



Design and Construction of Drilling Jig for Drilling Operations

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ABSTRACT

The project is chronicle to an effort to design and produce a drill jig. The work starts by considering special tools and the justification of their use. Different types of drill jigs are then examined. The design analysis involved considerations of the forces the jig was subjected to in operations. It was found that these forces could be easily borne by their components on the design. The complexity of the design has been kept to a minimum and was ensured that the jig could be constructed easily and cheaply in any standard workshop.

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INTRODUCTION

Jig is a device which holds work piece and locates or guides the tool relative to the work piece and usually is not fixed to the machine table. It is normally lightly in construction. Jigs are further identified by their basic construction (Tagade *et al.*, 2016). Jigs and fixtures are special purpose tools which are used to facilitate production when work pieces are to be produce on a mass scale. They provide a means of manufacturing interchangeable parts since they establish a relation with predetermined tolerance between the work and the cutting tool (Vathare *et al.*, 2014). New machine tools, high performance cutting tools and modern manufacturing processes enable today's industries to make parts faster and better than ever before. Jigs and fixtures form an important category of equipment that goes a long way in achieving productivity (Kumar *et al.*, 2017). Over the past century, manufacturing has made considerable progress. New machine tools, high performance cutting tools and modern manufacturing processes enable today's industries to make parts faster and better than ever before (Mewada *et al.*, 2017). Although metal cutting methods have improved in the manufacturing industry, conventional drilling process still remains one of the

most common processes. Drilling can be applied to various work piece materials.

The most obvious factors influencing the accuracy of drilled holes are cutting speed and feed rate. Cutting speed and feed rate significantly affect the surface roughness of the machined surface where by high cutting speed and low feed rate resulted in the better surface finish (Sultan *et al.*, 2015). The successful running of all over mass production depends upon the ability to facilitate easily to reduce unit cost (Prabakaran and Nanthakumar, 2014). One does not need to repeatedly clamp and unclamp the object for various purposes like positioning as locating, clamping and guiding of the tool is done by the jig itself. Drill jig helps to drill, ream and tap at a much faster speed and with great accuracy as compared to holes which is done conventionally by hand. These drill bushings guide the drill bit during the drilling operations. Generally work piece is held by a fixture and the fixture is arranged in such a way that the loading and unloading of the job is quick (Kataria and Bhimani, 2017). The jigs are introduced to reduce the same process to be done one by one on different work piece. In recent days, there are many technologies available for making effective drill jigs and some of these inventions are there in continues

process of development. But in those days the process with more accuracy is high consumptive and costlier (Joyson, 2018).

Research Objectives

The objective of this research is to carry out the design analysis of a drilling jig for drilling operations.

DIFFERENT TYPES OF JIGS

Different types of jigs are described below:

Drilling Jigs

Drill jig is a type of jig that expedites repetitive whole centre location on multiple interchangeable parts by acting as a template to guide. In metal working practice, typically a hardened drill bushing lines each hole on the jig

plate to keep the tool from damaging (Kataria and Bhimani, 2017).

Template Jig

This is a simple plate of metal or wood which carries correct locations of holes to be made in the work piece. Size of template jig should be the same as that of the work piece. It is overlapped with the work piece and drilling is done quickly. Use of this jig avoids the marking operation completely. It is placed on the work piece and the hole will be made by the drill, which guided through the holes in the template plate and should be hardened to avoid its frequent replacement. This type is suitable if only a few parts are made (Markham and Gordon, 1913)

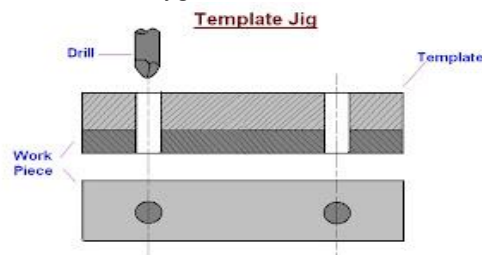


Fig. 1. Template jig type

Plate Type Jig

If the work is to be done on very large scale, an improvement can be made to template jig that is plate type jig. This uses a plate having drill bushes and suitable means to hold and locate the

works that it can be clamped to the plate and holds drilled directly through the bushes in correct positions. The plate jigs are employed to drill holes in large parts, maintaining accuracy to each other (Markham and Gordon, 1913).

