CONCEPTUAL DESIGN OF MULTIPURPOSE DRILL JIG HAVING VARIABLE P.C.D.

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Abstract— This paper introduces a multipurpose drill jig, which has the ability to locate as well as to machine/drill parts in a wide range of dimensions for the variety of shapes. Which makes use of this jig beneficial for small production units to reduce their tooling cost in a high variety production, by eliminating the need for designing and manufacturing a jig for producing a different/new product. As the title suggests, there is a provision of changing the pitch circle diameter is given, to manufacture parts having a difference in distance between part centre and the hole centre within some range. Also, some features of this jig like angular drilling, fast loading, and clamping of work piece help to increase its effectiveness. Because of the flexibility of this jig it is applicable to serve so many functions more than any standard/conventional jig, hence this jig is termed as "master jig".

Index Terms— master jig, variable P.C.D., drill based processes

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INTRODUCTION

In current scenario batch production is becoming more popular than mass production, because the demand of global market is to produce high-quality product to satisfy customer's requirement which frequently varies. Hence industries need to introduce new products in the market according to demand. Which reduces the overall product life cycle time, And to satisfy the manufacturing requirements industries have to change their machine and tool setup, to properly locate the part and to achieve desired tool motion. Which is not much difficult since the advent of automation and increase in the use of C.N.C. machines. But it requires larger investment in machinery, which sometimes might not be affordable for small production units like small industries and workshops due to their small quantity of production. So For them to change their setup every time as product varies leads to increase in their tooling cost and overall production time. Eventually, it increases their cost per product which results into the lower profit margin. Since jigs are the most commonly used tools in industries, to provide repeatability for manufacturing identical parts by accurate work piece locating/clamping and tool guiding [3]. This paper is focused on creating an alternative option of the standard jig which can eliminate all their limitations/drawbacks [but fast and economical too]. Because even small increase in usefulness/effectiveness of jigs can make a larger impact in the economics of manufacturing processes [in this case specifically for drill based processes] for producing identical parts.

Template jig, plate jig, leaf jig, box jig and angle plate jig are the few types of generally used jigs in industries for drilling purpose. All these jigs have relative advantages and disadvantages among them, and applicable for different types of parts and operations like, templet jigs are the most inexpensive jigs. Which is used for accuracy rather than speed, but they do not have any clamping facility. Plate jig works similar to templet jig but has an in-built clamping facility, and it is used for smaller parts. Box jig or tumble jig, usually totally surrounds the part, which allows the part to be completely machined on every surface without the need to reposition of the work in jig. Leaf jig are small box jigs provided with a hinged leaf to allow easier loading and unloading. The main difference between a leaf jig and a box jig is the size and part location. Angle plate jigs are used to hold parts that are to be machined at right angles to their mounting locators. Pulleys, collars, and gears are some of the parts that use this type of jig. A variation is the modified angle plate jig, which is used for machining angle other than 90 degrees. But both the jigs have a clearance problem with the cutting tool. And requires additional clearance to avoid interference problem. [1]All of them are quite good at their places but they have a similar limitation of no/less flexibility. So when there is any existence of a change in part dimensions, these jigs do not remain useful to serve the purpose. Hence every time industries have to design and manufacture a new jig. Which requires time and increases tooling cost. To solve these problems a jig is proposed called "master jig".

I. CONSTRUCTIONAL FEATURES

This jig is an assemblage of several parts in which parts like jig body, top plate, cam lock [1], clamps [1] and bushes [3] are very much identical to parts used in standard jigs but have some modifications in them. And parts like bush guide frame and work rest is completely new. Their constructional details and functions in this jig are shown as below.

1. Jig body

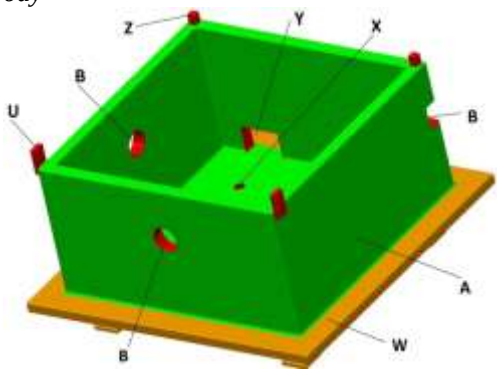

Fig. 1. *Jig body*

Fig.1 shows a frame which is mounted on a stand (W) and used to accommodate parts namely, clamps and work rest. It is the main part of this jig and some other parts like a top plate and cam lock are attached to it, which completes the assembly of jig [refer fig.11]. Several holes are provided in this body in which two of them are at two adjacent sides (B) for simple screw clamps, one at the opposite corner (B) for dual acting clamp and four at the bottom side (X) for work rest adjustment screws, and Some space (Y) is provided for easy swarf removal [Refer fig.12]. Use section 9 for the better understanding of nomenclature.

