

**DESIGN AND DEVELOPMENT OF SPECIAL PURPOSE MACHINE FOR
AUTOMATIC ASSEMBLY OF NUT AND SHACKLE ON BRAKE BOOSTER**V. R. Kale¹, Dr. S. P. Trikal²¹Department of Mechanical Engineering, S.S.G.M.C.E. Shegaon²Department of Mechanical Engineering, S.S.G.M.C.E. Shegaon

Abstract —In this project, the task is to design a machine for assembly of nut and shackle on stud of a brake booster and set the height of shackle pin on stud as per the requirements for each booster. Now this operation is done by manually. Generally two to three operators are required to perform this task, and take 1 to 1:30 min. to finish the job. This employs the manpower which introduces manual errors in the production. Thereby, giving rise to unnecessary errors and reduced productivity. This operation can be achieved by designing and developing a SPM for automatic assembly of nut and shackle pin on a break booster. This project is sponsored by Global Automation, talwade road, ganrsh nagar, pune

Keywords- Break booster, CAD, design, development, LVDT, Servo motor, Global automation.

INTRODUCTION

The brake booster is part of automotive vehicles. The booster amplifies the force applied by the driver's foot when pressing the brake pedal and thus reduces the required effort. It is combined with the master cylinder to form a single unit and is a component of a car braking system. . There are different types of brake booster, having different sizes, likes YP 8, U202 & EFC and number of types are there. Nut & Shackle pin are the components of brake booster which are assemble on stud of booster. Shackle pin work as coupling between brake booster and Brake pedal. When driver apply break on pedal then the force act upon the shackle pin. Due to this force the shackle pin can slip down, hence to resist the slipping of shackle pin the nut is tighten before the shackle on the booster. The nut, work as stopper for shackle pin.

In this project, the task is to design a machine for assembly of nut and shackle on stud of a break booster and set the height of shackle pin on booster stud as per the requirements of each booster. Currently this operation is done by manually. Generally two to three operators are required to perform this task, and one component takes 1 to 1:30 min. to finish the job. This employs the manpower which introduces manual errors in the production. Such as height of shackle pin, the operator adjusts the height of shackle by manually. Thereby, giving rise to unnecessary errors, expenses and reduced productivity.

PROBLEM STATEMENT

The industry is well automated but still due to modern technology there is need to save more labour charges with more efficient outcome. Mass production aims at high productivity to reduce unit cost and interchangeability to facilitate easy handling. This necessitates production devices to increase the rate of manufacturing and inspection device to speed up the inspection procedure.

In the conventional manner, there are two to three operators are required to assemble this nut and shackle pin on booster stud and to give torque to nut. On the booster the height of shackle is need to be set at particular distance from top and bottom shell of booster. The operators set this distance manually. There is a fixture in which one sliding rod is fixed, operator checks the height of shackle pin by using this fixture. Where the operator put the booster and try to check the rod can pass through the holes of shackle pin. If the sliding rod is pass through the shackle then the job is ok, if not then he adjust the shackle by his way. This leads to manual errors, due to this rejection of component is increase and productivity is reduced and time required to finish job is increase.

SOLUTION OF PROBLEM

So, automation is needed in the nut and shackle assembly operations of the booster that can replace older one with more efficiency, more production rate and other advantages and this leads to design and fabrication of a setup of nut and shackle assembly Machine, which gives better production.

So in order to remove all the errors as stated above we came up with an automation setup consisting of Pneumatic cylinders, LVDT, Touch sensor, main frame made of AL extrusion tube of 80x40mm, 40x40 mm, locator for nut & shackle pin, PLC and HMI, and systematic arrangement of mechanical components with all the mentioned components. Such a sturdy machine will eliminate the manual errors resulting in better, efficient and economical production.

METHODOLOGY

This chapter gives detailed information of the procedure in which the project work is carried out. The step by step implementation of project work includes:

- Problem Identification
- Problem Definition
- General Assembly Layout Communication
- Conceptual Design
- Detailed Design
- Communication of Detailed Design
- Selection of Materials and Processes for the Machine
- Procurement of Brought outs
- Manufacturing
- Primary Assembly of the Machine
- Trials
- Dismantling the Machine
- Finishing on required parts
- Final Assembly
- Dispatch of the Machine

The complete design and development of Special Purpose Machine for automatic assembly of nut and shackle pin on brake booster can be achieved by implementing the above mentioned steps.

CONCEPTUAL DESIGN:

Conceptual design of machine consist a 3D model generated in CAD software which clearly represents the final concept of the machine. This design describes how a new product will look and meets the required performance. A hypothetical functionality is focused by using the concept of conceptual design.

