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Design analysis of slide force testing machine

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ABSTRACT

Brake calipers are a vital part of vehicle's braking system. Brake calipers squeeze the brake pads against the surface of brake rotor to slow or stop the vehicle. The brake pads have high friction surfaces and serve to slow the rotor down or even bring it to a complete halt. The braking system will result in forces both mechanical and hydraulic during slow down or stop vehicle. These set of forces acting on brake caliper component result in deformations and stresses, which may cause the failure of the brake caliper. So, it is important to calculate the force carrying capacity of brake caliper in order to avoid the failure of it. The force carrying capacity of brake caliper can be calculated by using the slide force testing machine. The design of the slide force testing machine is developed by using solid edge software and by using thumb rule.

Keywords: *Brake calipers, Brake pads, Brake Rotor, Slide Force Testing Machine, Solid Edge software, Thumb Rule.*

1. INTRODUCTION

During the application of brake, the pedal is pressed, slide force is applied on the brake, in order to apply the brake and stop a vehicle. Hence to measure a slide load carrying capacity of the brake, in order to avoid uncertain breakdown of the brake is important. This load can be measure with the help of a slide force testing machine. The slide force testing machine consists of a pneumatic cylinder, electrical panel, load cells, Ball screws, PLC control and servo motor. In this machine, the job (brake) is mounted on fixture base plates, which is placed in between rail mounting plates. These Fixture base plates having pneumatic cylinders on one side for the proper clamping of the job (brake). These rail mounting plates having a strain gauge type load cell mounting on it and a pneumatic cylinder used to disengage a load cell from a fork base plate. This fork base plate used for pressing a job (brake).These rail mounting plates also having a Ball screw and lead screw mounting block actuated by a servomotor which gives linear motion to load cells.

PLC panel is used to control operations and HMI (Human Machine Interface) unit shows all results on screen. PLC operate servomotor, which operates Ball screw and lead screw mounting block. Lead nut carries a load cell in a forward direction toward the job (brake). In this way, load (force) is applied to the strain gauge type load cells which deform (strain) the foils in load cells, causing its electric resistance to change. Here the change in electric resistance is directly proportional to load. Here, an electric signal (resistance) is amplified first and then ADC is used to convert it in digital form.

In this way, load cells measure a load on the brake and indicate it on HMI (Human Machine Interface).

2. OBJECTIVE

The objective of this research work is to study the existing slide force testing machine in order to find a scope for the innovation to development a reliable and efficient slide force testing machine.

• Study of the existing slide force testing machine.

• Study the effect of forces acting on the brake caliper.

• Develop a conceptual design and find the processes involved in the development of the slide force testing machine.

• Study a geometric model of slide force testing machine on standard software.

• Verification of outcomes of the analysis.

• Develop the conclusion of design analysis.

3. GENERAL ASSEMBLY LAYOUT OF MACHINE

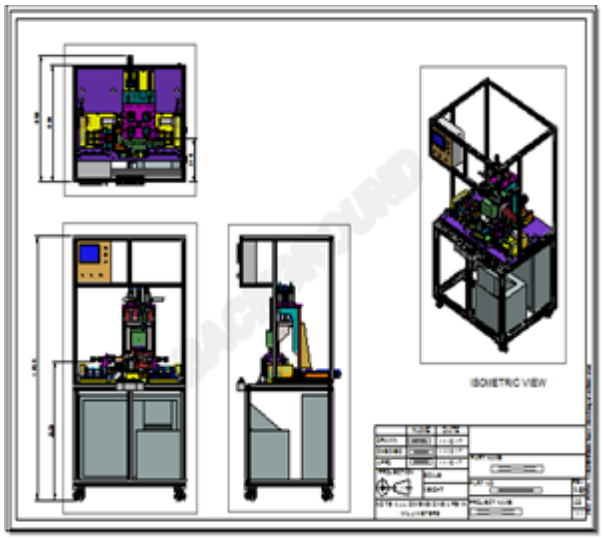

Figure1. General Assembly Layout of Slide Force Testing machine

According to customer requirement, availability of space and surrounding environment the general layout is developed. General assembly layout is the rough design of the machine based on:

• The concept of Working

• Space required for the machine

• Overall dimensions of the machine

• Operating height of the machine

General assembly layout is designed in Solid Edge st5 by considering all the mentioned parameters. In order to perform all the operations on a single unit having same base plate and Aluminum extrusion frame. Arrangement and position of all the parts are not final, the representation is generalized hence called general assembly (GA) Layout.