2. Top plate

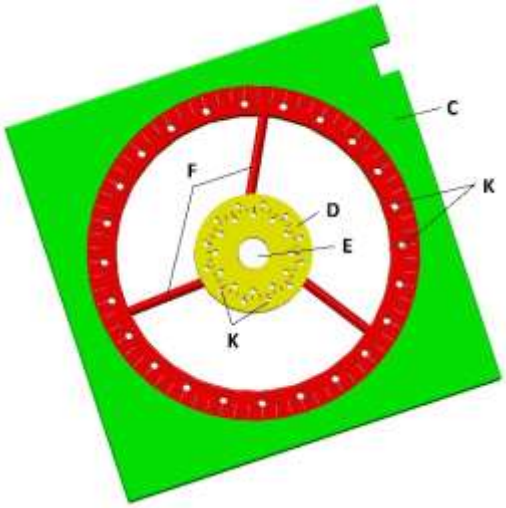

Fig. 2. *Top plate*

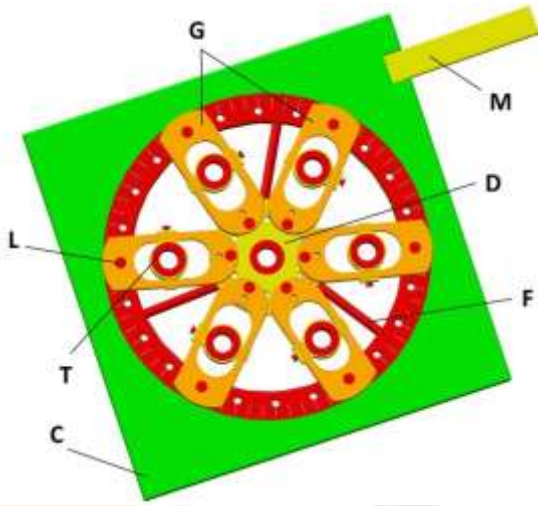

Fig. 3. *Top plate [assembly]*

It is a removable plate which is pivoted to jig body and it essentially consists a plate with circular space, central plate (D), and connecting rods (F) they are permanently joined with each other as shown in fig.2 and fig.3. In addition to that bush guide frame (G) are fastened to them by means of nut and bolts (L). Several holes (K) [24 nos.] are provided at both top plate (C) and central plate (D) at the equal distance of 15 degrees and employed for bush guide (G) frame attachment. [Refer fig. 11 and fig.13]

3. Central plate

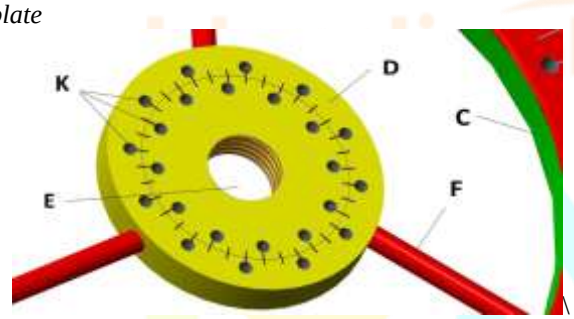

Fig. 4. *Central plate*

It is a hollow plate which is situated at the centre of the top plate (C) through connecting rods (F). It helps to achieve proper attachment of bush guide frame since its inner end is fastened at one of the holes (K) provide at the central plate (D) as shown in fig.4. These holes are given at two different radiuses to prevent tearing of this plate (D). A central hole (E) [can be internally threaded or plain] given in this plate which can be used to attach a bush in it to either drill a central hole or for the vertical clamp attachment to clamp parts having smaller thickness [i.e. plates]. [Refer fig.14]