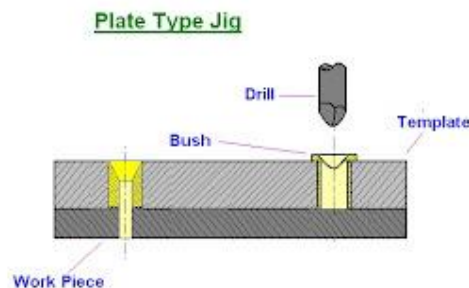


Fig. 2. Plate jig type

Open Type Jig

In this jig, the top is kept open and work piece is placed on the base of the jig and the drill plate carrying the drill bushes and is placed on the top to guide

the tool. After the operation is over, the drill plate is removed and work piece is replaced. A diagram showing open type jig is as shown in figure 3 below (Markham and Gordon, 1913).

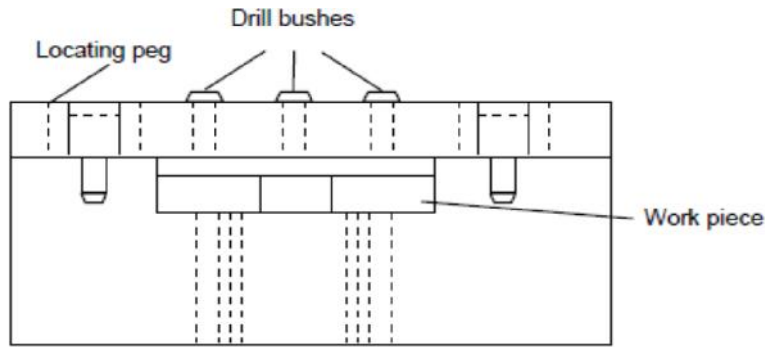


Fig. 3. Open type jig

Swinging Leaf Type

This type of jig carries a leaf or plate, arranged at the top or on one side, which is capable of swinging about a fulcrum. It is normally the drill plate itself

which is pivoted about a point at its one end. The work is loaded and unloaded with the help of swinging bolt (Markham and Gordon, 1913).

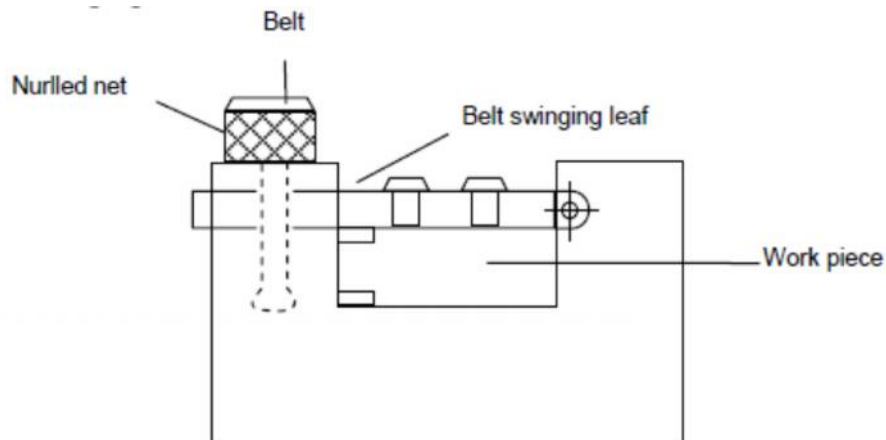


Fig. 4. Swinging leaf type

Box Type Jig

Its construction is like a box and it is used for the components having irregular shape and to be operated at different places. This type of jig provides rigid support, so machining on the various places of work piece becomes comfortable. When the holes are to drill

more than one plane of the work piece, the jig has to be provided with equal number of bush plate. For positioning jig, the machine table feet have to be provided opposite to each drilling bush plate, such that the jig would take the form of a box. Such a jig should be as light as possible (Markham and Gordon, 1913).

