Design and Analysis of a Drilling Fixture

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Abstract: The Automation field is rapidly taking over the production and manufacturing sectors because of its heightened performance with improved accuracy and precision. Therefore, it is essential to understand the application and the significance of the involvement of automation in conventional drilling machines. The CAD geometry of the project is prepared in Solid Works, and finite element analysis considering the von misses stress, and displacement theory is carried out to find the effects of external loads on the motors and critical components of the fixture. The analysis where performed based on load calculated to be of 580.75 N, which gives stresses ranging of 1.466 to 117.7 MPa in the components. The project goal underscores the advantages of automation in drilling, including identifying and correcting errors occurring due to manual handling of systems. This project raises procedures for maintaining, setting up the work and work holding devices to get the job done accurately.

Keywords: *Automation; Pillar drilling machine; Cutting force; FE analysis; Von misses stress; Solid works;*

I. INTRODUCTION

In this era, mass-produced workpieces account for around twenty-five percent of the total volume of metalworking production in all industrialized nations. Of the remaining seventy-five percent, nearly one-half is producing in batch sizes of less than fifty parts. Social and technological trends, such as demands for customized products, shorter product life cycles, higher reliability, closer component tolerances, and a wide variety of work materials, are leading to an increasing requirement for smaller batch sizes. Due to a higher demand for batch sizes, flexibility, versatility, and higher productivity, a flexible fixturing system is more appropriate than conventional fixtures. In this paper, it has been innovated how a conventional drilling operation is converted with the help of DC motors and proper guides into the process. Such conversions can be applied to the areas where products of high volume with good quality are demanded. [1], [10]

II. PURPOSE AND DRAWBACKS OF A CONVENTIONAL DRILLING MACHINE

Work holders are devices that hold, grip, or chuck a workpiece to perform a manufacturing operation. The fixture is a work holder designed to hold, locate, and support the workpiece during a machining cycle and provides a means to reference and align the cutting tool to the workpiece. It must position or locate a workpiece in a definite relation to the cutting tool and must withstand holding and cutting forces while maintaining that precise location. A fixture is made up of several elements, each performing a specific function. The locating elements position the workpiece; the structure or tool body withstands the forces; brackets attach the work holder to the machine and clamps; screws and jaws apply the holding forces. Each of these elements may have manual, or power activation and the functions must be performed with the required firmness of holding, accuracy of positioning and with a high degree of safety for the operator and equipment. [2], [12]

Currently, a conventional drilling machine uses a vice as a fixture and to clamp the workpiece, which is manually moved to align the workpiece and drill to the desired location. Vise jaw fixtures are modified vise jaw inserts that are machined to suit a particular workpiece, their limitations are in part size and the capacities of the available vises. Today the system aspects of manufacturing are more prominent than ever. In terms of human participation, not every drilling technology can meet the requirements of smart drilling systems. Generally, manual and semi-automated drilling systems have reliability issues, poor quality. Some problems regarding existing systems are as follows-

- Set up time is more.
- Because of manual operations less accuracy and precision.

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- Because of errors there are high possibilities of rework.
- Material handling and lead time is more.
- Low rate of production.

III. LITERATURE REVIEW

Utpal Roy & Pei-Liang Sun, Principles for selecting, supporting & locating surfaces, we can have a precise positioning control of workpiece—principles for selecting, clamping positions for the application to obtain desired clamping force. [3]

N. P. Maniar and D. P. Vakharia, with the help of solidworks, the unbalance mass and its location of C.G are found out, and it is remarkably the same as an experimental result on the dynamic balancing machine. So, Computer-aided mass balancing of quadrants is found more accurate to decrease in percentage error by almost 6%. [4]

Vaibhav S Warule and Suresh M Sawant proposed a computer-aided fixture design technique to avail the model of a designed fixture to the designer before getting manufactured. They can show inadequacy so that designers can modify without getting it to manufacture. The fixture is designed for a substantial component to perform drilling operations using a pillar drilling machine, and static workbench analysis carried out using Solidworks. The results obtained are CAFD dramatically reduces the time for designing a fixture, which is hard to design manually. [5]

