Design of Multi Spindle Drilling Machine

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***Abstract*-The paper discussed about the designing, modelling and development procedure of complete automation setup of conventional drilling process. The design is made in solid works includes automation of complete multispindle gearbox along with linear and z-axis travel. The design of drilling operation is made for minimum hole on a square shaft. Selection of gears for high speed drilling operation, high rotating speed of driver and driven gears, considering various forces acting on the unit are studied. To achieve maximum accuracy and increase in production rate without degrading the quality of the product and thereby reducing the labor cost and production time, such special purpose machine are also introduced.**

Keywords: Drilling Machine, Automation, Multi Spindle.

I INTRODUCTION

Gears are the most important components for power transmission at high speeds. If not selected properly can cause problems such as vibrations, heating due to friction and high frequency noise intolerable to human ears and jamming of gears. For this, the factors affecting are center distance between gears, gear material and their hardness, helix angle, pressure angle, bearing type, lubrication. Gearbox is specially designed for such special purpose machine. This includes gear selection and its material to be used. Types of gear failures and their causes are considered while design of gearbox. In this paper, it is proposed to carry out design, development and testing of multi-spindle gearbox along with the linear automation setup. The following point are to be considered for designed of which machine have vertical pressure known as a "Drill Press" [1]. Multi spindle drilling mount on drilling machine for automation [2]. The following key point from design point of view. To design a multi-spindle gearbox for maximum rotation rpm drilling speed. To design overall setup in solid works and manufacturing, calculations and assembly of overall setup as per the manufacturing drawings [3-4]. Testing the multi-spindle and linear x-axis & z-axis travel of setup. Testing the drilling operation at optimum feed and speed.

II DESIGN PROCEDURE AND CALCULATION

The initial step in design is the calculation of the power transmitting elements. This includes the types of gears used, no. of spindles, force and thrush exerted, drill sizes and material to be drilled for mild steel.

i) Gear Calculation:

Power required for drilling operation: For drill bit [D] = 4.2 mm. Material factor [K] = 2.1, Speed [N] = 1440 rpm, Feed rate [f] = 0.105mm/rev.

$$\therefore \text{Power} = \frac{1.25 \times n^2 \times k \times N \times (0.056+1.5f)}{10^5} \quad (1)$$

The total power required to drive spindles: -Selecting the motor of 1kW as it satisfies the requirement of 0.712kW power. The helical gear is to be designed to transmit 1kW.Hence Power=1kW. The Gear should transmit 1 kW. Hence, considering Power=1 kW.

a) Design Power= P×S.F. (2)

b) Virtual No. of teeth: Z_{v1}, Z_{v2} are the virtual number of teeth are calculated by using std. equ.

c) Checking for tooth strength:

$$\therefore F_s = \sigma_b \times b \times y_v \times P_{cn} \quad (3)$$

Where, F_s = Tooth Strength.

d) Dynamic load: $\therefore F_d = F_t \times C_v$ (4)

Where, F_t = Tangential Force, F_d = Dynamic Load, and C_v = Constant $\therefore F_s > F_d$

e) Wear load calculation: $\therefore F_w = \frac{b \times d_i \times Q \times k}{\text{Cos}^2 \beta}$ (5)

Where F_w = Wear load.

ii) Shaft Design: Consider material of shaft = Alloy steel.

Therefore, Shear stress = $\frac{0.5 \times 900}{FOS}$, (6)

Using Torsion equation, $\frac{\tau_{allow}}{\frac{D}{2}} = \frac{T}{J}$, (7) Hence, $\tau < \tau_{allow}$

iii) Bolt Calculation:

a) Shear Strength (S_{sy}): $\therefore\ \tau = \frac{S_{sy}}{FOS}$ (8)

b) Size of bolt: Shear area of 3 bolts = $3 \times \frac{\pi}{4} d^2$ (9)

iv) Bearing Calculation: Axial Thrust during drilling operation

For drill = 4.2mm, Speed = 1440 rpm.

a) Cutting speed = $v = \frac{\pi DN}{1000}$ (10)

b) Axial Thrust, $P = 42.6 \times F^{0.6} \times D^{1.4} \times V^{-0.25}$ (11)

c) Equivalent Load = $(0.56 \times 1.2 \times 0.5) + (1.4 \times 0.25) \times 1.1$ (12)

III Z-AXIS AUTOMATION

A conventional pillar-drilling machine consist of a manual arm that is used to lower the drill head and is retracted by the spring mechanism. In order to reduce worker fatigue and errors due to human intervention, the process of drill head travel (lowering and raising), is automated. Automation is done by including components such as :- a) Stepper motor for converting controlled rotary motion into required accurate linear travel. b) Worm gear box of ratio 15:1 to increase the ratio of rotary to linear motion conversion. c) A MS material bracket to support the worm gear box on the drilling machine. d) Control unit that consists of a microcontroller (Arduino), power supply, and other electronic essentials. Type of stepper motor:-Motor selected for this application is NEMA 46 considering the weight of the multi-spindle to be transmitted. The feed and depth changes as per the changes in work-piece sizes. The calculated feed and depth for various work-piece sizes are fed accordingly into the code that can be uploaded to Arduino for stepper motor controlling. The values for depth and feed are set using the keypad given on the control panel. Keypad is provided for easier machine operating by workers. A controller that consists of start, stop, kill switch and manual two-way switch, is used to control Z-axis. Lead screw selection. Lead Screw Material: - EN1 Similar to z-axis automation, the stepper motor of x-axis is controlled using the microcontroller, for precise required travel in microns or millimeters.