4. Bush guide frame

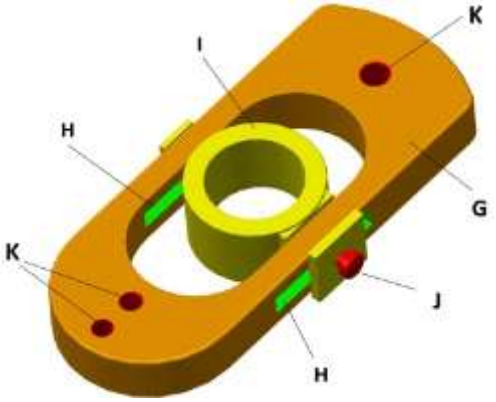

Fig. 5. *Bush guide frame*

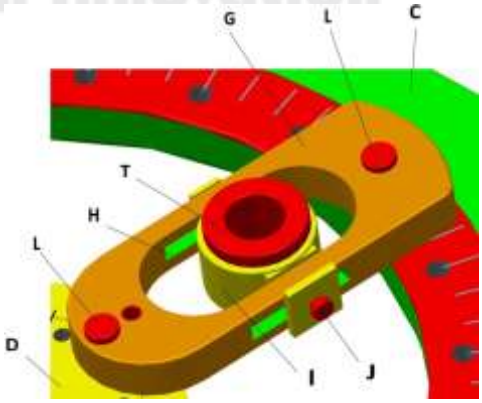

Fig. 6. *Bush guide frame*

It is a hollow frame kind of a structure which is used to change the P.C.D. by moving bushes forward or backward. It essentially consists a frame (G) having locating space as well as a lengthwise slot (H), sleeve (I) In which bushes (T) are attached by the press fit and a locking screw (J) to lock bushes at their places. Its outer end is attached with top plate (C) and its inner end is with central plate (D) by means of nut and bolts (L) as shown in fig.6. Any number of bush frames [e.g. 2, 3, 6, 9, 12] can be used to drill an equal number of holes and for obtaining better positioning of bushes some calibration can be made on frames or measuring instruments can be used too. [Refer fig.15]

5. Clamping panel

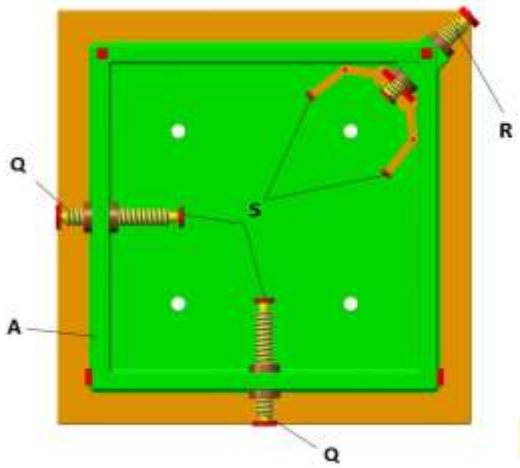

Fig. 7. *Clamping panel*

In this panel total three clamps is provided two simple screw clamps (Q) and one dual-acting [6] clamp (R). Each of them has a swivel head [1] type contact points (S) as shown in fig.7, which have an ability to swivel itself when shape/inclination of work piece changes. These simple screw clamps (Q) are the plain screw clamps have contact point (S) attached on to it and dual acting clamps (R) is fast acting clamp which can clamp or unclamp the work piece just by tightening or loosening two or three threads.

Though these clamps are parts of the same panel they have difference in their use like In case of identical parts there is no need to change the location of simple screw clamps (Q) only dual acting clamp (R) is operated to apply the clamping force and if part differs from previous part, the location of simple screw clamp changes too.

6. Cam lock

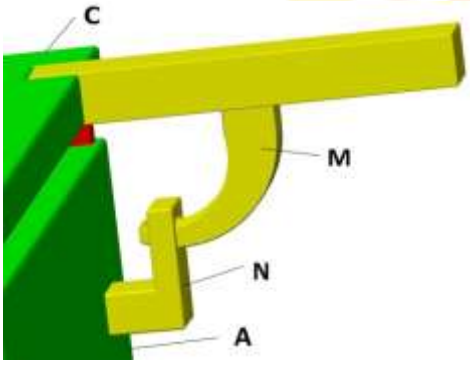

Fig. 8. *Cam lock*

It is an ordinary locking device which is used to facilitate the locking of the top plate (C) at its closed position. It comprises a cam profile (M) which is equipped with a handle and pivoted to the top plate (C) and an adaptor (N) is attached to jig body (A).

7. Bush

It is the part used to guide twist drill precisely into each intended hole centre. In this jig, some bushes [i.e. 6] are situated at some distance from centre with the help of bush guide frames and one bush is attached at the central hole of central plate. Bushes at bush guide frame are attached by press fit and bush at centre is by threads, but to reduce the machining difficulty an additional sleeve can be employed, which is externally threaded. [Not considered in this paper] [Refer fig.17 and fig.18]

8. liners/circular nuts/sleeves

In this jig total, two types of liners are used. A plain type and internally threaded type, in which plain liners are used at bush guide frame for bush attachment, and internally threaded are used at three places two adjacent sides, one at opposite corner and four at the bottom surface. These liners can be headless or headed type. This head helps to prevent the Lanier motion of liners. Which occurs due to the clamping force or weight of the work piece.