The overall length of the machine in the layout is 1000mm, overall width is 898mm and overall height is 1859mm.

4. INTRODUCTION METHODOLOGY OF EXISTING DESIGN

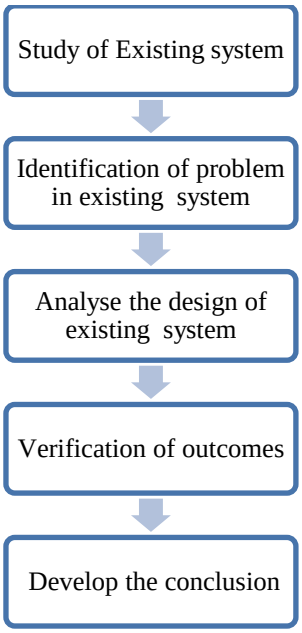

Fig2: Flow chart of methodology existing system

5. MATERIAL PROCESSING METHODS USED FOR VARIOUS PARTS OF MACHINE

• Hardening

• Hard anodizing

• Black dining

• Electro less nickel plating

Details of these processes in detail-

5.1 Hardening

Hardening is a metallurgical and metalworking process used to increase the hardness of a metal. The hardness of a metal is directly proportional to the uniaxial yield stress at the location of the imposed strain. A harder metal will have a higher resistance to plastic deformation than a less hard metal. The sliding force testing machine uses certain parts which are made up of materials like EN8 which need to be hardened to resist the deformation because of various forces acting on it.The use of this heat treatment will result in improvement of mechanical properties as well as an increase in the level of hardness, producing a tougher and more durable item. Alloys are heated above the critical transformation temperature for the material, then cool rapidly enough to cause the soft initial material to transform to a much harder and stronger structure. Alloys may be air cooled or quenched in oil, water, and another liquid, depending upon the amount of alloying elements in the material.

5.2 Anodizing

Anodizing is a process for producing decorative and protective films on articles made of aluminum and its alloys. The article is made the anode of an electrolytic cell with aqueous sulfuric acid as electrolyte where the following overall oxidation reaction occurs.

$$2Al + 3H2O \rightarrow Al2O3 + 6H+ + 6e-$$

A dense even layer of oxide about 0.08 μm thick is formed rapidly, followed much more slowly with a more porous layer up to 25μm thick. Before anodizing the surface of the article must be thoroughly cleaned, normally using a detergent-based process, and etched with a solution of sodium hydroxide. After anodizing the surface may be colored with a dye or by an electrolytic method using appropriate metal cations and then sealed by placing in boiling water, the pores in the oxide layer being closed off.We have used aluminum material for most of the parts of the slide force testing machine. After machining anodizing is required to give a glossy look to aluminum.

5.3 Blackodising

Chemical blacking of steel provides a uniform glossy black finish on steel, the film is a particular state of iron oxide which is black in appearance, it has very little protective value without a supplementary treatment of oil to retard corrosion. In fact, a dry coating will quickly revert to the more typical brown/rusty colored oxidation state of iron and corrode very quickly. The film is of negligible thickness and makes no discernible changes to the dimensions of the parts treated, however with the hot caustic blacking process; parts must be able to resist processing temperatures of up 1500 C. It is not feasible to process mixed materials, for instance, components that include copper such as bronze bushes, brazed, as the copper will not blacken and acts as a poison to the blacking solution.

5.4 Electroless Nickel Plating

Electroless (autocatalytic) plating involves the presence of a chemical reducing agent in solution to reduce metallic ions to the metal state. The name electroless is somewhat misleading, however. There are no external electrodes present, but there is electric current (charge transfer) involved. Instead of an anode, the metal is supplied by the metal salt; replenishment is achieved by adding either salt or an external loop with an anode of the corresponding metal that has higher efficiency than the cathode. There is, therefore, instead of a cathode to reduce the metal, a substrate serving as the cathode, while the electrons are provided by a reducing agent. The process takes place only on catalytic surfaces rather than throughout the solution (if the process is not properly controlled, the reduction can take place throughout the solution, possibly on particles of dust or of catalytic metals, with undesirable results).All the parts made up of mild steel are electro less nickel plated.

