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Design of Portable and Compact 'C' type Quick Acting Machine Vice

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Abstract - *In today's industrial world, predominantly in the field of Automobile, Aerospace, Machine tool industries, mass production of components has become a real challenge to engineers mainly due to its complex shape augmented with the requirement of high accuracy and precision. This mandates a better tooling and fixture design for a flawless production. Literature survey shows that most of the manufacturing industries rely heavily on tooling. Tooling embraces two things, Design of tools and Design of Jigs and Fixtures. Literature survey also indicates that sometimes even for a single component a proper tooling becomes a necessary part of the process planning standing. In this paper an attempt has been made to design a portable and compactable 'C' type quick acting machine vice and pneumatic operated fixture (Machine vice) for milling, drilling, shaping and hand grinding application. As it is a scaled proposed model it is designed for holding and clamping of size varying from 0mm to 100mm width of work piece. Few various conceptual designs are developed and comparative study was carried out to select the best design. Thus three best suitable designs are selected, in which primary locking is done by mechanical/manual mean. Pneumatic system is integrated in our design, so that it reduces the clamping time. This type of machine vise is faster and easy to operate. The design of 'C type machine vice is carried out by using CAD software- Solid edge, CATIA V5 and mathematical calculation for finding maximum clamping force and efficiency of power screw is made. MATLAB coding is prepared for selection for power screw depending on application and job size.*

Key Words: **'C' type, Portable and Compactable, Quick acting**

1. INTRODUCTION

Objective of mass production is to achieve high productivity by reduce unit cost and also to achieve interchangeability to facilitate easy assembly. In today's technology and modem industrial world, Products (components) have to be produced by fast, easier and less duration with good quality and less cost in order of customer needs and satisfaction. To develop any products or components in large qualities with a high degree of accuracy and interchangeability, at a competitive cost, specially designed tooling is to be used. These tooling consist of jigs, fixture and gauges. The use of specially designed tooling will lead to an improvement of accuracy, quality of the product and to the satisfaction of the consumer and community.

1.1 FIXTURES

All fixtures and clamping elements works on 3-2-1 principle. The 'c' type machine vice falls in the fixture category, which works on same principle.

- This principle is made to constrain the workpiece motion or degree of freedom.
- Three pin at the horizontal plane, two pin at the vertical plane and one pin at the side plane
- In order to constrain all degree of freedom, all 3-2-1 pins should be placed in respective planes. If any of the restricted motion is to be freed, pin at desired plane is to be removed. This is how the principle of 3-2-1 used in dimension control.
- So, the same principle is been adopted or used in machine vice, which is a fixture.

Figure 1.1 shows brief information of locating pins used to constrain motion of a part or workpiece in 3-2-1 principle.

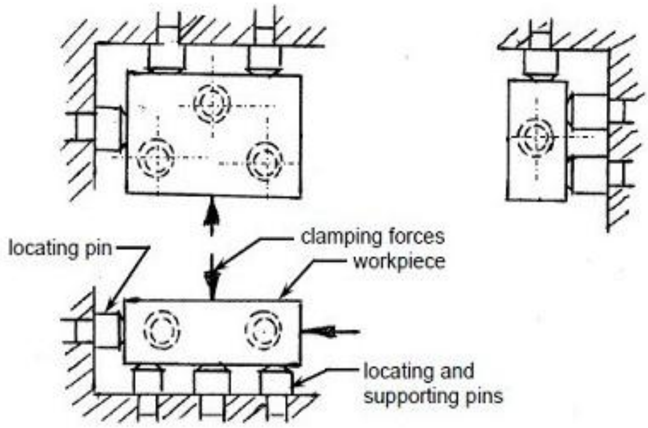

Figure 1.1: 3-2-1 principle

1.2 WORKING OF GENERAL MACHINE VICE

In machine vice there are two parallel jaws which work together to firmly clamp an object and hold work in place, most commonly jaws are always of rectangular type. One jaw is fixed, as it is attached to base of the vice, where the jaw is moveable.