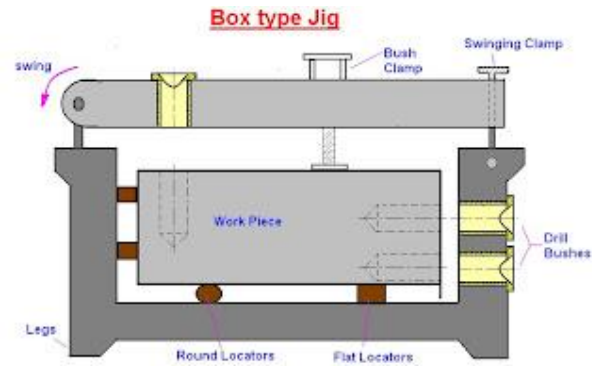


Fig. 5. Box type jig

Solid Type Jig

This is also used for drilling holes in articles of simple shapes and relatively smaller sizes. This is made of standard section of rolled steel. It is made up of high quality stainless steel for corrosion resistance. It contains one piece steel material that has been well smoothed for high strength (Markham and Gordon, 1913).

viii Channel jig

This jig is used for drilling holes in hollow cylindrical components having smaller size. Here the body of the jig is like a pot that is used to accommodate the work piece comfortably. Location on the inside surface of the component is provided by the clamp projecting from the bush plate located over the top of the work piece (Markham and Gordon, 1913).

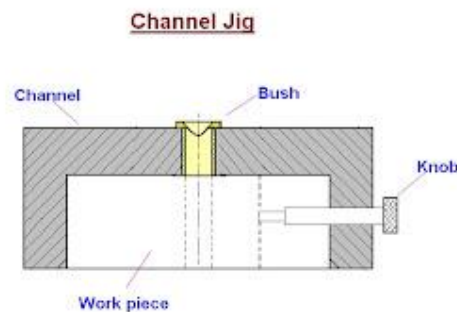


Fig. 6. Channel jig

Index Jigs

This type of jig is equipped with the facility of indexing, which creates positional division of the work piece suitably. This jig is used for quick drilling of equidistant holes on the circular surface of the work piece. By means of indexing device, a hole is drilled then the work piece is moved (indexed) to next position under the drill bush for drilling automatically (Markham and Gordon, 1913).

Multi-station Jigs

These jigs are designed for multi-spindle machine where many operations can be performed simultaneously. Each spindle of the machine carries a different tool to perform a different operation. Tools and spindles are arranged in the sequence in which operations are to be performed.

Universal Jig

As indicated by the name, universal jigs are meant to do large



number of operations. These may have replaceable elements on them. Selection and mounting of an element depends on the type of operations to be performed (Markham and Gordon, 1913).

MATERIALS AND METHODS

Design Considerations

The following factors were considered in the design of the jig:

- a. Material selection; this is based on availability and functionality.
 - i. Availability: It was found that material that is always available in the market is mild steel. And therefore is used for the construction of the jig.
 - ii. Functionality: As it has been stated earlier that mild steel was selected as a material for construction of jig due to its good wear resistance and can also withstand vibrations.
- b. Cost effectiveness: Cost is paramount important in any design work. Hence, it helps in knowing the total amount to which the construction of the jig can be made.

Size: A compact size has been uniform in this work for simplicity and reproducibly. It also plays an important role in knowing the shapes of work piece to which the jig can hold.

Design Calculations

This constitutes the main frame into which all other components were fitted.

Design Formulas and Forces Acting on the Components

Clamp Screw Design

During clamping, all the degree of freedom have been arrested by the locating pins, rest pins and axial trust of the drill. A minimum of clamping force is required.

$$\mu = \tan \phi \dots\dots\dots 2.1$$

$$\tan \alpha = p/d \dots\dots\dots 2.2$$

P = pitch (mm)

d = screw diameter (mm)

The tangential force required at the circumference of the screw when tightening

Is given by (Khurmi & Gupta, 2005):

$$P_t = W \left[\frac{t_i \alpha + t_i \phi}{1 - t_i \alpha t_i \phi} \right] \dots\dots\dots 2.3$$

Where,

P_t = Actual effort applied at the circumference of the screw (N)

W = load to be lifted (N)

ϕ = Angle of friction ($^\circ$)

$\alpha = H/a$ ($^\circ$)

Actual Torque due to tightening of the screw is given by;

$$T_t = p_t \times d/2 \dots\dots\dots 2.4$$

The tangential force of the screw when lowering the load is given by (Khurmi & Gupta, 2005):

$$P_L = W \left[\frac{t_i \alpha - t_i \phi}{1 + t_i \alpha t_i \phi} \right] \dots\dots\dots 2.5$$

Efficiency of the screw

$$\eta = W \left[\frac{t_i \alpha \times d/2}{T} \right] \dots\dots\dots 2.6$$

Total torque required to overcome friction between the screw and nut when lowering the load is given by; (Khurmi & Gupta, 2005)

$$T_L = P \times \frac{d}{2} \dots\dots\dots 2.7$$

Area due to compression

$$A = \frac{\pi}{4} d^2 \dots\dots\dots 2.8$$

Compressive stress due to tightening of the screw is given by;

$$\sigma_c = \frac{P}{A} \dots\dots\dots 2.9$$

Bush Design; Bush is used to protect a jig from wear during use.

