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GRAPHICAL APPROACH OF A COMBINED MULTIPURPOSE JIG AND FIXTURE WITH VARIABLE P.C.D. AND INCLINED MACHINING

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ABSTRACT:

This paper introduces the concept of a production tool, which can serve as a jig for drill based processes and as a fixture for milling, shaping and grinding based processes. The proposed tool has ability to machine and to produce parts in a variety of shapes and sizes over a wide range for both the cases, hence it is termed as "jigxture". Due to this ability it eliminates the need for designing and manufacturing a special jig or fixture and makes production process of small production units more efficient and economical. Facility of variable pitch circle diameter (P.C.D.) enables this tool to machine/drill parts having different P.C.D.s and provision of inclined machining facilitates angular drilling and inclined surface machining. Its virtual prototype is created with the aids of computer [CREO software] and demonstrated in this paper with detailed features and a case study. Where the dimensions of this tool are suggested, for a work-piece with outermost dimensions in the range of 50 mm to 150 mm and maximum permissible height as 80 mm.

KEYWORDS: *jig and fixtures, jigxture, fixturing system, variable P.C.D., inclined machining, multipurpose production tool, small production units, decreased tooling cost.*

1. INTRODUCTION

As jigs and fixtures are the most commonly used tools in industries to provide repeatability for manufacturing identical parts, by accurate workpiece locating/clamping and tool guiding. Our work is focused on creating an alternative option of the standard jigs and fixtures; which can eliminate all their limitations/drawbacks (but fast and economical too). In this paper, a new type of production tool is proposed which can have multiple applications, viz. as a jig for drilling based processes (which is its primary function) and as a fixture for milling, shaping and grinding based processes (its secondary function). Its use could be advantageous/helpful for small production units, like small industries or workshops, to reduce their tooling cost. And to sustain their position, in the current scenario of cutthroat competitions, in a global market. Where overall life cycle time of a product is reduced and batch production became more popular/favourable than mass production. Thus parts are manufactured in larger variety and smaller quantity (small batch sizes). This originates the need to change machine setup and tool setup every time as product changes. For the attainment of proper part location and tool motion.

This is not much difficult to achieve because of the automation and the advent of C.N.C. machines in industries. Where tool path is digitally programmed and stored in memory. Such types of machinery are quite fast, accurate and most favourable for production in small batches. But their use leads to larger capital investments. Which many a time becomes unaffordable for small production units to justify their small quantity of production. In addition to that, use of conventional machinery necessitates designing and manufacturing unique jigs and fixtures (fixturing systems) for each variety. Due to the fact that, standard jigs (which are commonly in use) like template jig, leaf jig, box jig and angle plate jig, all of them have a similar limitation of no or less flexibility. So whenever there is any requirement of a change in part's dimensions, the fixturing system becomes futile to serve the purpose.

In the case of fixtures, vices or variants of clamps; which mainly are an integral part of the machine or a work table are employed to clamp/hold the workpiece. They are easily available and suitable for almost every application. But when it comes to inclined machining (to tilt the upper surface upwards or downwards), only a few fixtures are having such capability. Those are very bulky, costly and generally referred as special purpose fixtures. Hence, the use of standard/conventional jigs and fixtures (fixturing systems) increases tooling cost and overall production time. Eventually, it results into lower profit margins or increase in cost of a final product. To solve all these problems a tool is purposed, which is called a "jigxture".

2. LITERATURE REVIEW

Initial practical work on jigs and fixtures was described by Collvin and Hass [1], Wilson [2, 3], Edward [4] Joshi [5] and Kempster [6] which provides the base to this invention. The constraining, positioning and stability of a fixtured workpiece were investigated by Early and Johnson [7]. Different aspects of fixturing systems design were considered by Henriksen [8] and by Bores et al. [9], who has assembled a set of useful guidelines for analytical design. Further analysis has been carried out by Asada and by [10] and Chou and Barash [11]. These authors have applied screw theory to study the kinematic constraint of a fixtured workpiece, as well as the conditions for accessibility and detachability of fixtures.