A power screw or threaded screw plays a very important role in actuation or motion of jaws for clamping, which is connected to the movable jaws. Power screw travels through the body of the vice, and movement is controlled manually by a hand liver which is located on the end of a mechanical machine vice.

Torque is applied to the hand liver which converts rotary motion in to linear motion through the screw, which then moves the sliding jaw. When power screw is rotated anti-clockwise, handle moves sliding jaw away from the fixed jaw and opens the gap between them. When rotated clockwise the handle moves the sliding jaw closer to the jaw which is mounted on body of machine vice, thus bringing jaws closer.

When machine vice jaws brought in contact with workpiece the power screw is tightened firmly, so that the jaws hold the desired object firmly. This helps to complete the application easily.

Mainly machine vice are used in fallowing application

- Metalworking
- Sawing
- Woodworking
- Drilling

2. METHODOLOGY

Complete manual process was time consuming as well as the productivity output was very less. The main aim of the project is to improve the efficiency and to increase the production with quality output. So, slider power screw and slicer is been integrated to the machine vice to overcome these problems along with pneumatic optional connection. Method of sliding lead screw helps in easy and quick clamping and unclamping.

Slicer technique is an added advantage for this project, which contribute more in mass production. Adopting this method is cost saving and increasing in productivity. Figure 2.1 shows the methodology adopted for this project. Initially Concept and problem statement is generated, and then material selection is to be made. Most commonly cast iron is preferred for all type of machine vice except CNC fixtures. But mild steel is chosen for this project and justification for selection of material is given in material selection part in next chapter.

Mathematical calculation for power screw fallowed by CAD model is to be made using CAD software. Provisional design of implying pneumatic system to vise is to be made. Lastly proposed costing and validation is to be done. These are the methods and methodology adopted in preparing this project.

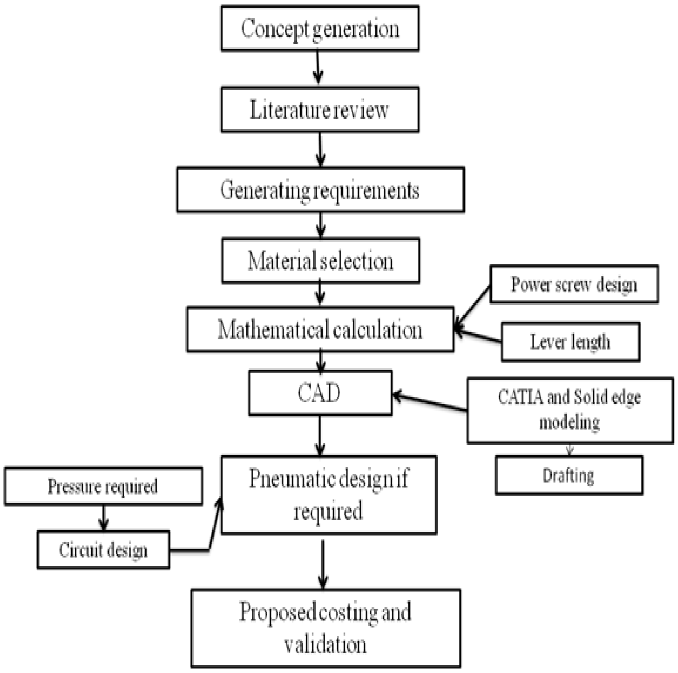

Figure 2.1: Work flow chart

2.1MATERIAL SELECTION

The selection of machine vice which is to be used to perform desired operation is directly depends on the type of work needs to be performed. As previously mentioned, a grey iron vice is the best choice for performing tasks such as drilling, hammering, milling, cutting, grinding or filing, where vibrations are likely to occur. If you need to clamp a wider or large workpiece, such as metal block, which will stretch the vice to its maximum limit, then a steel vice is better option because of its high tensile strength which means there is less risk of breakage.

