Hyogoken-Nanbu (Kobe) earthquake caused devastating damage to numerous buildings and the infrastructure in the Kobe area. However, this was not the first large Japanese earthquake. Along the Pacific Coast of Japan there is an ocean ridge called the Nankai Trough. The trough consists of three regions (Tokai, To Nankai, and Nankai), and slips and ruptures have occurred periodically in these regions. One or two of the regions ruptured in some cases while all three regions ruptured simultaneously in other cases. It is well known from historical records that these slips and ruptures in the Nankai Trough have caused several extremely large earthquakes over the past 500 years. Also, the interval between these super earthquakes is between 100 and 150 years. Even though no scientific prediction data exist, calculating from the pattern of previous large earthquakes, it is likely that Japan will be hit by very large earthquakes in the middle of the twenty-first century [3].

The Council of National Disaster Mitigation, chaired by the Prime Minister of Japan, reported in 2005 that, when the three regions of the Nankai Trough rupture at the same time, about 1 million buildings will collapse, about 25 000 people may lose their lives, and the economic loss will be 1 trillion US dollars. From these data, the earthquake danger is the most critical national problem in Japan. The 1995 Kobe earthquake and other recent large earthquakes have made the following two facts clear [4].

1. Throughout Japan, many old buildings and infrastructures exist whose seismic capacity is insufficient. To prepare for future large earthquakes, it is crucial to evaluate their seismic capacities accurately and strengthen them according to the evaluation results using appropriate retrofit technologies.

Since severe earthquake ground motions that would cause structural collapse to occur very rarely, it is difficult to monitor or measure the real behaviour of structures subjected to such events. Furthermore, building structures are massive and mostly beyond the capacity of existing laboratory test facilities, while miniature models are known to fail to duplicate real building behaviour because of lack of similitude. Advances in numerical analysis methods such as the finite element method are notable, but the analyses insufficiently duplicate the behaviour of structures to collapse, which involves significant material and kinematical non-linearity. For these reasons, the need for real data obtained by experiments with real-scale structures is extremely urgent for the advancement of earthquake engineering. E-Defense has been designed to meet this need.

2.1.1 LITERATURE REVIEW (EERC) shaking table

The 20x20 ft shaking table at the Earthquake Engineering Research Center in Berkeley (EERC) is tested for interaction effects. The tests include three. Loading configurations: a bare table, a table loaded with 70 kips mass and a Table loaded with 68 kips single degree of freedom structure with a height of 219 inches. The shaking table has 5 degrees of freedom, one horizontal, one. vertical and 3 rotational degrees of freedom. When loaded with heavy and tall structures, the shaking table undergoes pitching (rocking) motion even.

This is mainly due to the flexibility in the pitch degree of freedom. It is observed that the interaction effects. are negligible for the bare table and the table with rigid mass case. In the case of the tall and heavy structure the pitching of the seismic simulator was evident when using a table horizontal command signal, In addition, a change in the frequency component of the horizontal table motion near the Structural frequency was observed. These include a shaking table with a horizontal actuator, a pitching actuator and a passive pitch stabilizer. Simplified spring-mass-damper models are also discussed. Methods for Avoiding modeling of the table flexibilities are presented. These include the Use of a two-directional base input motion and the simpler uni-directional effective base motion. Interaction effects are studied using response spectra. and the equivalent single degree of freedom table-structure system. It is concluded that the interaction effects are similar to those encountered in soil structure interaction studies. The interaction causes a reduction in the structural frequency and usually, but not always, an increase in damping. The change in the frequency component of the command signal Near the structural frequency due to interaction does not significantly affect. The ability of the shaking table to produce damaging motions to the test structure.Shaking table pitching and interaction effects were traditionally dealt with. by adding two vertical springs to the mathematical model to represent the Pitching flexibility. The passive stabilizer system was added to the EERC table in 1977 to reduce the flexibility in the pitching degree of freedom. For this reason, springs in the mathematical model used by Tang [5] are different from the ones used by later researchers. The required pro properties of the springs were typically derived from trial-and-error analysis, so that the coupled frequency structure matches the measured frequency. This approach, though convenient, can lead to serious errors because the springs will hide other modeling errors. The performance of shaking tables was the subject of several researchers at D.C. Berkeley in the past. Rea et al. [5] tested a small unidirectional Shaking table and the EERC table. Mathematical models were formulated to represent these shaking tables; however the models did not include the pitch effects. Rea found that: “...The magnitudes of the peak and notch distortions in the frequency Response of shaking tables are sensitive to the amount of force feedback employed by the control system.

In addition, the magnitudes depend on the ratio of the mass of the structure to the mass of the shaking table, and to the transmissibility function of the structure with respect to the table. Although the peak and notch effect may cause difficulties in determining the frequency response of structures by means of shaking tables, it has little effect on the accuracy to which a shaking table can reproduce earthquake-type motions... " also studied the effect of foundation compliance on a shaking table frequency response and found that foundation compliance affects the frequency response of the EERC shaking table only at low frequencies, and that the magnitude of the effect depends on the transmissibility function of the foundation with respect to the table. Blondet et al. performed a similar study on the unidirectional shaking table at the Catholic University of Peru. In addition to Rea's model, a two Degree of freedom mass-spring-damper system was used to simulate the shaking table-structure interaction. Blondet et al. concluded the following[5].

1. The main aspects of the interaction problem can be studied from a mechanical viewpoint using a 2DOF spring-mass-damper system.

2. The interaction effects are mainly manifested by a peak and notch in the amplitude frequency response with the maximum attenuation occurring precisely at the natural vibration frequency of the test structure. This is particularly undesirable since the purpose of earthquake Simulation tests are to excite the structure at its own frequency in order to cause damage.

2.1.2 RESEARCH OBJECTIVES

The objective of this research project was to evaluate the EERC shaking table performance and to establish analytical models for the shaking table that can be used to account for and predict the shaking table-structure interaction effects. More specifically the objectives can be stated as:

1. To evaluate the table reproduction of typical earthquake records and to study the effects of the pitch motion on the structural response.

2. To establish a simplified mass-spring-damper system that can account for shaking table-structure interaction effects and can be easily incorporated in analytical models of the test structures; also, to devise ways for identifying the model parameters.

3. To develop an analytical model for a unidirectional shaking table system that includes feedback control loops.

4. To extend the mathematical model to include table pitching effects by means of

a. A mass-spring-damper system (hybrid model), and

b. A feedback control loop similar to that of the horizontal actuators;(Such models can be used to predict table performance and stability.)

5. To investigate ways of improving system performance through

6. Modification of the command signal, the addition of actuators,etc.;and

7. To study methods of analyzing tested structures on the shaking table, which may avoid dealing with interaction altogether.

Earthquake Induced Liquefaction Using Shak e Induced Liquefaction Using Shake Table Test

Prasad et al (2004) have developed a manual shake table using laminar box. However, It does not take into account pay load and the criterion for initiation of liquefaction in terms of CSR Behar K.C. et al (2005) studied liquefaction behavior of silty sand by Conducting shake table tests on samples with different silt contents. The work focused Mainly on resistance offered by silty sand to liquefaction for steady state of vibrations. Singh et al (2008) presented the liquefaction behavior of the Solani sand by Performing shake table tests at varying acceleration with constant frequency. The results were interpreted in terms of the pore water pressure and the time elapsed during various stages. It was observed that there was little effect of level of acceleration on the magnitude of maximum pore water pressure; however, time required in reaching the Peak value decreased at higher acceleration.[6]

Fig2.2 Test modle

Shake Table test apparatus is specifically designed to conduct the tests for studying the criterion for initiation of liquefaction by simulating ground shaking during Earthquake. It comprises mainly of three main components –

- **A vibrating platform:**

This is the platform which vibrates with the soil model attached to it. The size of the platform is 1000 mm X 1000mm. It is made up of cast iron which is coated with silver paste.

- **Control panel:**

This is most important component of the shake table as it controls the frequency of the shaking. The control panel has been given standard combinations of amplitude to produce the required acceleration

- **Motor:**

It actually vibrates the vibrating platform. The capacity of the motor is 3 H. P. with a three phase connection
In addition to this, a piston arrangement is provided which translates rotary motion of the piston into vibratory motion. The shake table is mounted on foundation plate of size 1900mm x 1600 mm. It is made of cast iron. The total pay load of the shake table is 300 kgs. With a frequency range of 1-10Hz. All the components of the Shake Table Apparatus are Shown in the Photograph 1. The soil model used at present The study is a square model of size 400 x 400 x 400 Height x 12mm thick (Photograph 2)

Chapter 3
Mechanical Design

3.1.1 Overview.

In this Section we will go through the mechanical design, drawings and the materials used to achieve the desired strength, and information aboutthe material used, With stress, strain, displacement analysis of the project.

3.1.2 Design Assembly 3D Model.

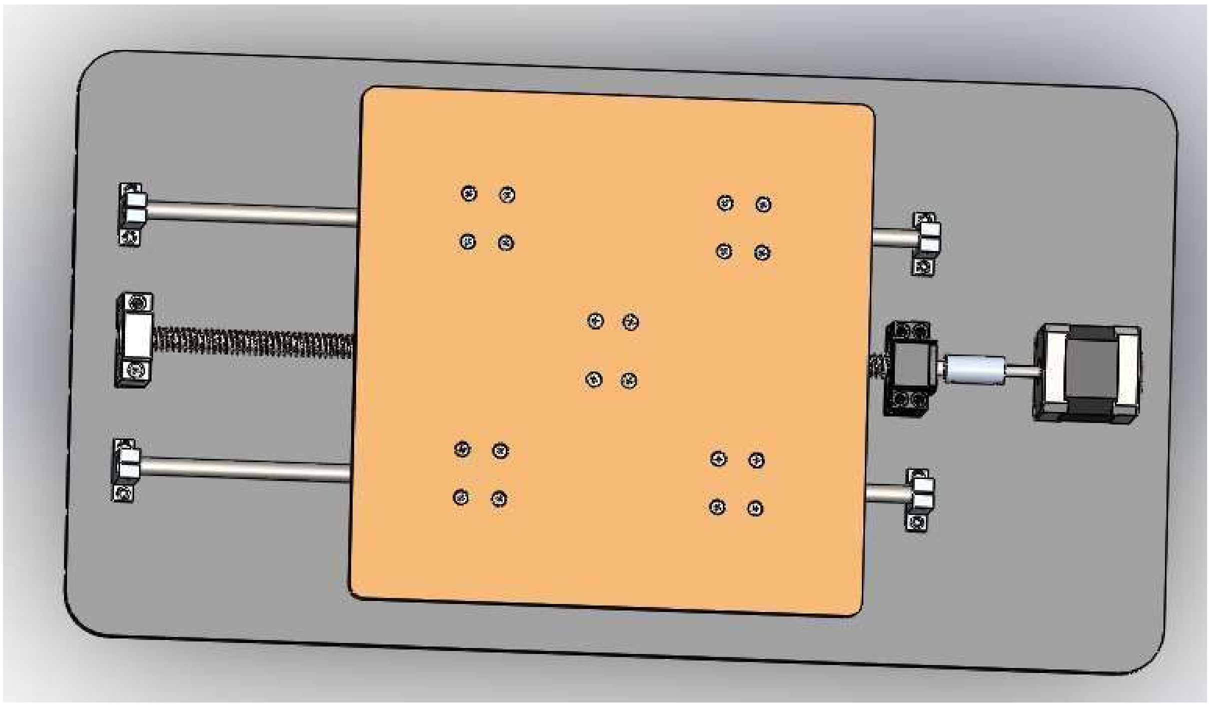


Fig. 3.1 design assembly 3D model

3.1.3 Assembly Parts

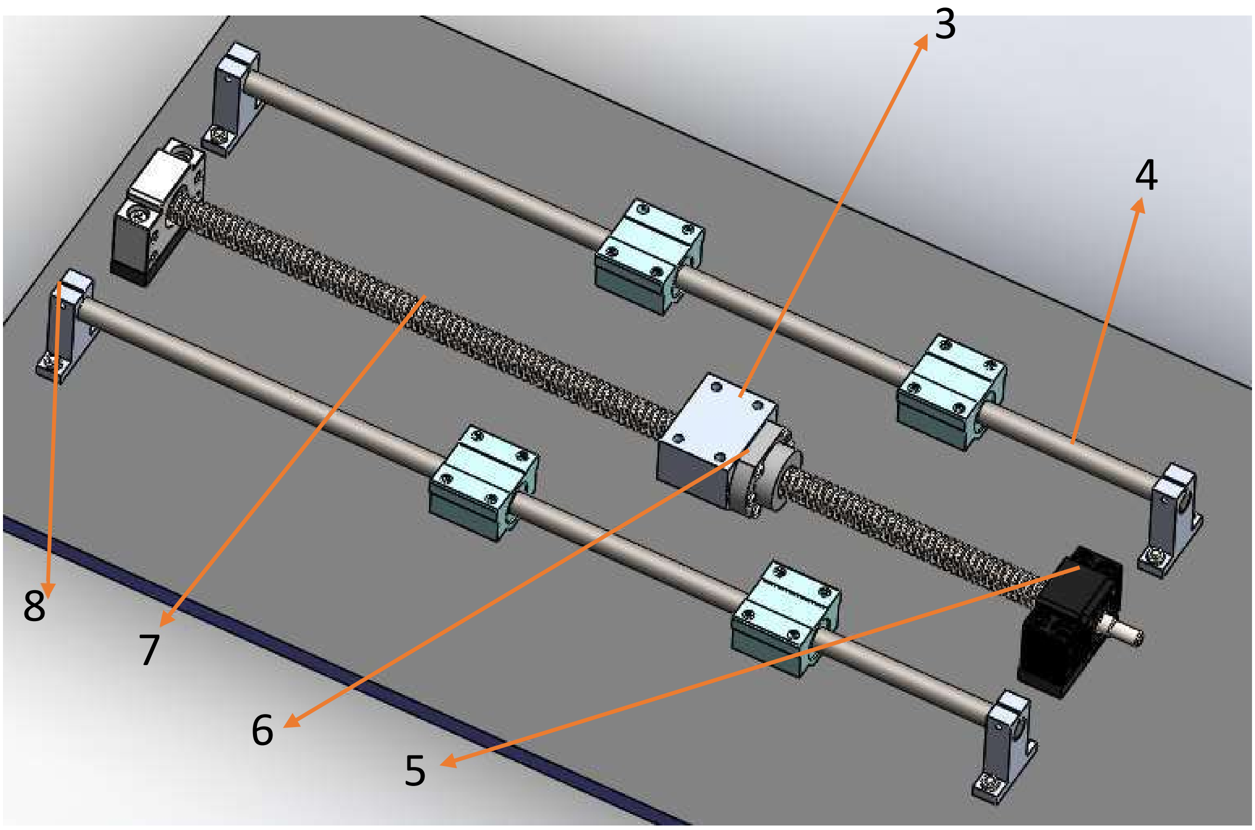


Fig. 3.2(a) Assembly Parts

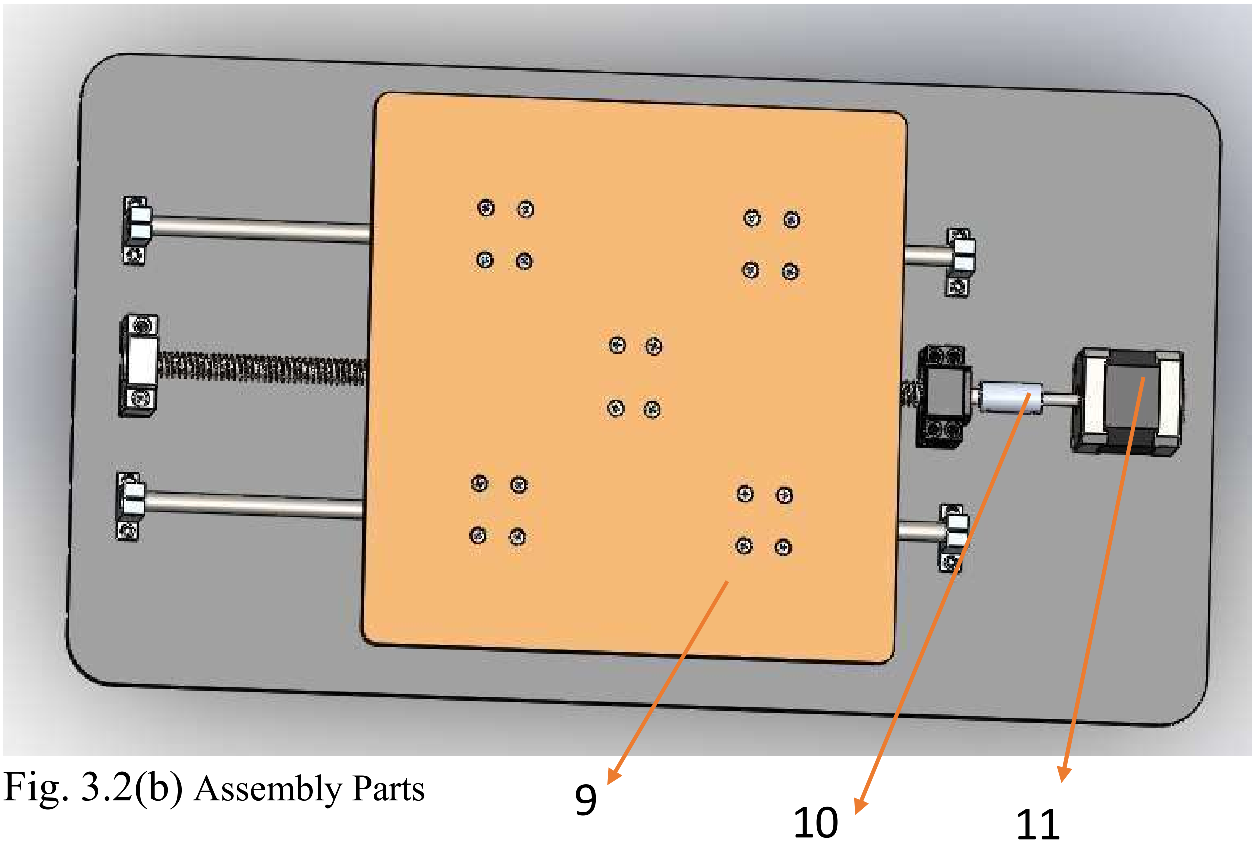


Fig. 3.2(b) Assembly Parts

NO.	PART NUMBER	MATERIAL	QTY.
1	Base Plate	Balsa	1
2	Linear Motion Ball Slide Bearings	Carbon steel	4
3	lead Screw Nut Seat Bracket Holder Mount Housing	Carbon steel	1
4	guide shafts.	Steel 1.1213	2
5	Lead Screw End Supports	Carbon steel	2
6	**Lead** nut		1
7	Lead screw.	304 Stainless Steel	1
8	**Linear Rail Shaft Support**	Carbon steel	4
9	Table	Balsa	1
10	Flex Coupling	Aluminium Stainless Steel	1
11	motor		1

Table 3.1. Assembly Parts

Mechanical components and its functions

- <u>**Nut and ball screws**</u>

Nut and ball screws are mechanical components used to convert rotational motion into linear motion. They are commonly found in various industrial applications, including CNC machines, robotics, and linear actuators. The function of nut and ball screws can be described as follows:

Ball Screw: A ball screw consists of three main components: a screw shaft, a nut containing recirculating ball bearings, and a ball return system. The screw shaft has helical grooves that form a track for the ball bearings. The nut, which is threaded onto the screw shaft, contains matching grooves for the ball bearings to roll along.