Work on modular fixturing systems (MFSs) was described by G. Lewis [12]with an objective to achieve flexibility through multipurpose fixturing. As modular fixtures are simple, easy to assemble and built up from a combination of elements to obtain

the variety of configurations. Finite-element analysis of the supports is investigated by Lee and Haynes [13] and F. Ozturk [14] to determine the optimum placement for the supports, particularly when larger specimens are being machined. The computer-controlled assembly of fixturing systems has been investigated in the work by Asada and by [10] and Woodward and Graham [15]. CAD programs for jigs and fixtures have been developed by several researchers [16-20]. In the end, the notion of making the fixturing system multipurpose is taken from the paper by Chirag & Nitinchandra [21].

3. CONSTRUCTIONAL FEATURES

3.1 Body

The part body has the vital importance in this tool. It is welded with stand and employed to support parts like a top plate and cam lock. It houses several other parts namely four clamps, two lifting screws and a work rest accompanied with the workpiece. Four larger holes (A3) along with the smaller holes (A4) are provided in this body at all its side, for attachment of clamps. Similarly, two pairs of smaller and larger holes are cut at its bottom side, for lifting screw attachment. Other than that, several spaces are given for easy swarf removal (A1), cam adaptation (A2) and holes for top plate guide attachment (A5) as shown in fig.1.

Grey cast iron, as a material of a body reduces the weight, provides good compressive strength but mandates other means of joining as it is difficult to weld. Low carbon steel gives ease of fabrication, low cost and serves well where no stress occurs. [4]

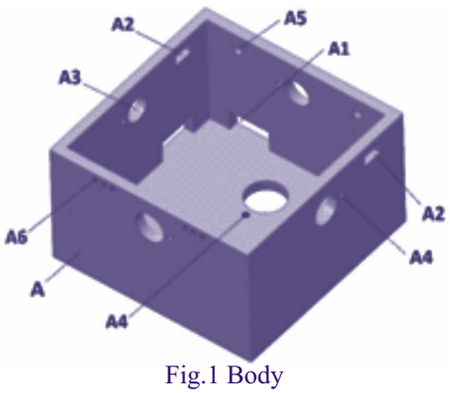


Fig.1 Body

3.2 Stand

Stand illustrated in fig.2 helps to achieve a proper height of tool from work table. To account for the out-coming length of lifting screws (more on this later). It is made of the same material as body and fastened to machine table through tee-bolts (or any other available means). For the purpose of fastening some space (B5) is provided at it's both the sides. Two pairs of smaller and larger holes (B2, B3) are cut on its top surface, identical to the holes cut at the bottom surface of a body. Some material is removed (B4) from all sides in order to reduce its weight. In such a manner that its strength remains unaffected.

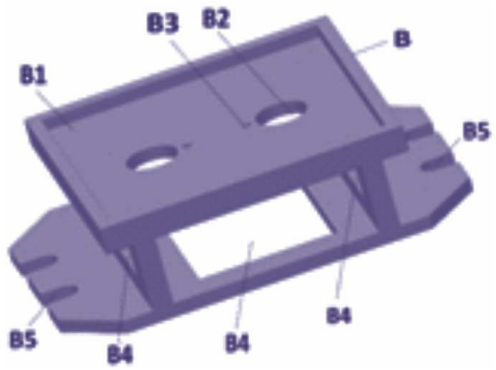


Fig.2 Stand

3.2.1 Top plate

A top plate is connected to the body (A), through hinges (T). It can be easily removed whenever required. In drill based processes, it helps to obtain the proper location of bushes (I). To drill a hole at the intended location and at the time of milling, shaping or grinding processes, where intimate contact between a cutting tool and workpiece mandatory, it is detached from the tool. As depicted in fig.3, top plate is an assemblage of several parts which essentially consists a main plate (D), bush guide plate (E), pressure plate (F), sleeves/liners (H), bushes (I) and washers (G). Besides that two cams (R) are hinged (U) on it, at its both the sides. All these elements are brought together to form an assembly by means of pairs of nut-bolts (V), screws and circular nuts.