IV MANUFACTURING OF THE MULTI-SPINDLE GEARBOX

Gearbox fabrication is done using part drawings based on the cad model. The Fig.1 shows Multi Spindle gearbox gear train in 2D. The ergonomic factors are considered which leads to ease in machine operation, human's safety and greater productivity. Bearing holes, gear-shaft, bolts, bush holes and other assembly features are indicated with appropriate tolerances. The method of manufacturing used is Machining and the material preferred is of Aluminum series. Fixture size and shape depends on the workpiece dimensions. A fixture must have hardened surface in order to resist wear and tear of surface due to direct metal contact.

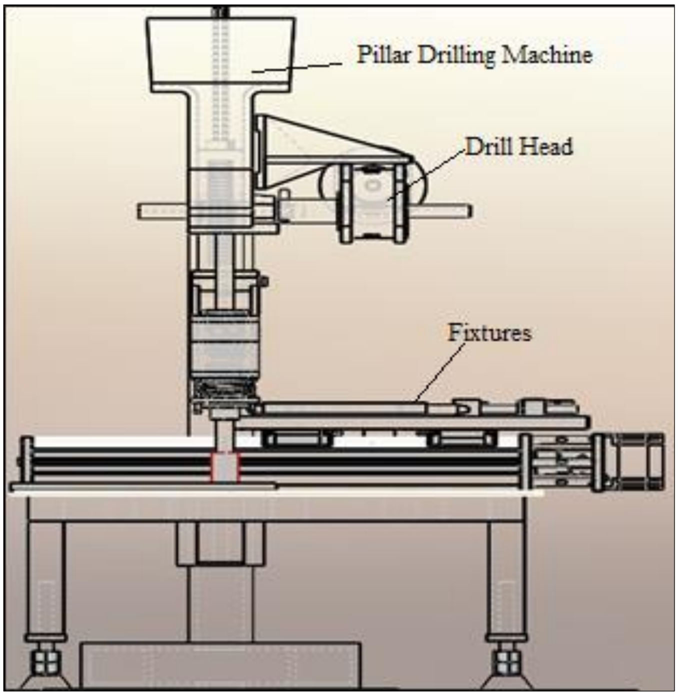

Fig.1 Multi-spindle gearbox gear train in 2D.

For this reason the fixture is specifically made up of hardened steel that gives strength and toughness to withstand forces due to metal contact.

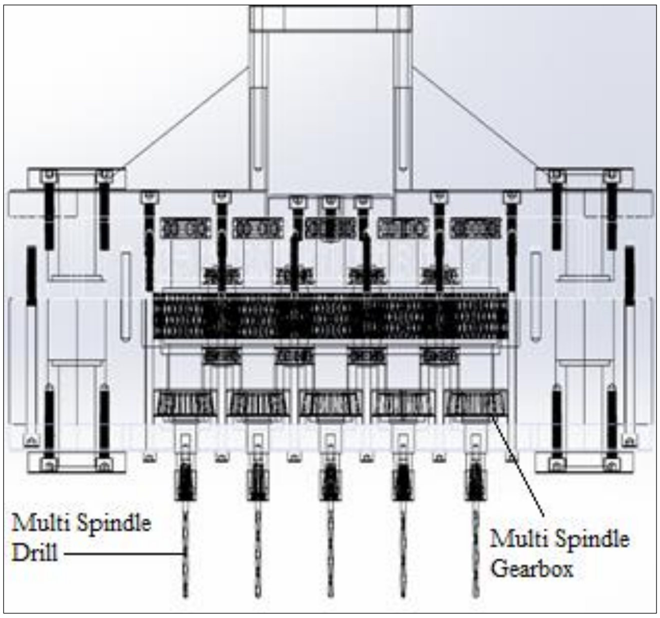

Fig.2 Cross-section of Multi-spindle gearbox.

The Fig.2 shows cross section of Multi spindle gearbox. Two Different fixture pallets are manufactured depending upon sizes of work piece. Fabrication is done on the basis of manufacturing drawing provided, that is made from cad model.

V RESULTS AND DISCUSSIONS

The designing, modelling and calculation of complete conventional drilling process is done for converting it in automation. The automation includes multispindle gearbox. The drilling operation is for minimum hole on a square shaft. Selecting a gears for high speed drilling operation. Also, various forces acting on the unit are studied. The design part also achieved with maximum accuracy and also increase in production rate without degrading the quality of the product and importance of labor cost and production time are also considered.

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