9. Work rest

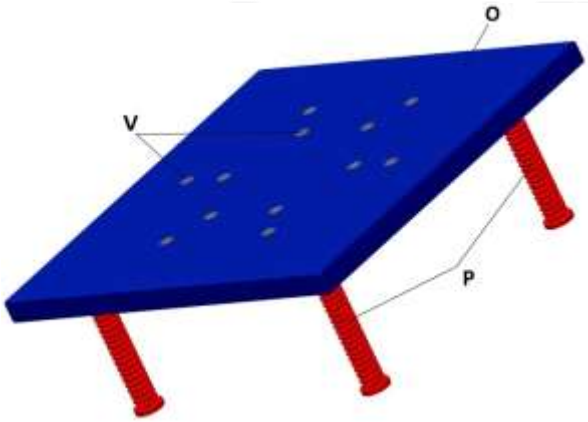

Fig. 9. *Work rest*

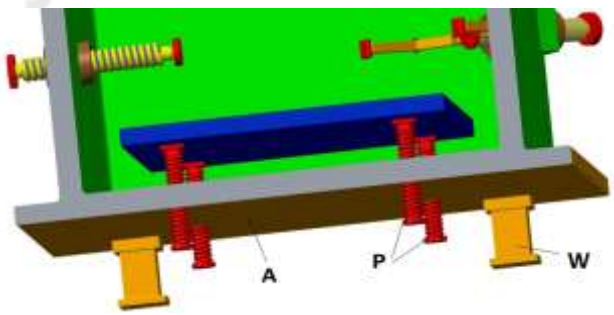

Fig. 10. *Jig [sectional view]*

This part is employed to provide support to the work piece from bottom side and to achieve proper height/location. It is comprised of a plate (O) and four adjustable locators [2] (P) as shown in fig.9. This plate is connected with these all four locators by the press fit. Which is achieved between a projection of locators and the recesses of plate [given at bottom side]. This plate has some circular spaces (V) on its top surface to accommodate solid locators on it, which is essential for swarf clearance while performing throughout drilling.

These adjustable locators (P) are externally threaded and passes through the holes given at the bottom surface of jig body as shown in fig.10. An individual liner/circular nut [internally threaded] can be provided to form a required screw pair and to prevent the wear of the holes or these internal threads can be directly cut on the internal surface of holes [not preferable]. Hence by operating these adjustable locators height of plate and/or work piece can be changed to facilitate the easy machining parts, having lesser thickness. Which is the secondary function of this work rest.

Its main function is to facilitate the angular drilling operation. For that swivel head is provided to each of the locators, which works similarly as used in clamps. This enables tilting of the plate without much constraint. So when there is any existence of height difference between these locators (P), it leads to the inclination of the plate (O). So when plate becomes inclined it results into the inclination of work piece [rests on the plate] too. However, the maximum allowable inclination with this arrangement is not much more [i.e. around 15 degrees], due to the maximum size of the work piece which lies in the range of this jig. This inclination can be increased to 30 degrees or 45 degrees by mounting a wedge shaped plate on top of the plate. [Refer fig.16]

II. SEQUENCE OF ASSEMBLY

1. Mount jig body on to a stand, by welding or by fastening [in case of de-similar metal].
2. Attach all seven liners [three on the sides and four at the bottom] by the press fit.
3. Assemble adjustable locators with liners and form a screw pair.
4. Attach the plate on to the projections of adjustable locators by the press fit.
5. Attach simple screw clamps and dual acting clamps at their places.
6. Attach cam adaptor to the jig body by any means [welding or fastening].
7. Attach central plate and connecting rod with the top plate by welding.
8. Attach bush on to the bush guide frame by means of press fit.
9. Attach bush guide frame with the top plate by using a pair of nut and bolts. [use number of bush guide frame to drill an equal number of holes]
10. Pivot cam lock with the top plate.
11. Pivot top plate with jig body
12. Attach central bush or vertical clamp at the hole given in central plate [this operation can be performed either when the top plate is connected to jig body or when it doesn't]