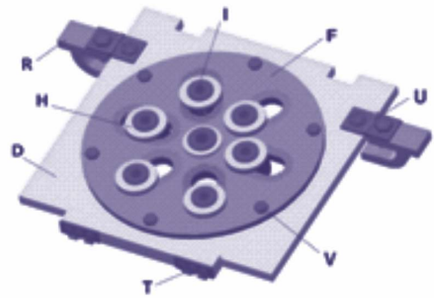


Fig.3 Top plate [assembly]

3.2.2 Main plate

Main plate is the part which is hinged to the body and provides support to the parts from which top plate is being constituted. Two large circular recesses made on this plate (D1 & D2) forms an annular region. Six holes (D6) cut in this region used to pass a bolt from them. Holes (D5) are internally threaded and used to attach a hinge with the help of screws. Rectangular spaces (D3)are cut corresponds to the size of projection that top plate guides has (refer to section 3.5).

To manufacture this plate, cast iron minimizes the manufacturing difficulties, encountered due to the annular region used. Medium carbon steel gives adequate strength and aluminium can fulfil all the requirements, because of its availability in a variety of grades [4]

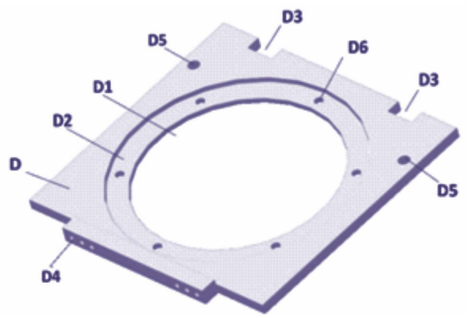


Fig.4 Main plate

3.2.3 Bush guide plate

Bush guide plate (fig.5) is situated at the top of the annular space formed in the main plate and enclosed between two pressure plates [refer section 4.2]. Its main function is to provide the reinforcement to pressure plates and has the same material requirements as the main plate. Six holes (E1) are identical in size to those which are cut on the main plate, as well as in the function. The central hole (E3) is used for the attachment of a central sleeve or vertical clamp. The array formed by the profiles (E2) is used for confined back and forth movement of sleeves/liners.

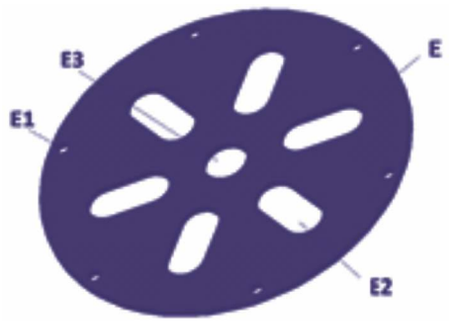


Fig.5 Bush guide plate

3.2.4 Pressure plate

Pressure plate has exact identical features as bush guide plate has except, at one of its sides, on each profile (F2) indentations (F4) are created (by the press); in such a manner that, the center distance between two conjunctive indentations remains 2.5 mm, throughout the length (for reason, refer section 3.3.7, also refer fig.30). Any softer material (could be metallic or non-metallic) on which fair indentation can be produced can work well for the pressure plate.

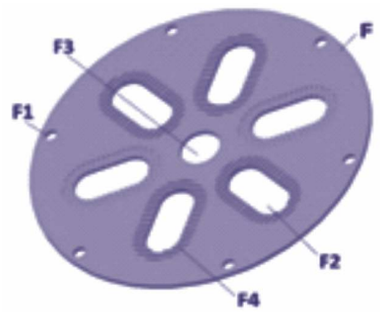


Fig.6 Pressure plate

3.2.5 Washers

Washer (fig.7) is circular in cross-section and work as a counterpart of the pressure plate. Projections (G1)are formed at its one of a side, which matches with indentations of a pressure plate. As the projections are similar in size and center distance, also the material is similar to the pressure plate.