When rotational motion is applied to the screw shaft, the ball bearings inside the nut recirculate within the grooves, causing the nut to move linearly along the screw shaft. The rolling motion of the ball bearings reduces friction, allowing for efficient and precise linear motion. The ball return system ensures that the ball bearings continue to circulate when the nut reaches the end of the screw shaft.

Nut: The nut is an essential component in the ball screw system. It houses the ball bearings and provides a threaded interface with the screw shaft. The nut's primary function is to convert the rotational motion of the scre w shaft into linear motion.

As the screw shaft rotates, the ball bearings roll along the helical grooves on the screw shaft and within the matching grooves in the nut. This rolling action creates a force that moves the nut linearly, either towards or away from the screw shaft, depending on the direction of rotation.

The precision and efficiency of ball screws make them ideal for applications that require accurate and smooth linear motion. They offer advantages over other screw mechanisms, such as lead screws, by providing higher load capacities, reduced friction, and increased positioning accuracy. Install the nut in lead screw as shown Fig 3.3

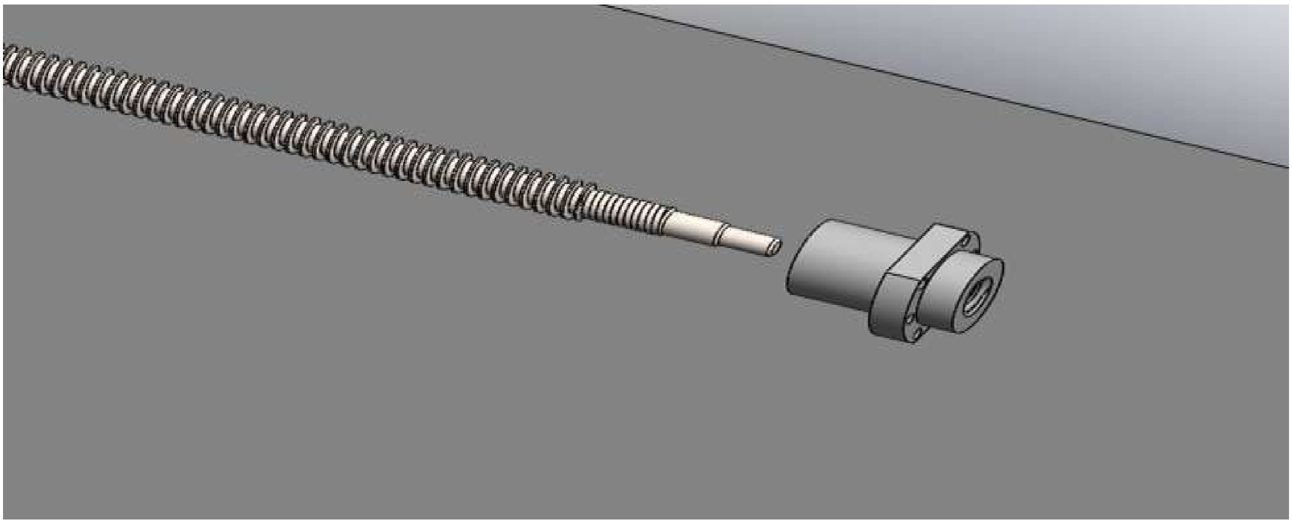


Fig 3.3- Install the nut in lead screw

- <u>**ball screw nut seat bracket holder mount housing**</u>

The function of a ball screw nut seat bracket holder mount housing is to provide a secure and stable mounting platform for the ball screw nut assembly. It serves several important purposes:

<u>**Mounting Interface:**</u> The housing typically has mounting holes or other provisions for attaching the ball screw nut seat bracket holder to a larger structure or machine. It allows for easy integration of the ball screw system into the overall mechanical assembly.

<u>**Load Distribution:**</u> The housing distributes the loads and forces acting on the ball screw nut assembly. It helps to minimize stress concentrations and ensures that the forces are evenly distributed, enhancing the overall stability and longevity of the system.

The ball screw nut seat bracket holder mount housing serves as a critical component in a ball screw system, providing support, protection, alignment, and stability. It helps optimize the performance and longevity of the ball screw assembly in various industrial applications. Install lead Screw Nut Seat Bracket Holder Mount Housing in lead screw as shown Fig 3.4

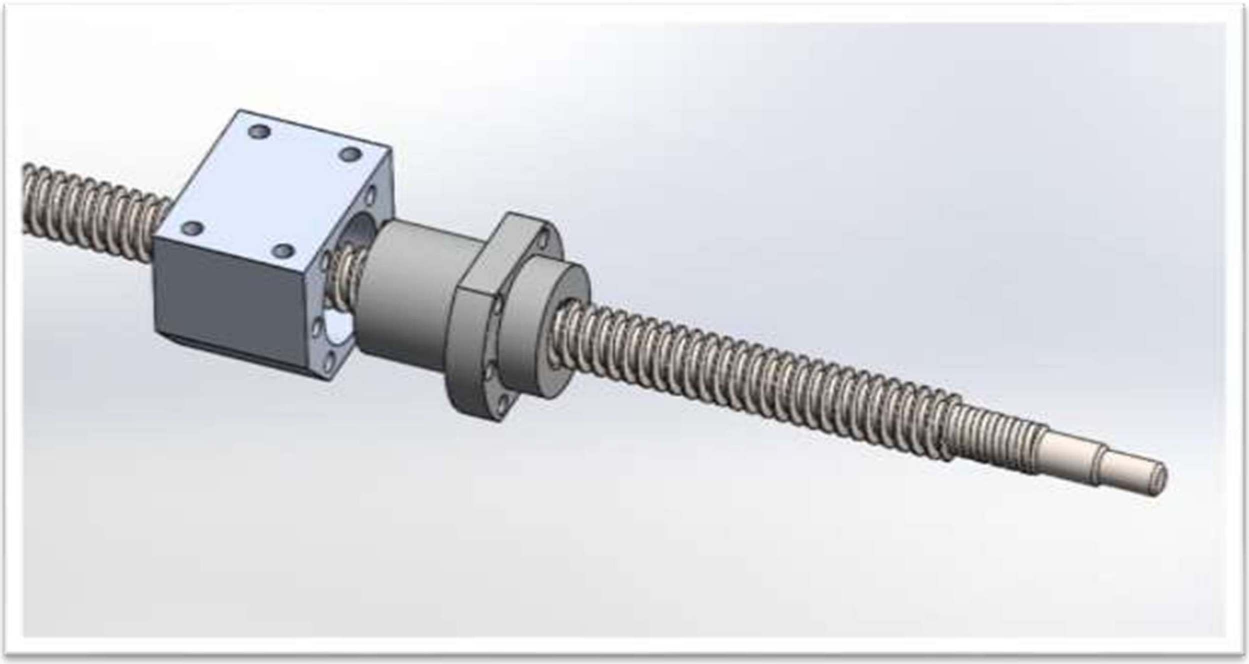


Fig 3.4 install lead Screw Nut Seat Bracket Holder Mount Housing in lead screw

- **Ball screw end supports**

Ball screw end supports are components used to secure the ends of a ball screw and provide stability and alignment for the screw shaft. These supports help prevent bending and vibration of the screw during operation, ensuring smooth and accurate movement. They are typically mounted on the ends of the ball screw assembly and are available in various sizes and configurations to suit different applications. install lead Screw Nut Seat Bracket Holder Mount Housing in lead screw as shown Fig 3.5

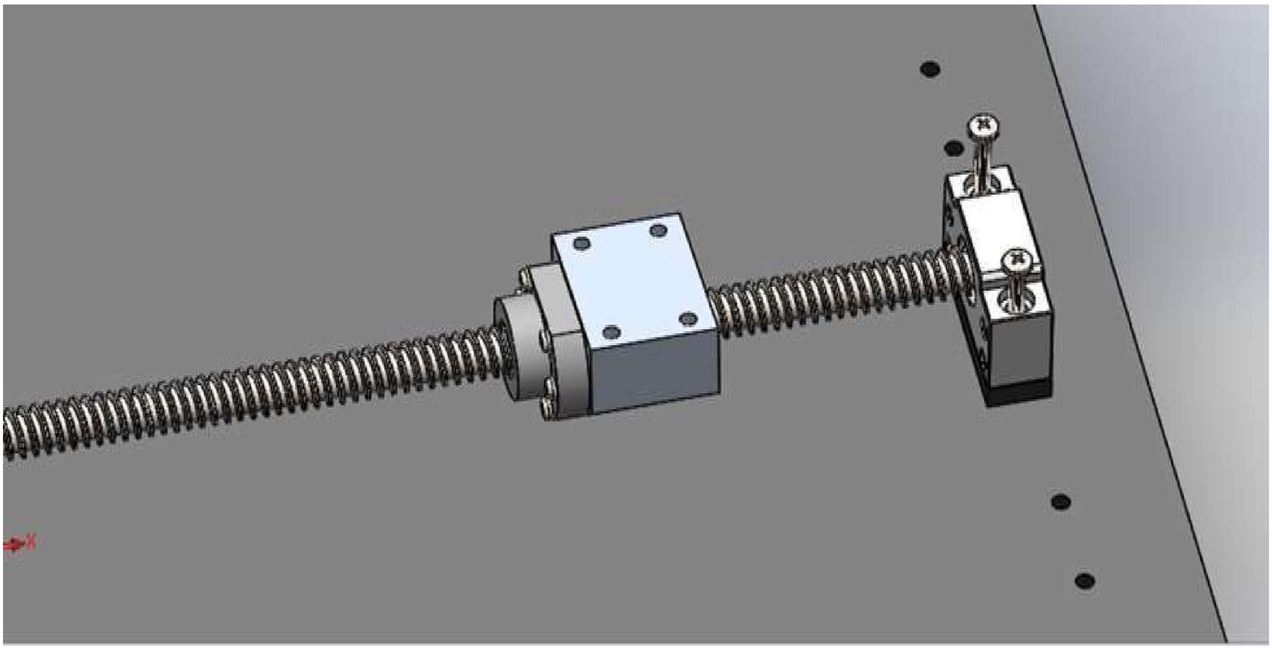


Fig 3.5 - install Lead Screw End Supports in lead screw

- **Linear guide shafts & Linear rail shaft supports**

Linear guide shafts are precision linear motion components that allow for smooth and precise movement of machinery or equipment along a specified path. These shafts typically consist of a hardened steel shaft with grooves or raceways for ball bearings or rollers to move along, providing low friction and high load capacity.
Guided Motion: The primary function of linear guide shafts is to provide a precise and smooth guided motion for linear components, such as slides, carriages, or bearings. They serve as a reference and support for the linear motion system, ensuring accurate and controlled movement.
Load Bearing: Linear guide shafts are designed to bear and distribute loads along their length. They provide structural support and help prevent excessive deflection, ensuring that the system can handle the intended loads.

Linear rail shaft supports are components that are used to support and guide linear guide shafts. They are typically constructed of aluminum or steel and are designed to securely hold the linear guide shaft in place while allowing for smooth and precise movement
linear guide shafts and linear rail shaft supports work together to provide guided motion, load-bearing capability, rigidity, stability, and smooth operation in linear motion systems. They ensure precise movement, minimize vibrations, and maintain the integrity of the system under various loads and operating conditions
install four Linear Rail Shaft Support in base plate, install in guide shafts and install guides shafts in Linear Rail Shaft Support as shown Fig 3.6

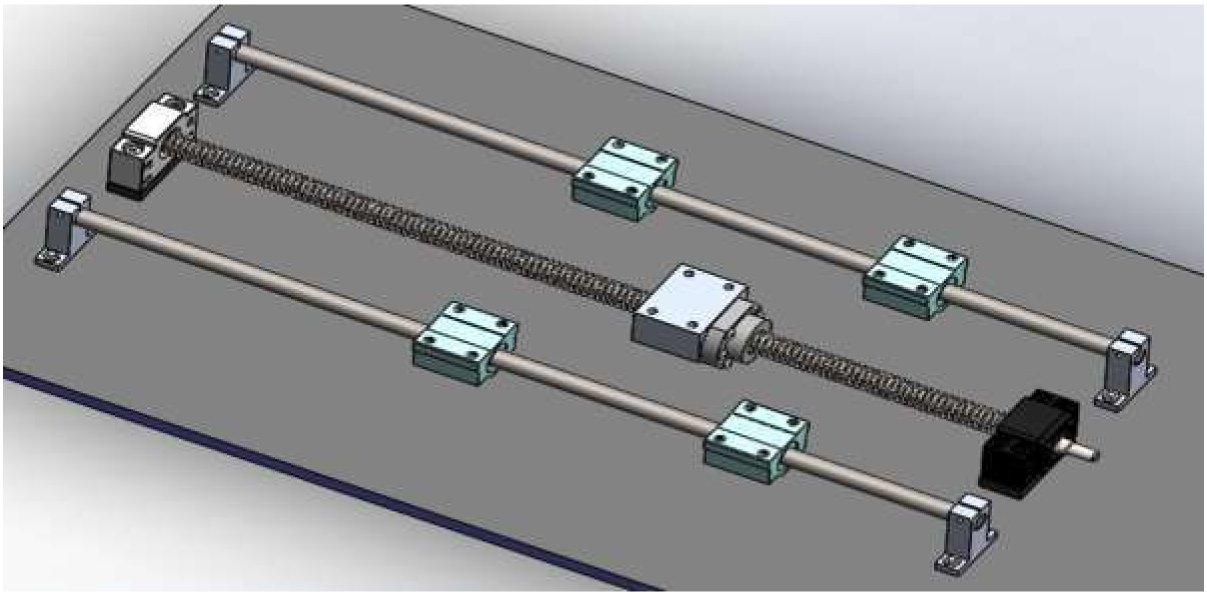


Fig 3.6- install four Linear Rail Shaft Support in base plate

- **Top plate and a base**

The shaking table consists **of a top plate and a base**. The top plate is where the test specimen or model structure is placed, and the base provides support. The movement plate base distributes the loads and forces generated during shaking across its structure. It helps to minimize stress concentrations and ensures that the forces are evenly distributed, maintaining the stability and integrity of the system. the movement plate works, as the mounting platform for the test specimen or the structure being subjected to the shaking motion. It provides a secure and stable surface for attaching and fixing the test specimen.

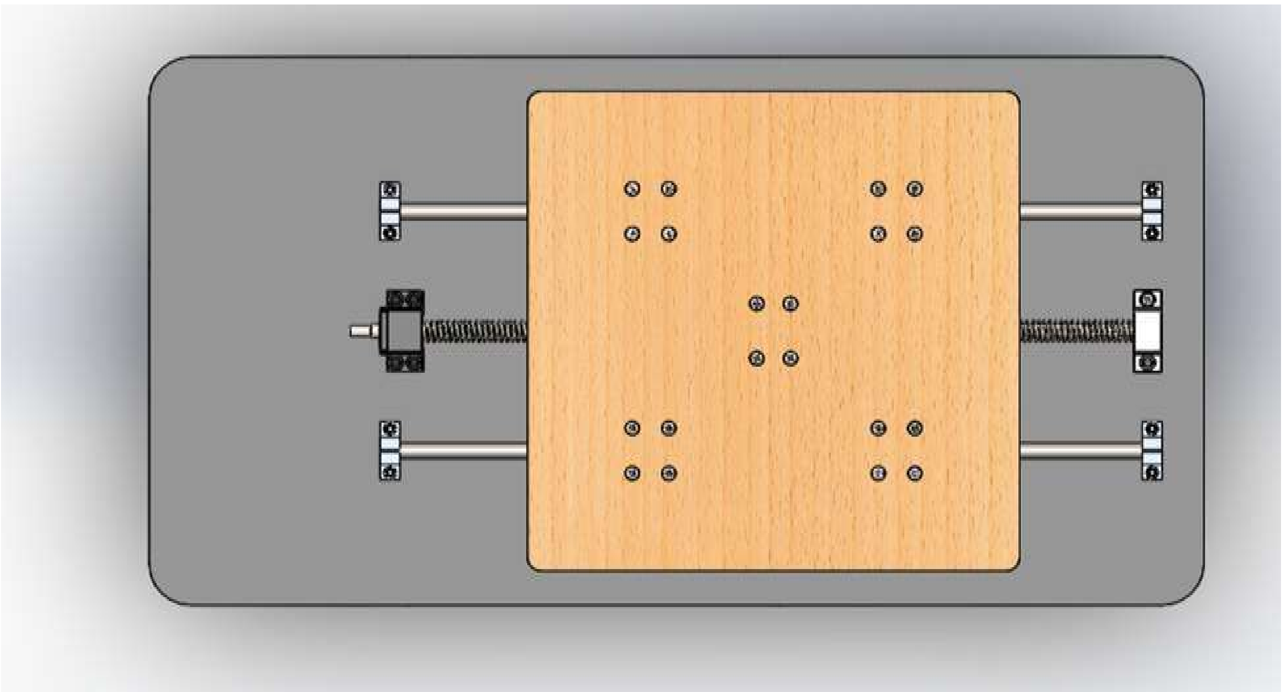


fig3.7- install stepper motor in lead screw by using flex coupling

3.1.1 Lead screws

The Lead screws (also known as translation screws) are used to convert rotary motion into translatory motion. For example, in the case of the lead screw of lathe, the rotary motion is available, but the tool has to be advanced in the direction of the cut against the cutting resistance of the material. In case of screw jack, a small force applied in the horizontal plane is used to raise or lower a large load. Power screws are also used in vices, testing machines, presses, etc. In most of the power screws, the nut has axial motion against the resisting axial force while the screw rotates in its bearings. In some screws, the screw rotates and moves axially against the resisting force while the nut is stationary and in others the nut rotates while the screw moves axially with no rotation [6]

3.1.1 Types of Screw Threads used for Lead screws.

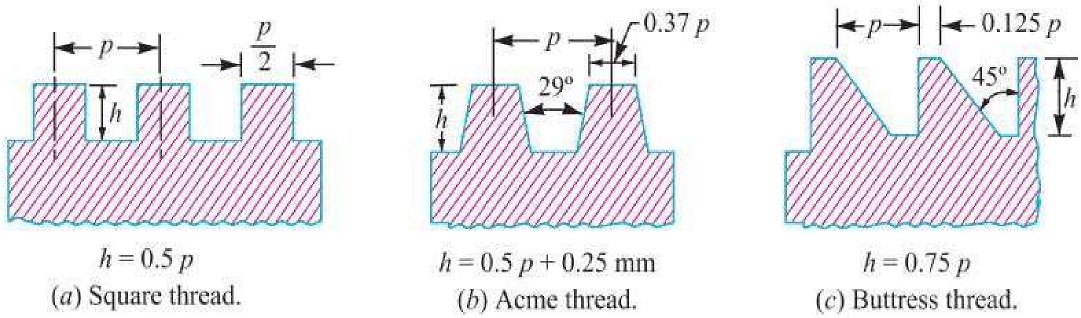


Fig. 3.8Types of Screw Threads

(i) **Square thread**: A square thread, as shown in Fig. 3.3 (a), is adapted for the transmission of power in either direction. This thread results in maximum efficiency and minimum radial or bursting

(ii) Acme or trapezoidal thread.