Material	Composition	
	Carbon%	Manganes %
Low carbon steel [LCS]	0.05 to 0.25	0.4
Medium carbon steel [MCS]	0.29 to 0.54	0.60 to 1.65
High carbon steel [HCS]	0.55 to 0.95	0.30 to 0.90
Very high carbon steel [VHC]	0.96 to 2.1	-

Mild steel C45 (Medium Carbon Steel) material is chosen because it is Tough, Ductile, Malleable, good tensile strength, poor resistance to corrosion. And mainly it is cheaper compared to other materials (COST EFFECTIVE). As the proto type model can't be casted for small size mild steel is chosen as it can be easily processed in machining process and also it is easy for analyzing and cost calculation. For a working scale model it is preferred to use Gray cat iron.

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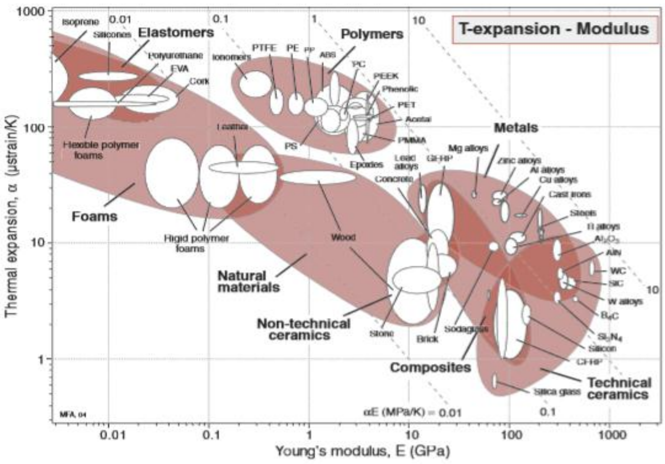
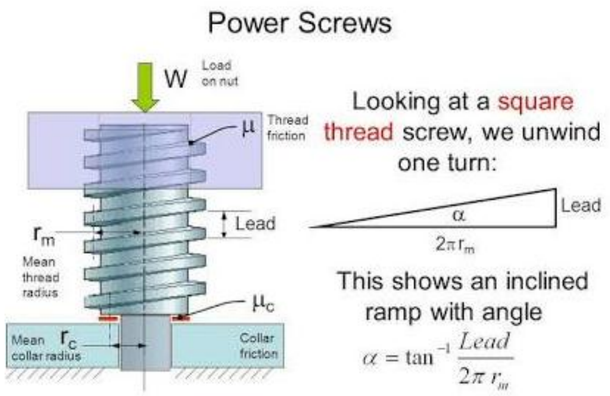


Figure 2.2: Thermal expansion v/s Young's modulus

3. MANUAL CALCULATION



Generally **α=14.5 degree**

If the friction angle is more than the helix angle then self locking occurs

Material: Mild steel (SAE 1045) (For calculation and proto type model purpose) for actual model we need to use HCS for accurate functioning of vice

3.1 MEAN DIAMETER OF POWER SCREW

From design of machine elements we know that mean diameter d2 is given by

$$d2 = D - 0.5p \text{ (For threaded fasteners)}$$

$$d2 = 12 - 0.5 * 1.5$$

$$d2 = 11.25 \text{ mm}$$

Where, D= major diameter M12

P is the pitch. From design data hand book page no. 141, table 9.8 for M12 diameter pitch is given as 1.5mm

Pitch diameter is given as 11.025721mm

Minor diameter - External thread 10.159696mm

Internal thread 10.376202mm

3.2 FRICTION AND HELIX ANGLE

$$Ø = \tan^{-1} \mu$$

Coefficient of friction for mild steel varies from 0.05 to 0.25 or can also find it by using formula **μ=tan α**

$$Ø = \tan^{-1} 0.15$$

$$Ø = 8.5307^0$$

$$\alpha = \tan^{-1}(1/(\pi * d2))$$

$$\alpha = \tan^{-1}(1/(\pi * 11.25))$$

$$\alpha = 2.43^0$$

3.3 MAXIMUM SAFE HOLDING FORCE OF SCREW

$$F = 6.344\, D^{2.31}$$

$$F = 6.344 * 12^{2.31}$$

$$F = 1973\text{N}$$

3.4 TWISTING MOMENT (TORQUE)

$$M_t = \frac{F}{2} * d_2 * \tan(Ø + \alpha) + M_{t\ collar}$$

(As we are not using collar, twisting moment of collar is neglected)