Fig.7 Washer

3.2.6 Sleeve/liner

The part shown in fig.8 accommodates a bush at its bore (H2) and work as the liner for the same. A collar (H3) is provided, at its upper end and its lower end is externally threaded (H1) up to some length, where a circular nut is tightened. Each sleeve is incorporated with two washers (from section 3.3.4) one at below the collar and another at above circular nut (refer fig.22). Thereby both of them are under compression force (for reason refer to section 3.3.7). Medium carbon steel which is case hardened up to require depth can work well for this part.

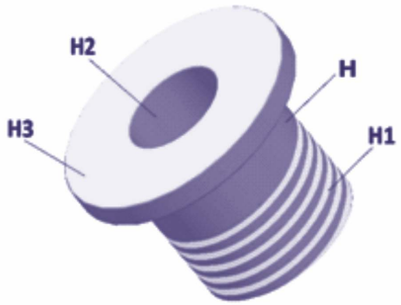


Fig.8 Sleeve/liner

3.2.7 Bushes

Bushes (refer fig.3& 22) are used to guide twist drill precisely, into each intended hole center. This tool is equipped with seven bushes,which entails one bush at center and six other bushes reside in the bore of sleeves.The preferable material for them is 2 mm thick (wall thickness)water hardened carbon steel [0.8% to 1% carbon] or tool steel.Hardened up to R.C. 60 to R.C. 64,to minimize wear due to contact with hard rotating tools. [23]

3.2.8 Utility of pressure plate, washer and sleeve

The reason behind using opposite profiles (F4 and G1) on washers (G) and pressure plates (F) is, an alone compression force is not sufficient for locating bushes. As there is always some possibility of linear movement, due to the cutting forces. Thus the use of opposite profiles can put one more constraint, in the path of movement, thereby can make the location of bushes

more accurate. Also known distance between two conjunctive slots enables the bushes to move precisely. In our case, the distance has kept as 2.5 mm, thus back or forth movement of the sleeve by one slot/indentation leads to a propositional change in radius from the center. Thereby varies the P.C.D. in order of 5 mm. If the indentations were produced, at the distance of 5 mm, instead of 2.5 mm, then the variation can be achieved in steps of 10 mms. Thus these features enables this tool to work on desired P.C.D., as well as helps to obtain better location accuracy.

3.3 Clamps and lifting screws

In this tool total seven clamps/screws are employed. Amongst them, four are horizontal clamps (K) and the other three being vertical. Horizontal clamps (fig.9) are devoted to impart a clamping force on the workpiece from all four directions. Whereas amongst these three vertical screws, one serves as a vertical clamp (refer section 3.4.1.) and remaining two are termed as lifting screws (N). They are accompanied by work rest and specially designed screw heads to achieve proper height and/or inclination of a workpiece (refer fig.10 and fig.18).

All four horizontal (K) and two vertical clamps/screws (N) are used with conjunction of separate collar nuts (P). Which uniformly distributes reaction force propagates because of clamping. It facilitates temporary joining as permanent joining (welding) is undesirable (in our case) and press fit alone cannot sustain that extent of force. All these nuts (refer fig.34-36) are made in two parts, a threaded sleeve and a collar (preferably). They are joined together welding and provided with a small hole, same as provided in the body (A4). Whilst hole of collar nut and body become concentric a bolt is passed through them and then a nut is finally attached. Use of this nut and bolt forbids any rotational or linear motion of collar nut. Which generally occurs, when a screw is operated at the unloaded condition and advances towards the workpiece.

For both, the screws and nuts medium carbon steel having 0.30% to 0.50% carbon can work well. It is easy to be hardened by case hardening or any other hardening process if required [24]In this clamping panel, amongst four horizontal clamps, two adjacent camps were intentionally kept larger, then clamps at opposite corner. It is not obligatory but advisory to do so, as it could be useful for the purpose of fool proofing and advantageous while producing identical parts.