An acme or trapezoidal thread, as shown in Fig. 3.3 (b), is a modification of square thread. The slight slope given to its sides lowers the efficiency slightly than square thread and it also introduce some bursting pressure on the nut, but increases its area in shear. It is used where a split nut is required and where provision is made to take up wear as in the lead screw of a lathe.

(iii) Buttress thread.

A buttress thread, as shown in Fig. 3.3 (c), is used when large forces act along the screw axis in one direction only. This thread combines the higher efficiency of square thread and the ease of cutting and the adaptability to a split nut of acme thread. It is stronger than other threads because of the greater thickness at the base of the thread. The buttress thread has limited use for power transmission. It is employed as the thread for light jack screws and vices.

In our project, we utilize ACME screws as a crucial component. ACME screws are trapezoidal screw threads that offer robustness, high load-bearing capacity, and efficient torque transmission. These threads are commonly employed in applications involving power transmission and linear motion systems.

The implementation of ACME screws in our project provides several advantages. The trapezoidal thread profile enhances the strength and durability of the screws, enabling them to withstand heavy loads and resist wear over time. Additionally, ACME screws offer superior efficiency in converting rotational motion into linear motion, making them ideal for our project.

ACME Screw Design: ACME screws have a trapezoidal thread profile with a 29-degree thread angle. The thread shape features flattened crests and roots, which improves load distribution and enhances the screw's strength. The design of ACME screws allows for efficient power transmission and high load-bearing capacity.

ACME Screw Materials: ACME screws are typically made from materials that provide high strength and wear resistance. Common materials include stainless steel, alloy steel, and hardened steel. The choice of material depends on factors such as the application requirements, environmental conditions, and desired longevity.

Versatile Applications: ACME screws find applications in various industries, including manufacturing, robotics, automotive, aerospace, and construction. They are commonly used in power transmission systems, lifting mechanisms, positioning stages, clamping devices, and other linear motion applications.

Thread Specifications: ACME threads are defined by parameters such as major diameter, pitch, and thread depth. These values determine the size and geometry of the thread. In the following standard table 3.2

Nominal or major diameter (d) mm.	Minor or core diameter (d_c) mm	Pitch (p) mm	Area of core (A_c) mm^2
10	6.5	3	33
12	8.5		57
14	9.5		71
16	11.5	4	105
18	13.5		143
20	15.5		189

table 3.2- Thread Specifications

3.1.2 Force Calculations of Power Screws

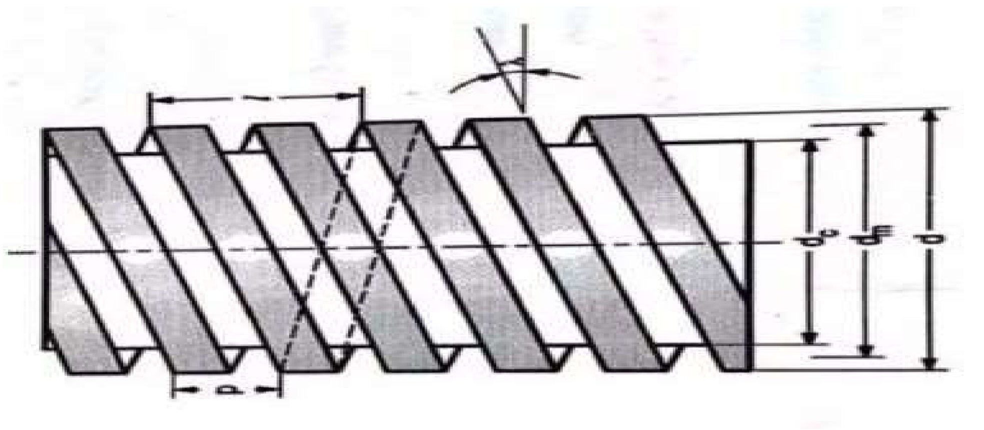


Fig. 3.9 Power Screws

(iv) Nominal Diameter (d):

It is the largest diameter of an external or internal thread. The screw is specified by this diameter. It is also known as outer diameter or major diameter.

(v) Core Diameter (dc):

It is the smallest diameter of an external or internal thread. It is also known as inner diameter or root diameter.

(vi) Mean Diameter (dm):

It is the average nominal diameter and the core diameter. It is

also known as pitch diameter.

(vii) 4.Pitch(p):

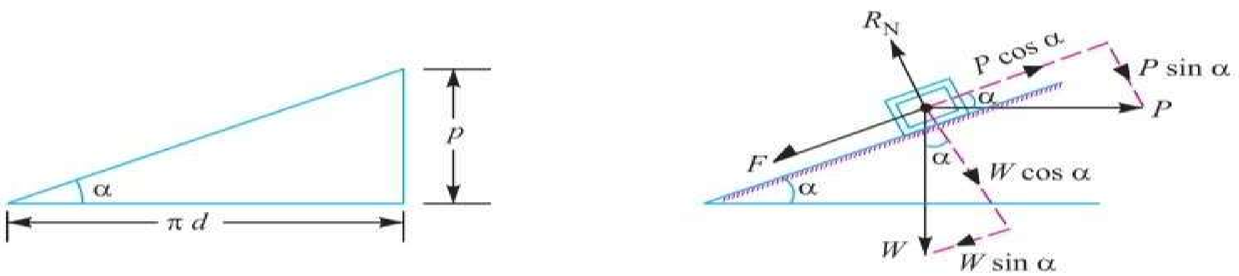
It is the distance from any point on the thread to the corresponding point on the adjacent thread, measured parallel to the axis.

(viii) lead(I):

It is the distance which a screw advances axially in one rotation of the nut. It may also be defined as the distance between two corresponding points on the same helix.

(i) Lead Angle (α):

It is an angle made by a helix or a thread with a plane perpendicular to an axis of screw.



(a) Development of a screw. (b) Forces acting on the screw.

Fig.3.10

P $\cos\alpha = W\ sin\alpha + \ \mu(Psin\ \alpha + Wcos\ \alpha)$
$= \ W\ sin\alpha + \ \mu Psin\ \alpha + \mu Wcos\ \alpha)$

P $\cos\alpha$ **-** $\mu Psin\ \alpha = W\ sin\alpha + \mu Wcos\ \alpha$

P $(\cos\alpha$ **-** $\mu sin\ \alpha) = W\ (sin\alpha + \mu cos\ \alpha)$

P = W $\times \frac{(sin\alpha + \mu cos\ \alpha)}{((cos\alpha - \mu sin\ \alpha))}$

Or

P = W tan $(\alpha + \emptyset)$ **=W** $\left(\frac{tan\ \alpha + tan\ \emptyset}{1 - tan\ \alpha\ tan\ \emptyset}\right)$

$$\mu = \ tan\ \emptyset = 0.05, \qquad tan\ \alpha = \frac{p}{\pi d} = \frac{4}{\pi \times 16} = 0.079$$

$$\mathbf{P = W} \times \left(\frac{tan\ \alpha + tan\ \emptyset}{1 - tan\ \alpha\ tan\ \emptyset}\right) = 98.1 \times \left[\frac{0.079\ \ -0.05}{1 - 0.079 \times 0.05}\right] = \mathbf{2.86N}$$

Calculate the Load Torque *TL*

$$Load\ Torque\ T_L = \frac{F\ .\ P_B}{2\pi\eta} + \frac{\mu\ .F_o}{2\pi}$$

F **= Force of moving direction**
= Pilot pressure weight (F) =2.59N
= Internal friction coefficient of pilot pressure nut
= Efficiency (0.85 to 0.95)
= Lead screw pitch = 4mm
= 2.86N

F = $F_A + m.g(sin\theta + \mu.cos\theta)$
F= 2.86 + **10**$\times$ 9.81$(sin\ sin\ 0\ + 0.05\ cos\ cos\ 0\ )$= **7.765 N**
$T_L = \frac{7.765\ \times 4 \times 10^{-3}}{2\pi \times 0.9} + \frac{0.05\ \times 2.59\ \times 4 \times 10^{-3}}{2\pi}$ = **0.0558 N.cm**
Calculate the Acceleration Torque *Ta*

$$T_a = J_{total} \times \alpha$$

Inertia of Lead Screw $J_B\ = \frac{\pi}{32}\ .\rho.L_B.D_B{}^4$
ρ Mass density of material:
Iron [density $\rho =\ (7.9 \times 10^{-3}$kg /cm3)]
L_B Total length of lead screw: = 500mm
D_B lead screw shaft diameter: = 16mm
$J_B = \ \frac{\pi}{32} \times 7.9\ \times 10^{-3}\ \times 500 \times 10^{-3} \times (16 \times 10^{-3})^4$= $2.776 \times 10^{-6}\ Km^2$
Inertia of Table and work $J_T\ = \left(\frac{P_B}{2\pi}\right)^2$
= **10**$\left(\frac{4 \times 10^{-3}}{2\pi}\ \right)^2$ = **1.01**$\times$ $10^{-6}\ Km^2$
Total Inertia $J_L = J_B + J_T$
= 2.776×10^{-6} + **1.01**$\times$ 10^{-6} = $\mathbf{3.786} \times 10^{-6}\ Km^2$
$T_m\ = \mathbf{0.0053m.N}$ + $0.146\ N.m\ \ \times 2 = 29.73\ N.cm$

3.2 Study Analysis.

Stresses in Lead screws

A power screw must have adequate strength to withstand axial load and the applied torque. Following types of stresses are induced in the screw.

3.2.1 **tensile or compressive stress due to an axial load**. The direct stress due to the axial load may be determined by dividing the axial load (W) by the minimum cross-sectional area of the screw ($\boldsymbol{A_c}$) i.e. area corresponding to minor or core diameter ($\boldsymbol{d_c}$).

∴ Direct stress (tensile or compressive)

$$\boldsymbol{\sigma = \frac{W}{A_c} = \frac{98.1}{105} = 0.934\ N/mm^2}$$

This is only applicable when the axial load is compressive and the unsupported length of the screw between the load and the nut is short.

3.2.2 **Torsional shear stress.** Since the screw is subjected to a twisting moment, therefore torsional shear stress is induced. This is obtained by considering the minimum cross-section of the screw. We know that torque transmitted by the screw,

$T = \frac{\pi}{16} \times \tau(d_c)^2$

or shear stress induced,

$$\tau = \frac{16T}{\pi(d_c)^3}$$

Torque required of lead screw

$$T_1 = P \times \frac{d}{2}$$

$T_1 = p \times \frac{d}{2} \quad = 2.86 \times \frac{16 \times 10^{-3}}{2} \quad = 0.02288$ N.m

$\tau = \frac{16T}{\pi(d_c)^3} \quad = \frac{16 \times 0.02288}{\pi(11.5 \times 10^{-3})^3} = 76618.4$ N.m

When the screw is subjected to both direct stress and torsional shear stress, then the design must be based on maximum shear stress theory, according to which maximum shear stress on the minor diameter section,

$$\tau_{max} = \frac{1}{2}\sqrt{(\sigma_t or \sigma_c)^2 + 4\tau^2}$$

$$\tau_{max} = \frac{1}{2}\sqrt{(0.934)^2 + 4(76618.4)^2}$$

= 76618.4N.m

Simulation of Assem POJECT

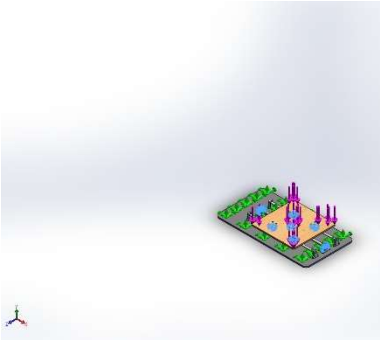
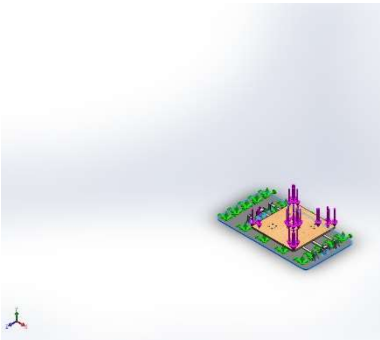
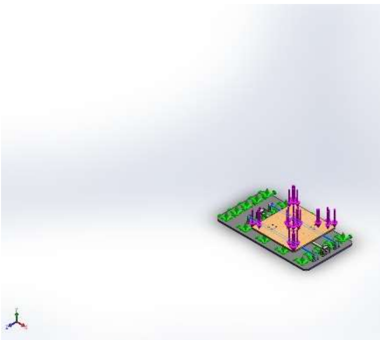
Study Properties

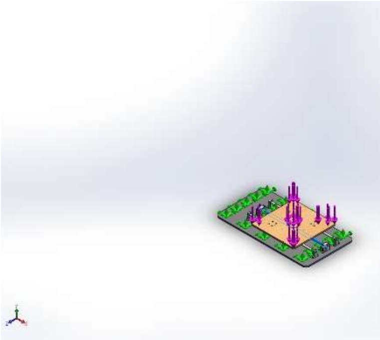
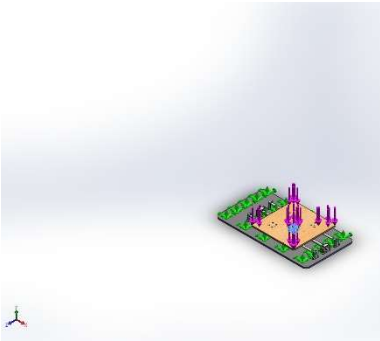
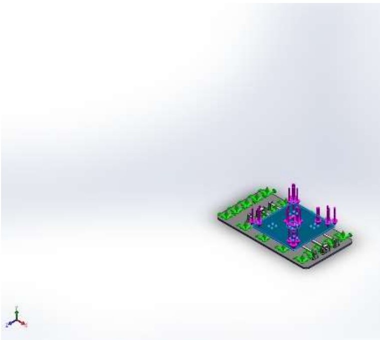
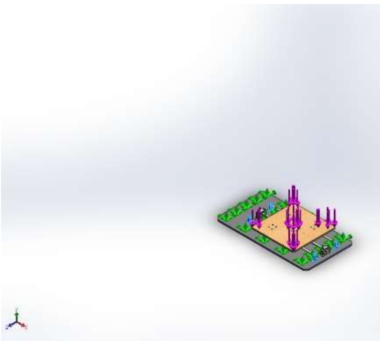
Study name	Static 4
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\Eng\Desktop\New project1\New project1)

Units

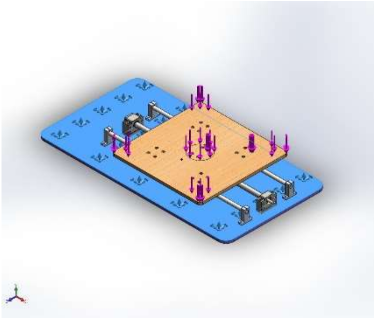
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	Name: **Plain Carbon Steel** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **2.20594e+08 N/m^2** Tensile strength: **3.99826e+08 N/m^2** Elastic modulus: **2.1e+11 N/m^2** Poisson's ratio: **0.28** Mass density: **7,800 kg/m^3** Shear modulus: **7.9e+10 N/m^2** Thermal expansion coefficient: **1.3e-05 /Kelvin**	**SolidBody 1(Cut-Extrude7)(Y0U1-1), SolidBody 1(Mirror3)(YOU12-1), SolidBody 1(Mirror3)(YOU12-2), SolidBody 1(Mirror3)(YOU12-3), SolidBody 1(Mirror3)(YOU12-4), SolidBody 1(Chamfer6)(YOU2-2), SolidBody 2(Revolve1)(YOU2-2), SolidBody 3(Chamfer4)(YOU2-2), SolidBody 4(Chamfer5)(YOU2-2), SolidBody 1(Chamfer6)(y-1), SolidBody 2(Chamfer4)(y-1)**
Curve Data:N/A		
	Name: **AISI 304** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **2.06807e+08 N/m^2** Tensile strength: **5.17017e+08 N/m^2** Elastic modulus: **1.9e+11 N/m^2** Poisson's ratio: **0.29** Mass density: **8,000 kg/m^3** Shear modulus: **7.5e+10 N/m^2** Thermal expansion coefficient: **1.8e-05 /Kelvin**	**SolidBody 1(Cut-Extrude7)(YIU14-1)**
Curve Data:N/A		
	Name: **Alloy Steel** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **6.20422e+08 N/m^2** Tensile strength: **7.23826e+08 N/m^2** Elastic modulus: **2.1e+11 N/m^2** Poisson's ratio: **0.28** Mass density: **7,700 kg/m^3** Shear modulus: **7.9e+10 N/m^2** Thermal expansion coefficient: **1.3e-05 /Kelvin**	**SolidBody 1(Chamfer1)(YOU16-1), SolidBody 1(Chamfer1)(YOU16-2)**
Curve Data:N/A		