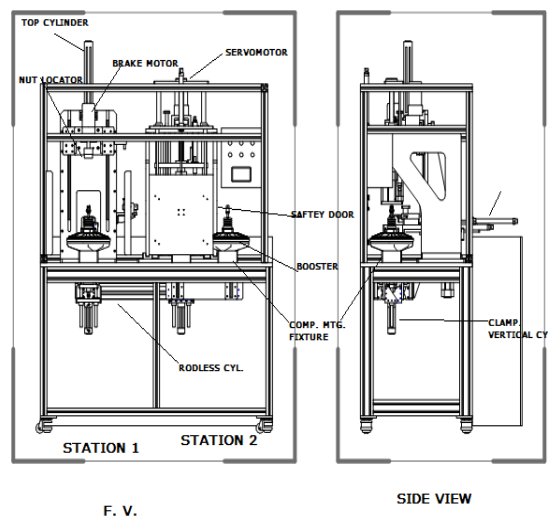


Figure 1 CONCEPTUAL DESIGN OF NUT AND SHACKLE ASSEMBLY MACHINE

NUT AND SHACKLE ASSEMBLY OPERATIONS DEVIDED IN TWO STATIONS:

Before designing the machine all the operations are divided in two stages, this means all the operations are to be done on two stations.

STATION NO. 1:

1. Stud height checked
2. Assemble the nut on booster stud
3. Touch sensor sense, machine will stop

STATION NO. 2:

1. Sensor sense component presence
2. Load shackle pin manually
3. Cycle starts, motor assembly down and assemble the shackle on booster stud

4. LVDT measure the required height, and stops machine.
5. Operator gives torque to the nut through Torque wrench manually.

In station 2 operations is same like nut assembly, only some structure is change, here shackle pin locator is change which can be actuated by pneumatic system. The locator is change for different shackle pins. the locator is connected to spline shaft which is driven by servo motor. The motor position is fixed only the shaft slides up and down. This assembly can be operated by pneumatic cylinder. In station 2, linear variable displacement transformer (LVDT) is used for to set the height of shackle pin on booster stud. Motor cylinder will come down then shackle will be assemble on Booster stud at the time of Shackle Assembly shackle height will be check through LVDT, stop motor on set limit.

L.V.D.T Unit:

The LVDT unit used in the shackle assembly unit. It is used for to set the height of shackle pin on the stud of brake booster during the assembly. In booster the height of shackle from center of booster is fixed. The shackle should not above or below the height. The height of shackle is different for different types of booster. We have some standard height of shackle pin for different types of booster.

Table 1 SHACKLE HEIGHT LIST

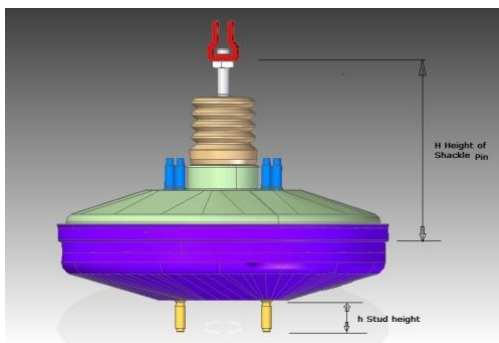


Figure 2 Shackle pin height

Booster	Height of shackle
Yp8	118
EFC	120
U202	116
Sx4	104

Cylinder Sizing

There are 14 cylinders are used in this machine combining both the stations

We know that

$$F = p / A$$

Where, F – force or load to be moved by cylinder

P – Pressure available = 5 bar

A – Cross sectional area of cylinder

D – Bore size of cylinder

The required thrust can be calculated by using design software, by applying material to the component in software & we have to consider factor of safety to calculate the bore size of cylinder.

STATION 1: Nut assembly section

1. Top cylinder

We have, pressure = 5 bar,

$$\text{Force} = 12 \times 9.81 = 117.72 \text{ N}$$

We know that,

$$F = P/A$$

$$A = P/A = 117.72/5 \times 10^5 = 0.0002354 \text{ m}^2$$

$$(\pi / 4) \times D^2 = 0.0002354$$

$$D = 0.018 = 18 \text{ mm}$$

By considering FOS

$$\text{F.O.S} = \text{Design load} / \text{Actual load} = 24/12 = 2$$

$$D = 18 \times 2 = 36 \text{ mm},$$

We have available bore size is 40 mm,

Therefore we have selected D = 40 mm & stroke of cylinder is 400mm selected from required applications