III. ASSEMBLY

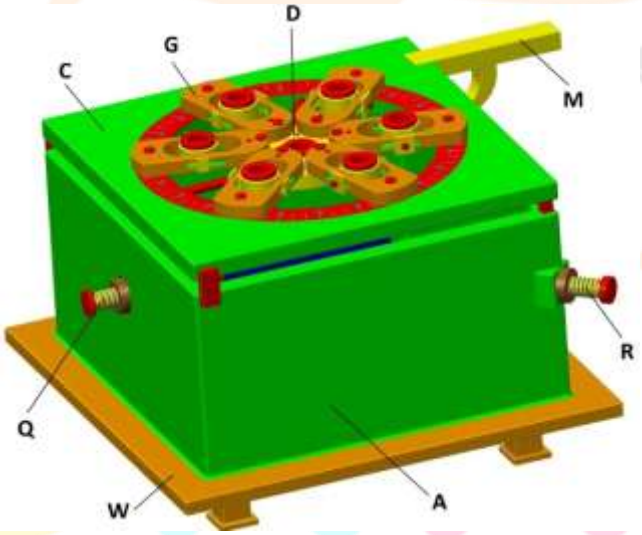

Fig. 11. *Master jig [assembly]*

IV. UTILITY OF JIG WHILE MACHINING

1. Prepare part specification list.
2. Accordingly use bush having required bore diameter, and set/lock them at required P.C.D. by using bush guide frame and locking screw provided with it. [use templets or measuring instrument to attain better locational accuracy]
3. Set simple screw clamps at a pre-defined distance from the centre. [again with help of templets or measuring instruments]
4. Adjust the height of work rest. [or incline it]
5. Open the cam lock and flip the top plate.
6. Load the work piece.
7. Apply clamping force by the dual acting clamp.
8. Flip the top plate at a closed position and lock it by using cam lock.
9. Do machining.
10. Remove the clamping force given by dual acting clamp.
11. Open the cam lock and flip the top plate.
12. Unload the work piece.
13. Clean the jig if needed.

Repeat operation no. 5 to 13, if work piece is identical or change the location of bushes and clamps if it is changed.

V. PREFERABLE MATERIALS

1. For jig body, stand, top plate, work rest plate, central plate, connecting rod and cam lock

- Cast iron

  Gray cast iron is sometimes used as the main body of jigs. It is sometimes easier to cast a shape than to build it up with several pieces of steel which results as a weight of the jig may be reduced. The stability and compressive strength of gray cast iron, as well as its ease of casting, make it suitable for this purpose [5]. But it is generally being replaced by other materials that are less expensive and take less time to fabricate the tools. The chief disadvantage of cast iron is the large amount of lead time required. Before a cast tool body can be used, it must be made into a pattern and then a mould, and then poured. These added steps not only take longer but also cost more. [1]

- Carbon steel

  Carbon steel is the primary material of jig and fixtures tooling. Its ease of fabrication, low cost, availability and versatility have made it popular for tooling construction. Low carbon steel is the most popular among them, but it should be used only in areas where mass is required and no wear or stress occurs. Standard structural shapes [bars, strips, sheets and many special shapes] are used in the construction of frameworks for large jigs and fixtures. They are also available in a variety of conditions such as cold-rolled, cold-drawn, hot rolled, or ground. [5]

- Aluminium

  Aluminium is most widely used non-ferrous material. The primary reason for this are machinability, adaptability and weight. Aluminium plates are available in wide variety of forms and another advantage of aluminium is the elimination of heat treatment or processing to increase its hardness or stability. [1]

2. Bushings

   Material preferable for drill bushes are water hardened carbon steel [0.8 to 1% carbon] or tool steel. Which are hardened up to RC 60-64 to minimize wear due to contact with hard, rotating tools. [2]

3. Clamps

   In areas of tooling that requires more strength as well as toughness, medium carbon steel work well as clamps. This steel contains 0.30% to 0.50% carbon in it, which allows the material to be easily hardened by case hardening or other conventional hardening process [1].

4. Bush guide frame

   Since, the accuracy of bush location is very much dependent upon this part and it is made of a frame kind of structure it requires toughness to prevent deformation as well as small amount of hardness too, to reduce wear. For satisfying these requirements alloy steel comprised of carbon, nickel and chromium is an ideal choice. Or it the applications like light working medium carbon steel also works well.

5. Sleeves and liners

   Though in this jig the liners are used to prevent the wear between the matching parts they works as nut also [since they are internally threaded], which requires equal strengths as bolts. So liner material can be used as clamps or nearer to that [slight lower in grade to prevent failure of clamps] since they are easy to replace. And the material of sleeve can be either ferrous metal [medium carbon steel having less case hardness] or non-ferrous metal [bronze or gun metal] according to availability. [3]

VI. CAPABILITY OF JIG TO ACCOMMODATE THE WORK PIECE

Dimensions of this jig is completely work piece oriented, and it is taken as the final assembly can accommodate and machine the work piece which ranges as shown below.

- Outer dimension:- maximium150 mm to minimum 60 mm for cylindrical parts
- Outer dimension:- maximum 130 mm to minimum 50 mm for square or rectangular parts
- Height of work piece/thickness:- maximum 80 mm to minimum 2 mm or 3 mm plate thickness
- Maximum diameter of hole: - 10 mm for a central hole and 8 mm for holes at P.C.D.
- Maximum number of holes to be drilled:- 6
- Range of P.C.D.:- maximum 120 mm to minimum 80 mm.