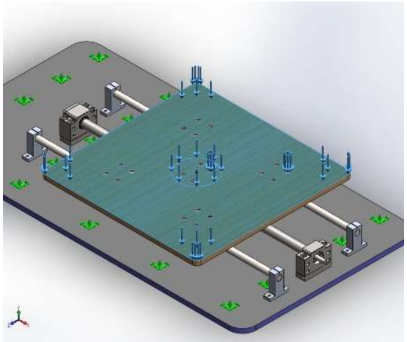
	Name: **AISI 1020** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **3.51571e+08 N/m^2** Tensile strength: **4.20507e+08 N/m^2** Elastic modulus: **2e+11 N/m^2** Poisson's ratio: **0.29** Mass density: **7,900 kg/m^3** Shear modulus: **7.7e+10 N/m^2** Thermal expansion coefficient: **1.5e-05 /Kelvin**	**SolidBody 1(Cut-Extrude9)(YOU3-1)**
Curve Data:N/A		
	Name: **1060 Alloy** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **2.75742e+07 N/m^2** Tensile strength: **6.89356e+07 N/m^2** Elastic modulus: **6.9e+10 N/m^2** Poisson's ratio: **0.33** Mass density: **2,700 kg/m^3** Shear modulus: **2.7e+10 N/m^2** Thermal expansion coefficient: **2.4e-05 /Kelvin**	**SolidBody 1(Cut-Extrude5)(YOU5-1)**
Curve Data:N/A		
	Name: **Balsa** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **2e+07 N/m^2** Elastic modulus: **3e+09 N/m^2** Poisson's ratio: **0.29** Mass density: **159.99 kg/m^3** Shear modulus: **3e+08 N/m^2**	**SolidBody 1(Split Line2)(you116-2)**
Curve Data:N/A		
	Name: **Liga 6061** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **5.51485e+07 N/m^2** Tensile strength: **1.24084e+08 N/m^2** Elastic modulus: **6.9e+10 N/m^2** Poisson's ratio: **0.33** Mass density: **2,700 kg/m^3** Shear modulus: **2.6e+10 N/m^2** Thermal expansion coefficient: **2.4e-05 /Kelvin**	**SolidBody 1(Extrusão3)(you23-1), SolidBody 1(Extrusão3)(you23-3), SolidBody 1(Extrusão3)(you23-4), SolidBody 1(Extrusão3)(you23-5)**
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** **1 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	**0.00605356**	**199.983**	**-0.00293767**	**199.983**
Reaction Moment(N.m)	**0**	**0**	**0**	**0**

Load name	Load Image	Load Details
Force-1		**Entities:** **2 face(s)** **Type:** **Apply normal force** **Value:** **100 N**

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.00605356	199.983	-0.00293767	199.983

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

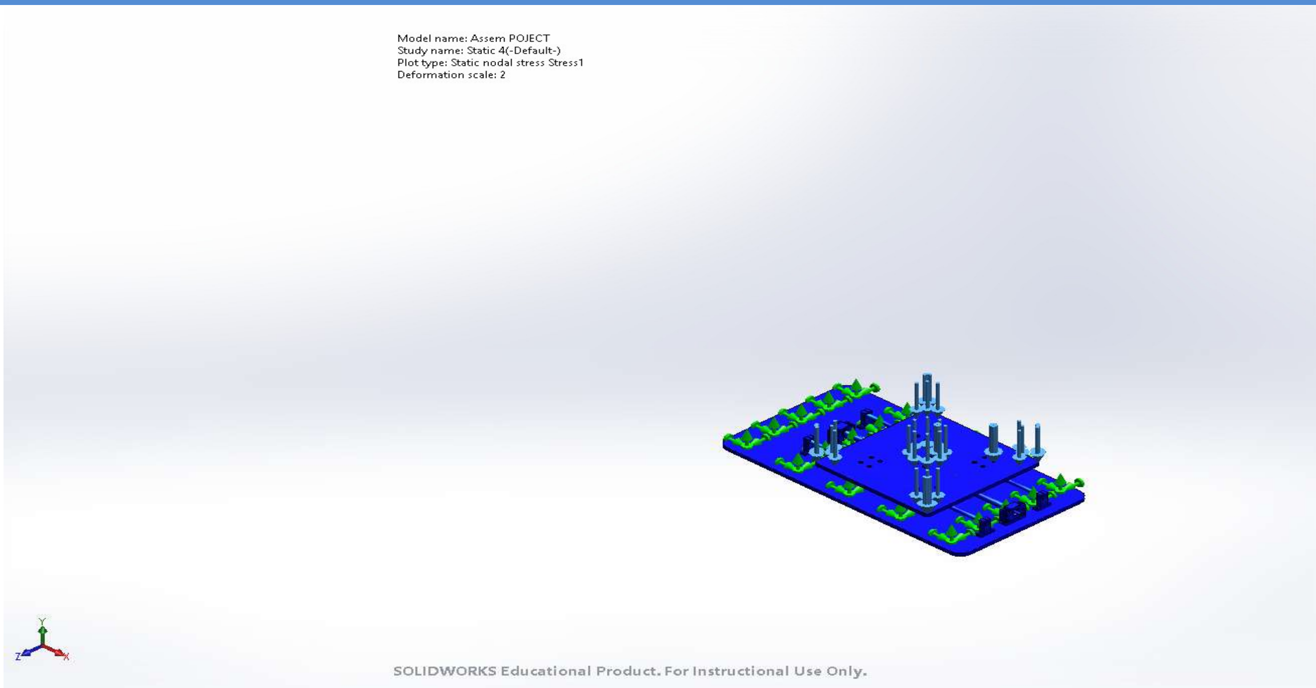
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.00570817	0.169119	0.167474	0.238079

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.877e-03N/m^2 Node: 26445	5.939e+07N/m^2 Node: 167434

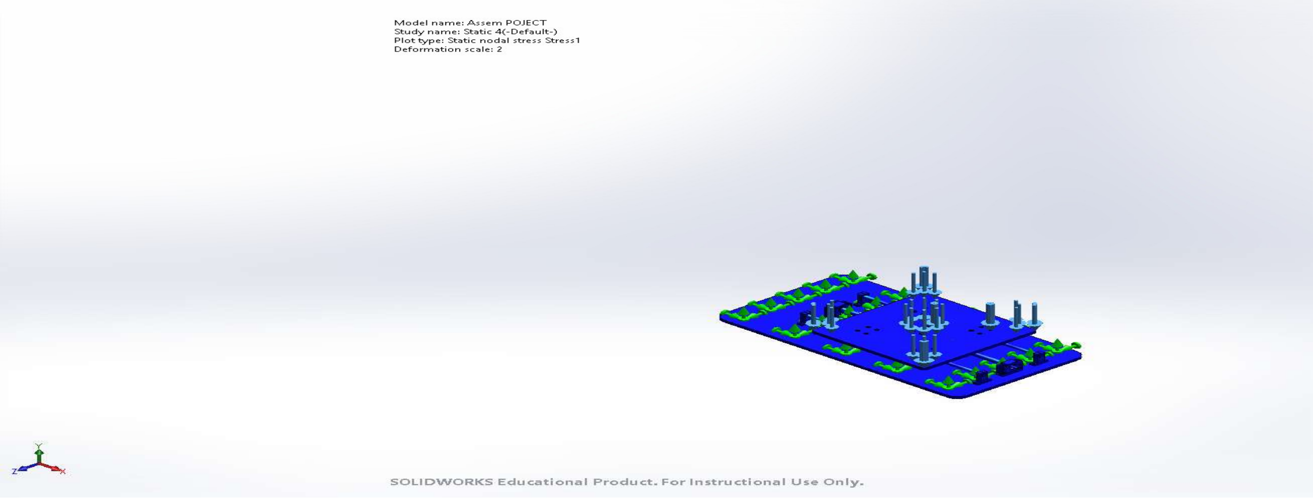


Assem POJECT-Static 4-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 6885	9.619e-02mm Node: 167752

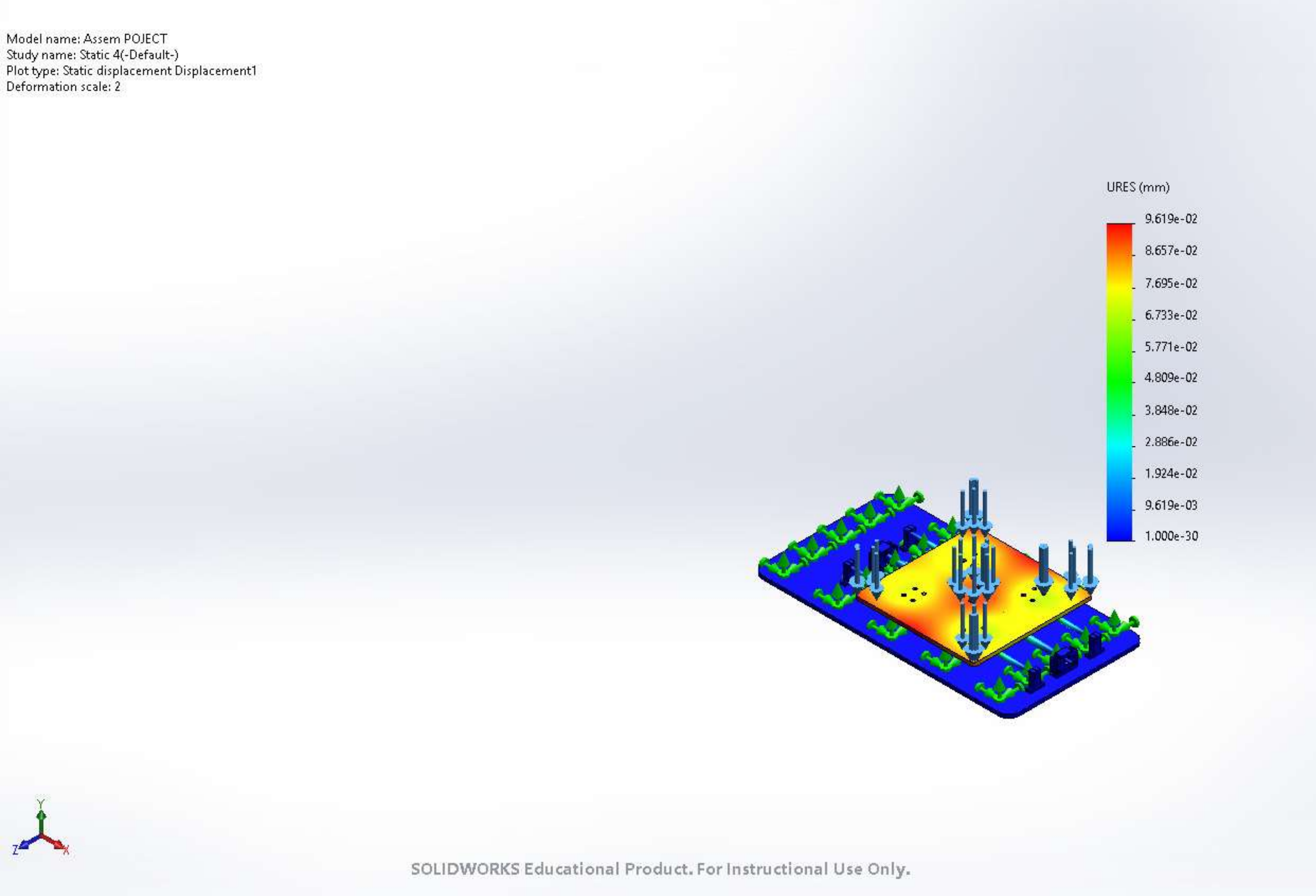
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.877e-03N/m^2 Node: 26445	5.939e+07N/m^2 Node: 167434



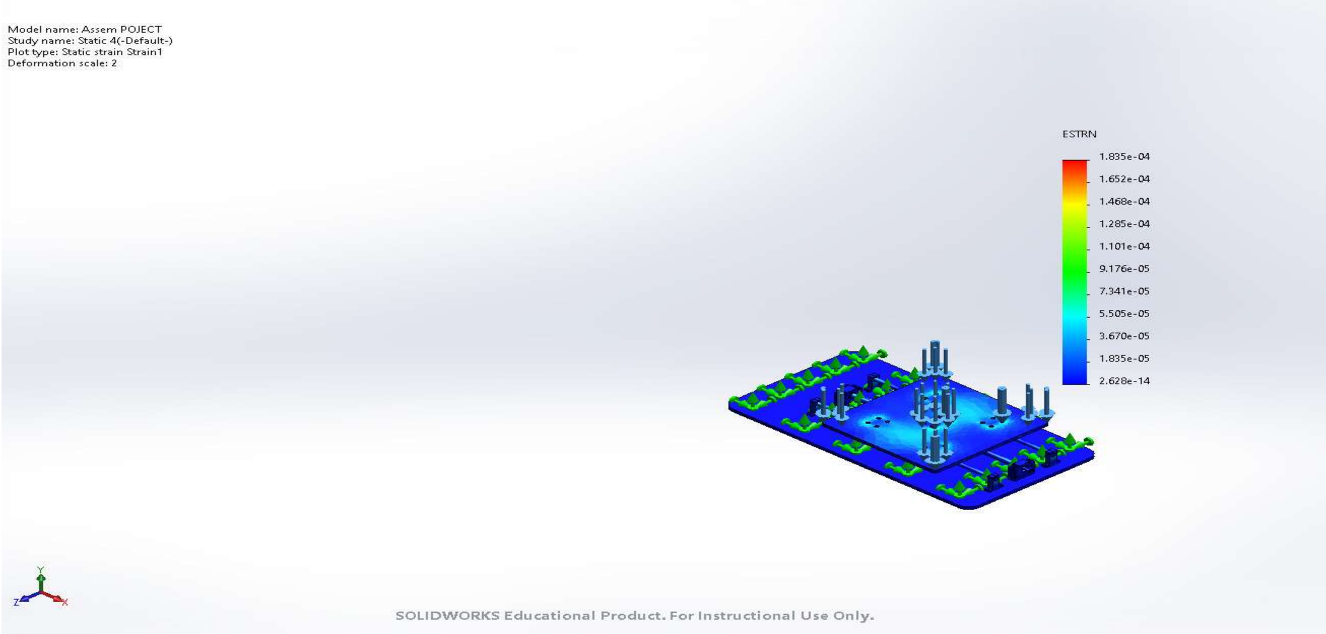
Assem POJECT-Static 4-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 6885	9.619e-02mm Node: 167752



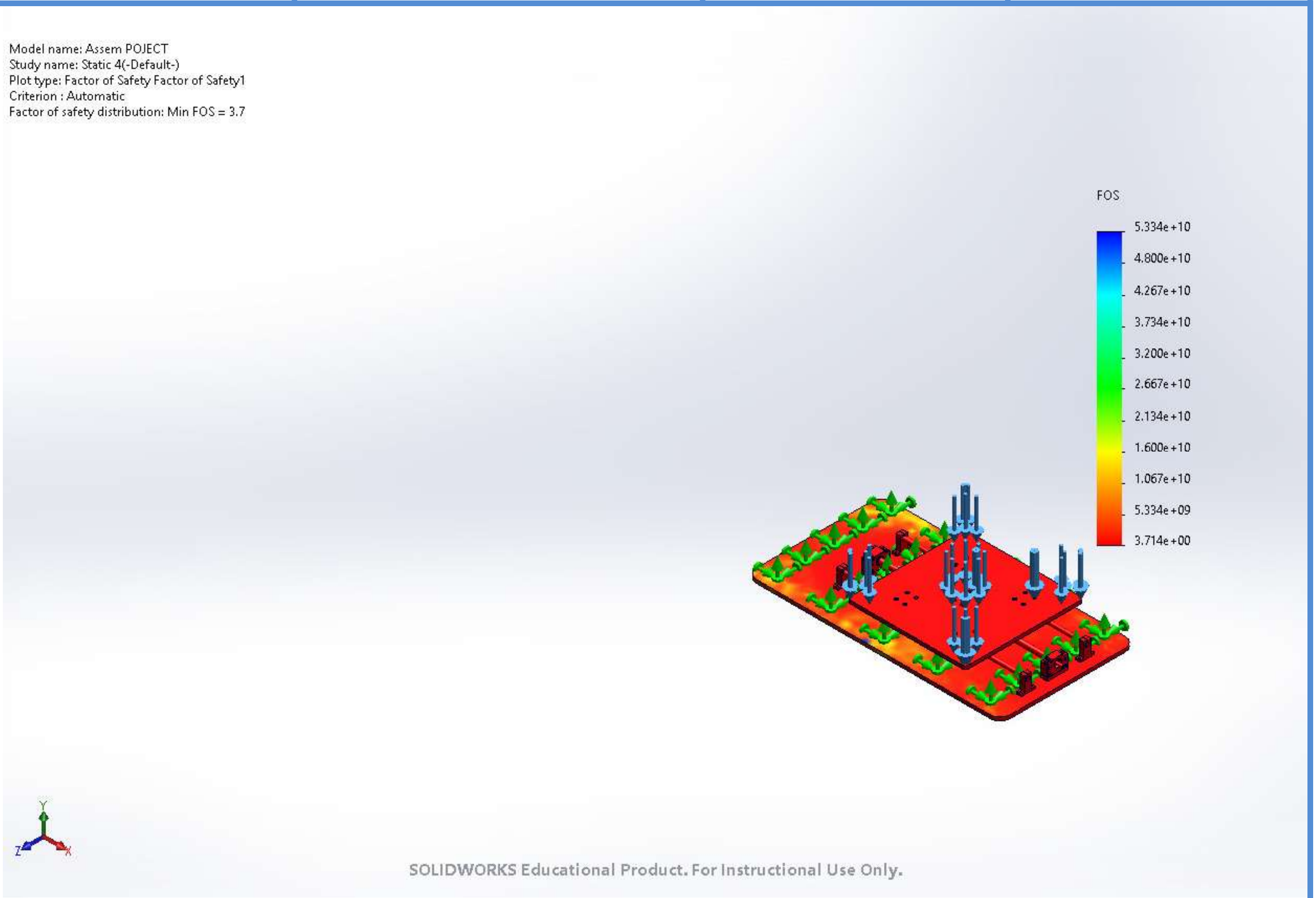
Assem POJECT-Static 4-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.628e-14 Element: 11216	1.835e-04 Element: 109031