In the first case of fool proofing with regards to the milling, shaping and grinding processes, when a tool is moving, the maximum amount of cutting force is imparted in the direction of movement of the tool. Thereby if the larger clamps are positioned along the direction of tool movement, they encounter maximum cutting forces and smaller ones are just provides the required clamping force. In the second case, if parts are having analogous features or fall in the same part family; a workpiece can be clamped or unclamped just by operating these two clamps, in place of all four. Here clamping force is imparted by larger clamps and smaller clamps work as locators only. This prevents the early failure of clamps and saves time.

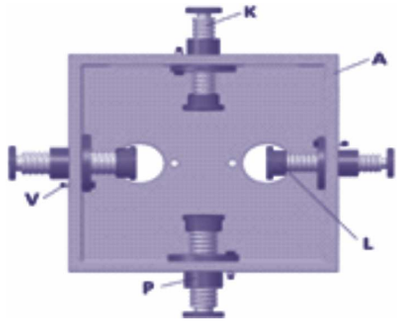


Fig.9 Clamping panel

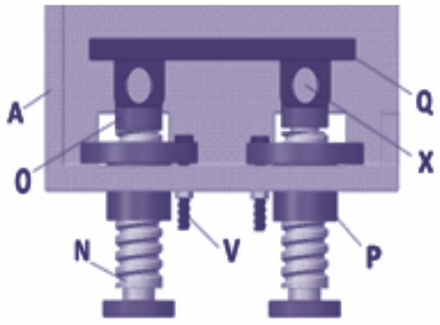


Fig.10 Lifting screws (Sectional view)

3.3.1 Vertical Clamp

Vertical clamp [22] is used for clamping parts of a lesser thickness (i.e. plates) particularly in the situations, where horizontal clamps cannot be used for clamping and due to the shortage in an area of clamping surface. This vertical clamp is situated at the center of the top plate (at central hole of bush guide& pressure plate). For that, a sleeve having a collar, internal threads as well as external threads (up to some length only) is used with conjunction of a circular nut (similar that mentioned earlier). It is advisory to keep collar side downward and nut side upward for better functioning and prevention of early failure.

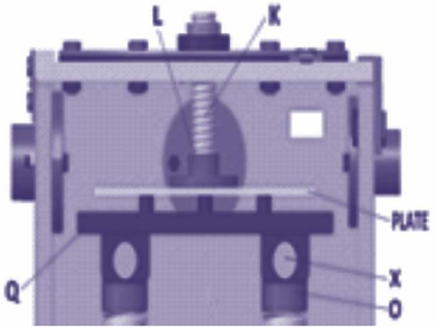


Fig.11 vertical clamping (Sectional view)

3.4 Clamp heads

In this tool, the term clamp head refers to a part which is situated on the top of the screws/clamps (K, N). It is used to convey the load (dead weight), in the case of lifting screws or to impart clamping force uniformly on a larger area for clamps. They can be produced by the same material as screws.

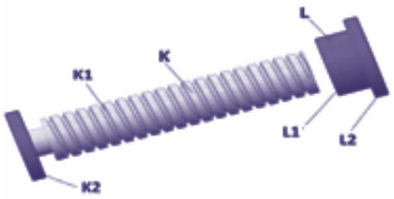


Fig.12 Screw with clamp head (Exploded view)

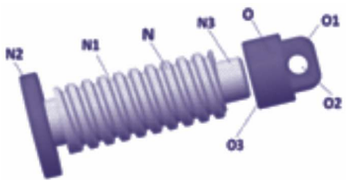


Fig.13 Lifting screw with lifting head (Exploded view)

The clamp head (L) used for clamps (K), has internal threads (L1) and attaches directly on to the end of a bolt (K). In the case of lifting screws (N), the head is hollow (O3) and rests on the top of the circular projection (N3). It is left unlocked, in the sense, it is free to rotate. This attribute is essential due to the requirement that, while screw rotates the head must move only in upward or downward direction. This head is customized in a manner that, it can comprehensively sustain the downward forces in all directions and occupy minimum volume.