VII. DIMENSIONS OF JIG [DIS-ASSEMBLY]

Since the material is not specified, it is difficult to show exact dimensions. So few of the dimensions are not mentioned in figures. In which some of them are can be taken as standard values [metric size of clamps/bolts and nuts] so they can be taken as per the availability, and some others like cam and cam adaptor are independent parts, whose dimensions do not effect much in the functioning of this jig. However it is not necessary to use same set of dimensions as shown in fig.12 to fig.18, but they are helpful for the reference purpose.

1. Jig body

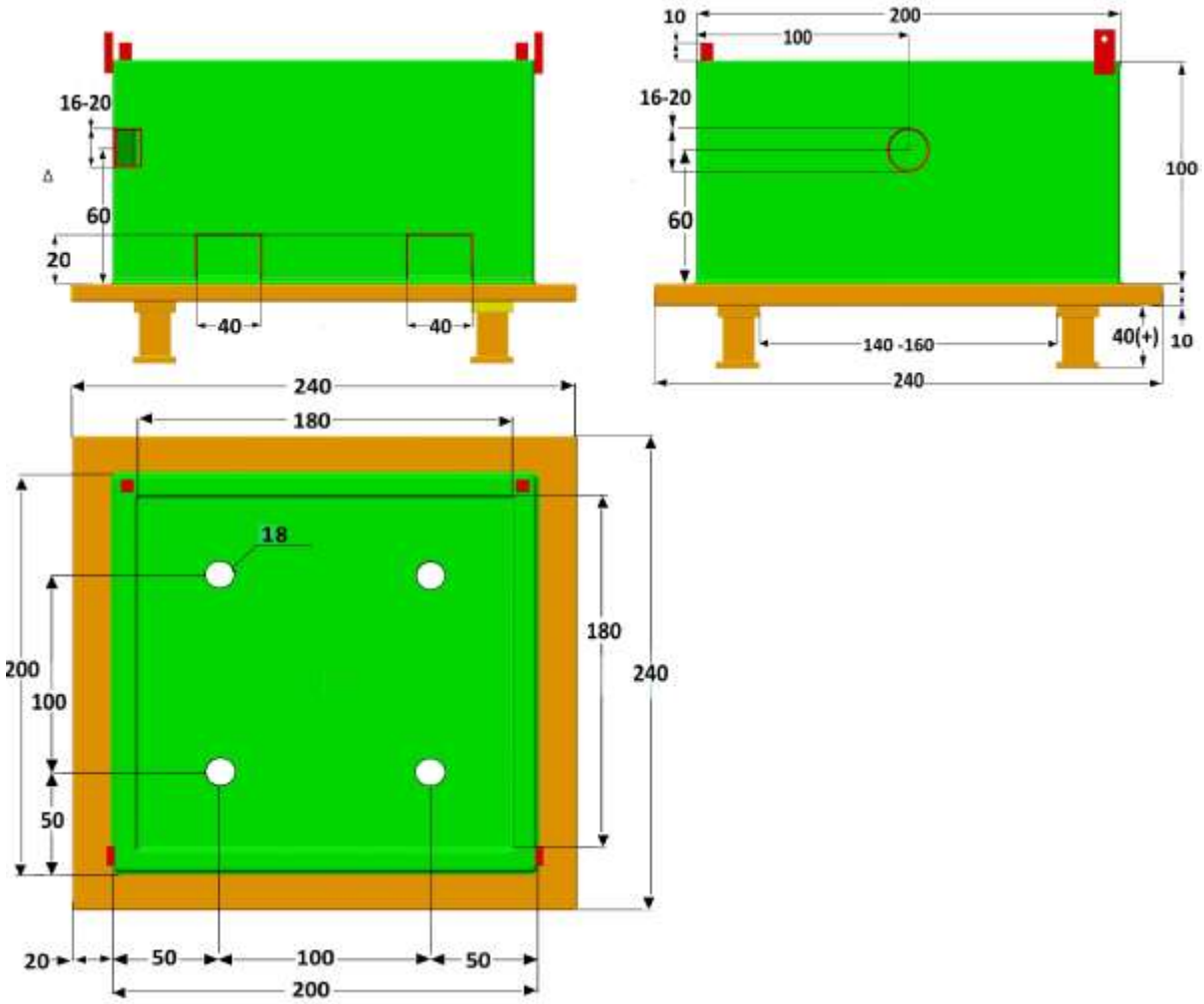

Fig. 12. *Jig body*

2. Top plate

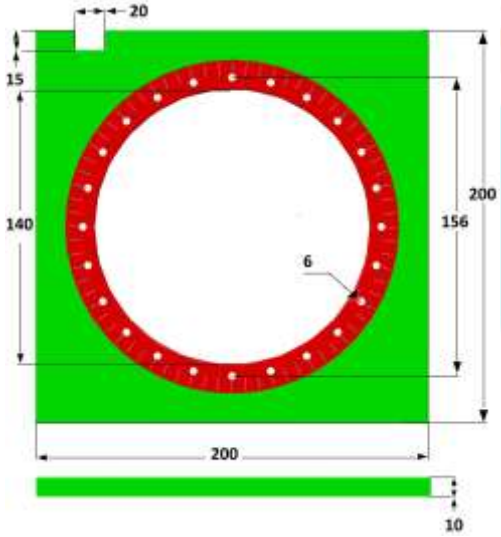

Fig. 13. *Top plate*

3. Central plate

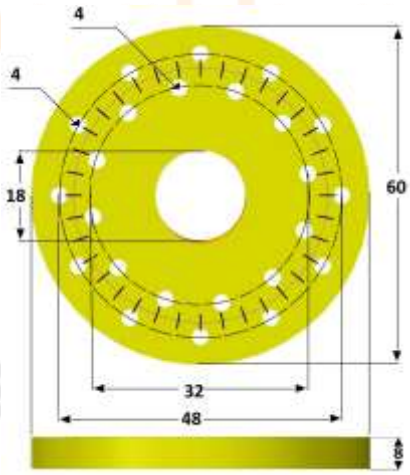

Fig. 14. *Central plate*

4. Bush guide frame

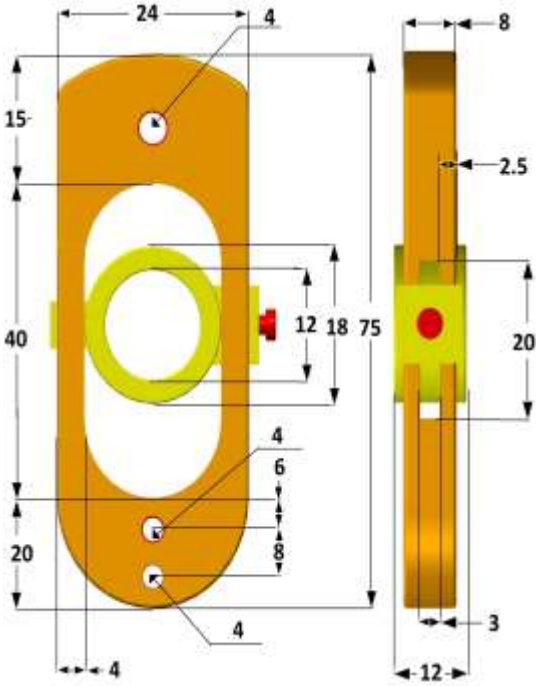

Fig. 15. *Bush guide frame*

5. Work rest

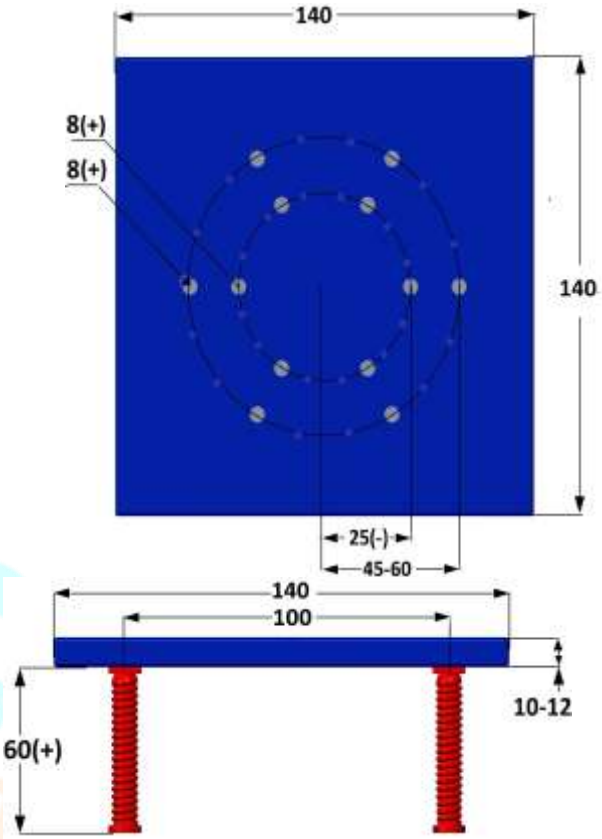

Fig. 16. *Work rest*

6. Bush

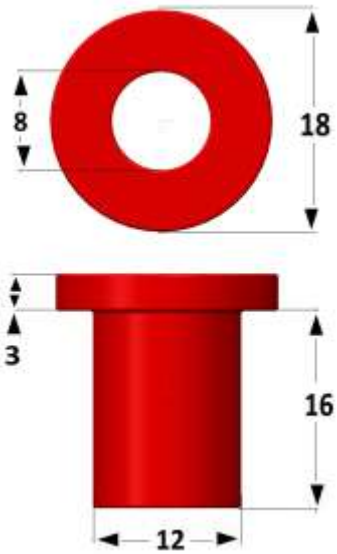

Fig. 17. *Bush [P.C.D.]* [4]