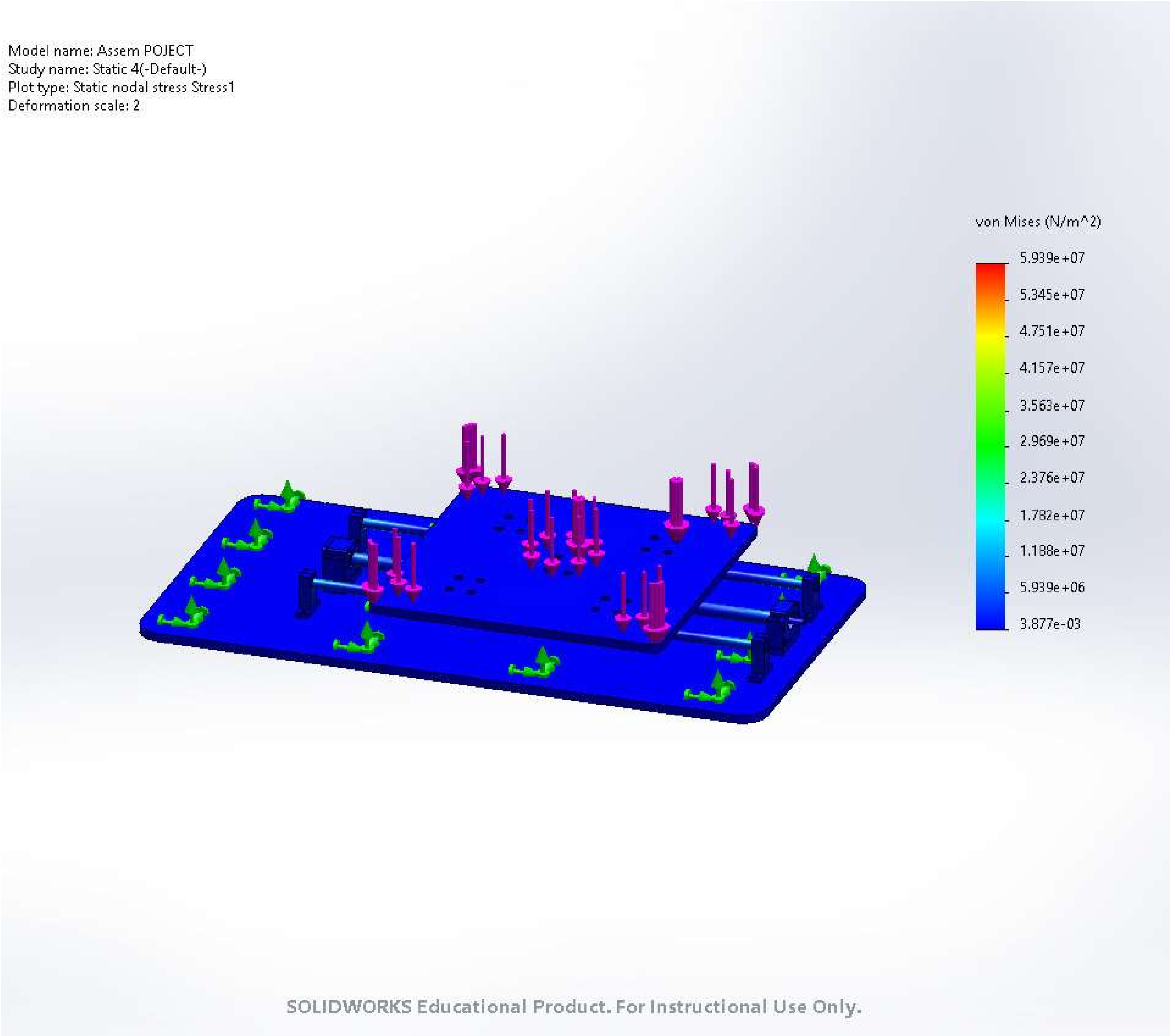


Assem POJECT-Static 4-Strain-Strain1

Name	Type	Min	Max
Factor of Safety1	Automatic	3.714e+00 Node: 167434	5.334e+10 Node: 26445



Assem POJECT-Static 4-Factor of Safety-Factor of Safety1



Model name: Assem POJECT
Study name: Static 4(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 2
von Mises (N/m^2)
5.939e+07
5.345e+07
4.751e+07
4.157e+07
3.563e+07
2.969e+07
2.376e+07
1.782e+07
1.188e+07
5.939e+06
3.877e-03
SOLIDWORKS Educational Product. For Instructional Use Only.

Image-1

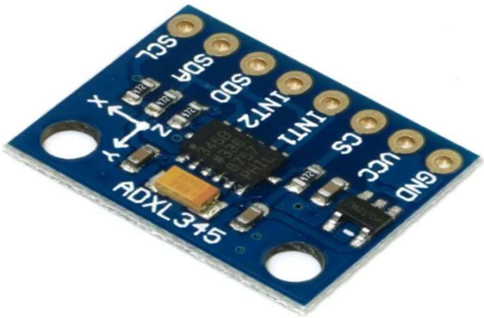
Chapter 4
Electrical Design

4-1 electrical sensor

1- ADXL345 sensor

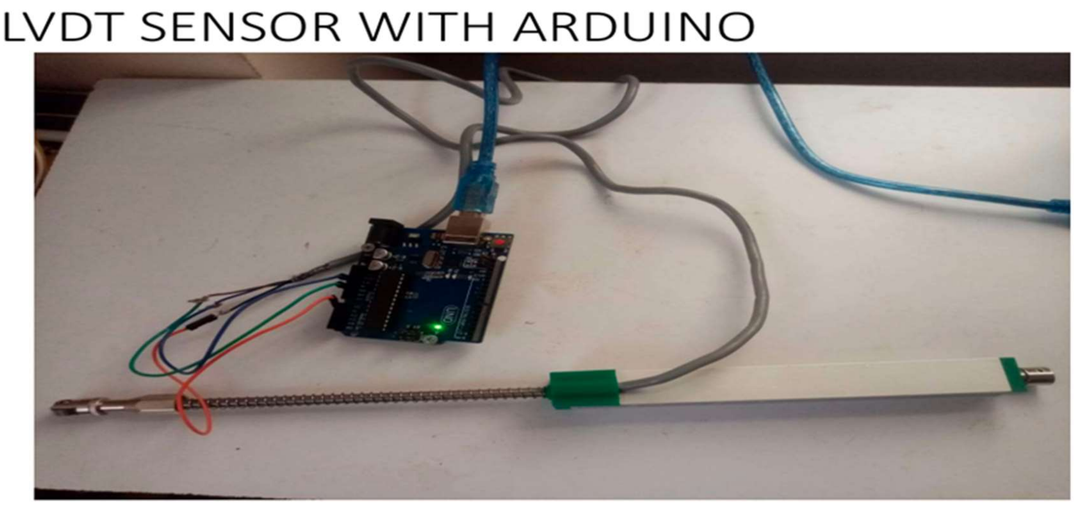
1-Overview

1-The ADXL345 is a small, thin, low-power, 3-axis digital accelerometer from Analog Devices.
2-It can measure acceleration with a maximum range of ±16g, and can be used to detect motion or static acceleration (like gravity).
3-The ADXL345 communicates via a digital interface (I2C or SPI) and provides 13-bit resolution (4mg/LSB) at ±16g range.



2-Key Features
-axis digital accelerometer with 13-bit resolution
2-Measurement range of ±2g, ±4g, ±8g, and ±16g
3-Low power consumption (down to 23µA in measurement mode)
4-Embedded self-test function
5-Supports I2C and SPI digital interfaces
6-Interrupt features for free-fall, activity/inactivity detection, and tap/double-tap sensing
7-Small, lightweight package (3mm x 5mm x 1mm LGA).
3-Integration with Microcontrollers
The ADXL345 is widely used with microcontrollers like Arduino, Raspberry Pi, and various MCU development boards. It allows these systems to easily detect orientation changes, motion, and vibrations, enabling a wide range of motion-based applications.

2- LVDT Sensor



1-Overview

1-LVDT is a type of electromechanical transducer that is used to measure linear displacement or position.
2-It consists of a primary winding and two secondary windings wound around a hollow cylindrical core. A movable magnetic core is free to slide along the axis of the windings.
3-As the core moves, it changes the mutual inductance between the primary and secondary windings, producing a differential output voltage that is proportional to the core's position.
2-Key Features
1-Contactless measurement - the core moves without touching the sensor housing
2-High accuracy and repeatability (typically 0.1-0.5% of full range)
3-Wide measurement range (from fractions of a millimeter to hundreds of millimeters)
4-High resolution and linearity over the measurement range

5-Robust and durable construction, suitable for harsh environments
6-Immune to electromagnetic interference (EMI)
7-No sliding contacts, resulting in very low wear and long lifetime.

3-Working Principle

1-The primary winding is excited by an AC voltage source, creating a magnetic field.
2-As the movable magnetic core inside the LVDT moves, it changes the mutual inductance between the primary and two secondary windings.
3-This change in mutual inductance results in a differential output voltage across the two secondary windings, which is proportional to the core's position.
4-The output voltage can be measured and interpreted to determine the linear displacement of the core.

4.2_ electrical component

1_DC MOTOR

Electrical Data

Rated Voltage	V	24
Max. Continuous Current	A	4.5
Max. Operating Voltage	V	36
Inductance	mH	2.0
K_t Torque Constant (± 10%)	oz-in/A [N-m/A]	8.9 [0.062]
K_v Voltage Constant (± 10%)	V/kRPM	6.5
Winding Resistance @ Ambient	Ohms	1.0

1-**Voltage Rating**: 24 VDC

2-**Power Rating**:

The power rating of a 24V DC motor can vary depending on the specific model and application, but the common range is from 50 watts to 500 watts.

3-**Speed Range:**

24V DC motors typically have a no-load speed range of approximately 1,000 to 5,000 RPM.

The actual speed of the motor will depend on the load applied and the motor's torque characteristics.

4-**Torque**:

24V DC motors can provide a wide range of torque output, usually from 0.1 Nm to 10 Nm or more, depending on the motor size and design.

The torque output will decrease as the motor speed increases.

5-**Efficiency:**

The efficiency of a 24V DC motor can range from 60% to 90%, depending on factors such as the motor design, load, and operating conditions.

Common Features:

Permanent magnet or wound field construction

Brushed or brushless designs

Gearbox options for increased torque output

Encoders or Hall-effect sensors for speed and position feedback

<u>2 power supply 24 v</u>

1_Voltage and Current Output

1_The power supply provides a constant 24 volts of direct current (DC) output.

2_It can deliver up to 10 amps (A) of current to the connected load.

2_Input Voltage

1_The input voltage for this power supply is typically 100-240 VAC, 50/60 Hz. This allows it to be used internationally with different mains voltages.

3_Efficiency and Power

1_With a 24V 10A output, the power rating of this supply is 240 watts (24V x 10A = 240W).
High efficiency, typically 80-90%, helps minimize energy losses and heat generation.

4_Connections

1_The power supply will have an input power cord that plugs into a wall outlet.
On the output side, it will have a DC connector (e.g. barrel jack, screw terminals) to attach to the device being powered.

5_Features

Overcurrent, overvoltage, and overtemperature protection to ensure safe operation.
Compact, lightweight design for easy placement.
Suitable for powering a wide range of 24V DC devices like LED lighting, security systems, industrial automation, and more.

6_Power Supply Specifications

1_Input: 100-240 VAC, 50/60 Hz
2_Output: 24 VDC, 10A (240W)
3_Efficiency: 85-90% typical
4_Dimensions: 6 x 4 x 2 inches (approximate)
5_Weight: 2.2 lbs (1 kg)
6_Features: Overload, overvoltage, overcurrent, and short circuit protection

3-arduino Uno

1-Overview

1-The Arduino Uno is a popular and widely-used open-source microcontroller board based on the ATmega328P microcontroller.
2-It is a simple, low-cost, and easy-to-use platform that allows users to create a wide variety of interactive projects and prototypes.

2-Key Features

1-Microcontroller: ATmega328P

fig 5.4 Arduino uno

2-Operating Voltage: 5V
3-Input Voltage (recommended): 7-12V
4-Digital I/O Pins: 14 (of which 6 provide PWM output)
5-Analog Input Pins: 6
6-Flash Memory: 32 KB (of which 0.5 KB is used by bootloader)
7-SRAM: 2 KB
8-EEPROM: 1 KB
9-Clock Speed: 16 MHz
10-USB connection for programming and power
11-Supports serial communication (UART), I2C, and SPI
12-Can be expanded with various shields (boards that plug on top)

3-Programming

1-The Arduino Uno can be programmed using the Arduino Integrated Development Environment (IDE) software.
2-The IDE provides a simple and user-friendly interface for writing, compiling, and uploading code to the board.
3-The programming language used is based on C/C++, but with a simplified syntax and additional libraries.

4-Community and Ecosystem

1-The Arduino platform has a large and active community of makers, hobbyists, and developers.
2-There is a wealth of tutorials, example code, and third-party libraries available online to help users get started and expand their projects.
3-The Arduino Uno is compatible with a wide range of shields and expansion boards, allowing users to easily add new functionalities to their projects.

4- PWM DC Motor Speed Controller

1-Input Voltage Range: 12-40 VDC
2-Maximum Current: 10A

A PWM DC Motor Speed Controller is a device used to control the speed of a DC motor by varying the duty cycle of

Power supplied to the motor. It works on the principle of PWM, where the motor is supplied with a series of

high frequency pulses, and the speed of the motor is controlled by varying the width (or duration) of these pulses.

3-Key Features and Functionality:

Input Voltage Range: The controller can operate with an input voltage ranging from 12 VDC to 40 VDC, which makes

It is suitable for a wide range of DC motor applications.

Maximum Current: The controller can handle a maximum current of 10A, which is sufficient for controlling

medium- sized DC motors.

PWM Control: The controller uses PWM technology to regulate the speed of the DC motor. By adjusting

the duty cycle of the PWM signal, the average voltage supplied to the motor is varied, resulting in speed control.

Overcurrent Protection: The controller typically includes overcurrent protection to prevent damage to the motor
and the controller itself in case of overload or short-circuit conditions.
Reverse Polarity Protection: The controller may have reverse polarity protection to prevent damage in case

the input power supply is connected with the wrong polarity.

Heat Sink: The controller may have a built-in heat sink to dissipate the heat generated during operation,

especially when the motor is under heavy load.

Control Input: The controller can be controlled using various input signals, such as a potentiometer, analog voltage,

or digital control signals (e.g., microcontroller, Arduino, Raspberry Pi).

3- LEVER LIMIT SWITCH

1-Overview:

1-A lever limit switch is a type of electromechanical switch that uses a mechanical lever to detect the position or movement of an object.

2-When the lever is actuated by coming into contact with the object, it triggers the switch to change its electrical state (open/close a circuit).

3-Lever limit switches are used to provide position feedback or limit control in a variety of applications

2-Key Features:

1-Mechanical lever that extends out from the switch housing

2-Variety of lever styles, lengths, and actuation forces available

3-Normally open (NO) and normally closed (NC) contact configurations

4-Wide range of operating temperatures and environmental ratings

5-Rugged, durable construction for industrial use

6-Variety of mounting options - surface mount, flush mount, etc.

7-Long mechanical life, typically millions of operations

3-Working Principle:

The mechanical lever extends out from the switch housing

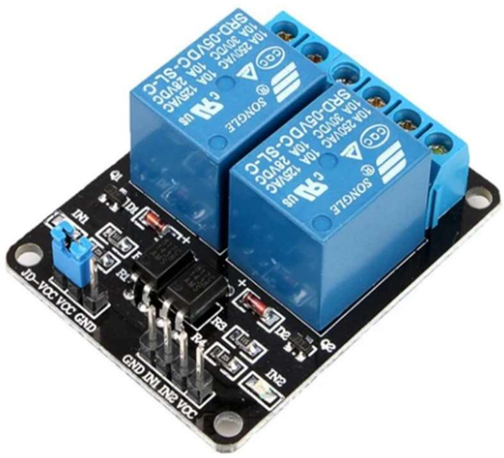
When the lever contacts an object, it physically moves the internal switch mechanism

This changes the conductive state of the electrical contacts, opening or closing the circuit

The switch can be wired to provide a signal indicating the position or movement detected

4-Relay Module (2 Channels - 5V)

1-Overview



1-The Relay Module (2 Channels - 5V) is an electronic control device that allows you to switch two separate circuits on and off using a low-voltage signal.
3-It contains two independent relay channels that can be controlled by a 5V logic signal, such as from a microcontroller or computer.
4-This module is commonly used in projects that require the control
of higher-power electrical devices, like motors, lamps, solenoids, etc.

2-Specifications
1-Power Supply: 5VDC
2-Relay Type: 2-channel
3-Relay Coil Voltage: 5VDC
4-Maximum Switching Voltage: 250VAC/30VDC
5-Maximum Switching Current: 10A per channel
6-Dimensions: Approximately 35mm x 45mm
7-Mounting: Breadboard, perfboard, or PCB
3-Key Features
Two independent relay channels that can be controlled separately
Opto-isolated inputs for electrical isolation between control signal and switched circuit
LED indicators to show when each relay is energized
Screw terminals for easy wiring of load circuits
Can interface directly with microcontrollers, Raspberry Pis, Arduinos, etc.

5 16×2 I2C LCD Display Module with Yellow Backlight

Overview:

1_The module consists of a 16-character by 2-line liquid crystal display (LCD) with a built-in I2C interface.