Its area is given by ; (Ryder, 2006)

$$A_b = \frac{\pi}{4} d_b^2 \dots\dots\dots 2.10$$

Laod transmitted is given by;

$$P_b = \sigma_b A_b \dots\dots\dots 2.11$$

Where,

A_b = bush Area (mm^2)

d_b = bush diameter (mm)

p_b = laod transmitted to bush (N)

σ_b = stress transmitted to the bush

Jig Body Design; This is a component to which bush is fitted.

$$A_p = L \times b - \frac{\pi}{4} d_1^2 - 2 \frac{\pi}{4} d_2^2 \dots\dots\dots 2.12$$



Load transmitted is given by; (Ryder, 2006)

$$P_p = \sigma_p A_p \dots\dots\dots 2.13$$

Where,

A_p = plate Area (mm²)

d = plate diameter (mm)

P_p = load transmitted to plate (N)

σ_p = stress transmitted to the plate (N/mm²)

Clamp Ring Design; This is a circular component that is attached with the clamp ring. It helps in holding a work piece in a proper position.

$$A_r = \frac{\pi}{4} d_c^2 \dots\dots\dots 2.14$$

Load transmitted is given by; (Ryder, 2006)

$$P_r = \sigma_r A_r \dots\dots\dots 2.15$$

Where,

A_r = Clamp ring Area (mm²)

d_r = clamp ring diameter (mm)

P_r = load transmitted to the clamp ring (N)

σ_r = stress transmitted to the clamp ring (N/mm²)

v Swing Plate Design; it is a rectangular component that holds the upper and lower plate in proper position.

$$A_s = L \times b - 2 \frac{\pi}{4} d_s^2 \dots\dots\dots 2.16$$

Subjected load in swing plate is given by; (Khurmi & Gupta, 2005)

$$P_s = \sigma_s A_s \dots\dots\dots 2.17$$

Where,

L = plate length (mm)

b = plate width (mm)

A_s = Swing plate Area (mm²)

d_s = Swing plate diameter (mm)

P_s = load transmitted to the swing plate (N)

σ_s = stress transmitted to the swing plate (N/mm²)

Shoulder Screw Design; Is a screw that is been tightened to hold the swing plate

$$A_{sh} = \frac{\pi}{4} d_{sh}^2 \dots\dots\dots 2.18$$

Subjected load is given by; (Ryder, 2006)

$$P = \sigma_{sh} A_{sh} \dots\dots\dots 2.19$$

Where,

A_{sh} = Shoulder screw Area (mm²)

d_{sh} = Shoulder screw diameter (mm)

P_{sh} = load transmitted to the shoulder screw (N)

σ_{sh} = stress transmitted to the shoulder screw (N/mm²)

Jig Foot Design; This is a component that serves as a stand to the drilling jig.

$$A_j = \frac{\pi}{4} d_j^2 \dots\dots\dots 2.20$$

Subjected load is given by; (Khurmi & Gupta, 2005)

$$P_j = \sigma_j A_j \dots\dots\dots 2.21$$

Where,

A_j = Jig foot Area (mm²)

d_j = Jig foot diameter (mm)

P_j = load transmitted to the jig foot (N)

σ_j = stress transmitted to the jig foot (N/mm²)

Locating Pin; This serves as a support when the drill jig is been tightened.

$$A_l = \frac{\pi}{4} d_l^2 \dots\dots\dots 2.22$$

Load transmitted is given by; (Khurmi & Gupta, 2006)

$$A_m = F_m / \tau_s \dots\dots\dots 2.23$$

Where,

A_m = maximum permissible area to resist shear (mm²)

d_l = locating pin diameter (mm)

F_m = maximum force (N)

τ_s = resisting shear stress (N/mm²)

Forces Subjected During Use

For the jig to function properly, its components must be able to withstand all forces that will be subjected to during use. The components must bear such forces without undue stress, strain or distortion. The main forces to which the jig is subjected are:

- i. Vertical downward thrust of the drill
- ii. Clamping force
- iii. Torque due to rotation of drill in work piece

The magnitude of the thrust and torque can be determined through the use of empirical formulae or tool dynamometer, but for this analysis empirical formulae stage and a suitable device was selected to meet the requirements.