6. MAIN COMPONENTS OF SLIDE FORCE TESTING MACHINE

The slide force testing machine consists of following components-

6.1 Servomotor

A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration It is mounted on both rail base plates. It is connected to the PLC control panel.PLC operate servomotor, which operates Ball screw and lead screw mounting block. Servomotor rotates the driving pulley, driving pulley drives the driven pulley. Then the driven pulley gives a moves a lead screw mounting block in the forward direction.

Figure3. Servomotor used in Slide Force Testing machine

6.2 Load Cell

A load cell is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured. The various load cell types include hydraulic, pneumatic, and strain gauge. In slide force testing machine strain gauge type of load cell is used.The basic principle of the strain gauge load cell is "the change in dimension of the strain gauge causes its resistance to change. This change in resistance or output voltage of the strain gauge becomes a measure of applied force. It is mounted on the rail mounting plates and a pneumatic cylinder used to disengage a load cell from a fork base plate.

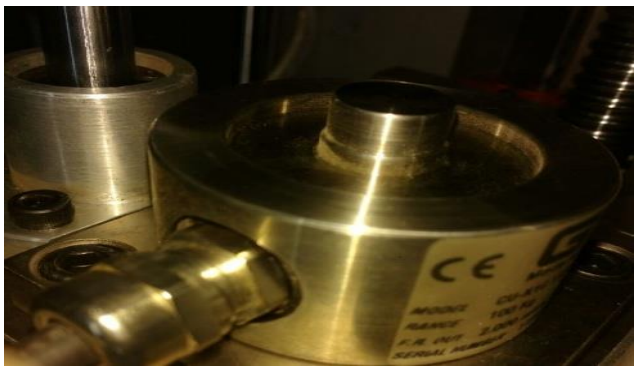

Figure4. Load Cell used in Slide Force Testing machine

6.3 Pneumatic Cylinder

Pneumatic cylinders (sometimes known as air cylinders) are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion. It is mounted on the fixture base plate and both of the rail mounting plate. The fixture base plates having pneumatic cylinders on one side for the proper clamping of job (brake). The rail mounting plates having a pneumatic cylinder used to disengage a load cell from a fork baseplate.

Figure5. Pneumatic Cylinder

6.4 Transformer

A transformer is a static electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. In slide force testing machine step down transformer is used.

6.5 Proximity Sensor

A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact. A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. It is used to sense the position of rail base plate.

Figure6. Proximity Sensor

6.6 Photoelectric Sensor

A photoelectric sensor, or photo eye, is an equipment used to discover the distance, absence, or presence of an object by using a light transmitter, often infrared, and a photoelectric receiver.It is used to detect the presence of brake caliper.

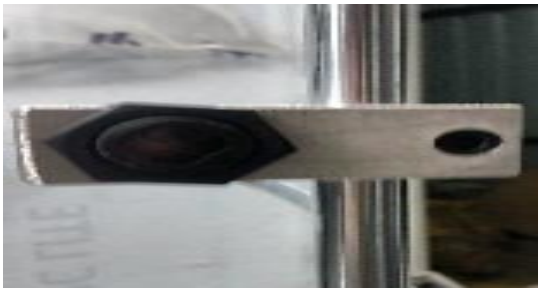

Figure7. Photoelectric Sensor

6.7 Programmable Logic Controller (PLC)

A programmable logic controller (PLC) or programmable controller is an industrial digital computer which has been ruggedized and adapted for the control of manufacturing processes, such as assembly lines, or robotic devices, or any activity that requires high reliability control and ease of programming and process fault diagnosis. It controls all the activity of slide force testing machine by using PLC program.

Figure8. Programmable Logic Controller

6.8 Human Machine Interface Unit (HMI)

A human-machine interface (HMI) is the user interface that connects an operator to the controller. A human-machine interface (HMI) connected to a separate programmable logic controller (PLC) is the standard system for machine automation.. A load cell measure a load on brake Caliper and indicate it on HMI (Human Machine Interface).

Figure9. Human Machine Interface Unit

6.9 FRL Unit

Air line filters remove contaminants from pneumatic systems, preventing damage to equipment and reducing production losses due to contaminant-related downtime. Pressure regulators reduce and control fluid pressure in compressed air systems. A lubricator adds controlled quantities of oil into a air system to reduce the friction of moving components. It is used air supply unit.

Figure10. FRL Unit

6.10 Timer Belt

A timing belt is a non-slipping mechanical drive belt and it may also referred as toothed belt, a flexible belt with teeth moulded onto its inner surface. It is mounted on driving and driven pulley.