2_It allows microcontrollers, such as Arduino, Raspberry Pi, and others, to control the LCD display using the I2C protocol, which requires only two data lines (SDA and SCL) for communication.

3_This simplifies the wiring and connection compared to using a standard parallel LCD interface, which would require multiple data and control lines.

Features:

1_Display size: 16 characters x 2 lines

2_Interface: I2C (Inter-Integrated Circuit)

3_Operating voltage: 5V

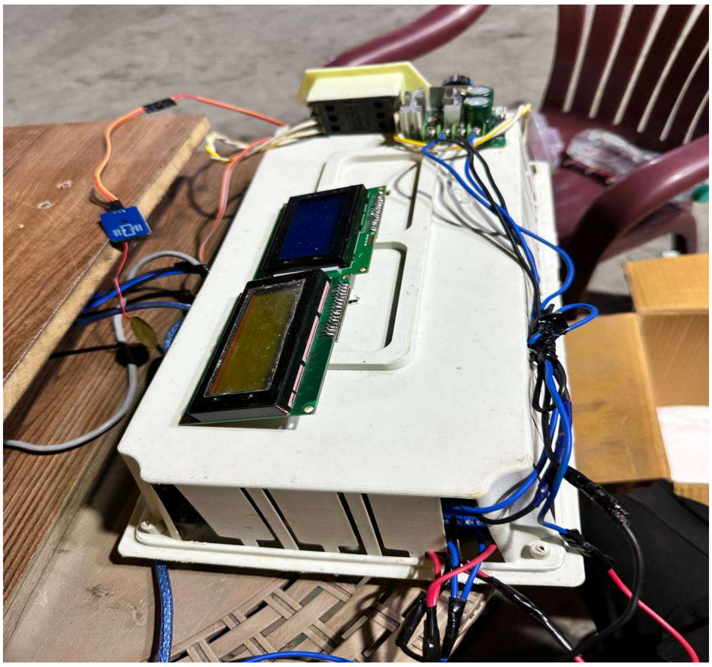
4_Communication speed: Up to 400kHz

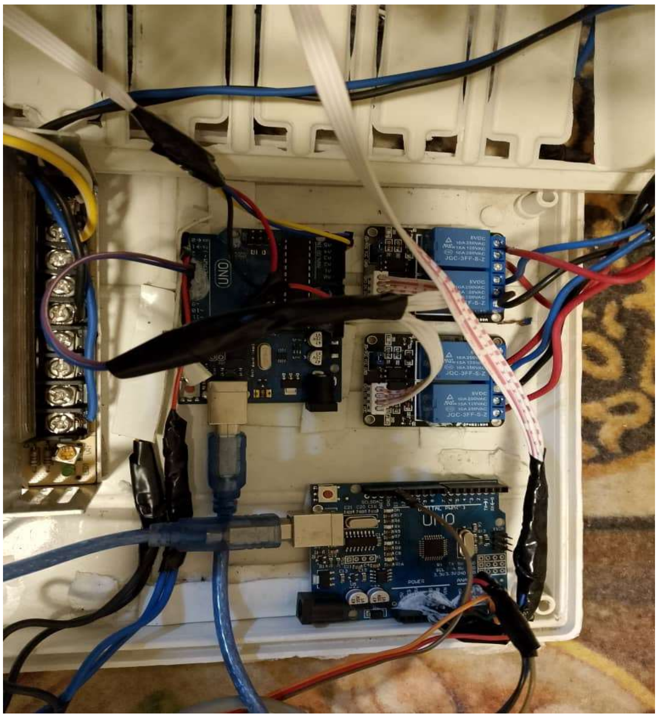
5_Backlight control: Adjustable brightness

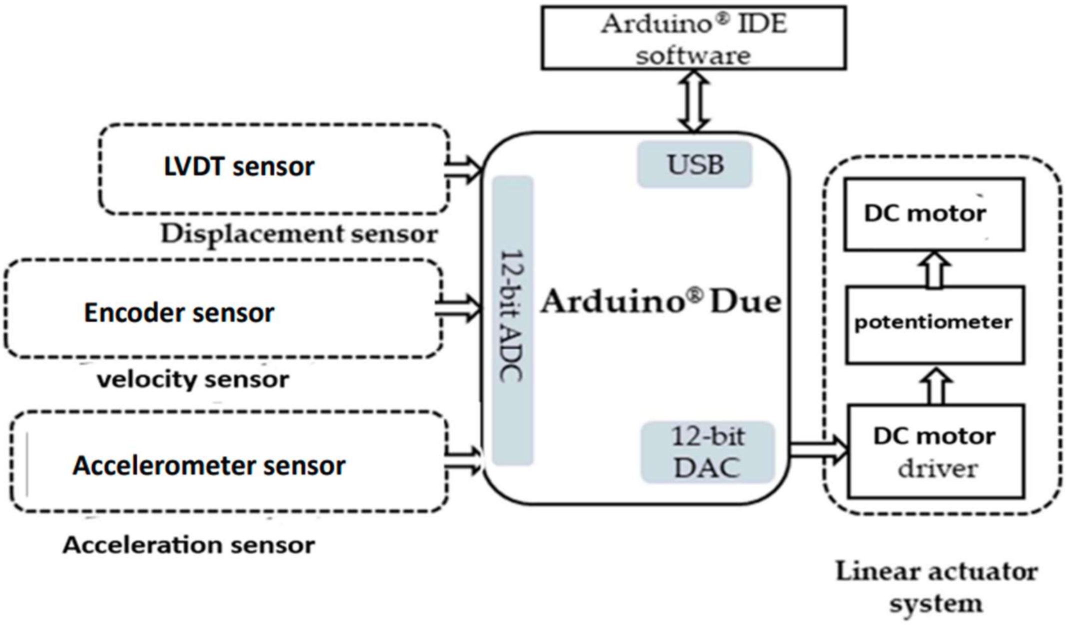
6_Supported character sets: ASCII, Japanese, Chinese, etc.

7_Easy to integrate with microcontrollers and single-board computers

4.3_ shaking table control circuit







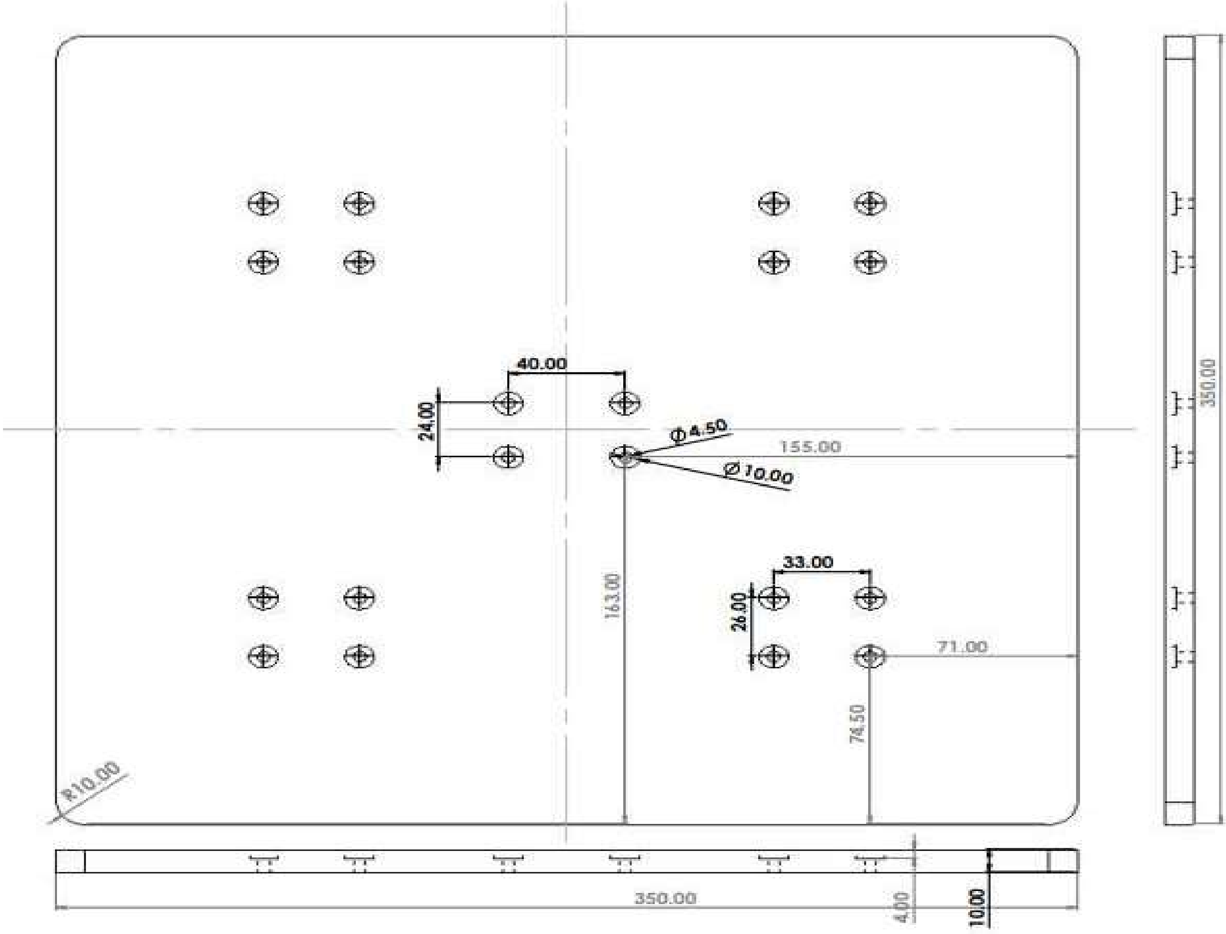
Block diagram of the data acquisition process.

Chapter 5
Appendices

5.1 Drawing sheets

Name part: Table

Material:` Balsa



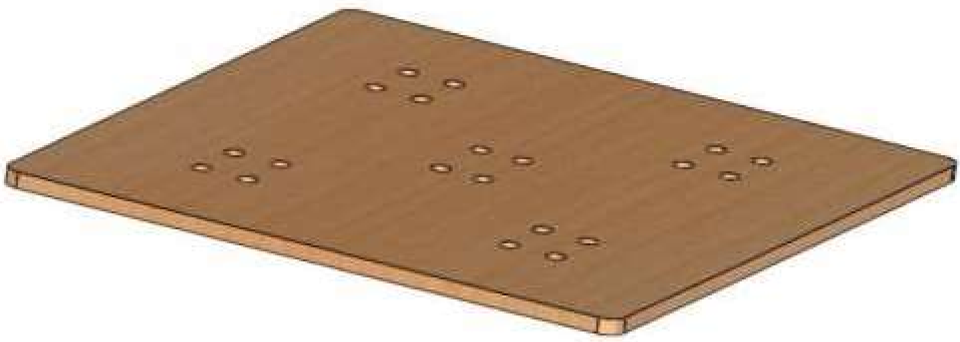
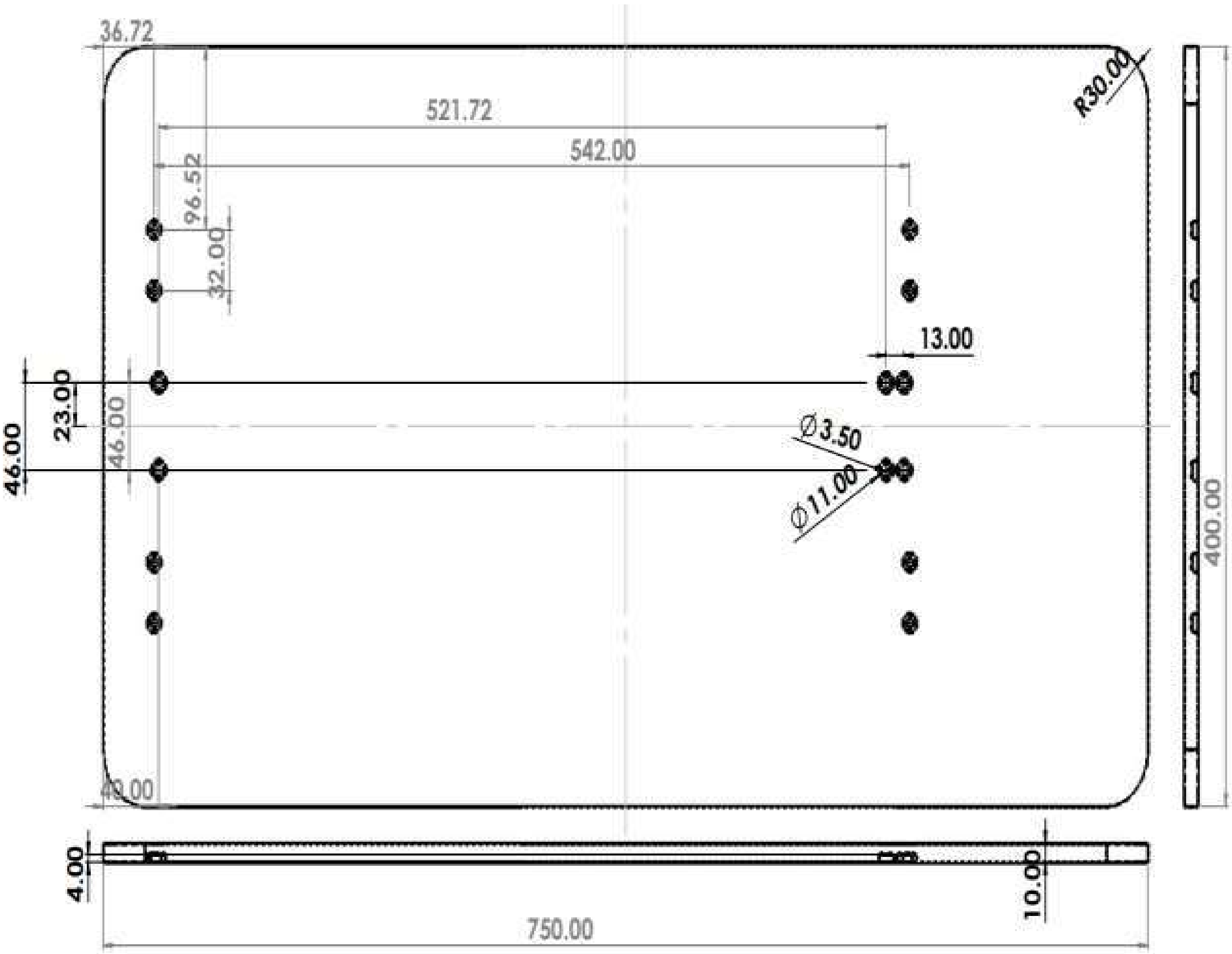


Fig 5.1 Tabe

Name part: Base Plate

Material: Balsa



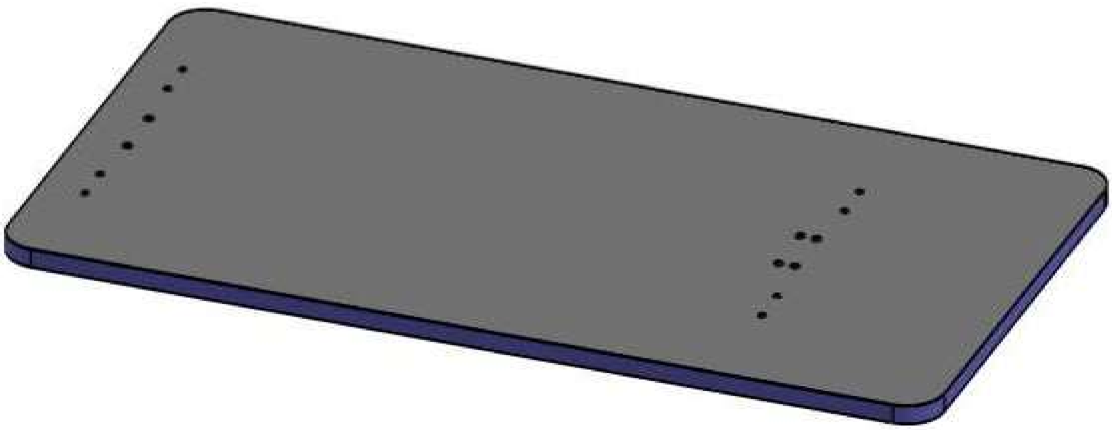
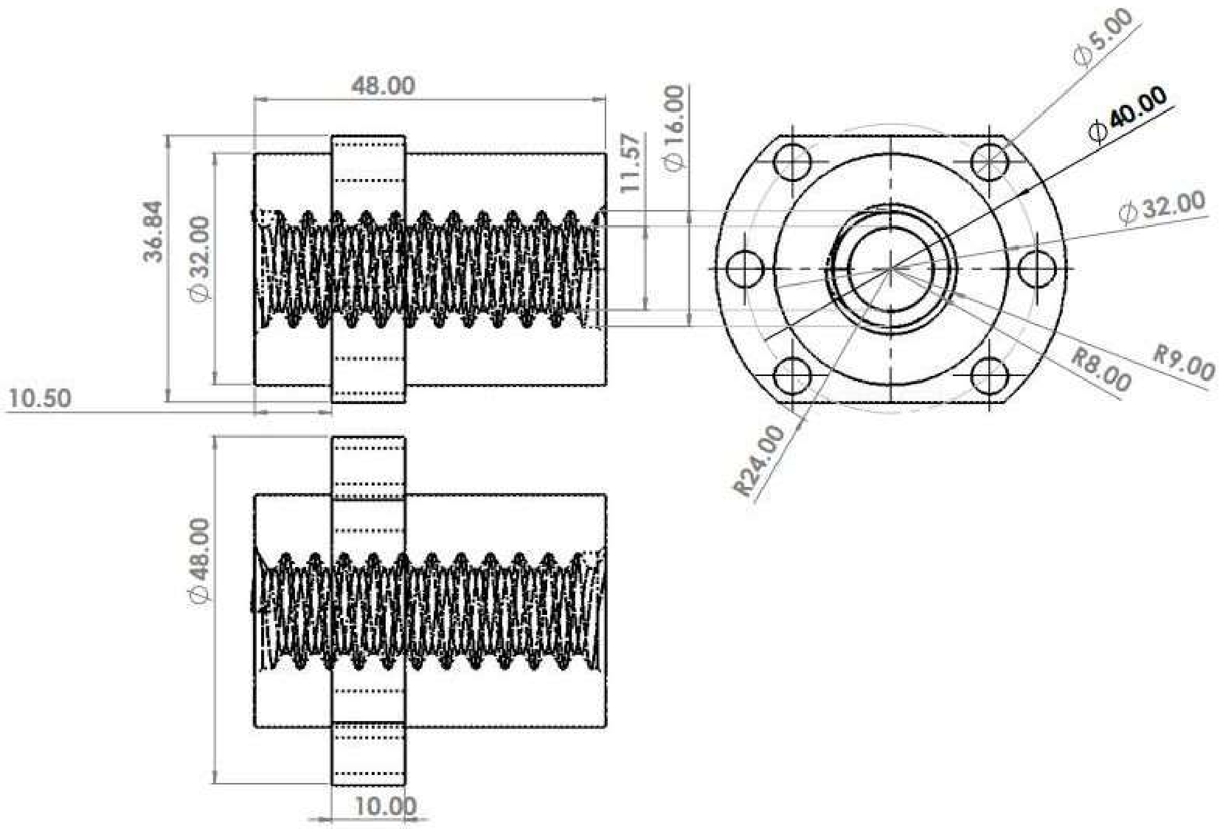