2. **Gripper slide cylinder:**

Actual load to be move by cylinder is 1 kg = 1 x 9.81 = 9.81 N

We have, pressure = 5 bar,

$$\text{Force} = 9.81 \text{ N}$$

We know that, $A = P/A = 9.81/5 \times 10^5 = 0.0000981 \text{ m}^2$

$$(\pi/4) \times D^2 = 0.0000981$$

$$D = 0.0111 \text{ m} = 11.1 \text{ mm}$$

By considering FoS of 1.5

$$\text{Hence, } D = 11 \times 1.5 = 17.25 \text{ mm}$$

We have available size is 20 mm, therefore D=20mm, stroke of cylinder is 200 mm selected from required application.

3. **P & p Rod less cylinder:**

The load to be move by cylinder is 7 kg,

$$\text{Force } F = 7 \times 9.81 = 68.67 \text{ N}$$

Pressure p = 5 bar,

We know that, $A = P/A = 68.67/5 \times 10^5$

$$A = 0.000137 \text{ m}^2$$

$$(\pi/4) \times D^2 = 0.000137$$

$$D = 0.0132 \text{ m} = 13.2 \text{ mm}$$

By considering FoS of 2

$$\text{Hence, } D = 13.2 \times 2 = 26.4 \text{ mm}$$

We have available standard size is 25mm, therefore D=25mm, stroke of cylinder is 600 mm selected from required application.

4. **P & P vertical cylinder:**

The actual load should be move by cylinder is 5 kg

$$\text{Hence } F = 5 \times 9.81 = 50 \text{ N,}$$

$$A = P/A = 50/5 \times 10^5$$

$$A = 0.0001 \text{ m}^2$$

$$(\pi/4) \times D^2 = 0.0001$$

$$D = 0.01128 \text{ m} = 11.28 \text{ mm}$$

By considering FoS of 2

$$\text{Hence, } D = 11.28 \times 2 = 22.56 \text{ mm}$$

We have available standard size is 32mm, therefore D=32mm, stroke of cylinder is 125 mm selected from required application.

STATION 2: Shackle Assembly section:

There are two cylinders have same size as in station 1, therefore no need to do the calculation for the cylinders in station 2.

1. **P & P vertical cylinder** D=32mm & stroke =125mm

2. **P & P Rod less cylinder** D=25 mm, here stroke length of rod less is change only we have taken it 300 mm.

3. **Gripper slide horizontal cylinder:** The actual load should be move by cylinder is 8 kg, Hence $F = 8 \times 9.81 = 78.48 \text{ N}$,

We know that $A = P/A = 78.48/5 \times 10^5$

$$A = 0.0001569 \text{ m}^2$$

$$(\pi/4) \times D^2 = 0.0001569$$

$$D = 0.01414 \text{ m} = 14.14 \text{ mm}$$

By considering FoS of 1.5, Hence $D = 14.14 \times 1.5 = 21.21 \text{ mm}$

We have available standard size is 25mm, therefore D=25mm, stroke of cylinder is 300 mm selected from required application.

4. **Component clamp bottom vertical cylinder:**

The actual load should be move by cylinder is 24 kg, Hence $F = 24 \times 9.81 = 235.44 \text{ N}$. We know that, $A = P/A = 235.44/5 \times 10^5$

$$A = 0.000470 \text{ m}^2$$

$$(\pi/4) \times D^2 = 0.000470$$

$$D = 0.02444 \text{ m} = 24.44 \text{ mm}$$

By considering FoS of 2

$$\text{Hence, } D = 24.44 \times 2 = 48.88 \text{ mm}$$

We have available standard size is 63mm, therefore D=63mm, stroke of cylinder is 50 mm selected from required application.

5. **Torque slide cylinder**

The actual load should be move by cylinder is 18.79 kg, Hence $F = 18.79 \times 9.81 = 184.329\text{N}$, We know that, $A = P/A = 184.32/5 \times 10^5$

$$A = 0.0003686 \text{ m}^2$$

$$(\pi/4) \times D^2 = 0.0003686$$

$$D = 0.02167 \text{ m} = 21.67 \text{ mm}$$

By considering F o S of 1.5

$$\text{Hence, } D = 21.67 \times 1.5 = 32.505\text{mm}$$

We have available standard size is 30mm, therefore D=32mm, stroke of cylinder is 250 mm selected from required application.