R. Singla , Sushil Kumar has given a method of solving the clamping force optimization is given in which the positioner is considered to be deformable, and the workpiece is rigid. It is found that the maximum clamping force can reduce the position error due to the application of the machining force. [6]

IV. DETAILS OF FIXTURE FOR COMPONENT

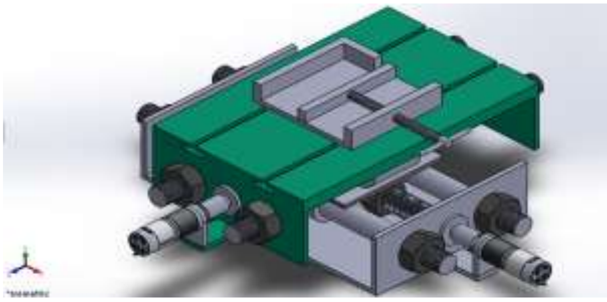

Figure.1 Isometric view of component

Figure.1 shows the design of fixture prepared in solid works considering the bed dimensions of 300 x 300mm of a pillar drilling machine, components to be installed and also in a way which provides the fixture with least mass. The fixture is designed for 2 horizontal axis movements, X. The bottom section helps the fixture move in the direction of X-axis and the top section shown in green moves the fixture in the direction of Z-axis. Table1 shows the name and number of individual components used in the fixture. As shown in Figure.1 and Table.1 components like nuts and brackets are used to hold the frame and structure of fixture rigidly, while parts like ball bearings and couples provide provision of motion transfer. The vise is used to hold the workpiece in position during drilling operation.

Table.1 Individual parts list with quantities

Sr.No	Individual Parts	Quantities
1	DC motors	2
2	Lead screws	2
3	Ball bearings	2
4	Couples	4
5	Vise	1
6	Cylindrical guides	4
7	Frame	2
8	Brackets	2
9	Nuts	10

1) Lead screw and Nut

The lead screw or power screw is a screw used as linkage in the machine, to translate the turning motion of the DC motor into linear motions in both X and Y-axis. As shown in Figure.2, it is used with a nut which allows the nut to engage with the thread and moved axially, independently of the screw's rotation.

Figure.2 Assembly of nut and leadscrew

2) Cylindrical guides

They are designed to provide support to the moving fixtures. Cylindrical guide way is used because cylindrical slide fulfils the conditions of kinematic principles being fully constrained. They serve the purpose to allow the fixture to freely slide over them and distribute the load acting on the lead screw and nut as shown in figure.3.

Figure.3 Cylindrical guideway in assembly

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3) DC motors

A three phase heavy duty planetary geared motor, which is operated at approximately the same speed and output with high torque capable of withstanding the load and drilling forces is used. This provides the rotational motion to the lead screw.

V. LOAD CALCULATIONS ON MOTORS AND FIXTURE

Two DC motors are used to provide motion, here the motor to be selected depends on the load acting on it (the total weight it has to move). Here the load is, the total weight of the system acting perpendicular to the direction of axis of motor in downward direction. By finding the load acting, the possible torque produced is calculated by the following method.

Load acting
Weight of fixture (F) = 7.1 kg f
Lead screw diameter (d) = 20 mm

Torque on Motor = F x r
= 7.1 kg x 10 mm
= 71 kg f mm
Let Factor of Safety = 2.5
Therefore, Torque = 71 x 2.5
= 177.5 kg f mm

The motor providing an approximate torque of 177.5 kg f mm. Hence a motor having high torque and low rpm is to be considered.

Selected Motor specification

- Torque 250 kg f mm and 100 rpm
- 6mm Diameter shaft with M3 thread.
- Back shaft length is 9 mm
- Gearbox diameter is 32 mm.
- Motor Diameter 28.5 mm
- Length 76 mm without shaft300 gm weight
- Supply Voltage : 12 V DC
- No-load current : 800 mA, Load current : up to 7.5A

Cutting force acting on the fixture

When machining a hole using drill, cutting forces are experienced as the tool machines the work piece. A force is directly generated by the relative motion of the cutting tool with respect to the workpiece during machining. In response to this force a secondary force is generated which causes vibration in the system. By the help of cutting force the loads acting on the system components can be found, which are the sources for stress accumulation and deformation in parts.[7], [9]