Fig 5.2-base plate

Name part: Lead nut

Material: Carbon Steel



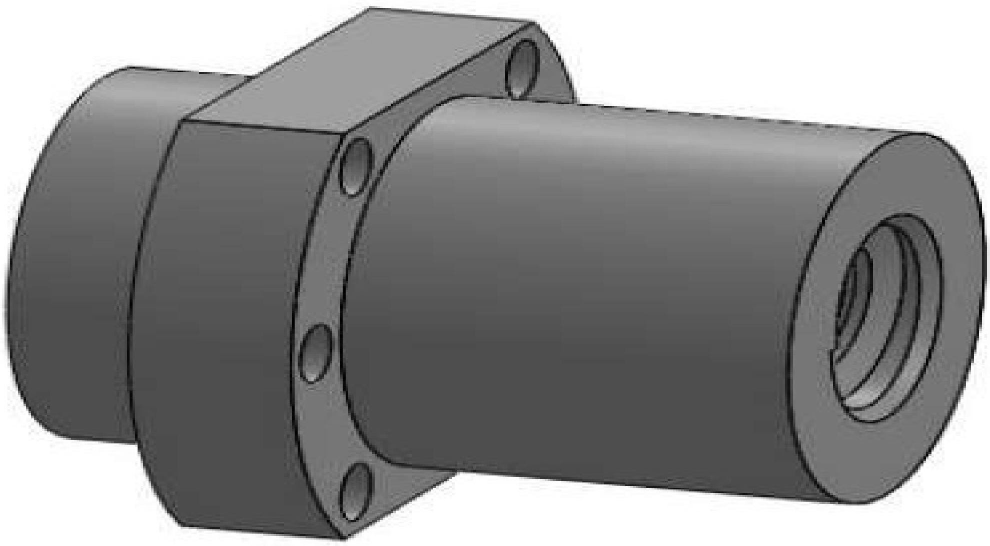
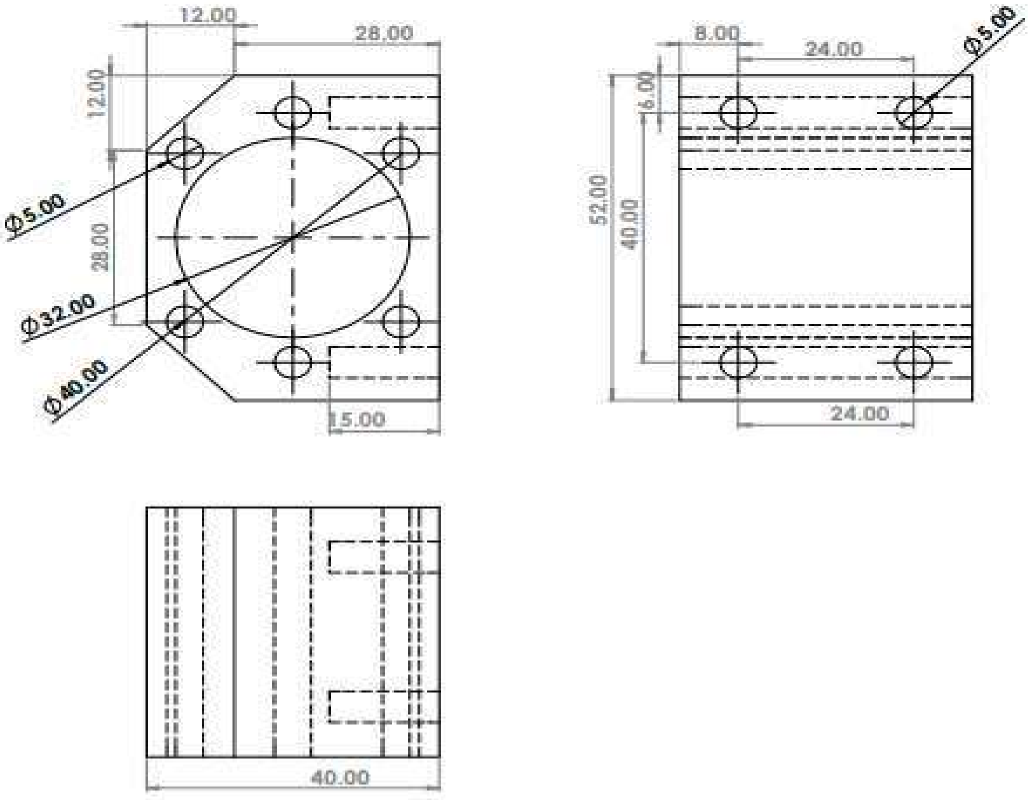


Fig 5.3 -lead nut

Name part: lead Screw Nut Seat Bracket Holder Mount Housing

Material: aluminum alloy



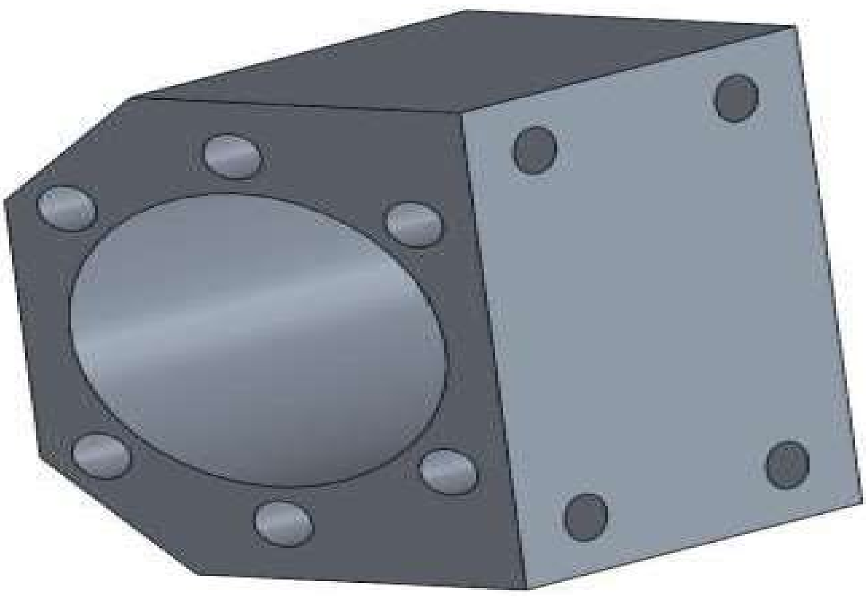


Fig 5.4- lead screw nut seat bracket holder mount housing

Name part: Linear Rail Shaft Support

Material: Carbon Steel

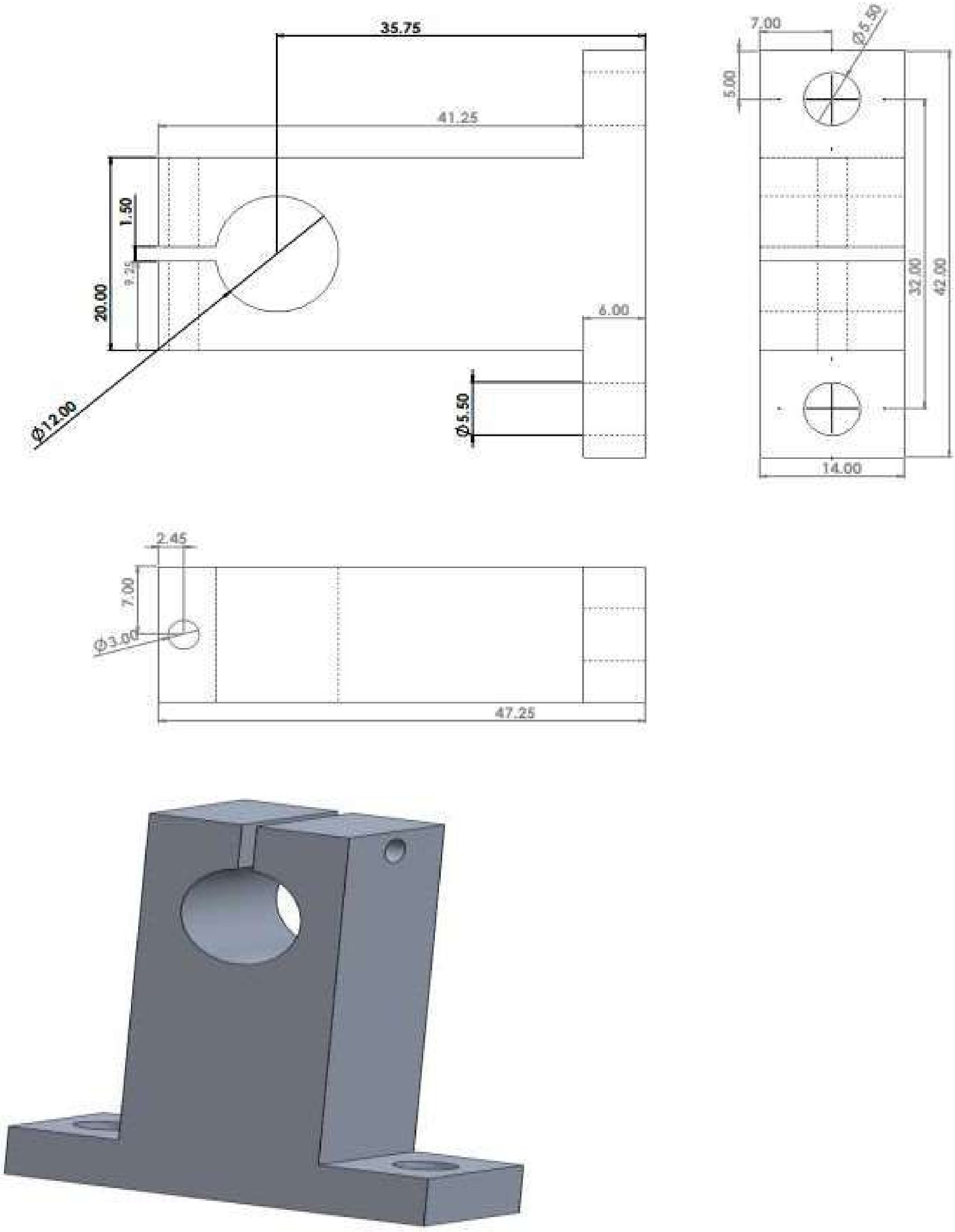


Fig 5.5- linear rail shaft support

Name part: Lead Screw End Supports

Material : Carbon Steel

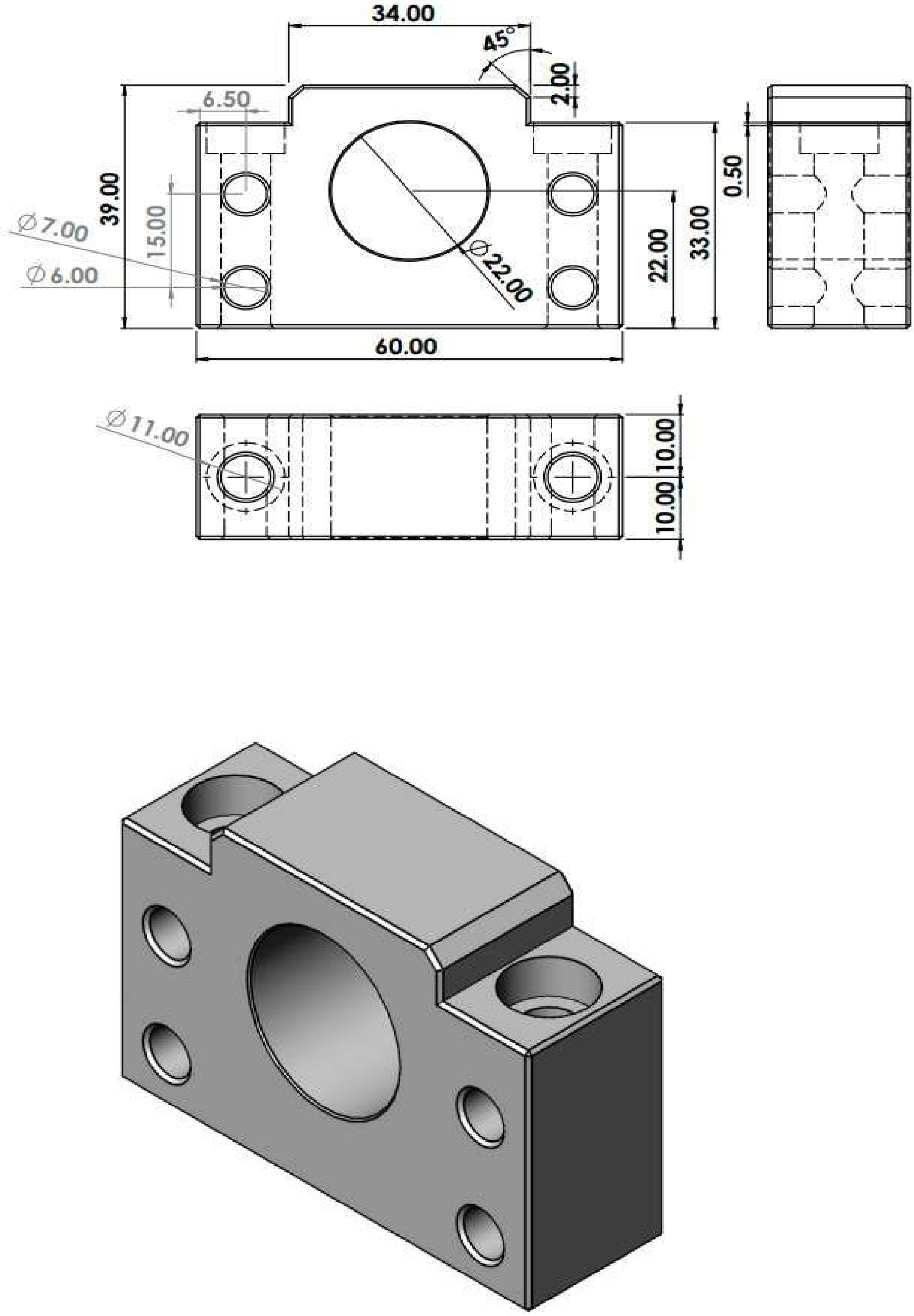


Fig 5.6-lead screw end supports

Name part: Lead Screw End Supports

Material: Carbon Steel

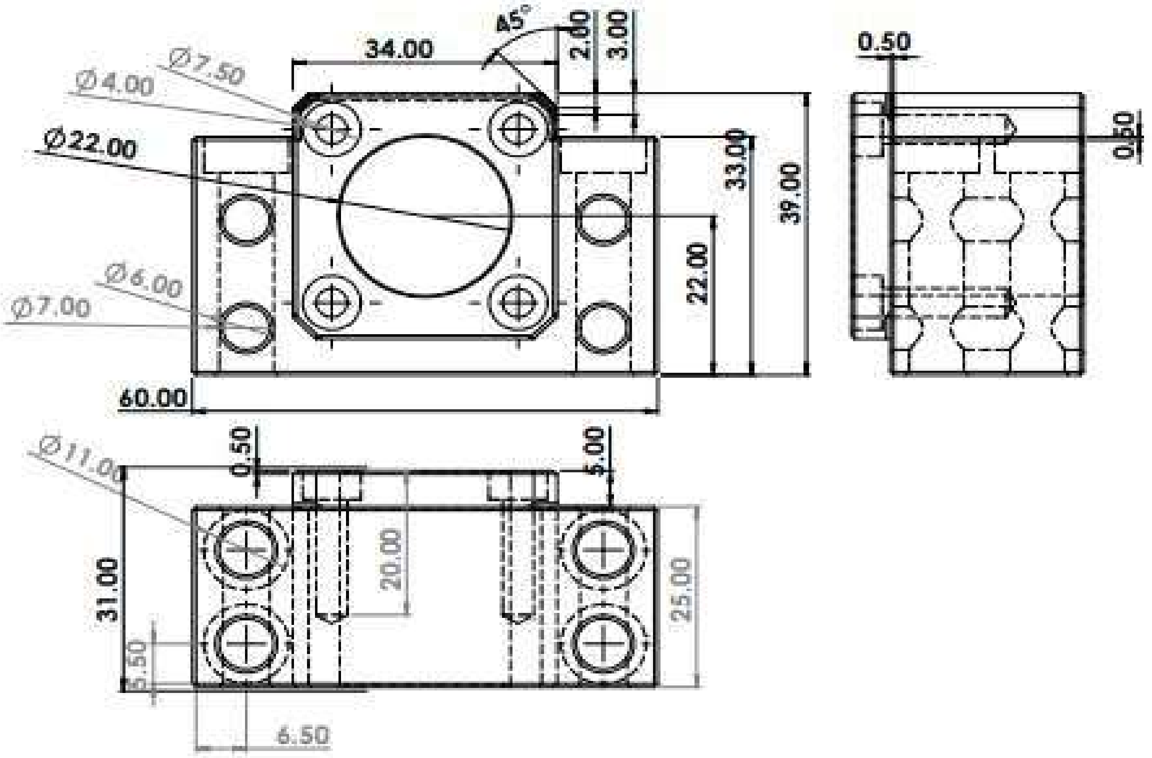


Fig 5.7-lead screw end supports.