3.4.1 Swivel head clamp

Swivel head clamp [4]has a special type of a head, which can automatically adapt the profile/shape of a given specimen by swivelling its head. So that any inclined part can be easily clamped and machined. Thus it is the sole element which enables this tool for inclined machining (refer appendix.1).

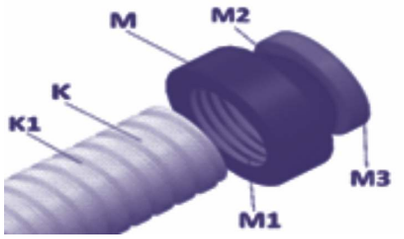


Fig.14 Swivel head (Exploded view)

3.6 Work rest

Work rest is a rectangular plate which is enclosed in the body, on which the workpiece lies. It is employed to obtain proper height and/or angle of the workpiece. The height is adjusted by simultaneous or (in small) stepped motion of lifting screws (N) and inclination by creating height difference between them.It has several holes (Q1, Q2) cut on it and two pairs of projections (Q4) at its bottom side. These projections are symmetrical and have a recess (Q4) to accommodate a pin (X), whose end is threaded (refer fig.17&18 throughout the section). This pin (X) couples work rest (Q) with the clamp head (O), which rests on the top of the lifting screw (N). The recess (Q4) has short of an elliptical profile, to facilitate relative movement. Due to the fact that, when work rest will be tilted, it will make an arc and if space for relative movement is not provided then pin will not remain in line with a head (O). This part can be produced as a product of cast iron, to avoid the welding of projection with the plate. In this wok rest, four throughout holes (Q1) are provided to house adjustable locators accompanied with collar sleeve. All these locators have a hemispherical head and their height can be adjusted as per the requirement. Another thin plate is placed on the top of these locators and then workpiece is placed on it. This helps to achieve a small compound angle (with respect to a horizontal plane as well as a vertical plane). However, the angle obtained is not large but useful for special purpose applications. Several other holes (Q2) are also provided (not throughout) on its top surface for the accommodation of solid locators (pin or button type). They are drilled at three different diameters and facilitates throughout drilling, by creating a space between plate and the workpiece; for the purpose of swarf clearance and burr clearance. It is advised to use four lifting screws instead of two. If a larger compound angle is required and size of the body is sufficiently larger.

In this tool inclined machining is comprised of two possibilities. In the first case, upper and lower (one or both) the already has some slope and one of them is to be machined flat as demonstrated fig.17. Another possibility is workpiece has all sides flat/perpendicular/square and a hole to be drilled at some angle or upper surface is to be machined at some angle as demonstrated in fig.18. (Refer to appendix.1)

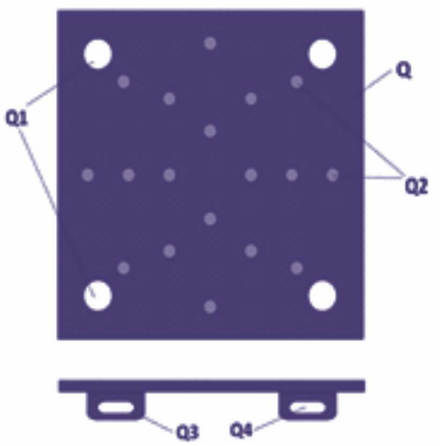


Fig.15 Work rest

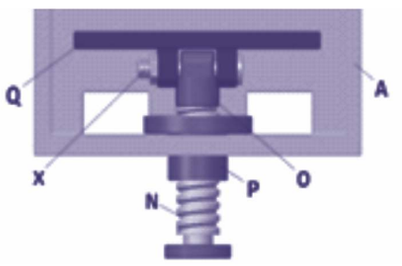


Fig.16 Work rest with the pin (sectional view)