Considering maximum safe holding force of vice then torque is given be,

$$M_t = \frac{1973}{2} * 11.25 * \tan(8.5307 + 2.43)$$

$$M_t = 2149.35 \text{ N} - \text{mm}$$

3.5 EFFICIENCY

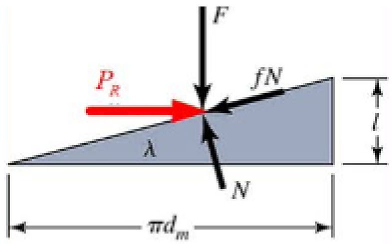
$$\eta = \frac{Fp}{2\pi T}$$

Let us assume applied force to be 125N, then torque required will be

Torque = Force * perpendicular distance

T=125*12.5 (lever length)

T=1562.5N-mm



Let F be the maximum force on lead screw 1973N

$$\eta = \frac{1973 * 1.5}{2\pi * 1562.5}$$

Efficiency = 30.14%

If efficiency of screw is less than 50% then it is self locking screw if it is more than 50%, it will be overhauling.

4. PNEUMATIC CIRCUIT DESIGN

Pneumatic system uses air as a working fluid to transmit and control energy or motion. For example they are used in controlling bus doors, metro train doors, automatic production lines in industries, mechanical clamp, fixtures and in many more applications.

4.1 ADVANTAGES OF PNEUMATIC SYSTEM

Pneumatic systems are widely used in industrial sectors for the driving of machines. Following are the advantages of Pneumatic systems.

- High effectiveness
- High durability and reliability
- High adaptability to environment
- Safety
- Simple design
- Easy selection of speed and pressure
- Environmental friendly
- Economical

4.2 LIMITATIONS OF PNEUMATIC SYSTEM

Even though pneumatic system has a lot of advantages, they are also many limitations too. Following are some of it.

- Relatively low accuracy compared to hydraulic because working fluid is comprisable.
- Chances of breakdown is more
- Low load baring capacity
- Uneven moving speed
- Noise

4.3 PNEUMATIC CIRCUIT

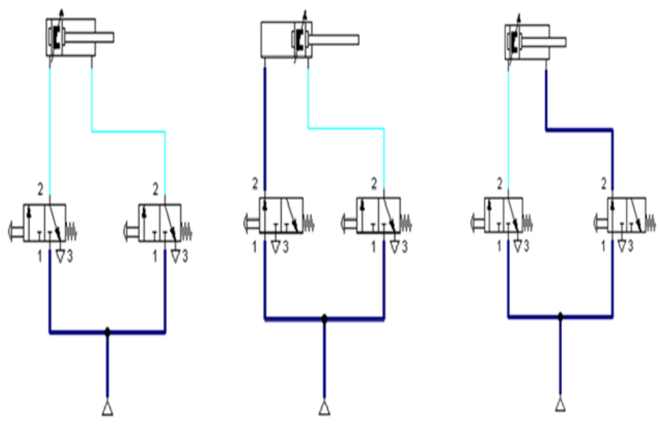


Figure 4.1 Figure 4.2 Figure 4.3

Initial (Floating)

Figure 4.1 shows how double acting cylinder is controlled by two 3/2 way valve. Two ports of double acting cylinder connected to exhaust port 3. So initially this is in floating condition and there is a free movement of piston inside a cylinder.