6. **Safety door cylinder**

7. To move the door up and down load will be 0.5 kg, Hence $0.5 \times 9.81 = 4.905 \text{ N} = F$

8. We know that, $A = P/A = 4.905/5 \times 10^5$

$$A = 0.00001 \text{ m}^2 = (\pi/4) \times D^2 = 0.00001 \text{ D} = 0.00356 \text{ m} = 3.56 \text{ mm}, \text{By considering FoS of 2. Hence, } D = 3.56 \times 2 = 7.13\text{mm}$$

We have available standard size is 25mm, therefore D=25mm, stroke of cylinder is 320 mm selected from required application.

SPECIFICATIONS OF PNEUMATICS CYLINDERS AND FORCE VALUES

Table 2 Station 1

S.N	Cylinder	Force (N)	Bore Dia. (mm)	Rod Dia. mm	Stroke (mm)	Qty.
1	Top cylinder.	117.72	40	16	300	1
2	Gripper slide cylinder	9.81	20	8	200	1
3	P & p ver. cylinder	68.67	32	12	125	1
4	Rod less cyl.	50	25	-	600	1

Table 3 station 2

S. N.	Cylinder	(N)	Bore Dia. (mm)	Rod Dia. (mm)	Stroke (mm)	Qty.
1	Torque slide cylinder.	184.32	32	12	250	1
2	Gripper slide cylinder	78.48	25	10	300	1
3	P&P ver cylinder.	50	32	12	125	1
4	Comp. clamp. Bottom cyl.	235.44	63	20	50	1

5	Rod less cylinder	68.67	25	-	300	1
6	Shaft assembly support cyl.		25	10	250	2
7	Safety door cylinder	4.905	25	10	320	1

Some other pneumatic component used in the machine are purchased from SMC is,

- Pneumatic gripper
- Rotation seal coupling
- Pneumatically actuated shackle pin gripper

DESIGN OF SPLINED SHAFT

The machine shaft can be designed on the basis of load on shaft & required torque. Assume the load on shaft is 25 kg (load calculated by using design soft by apply density to each part on shaft). Distance between shaft and motor is 150 mm,

hence $L=150$ mm. Hence $P=25\text{kg}=25 \times 9.81, P=245.25\text{N}$,

We know that, Torque= Force X Length

$T=245.25 \times 150 = 31.90 \times 10^3 \text{ N mm}$,

We know that

$T = (\pi/16) \times \tau \times D^3$

Where, τ – Allowable shear stress, = 42Mpa

Therefore,

$31.90 \times 10^3 = (\pi/16) \times 42 \times D^3$

$D^3 = 3868$, $D = 16$ mm, by considering $Fos=2$

Then $D=16 \times 2 = 32$ mm,

We have available standard size is 30 mm, hence shaft diameter is 30 mm. for the rotation of shackle pin locator we need splined cut on shaft therefore,

we know that for splined shaft ,

$D = 1.25 d$, where d – is small diameter of shaft.

Hence ,we know that for splined shaf

$t d = D/1.2$, $d = 30/1.25 = 24$ mm.

In this way we have diameter of shaft are, $D = 30$ mm & $d = 24$ mm.

SELECTION OF MOTOR

Station 1: The driving motor is selected from stock of the industry for nut assembly unit. By considering the cost issue and ability of motor to solve the purpose of nut fasten on stud, the selection is done. The brake motor can be selected on the basis of, Availability, Accessibility and Cost . Specifications of motor selected, Oriental 25W Electromagnetic Brake Type Speed Control Motor (Single-Phase 200VAC, 50/60Hz) With gear head (ratio 5:1) Purchased code: MBM425-412 , 4GN5K

- Revolutions per minute: 1400/1700
- Power: Max. power o/p 25 W
- Voltage: 200
- Power factor: 0.71
- Frequency: 50

Station 2: For shackle assembly unit, we have to assemble the shackle pin on booster stud, for that purpose we need motor for the rotation of shaft. Our requirement is that, the motor shaft assembly down with specified speed and frequency but when at the time of engagement of shackle pin on booster stud, the speed of rotation should be reduced and frequency also reduced. For this purpose we need a servo motor which can fulfil our requirements.