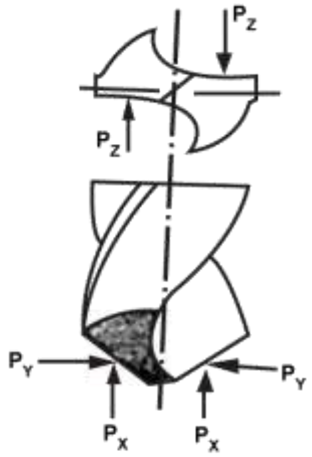

Figure.4 Forces acting on drill bit, image from researchgate.net

The above figure shows the different loads acting on the drill bit during operation, the cutting force denoted by (P_z), occurs in the same direction as cutting tool movement. The cutting force is calculated by taking the drill bit properties and the feed rate in experimental conditions.[8]

For a Stainless steel drill bit with
K. Factor = 0.50 (for SS drill bit)
Feed (s) = 0.20 mm/rev
Diameter (d) = 8 mm
Cutting Force = 1.161 x K x d $(100 \times s)^{0.85}$
= 1.161 x 0.50 x 8 $(100 \times 0.20)^{0.85}$
= 580.75 N
Cutting force for drilling operation is 580.75 N

VI. FINITE ELEMENT ANALYSIS

Nut, lead screw and guide are critical parts of the fixture, as these are the parts under motion and constant loading. Because of these stress and deformation has been found under operating conditions for them. Here the von Mises stress is used to predict yielding of materials under complex loading from the results of uniaxial tensile tests. The finite element analysis is also performed in Solid works 2019.

Results of Finite element analysis on Nut

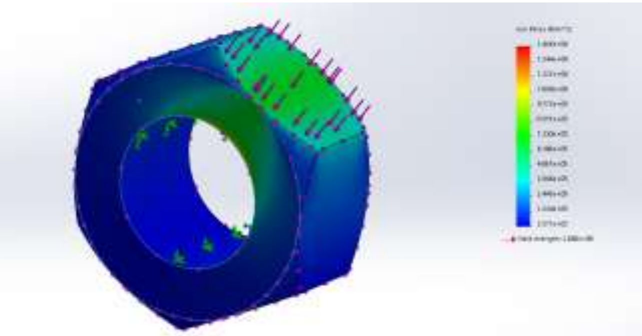

Figure.5 Von misses stress on nut

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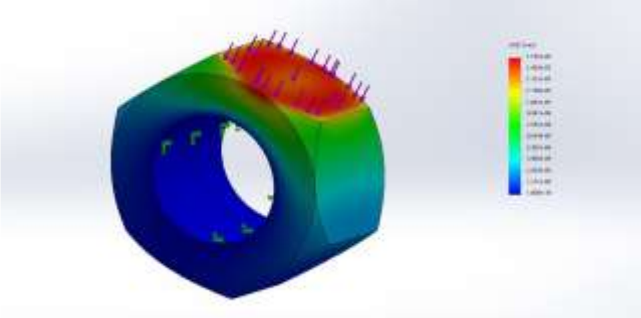

Figure.6 Displacement plot of nut

For stress and displacement acting in nut, the nut is made fixed in its female part in radial direction moving outwards from center shown by green arrows in figure 5 and 6, whereas 580.75 N force is applied perpendicularly from the top denoted by pink arrows. There are two nuts in each lead screw, hence the total loads are distributed.