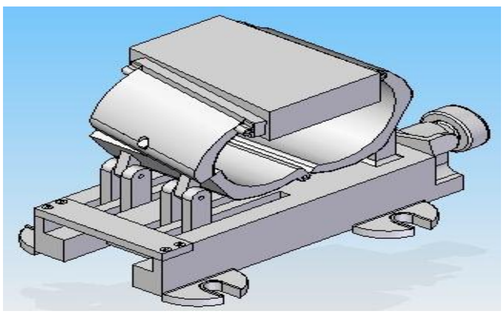
Extension

Figure 4.2 shows how Extension takes place when the pushbutton (PB1) is pressed, then DC valve is operated by compressed air and air flows from Port1 to Port 2. The piston travels to the final forward position and direction control valve deactivated due to spring mechanism. Again there is a floating condition for piston.

Retraction

Figure 4.3 shows how retraction takes place when the push button (PB2) is pressed, then DC valve is operated by compressed air and air flows from Port1 to Port 2. The piston travels to the final retract position and direction control valve deactivated due to spring mechanism. Again there is a floating condition for piston.

5. MODELING OF 'C' TYPE QUICK ACTING MACHINE VICE



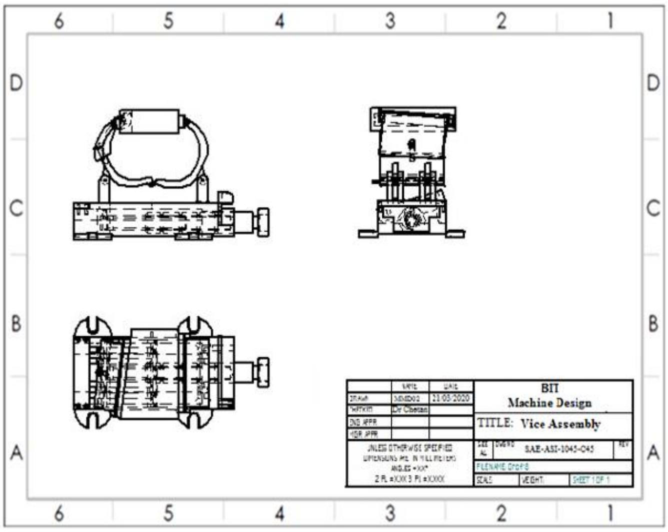


Figure 5.1: Drafted CAD model of machine vice

5.1WORKING PROCEDURE

Take a workpiece which is of taper section and hold between jaws. Firstly will discuss about manual operated 'C' type vice, in this type of vices a power screw assembly is pushed till both the jaws touches workpiece. Soft jaw clamp can rotate in a soft jaw pin axis. This helps in holding the complex shape parts as it can rotate till it touches work surface completely.

Sliding jaw and fastened jaw assembly is fastened with bolt, where it has motion or rotation only in Z-axis or can say rotation motion on the top face of fastened jaw. As a taper section is been clamping one side of the workpiece will completely fits in to the right jaw but in sliding and fastened jaw assembly if the sliding jaw is kept at 90^0 then it is not possible to clamp or but the taper surface completely. So, while performing any machining operation there are chances of accidents like slip of workpiece.

Fastener in sliding and fastened jaw assembly is slightly loosened and sliding jaw is adjusted till it completely touches taper body, then tight the bolted fastener firmly. Now workpiece is completely touched by both the jaws. Now adjust the power screw shaft grove with the slicer and lock the jaw position with slicer and apply torque to the handle knob of lead screw shaft. There are two mechanisms for clamping workpiece which depends on dimension of workpiece.

If the workpiece width is between 5mm to 50mm then power screw is to be rotated anticlockwise direction for job clamping and for unclamping rotate knob in clockwise. If the workpiece width is between than 50mm to 100mm then power screw is to be rotated clockwise direction for job clamping and for job unclamping rotate knob in anticlockwise direction.