Servo motors should have just enough speed, peak torque and rms torque capabilities, along with optimal gearing

arrangement, to meet the load requirement as well as the cost objective. Equally important is selecting the type and size of the drive and power supply to meet the system requirements. Motor selection for shackle, we need to know the torque for motor. Therefore, we have

$$\text{Weight of shaft} = 6 \text{ kg} \times 9.81 = 58.86 \text{ N}$$

Torque required for motor is

$$T = F \times R$$

Here, R = Radius of motor pulley = 36 mm

F = load on motor

Using equation,

$$T = F \times R$$

$$= 58.86 \times 36 = 2118.16 \text{ N mm}$$

$$T = 2.118 \text{ Nm}$$

We have available motor whose torque is 3.4 Nm & 3000 rpm

Specifications of motor selected:

- Revolutions per minute: 3000
- Gear head ratio 15:1
- Power: 750 watt
- Voltage: 240
- Frequency: 50

SELECTION OF PLC, HMI AND SEFETY LIGHT CURTAIN

HMI is selected by considering certain parameters like screen size in inches, display mode (BW/colour/multicolour), memory (kb/mb). The HMI used for human interface with is PROFACE make with screen size of 7 inch, display mode with multicolor and memory in megabytes which allows safety operation of machine when maintenance is to be carried out. Safety light curtains are most commonly used in industries to avoid accidents during machine operations. Safety light used for the machine is of P&F make with operating range of 0.3-6m.

SELECTION OF MATERIALS FOR VARIOUS PARTS OF THE MACHINE

The Nut & Shackle pin assembly machine consist of various mechanical parts which need to be manufactured for various purposes. Each part has a 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

DEVELOPMENT OF THE MACHINE

After design of complete machine fabrication was the major task to be done. Fabrication of complete project took almost 3 months of duration. Machines like semi automatic milling machines, lathe machines, distance reading operation M1TR machines are majorly used in the manufacturing of various parts of both the stations. Step by step manufacturing of machine is

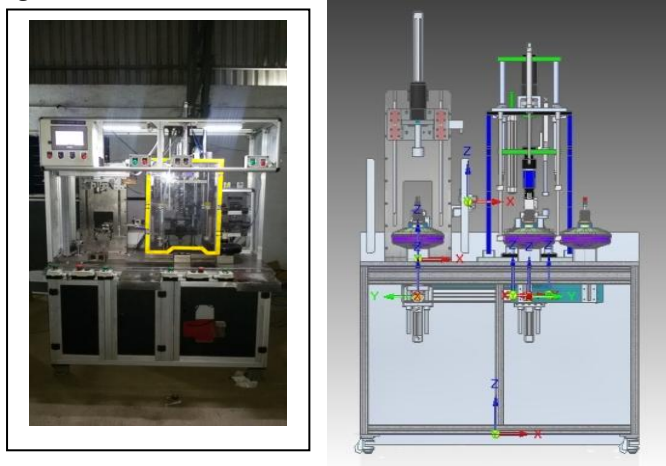


Figure 3: Actual Machine & Final Design

Results and Discussion

After the complete manufacturing of the machine, several trials were taken. In these trials it is found that the components are assembled without leaving behind any errors related to shackle pin height

Table 4 Results

Sr No.	Parameters	Before Automation	After Automation
1	Cycle Time (Sec)	120	40 (26+14)
2	No. of Components Finished / month	27720	41580
3	No. of Operators Required	3	1

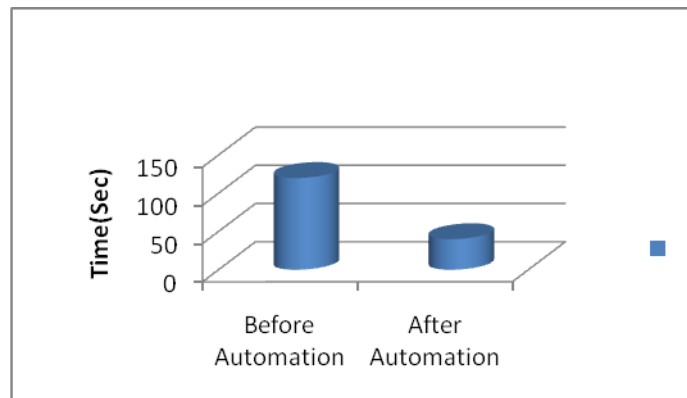


Figure 4 Bar chart showing cycle time required per component

CONCLUSION

The project describes a special purpose machine is capable of assembling the nut and shackle on break booster automatically. It includes the design of Locator for nut and shackle pin, selection of pneumatic cylinders, power pack, PLC, HMI. By implementing the machine for described purpose the productivity of the process will surely increase. The machine is capable of performing the operations sturdily. a special care is taken for future development of the machine. The project work can be concluded with major points such as the rejection rates are almost eliminated. Requirement of operators got reduced from 3 operators to a single operator. The great achievement is the drastic reduction in cycle time. The machine requires very less maintenance. We consider the developed machine is an important step towards fulfilling the need for the company.

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