Results of Finite element analysis on Thread

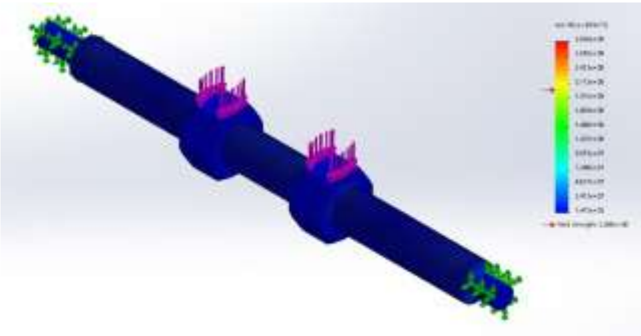

Figure.7 Von misses stress on lead screw

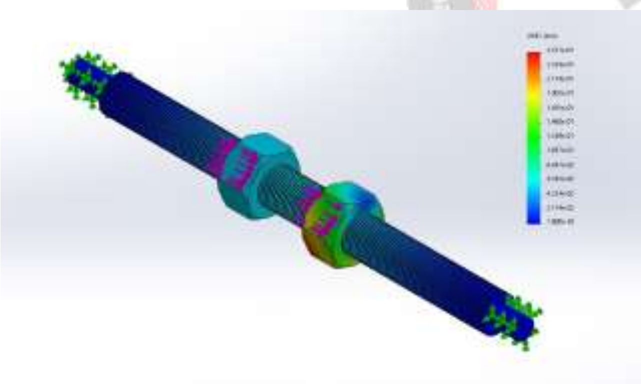

Figure.8 Displacement plot of lead screw

In figures 7 and 8, as denoted by green arrows the screw is constrained from both ends but free to rotate in its axis, as it rests inside a bearing. Whereas a transvers load of 580.75 N is applied on the top face of the nuts perpendicular to the axis of thread as shown by pink arrows, by providing a proper mate between the nut and thread. Hence the load on the nut is distributed on the screw, at the position of contact.

Results of Finite element analysis on Guide way

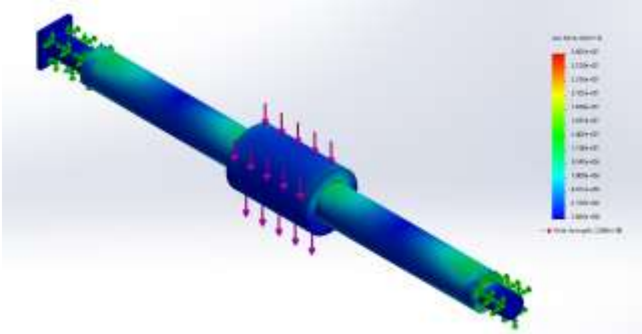

Figure.9 Von misses stress on guide way

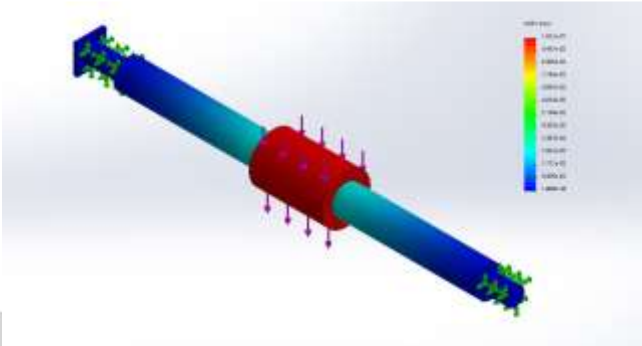

Figure.10 Displacement plot of guide way

As shown in figures 9 and 10, transverse load is acting on the guide way so it is solved by considering it as a beam. Both ends of the guides are fixed and a traverse load of 580.75 N is applied on the cylinder sliding over the guide shaft, perpendicular to the axis of guide way shown in pink arrows. Hence the stress accumulation and deformation is shown by colored region on the contact point and over the sliding part

Table.2 Finite element result values

Component	Stress (MPa)	Displacement (mm)
Nut	1.466	0.000159
Thread	117.7	0.253
Guide way	28.03	0.103

The above table shows the values of stress and displacement found by analysis of component body denoted by colored regions in the figures, when a load of 580 N is subjected on the fixture. The yield strength of each component is 206.8 MPa according to the analysis, shown in each figures of stress plots.

VII. CONCLUSION

This project is designed to apply the concept of automation to conventional drilling machine. The fixture for component body is designed successfully in order to increase quality and productivity. For the selection of motor for this fixture an approximate torque range of 200 to 250 Kg f mm is advisable. The maximum cutting force was found in drilling operation i.e. 580 N. For analysis purpose it was found that the maximum possibility of failure and error are for the components like nut, lead screw and guide way which are

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under continuous motion. Values of Stress and deformation obtained for Nut, Thread and Guide way in Finite element analysis are within the elastic limits and shows good results, which shows that load distribution on the fixture is efficient. Hence the analysis shows a promising result against the loads incurred on the assembly.

VIII. ACKNOWLEDGMENT

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