When the power screw is rotated in anticlockwise direction during clamping of workpiece width less than 50mm both the machine vice jaws come closer as the slider is pushed away. Then slicer is locked and tightening of job is done by power screw reverse of this process is done for unclamping. This is how clamping and unclamping is done in 'C' type vice.

Coming to pneumatic 'C' type vice slider is pulled by double acting pneumatic piston cylinder for clamping and push for unclamping. Proposed pneumatic circuit is shown in further chapter. This is how the clamping and unclamping action is taken place in 'C' type quick acting machine vice.

6. ESTIMATED COST

Total cost of 'C' type quick acting Machine vice = Total Raw material cost + cutting cost + Standard item cost + Total milling machining cost + Total Turning cost

= 145 + 700 + 5185 + 950

= Rs.6980 /-

Total cost of Pneumatically operated 'C' type quick acting Machine vice = Total Raw material cost + cutting cost + Standard item cost + Total milling machining cost + Total Turning cost

= 145 + 700 + 5185 + 950 + 2460

= Rs.9440 /-

7. APPLICATION

Machine vice in generally a mechanical fixture is a work holding or clamping device. Most commonly used in all type of industries for example paper industries, timber industries, textile industries, Automobile or mechanical industries and also in forming and medical industries.

As in the drilling, milling and shaper machine operation reaction force depend on the rpm of tool in drilling and milling operation and stroke speed in shaper machine, if the fixture is designed for clamping force which is less than the reaction force produced during the operation then the fixture or machine vice will splash out from the working table. So, while designing machine vice clamping force plays an important role. In our proposed model machine vice is designed to withstand a reaction force up to 2000N.

As our proposed model is designed for 2000N, if the reaction produced in any of the above listed machining operation is more than the maximum clamping force of 'C' type machine vice then increase the diameter of the power screw to increase the efficiency and clamping force.

8. RESULT

The main aim of this project is to reduce the cost of production, to clamp taper section and complex shape job. We achieved it by integrating 'C' type slider mechanism and slicer mechanism in machine vice. Rapid extension and retraction of integrated pneumatic cylinder helps in minimal the time of jaw travel, which can't be achieved in normal mechanical vice.

We showed the mathematical calculation of maximum clamping force and twisting moment required of machine vice. The result we got were as follows

1. F (Force) = 1,973N
2. Twisting Moment (Torque) = 2,150N-mm, and
3. Efficiency = 30.14%.

So, the proposed model is suitable for machining activity in drilling, milling and shaping operation, as normally drilling rpm ranges from 700 to 1800 our proposed model can withstand this amount of torque.

9. CONCLUSION

Design process is achieved by relying on new design methods and with the help of computer software's like solid edge and CATIA. Necessary calculations requited are calculated by using mathematical mean and MATLAB coding. The need in re-design is to reduce overall cost of the product, reduce work clamping duration, to increase the production rate, and clamping complex shape (taper). These are achieved in the modifications of machine vise design. Individual part design is made to make manufacturing easy by conventional methods such as milling, grinding, turning etc for prototype manufacturing.

The pneumatic system was successfully stimulated using fluid SIM software and necessary calculation was made to find the dimension of double acting cylinder and pressure required to actuate and retract the vice. Since the entire model is scaled down to reduce the cost of manufacturing, but necessary modification are made in design and in calculation to account for changes when it is manufactured to actual dimension.

Conventional machine vice was compared with our design, it has be noted that the time required to clamp and unclamp the work piece for a certain machining operation is less compared to conventional machine vice. Assembly and disassembly of our machine vice is simple and easy in case of any unexpected failure of components. As the cost of pneumatic and hydraulic machine vice ranges from 35,000 to 2, 00,000+ Indian rupees, it can't be offered by small scale industries. So, our proposed model can clamp a job having width varying from 0 mm to 100 mm which is a pneumatic integrated machine vice costing at just 9,500 Indian rupees. So, from comparing our proposed model with other machine vice in market we can conclude that our model is best in cost aspect, production rate, clamping force, accuracy, and clamping complex shape jobs.

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