Figure11. Timer Belt

7. TWO MAIN SUBASSEMBLIES OF SLIDE FORCE TESTING MACHINE

Details of these subassemblies are as follows-

7.1 Rail Mounting Plate

There are two rail mounting plate. One is RH plate and another is LH mounting plate. Fixture mounting plate is placed in between a RH plate and LH mounting plate. It consists of a load cell, a pneumatic cylinder, fork plate, a servomotor, driving and driven pulley. Rail mounting plates having a strain gauge type load cell mounting on it. Here the pneumatic cylinder used to disengage a load cell from a fork base plate. This fork base plate used for pressing a job (brake caliper).These rail mounting plates also having a Ball screw and lead screw mounting block actuated by servomotor which gives linear motion to load cells. PLC operate servomotor, which operate Ball screw and lead screw mounting block. Lead nut carry a load cells in forward direction toward the job (brake). In this way, load (force) is applied on the strain gauge type load cells which deform (strain) the foils in load cells, causing its electric resistance to change. Here the change in electric resistance is directly proportional to load.

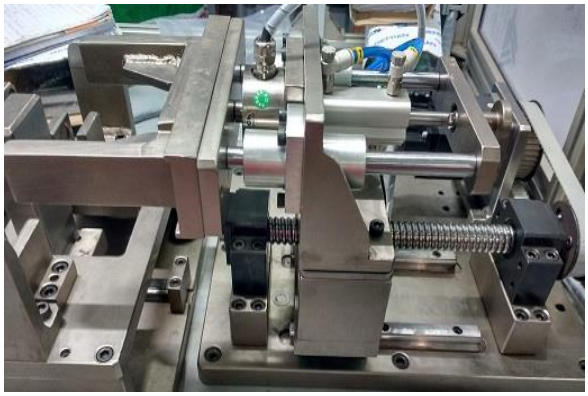

Figure12. Rail Base Plate

7.2 Fixture Base Plate

Fixture base plate is located in between the two rail mounting plate. This is the stationary part of machine. This plate is can be replace easily by lock nut. A brake caliper is mounted on fixture base plate. These Fixture base plates having pneumatic cylinders on one side for the proper clamping of job (brake caliper). The force is applied on brake caliper from both the side of fixture base plate. It consists of two pneumatic cylinders.

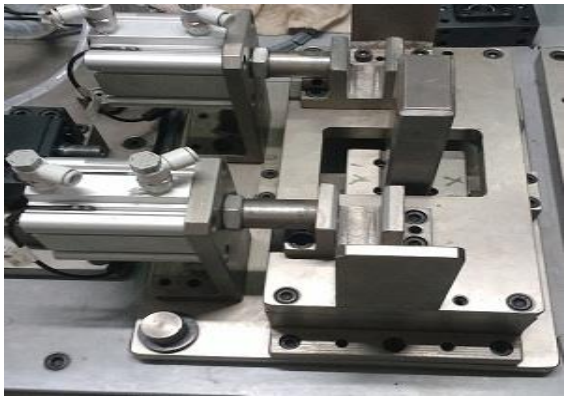

Figure13. Fixture Base Plate

8. SELECTION OF MATERIALS FOR VARIOUS PARTS OF THE MACHINE

The Slide Force Testing Machine consists of various mechanical parts which need to be manufactured for various purposes. Each part has its specific importance in the machine and hence a careful selection of material is required in order to develop the machine with enough strength and with more life. Certain parts in the machine requires strength and some parts need to be soft in nature. Various materials required in the machine are listed below:

• Mild Steel

• EN-8

• Chrome plated shaft

• Aluminium HE30

8.1 Mild Steel

Mild steel also known as plain carbon steel, is a metal alloy, a combination of two elements are present in quantities too small to affect the properties. The only other alloying elements allowed in plain carbon steel are manganese (1.65% max), silicon (0.60% max), and copper (0.60% max). Steel with low carbon content has the properties of iron, soft but easily formed. As carbon content rises the metal becomes harder and stronger but less ductile and more difficult to weld.Mild steel is the running material in all automation industries because its price is comparatively low and it provides material properties that are acceptable for many applications. It contains very low amount of carbon up to 0.3% and is therefore neither extremely brittle nor ductile. It becomes malleable when heated, and so can be forged. It is also often used where large amounts of steel need to be formed, for example as structural steel. Density of this metal is 7861.093 kg/m^3 (0.284 lb/in^3) and the tensile strength is a maximum of 500 MPa (72500 psi). Mild steel is available in market by two types:

1) Bright Mild Steel

2) Black Mild Steel

Generally black mild steel is used in the industries because black mild steel turns bright after machining. Bright steel is used for applications where very less or no machining is required.