Name part: Linear Motion Ball Slide Bearings
Material: Carbon Steel

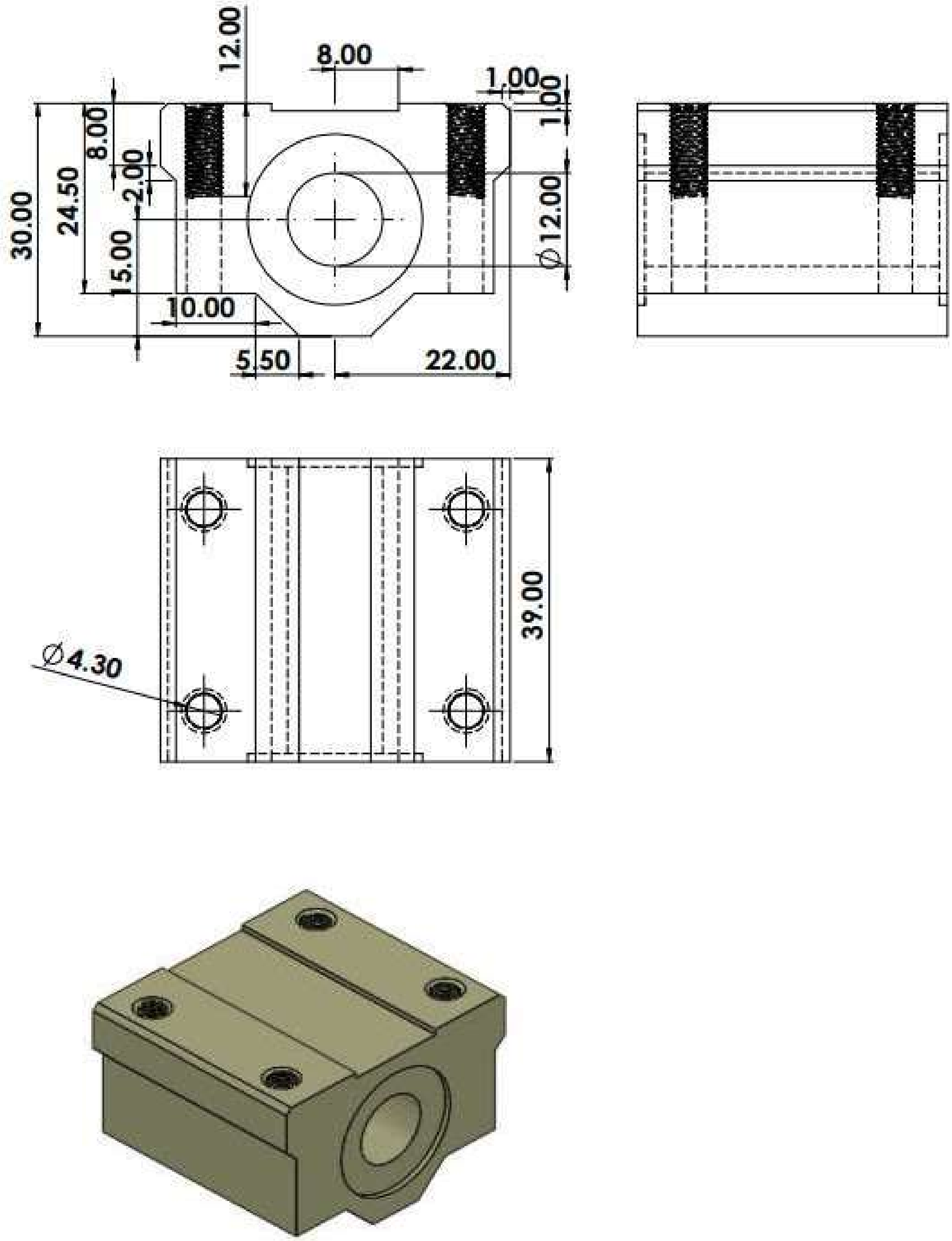


Fig 5.8-Linear Motion Ball Slide Bearings

Roller bearing

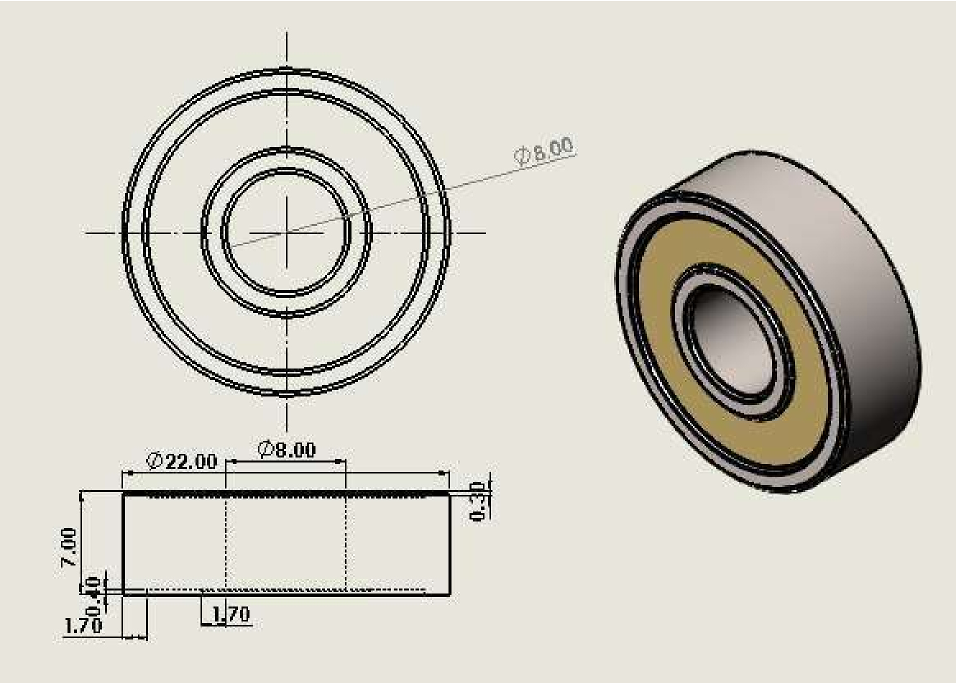


Fig 5.9-roller bearing.

Mass properties of Table

Configuration: Default

Coordinate system: -- default --

Density = 0.00 grams per cubic millimeter

Mass = 680.93 grams

Volume = 1215949.89 cubic millimeters

Surface area = 262230.20 square millimeters

Center of mass: (millimeters)

X = 0.00

Y = 5.01

Z = 0.00

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)

Taken at the center of mass.

Ix = (0.00, 0.00, 1.00)	Px = 6964748.42
Iy = (1.00, 0.00, 0.00)	Py = 6965362.21
Iz = (0.00, 1.00, 0.00)	Pz = 13918773.20

Moments of inertia: (grams * square millimeters)

Taken at the center of mass and aligned with the output coordinate system.

Lxx = 6965362.21	Lxy = 0.00	Lxz = 0.00
Lyx = 0.00	Lyy = 13918773.20	Lyz = 0.00
Lzx = 0.00	Lzy = 0.00	Lzz = 6964748.42

Moments of inertia: (grams * square millimeters)

Taken at the output coordinate system.

Ixx = 6982469.79	Ixy = 0.00	Ixz = 0.00
Iyx = 0.00	Iyy = 13918773.20	Iyz = 0.00
Izx = 0.00	Izy = 0.00	Izz = 6981856.01

Mass properties of Base plate

Configuration: Default
Coordinate system: -- default --

Density = 0.01 grams per cubic millimeter

Mass = 24052.47 grams

Volume = 3006558.99 cubic millimeters

Surface area = 627595.66 square millimeters

Center of mass: (millimeters)
X = -0.28
Y = 5.07
Z = 0.00

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.

Ix = (1.00, 0.00, 0.00)	Px = 317704834.97
Iy = (0.00, 0.00, -1.00)	Py = 1125039099.40
Iz = (0.00, 1.00, 0.00)	Pz = 1442313703.00

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 317704840.48	Lxy = -78715.67	Lxz = 39.17
Lyx = -78715.67	Lyy = 1442313697.49	Lyz = 0.88
Lzx = 39.17	Lzy = 0.88	Lzz = 1125039099.40

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 318323221.58	Ixy = -112895.75	Ixz = 39.33
Iyx = -112895.75	Iyy = 1442315586.74	Iyz = -2.08
Izx = 39.33	Izy = -2.08	Izz = 1125659369.76

Mass properties of Lead screw

Configuration: Default

Coordinate system: -- default –

Density = 0.01 grams per cubic millimeter

Mass = 577.95 grams

Volume = 75058.89 cubic millimeters

Surface area = 42211.83 square millimeters

Center of mass: (millimeters)
X = 279.96
Y = 0.00
Z = 0.01

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.

Ix = (1.00, 0.00, 0.00)	Px = 13340.45
Iy = (0.00, 0.71, -0.70)	Py = 14576886.64
Iz = (0.00, 0.70, 0.71)	Pz = 14577623.13

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 13340.46	Lxy = -247.46	Lxz = 101.43
Lyx = -247.46	Lyy = 14577250.65	Lyz = -368.23
Lzx = 101.43	Lzy = -368.23	Lzz = 14577259.11

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 13340.49	Ixy = -870.78	Ixz = 1032.93
Iyx = -870.78	Iyy = 59874729.99	Iyz = -368.24
Izx = 1032.93	Izy = -368.24	Izz = 59874738.44

Mass properties of guide shafts

Configuration: Default

Coordinate system: -- default --

Density = 0.01 grams per cubic millimeter

Mass = 483.92 grams

Volume = 62846.51 cubic millimeters

Surface area = 21140.13 square millimeters

Center of mass: (millimeters)

X = 278.00

Y = 0.00

Z = 0.00

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)

Taken at the center of mass.

Ix = (1.00, 0.00, 0.00)	Px = 8706.61
Iy = (0.00, 0.00, -1.00)	Py = 12456656.68
Iz = (0.00, 1.00, 0.00)	Pz = 12456656.68

Moments of inertia: (grams * square millimeters)

Taken at the center of mass and aligned with the output coordinate system.

Lxx = 8706.61	Lxy = 0.00	Lxz = 0.00
Lyx = 0.00	Lyy = 12456656.68	Lyz = 0.00
Lzx = 0.00	Lzy = 0.00	Lzz = 12456656.68

Moments of inertia: (grams * square millimeters)

Taken at the output coordinate system.

Ixx = 8706.61	Ixy = 0.00	Ixz = 0.
Iyx = 0.00	Iyy = 49855788.06	Iyz = 0.00
Izx = 0.00	Izy = 0.00	Izz = 49855788.06

Mass properties of Lead Screw End Supports

Configuration: Default
Coordinate system: -- default --

Density = 0.00 grams per cubic millimeter

Mass = 48.57 grams

Volume = 48570.57 cubic millimeter

Surface area = 23080.31 square millimeters

Center of mass: (millimeters)
X = 0.00
Y = -3.55
Z = 1.31

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.

Ix = (1.00, 0.00, 0.00)	Px = 9014.86
Iy = (0.00, 1.00, 0.09)	Py = 14725.51
Iz = (0.00, -0.09, 1.00)	Pz = 17272.42

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 9014.86	Lxy = 0.00	Lxz = 0.02
Lyx = 0.00	Lyy = 14745.64	Lyz = 225.55
Lzx = 0.02	Lzy = 225.55	Lzz = 17252.29

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 9709.89	Ixy = -0.01	Ixz = 0.02
Iyx = -0.01	Iyy = 14829.41	Iyz = -0.73
Izx = 0.02	Izy = -0.73	Izz = 17863.55

Mass properties of lead Screw Nut Seat Bracket Holder Mount Housing

Configuration: Default

Coordinate system: -- default --

Density = 0.00 grams per cubic millimeter

Mass = 106.32 grams

Volume = 39379.61 cubic millimeters

Surface area = 17559.16 square millimeters

Center of mass: (millimeters)

X = 21.97

Y = 20.00

Z = 26.00

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)

Taken at the center of mass.

Ix = (0.00, 0.00, 1.00)	Px = 31589.90
Iy = (1.00, 0.00, 0.00)	Py = 47007.05
Iz = (0.00, 1.00, 0.00)	Pz = 50321.43

Moments of inertia: (grams * square millimeters)

Taken at the center of mass and aligned with the output coordinate system.

Lxx = 47007.05	Lxy = 0.00	Lxz = 0.00
Lyx = 0.00	Lyy = 50321.43	Lyz = 0.00
Lzx = 0.00	Lzy = 0.00	Lzz = 31589.90

Moments of inertia: (grams * square millimeters)

Taken at the output coordinate system.

Ixx = 161412.68	Ixy = 46711.40	Ixz = 60724.82
Iyx = 46711.40	Iyy = 173501.02	Iyz = 55288.97
Izx = 60724.82	Izy = 55288.97	Izz = 125423.80

Mass properties of Lead nut

Configuration: Varsayılan
Coordinate system: -- default --

Density = 0.01 grams per cubic millimeter

Mass = 297.73 grams

Volume = 37888.67 cubic millimeters

Surface area = 11995.48 square millimeters

Center of mass: (millimeters)
X = 22.52
Y = 0.01
Z = 0.01

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.

Ix = (1.00, 0.00, 0.00)	Px = 57677.23
Iy = (0.00, 0.00, -1.00)	Py = 76069.24
Iz = (0.00, 1.00, 0.00)	Pz = 82083.07

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 57677.40	Lxy = 41.79	Lxz = -41.78
Lyx = 41.79	Lyy = 82082.98	Lyz = 8.67
Lzx = -41.78	Lzy = 8.67	Lzz = 76069.16

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 57677.44	Ixy = 93.82	Ixz = 12.92
Iyx = 93.82	Iyy = 233043.06	Iyz = 8.69
Izx = 12.92	Izy = 8.69	Izz = 227029.24

Mass properties of Linear Motion Ball Slide Bearings

Configuration: Default
Coordinate system: -- default --

Density = 0.01 grams per cubic millimeter

Mass = 278.09 grams

Volume = 35653.18 cubic millimeters

Surface area = 10321.94 square millimeters

Center of mass: (millimeters)
X = 0.00
Y = 16.93
Z = 0.00

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.

Ix = (0.00, 0.00, 1.00)	Px = 52435.51
Iy = (1.00, 0.00, 0.00)	Py = 59850.90
Iz = (0.00, 1.00, 0.00)	Pz = 74961.31

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 59850.90	Lxy = 0.00	Lxz = -0.47
Lyx = 0.00	Lyy = 74961.31	Lyz = 0.00
Lzx = -0.47	Lzy = 0.00	Lzz = 52435.51

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 139553.54	Ixy = 0.00	Ixz = -0.47
Iyx = 0.00	Iyy = 74961.31	Iyz = 0.00
Izx = -0.47	Izy = 0.00	Izz = 132138.15

Mass properties of Linear Rail Shaft Support

Configuration: Valor predeterminado
Coordinate system: -- default --

Density = 0.00 grams per cubic millimeter

Mass = 34.93 grams
Volume = 12936.08 cubic millimeters

Surface area = 5313.30 square millimeters

Center of mass: (millimeters)
X = -19.23
Y = 21.00
Z = 7.00

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.

Ix = (1.00, 0.00, 0.00)	Px = 2775.58
Iy = (0.00, 1.00, 0.00)	Py = 7401.86
Iz = (0.00, 0.00, 1.00)	Pz = 9000.92

Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.

Lxx = 2775.58	Lxy = 0.00	Lxz = 0.00
Lyx = 0.00	Lyy = 7401.86	Lyz = 0.00
Lzx = 0.00	Lzy = 0.00	Lzz = 9000.92

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 19890.02	Ixy = -14101.88	Ixz = -4700.63
Iyx = -14101.88	Iyy = 22023.97	Iyz = 5134.33
Izx = -4700.63	Izy = 5134.33	Izz = 37314.58

Conclusion

Our one-direction shake table test has unearthed significant insights into the earthquake resistance of the studied structure(s) or component(s). Simulated seismic loading unveiled crucial details about its behavior, including its strength, deformation patterns, failure modes, and dynamic characteristics. These observations have both validated and challenged our initial design assumptions, exposing potential vulnerabilities previously unaccounted for. The effectiveness of implemented mitigation strategies, like base isolation systems or energy dissipation devices, has been rigorously evaluated, guiding us towards recommendations for design improvements, construction practices, and avenues for future research. While acknowledging the inherent limitations of our testing, such as simplified loading conditions and inherent scale effects, we cannot overstate the importance of shake table testing in verifying and ultimately enhancing the earthquake resilience of our structures. This knowledge not only strengthens our specific project but also contributes valuable data to the ongoing quest for safer, more resilient infrastructure in the face of seismic threats.

Cost Tabe

Id	Components	cost
1.	Accelerometer sensor	**170،00 EGP**
2.	LVDT sensor	مستخدم من قسم مدنى
3.	Arduino nano shield	**180،00 EGP**
4.	Motor DC(24v)	**1300,00 EGP**
5.	Lead screw/500mm	**1500,00 EGP**
6.	linear guide(1 Meter)	**800,00 EGP**
7.	Linear motion ball bearing	**1200,00 EGP**
8.	Nuts(one price)	**20،00 EGP**
9.	Washer(one price)	**10،00 EGP**
10.	Lead screw housing nut	**90,00 EGP**
11.	Arduino uno(2)	**1500,00 EGP,**
12.	Limit switch(2)	**100,00 EGP**
13.	Base plate	**300،00 EGP**
14.	plate	**450,00 EGP**
15.	Pwm DC motor speed control	**300,00EGP**
16.	Power supply(24v,15A)	**900،00 EGP**
17.	Usb موزع	**180،00 EGP**
18.	Relay module shield 4 channel	**850،00 EGP**
19.	Arduino usb cable(2)	**80,00 EGP**
20.	LCD2004 blue(2)	**750،00 EGP**
21.	Stands (3Dprinter)	**650،00 EGP.**
22.	Motor stand	**150،00 EGP**
23.	pins	**50،00 EGP.**
24.	wires	**100,00 EGP**
TOTAL		**11630EGP**

References

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