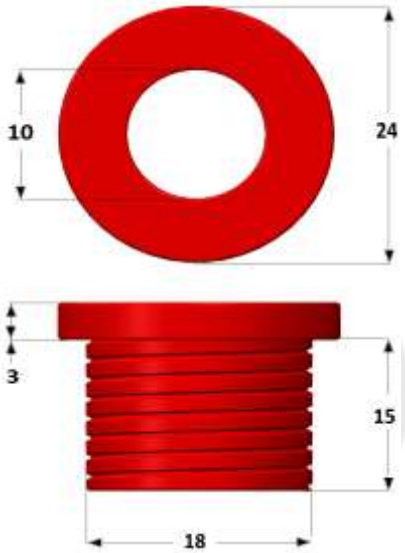

Fig. 18. *Bush [central]* [4]

VIII. NOMENCLATURE

A	Jig body	H	Slot	O	Work rest [plate]	V	Holes for solid locators
B	Holes given in jig body for clamp attachment	I	Sleeve	P	Adjustable locators	W	stand
C	Top plate	J	Lock screw for sleeve	Q	Simple Screw clamp	X	Holes given for adjustable locators
D	Central plate	K	Hole given for bolt attachment	R	Dual acting clamp	Y	Space for swarf removal
E	Threaded hole given in central plate	L	Nut/Bolt	S	Swivel head type contact point	Z	Support for top plate
F	Connecting rods	M	cam	T	bush		
G	Bush guide frame	N	Cam adaptor	U	Pivot/fulcrum		

IX. RESULTS AND DISCUSSION

In this paper, the aim was to develop an alternative option of standard jigs. To eliminate their limitation of no/less flexibility. And to produce the variety of parts for drill based processes. So to satisfy this need a jig requires a very large range of work piece accommodation, pitch circle diameter variation, and angle variation.

If this jig is manufactured as per the dimensions are shown in fig.12 to fig.18, then it is capable to accommodate parts having outer most dimensions ranges from, maximum 150 mm to minimum 60 mm for cylindrical parts and maximum 130 mm to minimum 50 mm for square or rectangular part. Also, it gives a range in terms of height/thickness of maximum 80 mm to the plates having the thickness of 2 mm or 3 mm. And in terms of P.C.D., it gives range of minimum 80 mm to maximum 120 mm because of bush guide frame which allows the bush to move back or forth by 20 mm. [Refer fig.19 and fig.20]

Inclination obtained by this setup is 15 degrees, but it can be increased by 30 degrees or 45 degrees by using angle plate attachment. This angle either can be simple [one sided] or compound [with horizontal and vertical both the plane].

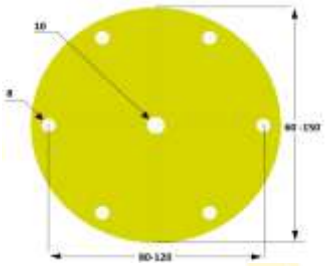

Fig. 19. *Cylindrical part*

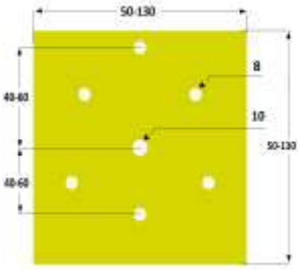

Fig. 20. *Square/rectangle part*

CONCLUSION

After studying this paper it can be observed that use of parts like bush guide frame and work rest enables a jig to produce the variety of parts in terms of P.C.D. as well as angle. Their use reduces the requirement of any special jig. And parts like cam lock and clamping panel requires less time to operate and easy too. Which helps to reduce the fatigue of operator and overall cycle time required to manufacture a product. But some reasons like no provision of fool-proofing, less user-friendly construction, high maintenance and need of frequently checking the location of bushes and clamps prevents the use of this jig for mass production.

Since it is an assemblage of so many parts it is difficult to manufacture and manufacturing cost is also high. But it can be compensated by time and money saved because of its use. Hence it can be concluded that master jig can reduce tooling cost of small production units and capable to make their production more economical as well as fast.

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