Parts manufactured by using mild steel as a raw material are:

• Structure top plate.

• Rail Mounting Plate

• Block Mounting Plate

• Fork Mounting plate

8.2 EN8 Steel Material

EN8 is a very popular grade of through- hardening medium carbon steel, which is readily machinable in any condition. It is usually supplied untreated but can be supplied to order in the normalized or finally heat treated, which is adequate for the wider range of applications. It is suitable for the manufacture of parts such as general purpose axles and shafts, gears, bolts, seams, and studs. It can be further surface hardened typically to 50-55 HRC by induction process, producing components with enhances wear resistance. The chemical composition of EN8 tool steel includes carbon 0.35-0.45%, manganese 0.60-1.0%, sulphur 0.060%, phosphorus 0.060%, and silicon 0.05-0.35%. Typical parts manufactured by using EN8 material are locators used in the machine.

8.3Chrome Plated Shaft

Chrome plated shafts are used in automation machines for various purposes like guide shafts, supporting shafts, sensor mounting brackets etc. 1045 is a medium tensile carbon steel supplied in cold drawn or turned, precision ground, polished, chrome plated, and final polished condition, with atypical base metal tensile strength of 670-800 Mpa plus a typical hard chrome plated surface hardness of HV 1000-1150. It has advantageous mechanical properties of extremely smooth surface finish with excelled wear and corrosion resistance, coupled with the base material gives good strength and impact properties, good machinability and reasonable weldability. Chrome plated shafts are available with a color code serpentine with stock size ranging from 6mm – 200 mm diameter. Its chemical composition includes carbon 0.43-0.5%, silicon 0.1-0.35%, manganese 0.60-0.90%, Phosphorus 0-0.04%, sulphur 0-0.04%, and steel in balanced form. These shafts are heat treated with case hardening process. Hard chrome is plated with the hard chrome plating process with typical surface roughness value of HV 1000-1150, surface smoothness of 0.10- 0.050 microns, and surface deposit of 0.025-0.050 mm. Chrome plated shafts are available in standard lengths depending upon diameters. These are available in the length range of 2000-3600 mm with diameters up to 18mm, 4000mm length with a diameter range of 19-25mm, 6000mm length with diameters above 25mm.A special care is to be taken to protect the polished chrome surface, soft materials such as copper, aluminum or ms should be used as clamping materials.

8.4 Aluminium HE 30

Aluminum is a chemical element in the boron group. It is silvery white, soft, nonmagnetic, ductile metal. Aluminum is the third most abundant element after oxygen and silicon. It is a good thermal and electrical conductor, having 59% conductivity of copper. Corrosion resistance can be excellent due to a thin surface layer of aluminum oxide that forms when the metal is exposed to air, effectively preventing further oxidation. Aluminum is a widely used metal, particularly in an automotive industry. To survive in a competitive market the major task for automotive industries is to reduce the fuel consumption by reducing the weight of an automobile hence a wide market is open for aluminum.

Aluminum alloy 6082 commonly known as HE 30 is selected for manufacturing of various aluminum parts of the machine because of certain properties like medium strength alloy with excellent corrosion resistance, machinability. The addition of a large amount of manganese controls the grain structure which in turns results in the stronger alloy. The HE 30 aluminium chemically composed of manganese 0.40-1.00%, Iron 0-0.50%, magnesium 0.60-1.20%, silicon 0.7-1.30%, copper 0-0.10%, zinc 0-0.20%, titanium 0-0.10%, chromium 0-0.25% and aluminium as balance material.

Following are the parts manufactured and used for aluminum material

• Aluminum Extrusion of size

• Driving and drove Pulley

9. CONCLUSION

Slide force testing machine is studied in detail from all aspects of design. The outcomes of the detail study are-

1) The slide force testing machine used to measure a slide load carrying capacity of the brake, in order to avoid uncertain breakdown of the brake.

2) The sliding force testing machine design by using thumb rule. So, there is a scope to optimize the design, in order to reduce the overall cost of production.

3) Proper design analysis helps to optimize the design of the slide force testing machine.

4) By using alternate materials, it is possible to reduce the cost of material.

5) By the proper design analysis, it is a possible to achieve high-quality production with lesser cost, which enhances both the efficiency and productivity.

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