The magnitudes of the drill torque and thrust can be calculated using the formulae given below (Conway, 2011)

$$Th = 1.15kd(100S)^{0.85} \dots\dots\dots 2.24$$

Where

Th = Thrust in (N)

K = Material constant

d_L = drill diameter (mm)

S = Feed/revolution (mm/rev.)

Crippling load (P_c) = $\sigma_c A$

Where σ_c = Compressive stress

A = Area (mm²)

S = Feed/rev

Stress for Mild Steel

Stress for mild steel materials is 320N/mm² (Rajput, 1998)

$$T_s = 975(1.25 D^2 K (0.0056 + 1.5S))/10^5$$

Where,

T_s = Torque in Nmm

d_L = Drill diameter in mm

K = Material constant

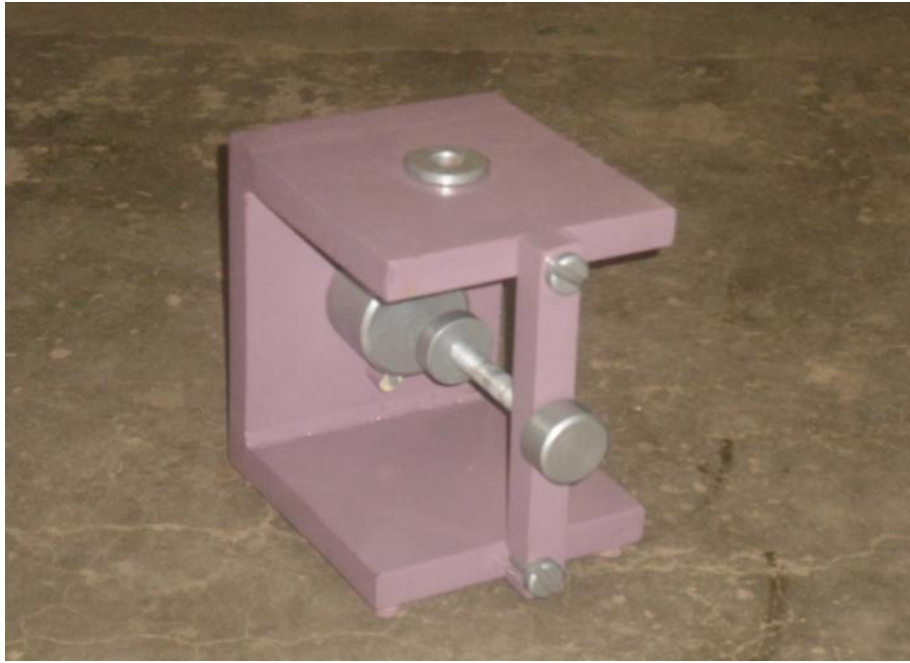


Fig. 15. The Constructed Drilling Jig

RESULTS AND DISCUSSIONS

From the results obtained in the design analysis, it was observe that the jig components could withstand much more than the normal stresses they will be subjected to during operation. This suggests that in the design and construction of this type of unit, detailed stress analysis is not or utmost necessity. After construction and assembling, the jig was tested on a drilling machine. The results obtained were satisfactory as the back plate drilled was within required specifications. It helps in drilling 60mm and below cylindrical work pieces. However it was discovered that the work

piece was tightened by the clamp screw and the drilling operation undergoes successively.

CONCLUSION

This is to conclude that during the test, the drill jig was able to drill different shapes of work piece and it was found to be working properly. No vibration effect due to the present of jig foot. Also Clamp screw and locating pin was served as support that hold the work piece to its proper position during drilling operations. However, present of bushing enable the drill jig to maintain its life and also helps for proper positioning of the

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work piece. Swinging plate was designed for further adjustment of the work piece.

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