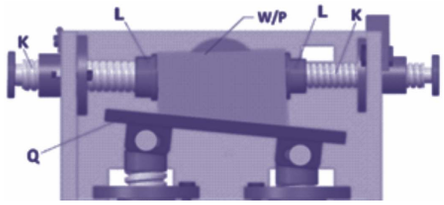


Fig.17 Inclined clamping case 1 (sectional view)

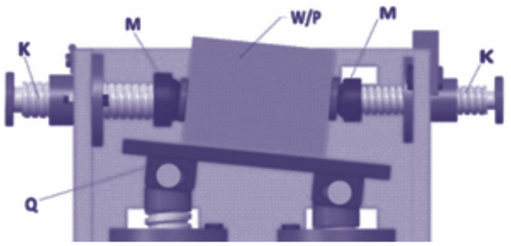


Fig.18 Inclined clamping case 2 (sectional view)

3.7 Top plate guide

Top plate guide (shown in fig.19) is an L- shaped strap, which is fastened to the body (A) by nut and bolts (V). It ensures proper alignment, between a top plate (C) and body (A). It doesn't have any specific material requirements, thus any available material can be employed. Its upper portion fits in the rectangular space provided in the top plate (D3), and for smooth functioning, appropriate clearance is provided. As it is attached by means of temporary fastening, it can be easily removed, at the time of milling, shaping or grinding operations.

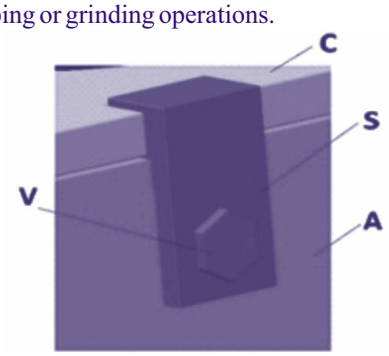


Fig.19 Top plate guide

3.8 Cam lock

In this tool total two cam locks are used. To facilitate the locking action when the top plate is at a closed position. To provide a locking action, a cam shape (R2), is adopted by the rectangular space (A2) given in the body. As they are two in number both of them are situated at two opposite sides of the top plate and attached through hinges (U). They are equipped with a short handle (R1) for easy working and manufactured as a product of cast iron, to reduce the difficulties faced due to its shape.

(note:- for the attachment of hinge (U) a screw is employed at top plate side and a pair of nut and bolt is employed at cam side, as shown in fig.20)

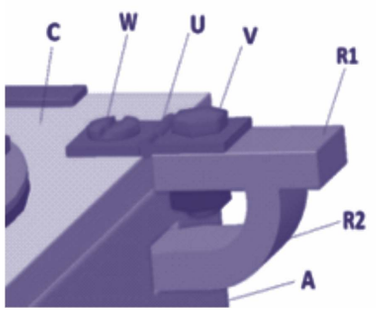


Fig.20 Cam lock

4. SEQUENCE OF ASSEMBLY

4.1 Assembly of Body

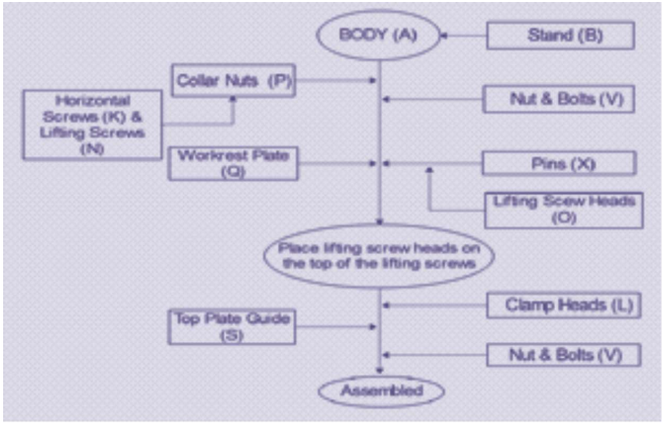


Fig.21 flowchart for the assembly of a body

4.2Assembly of Top plate

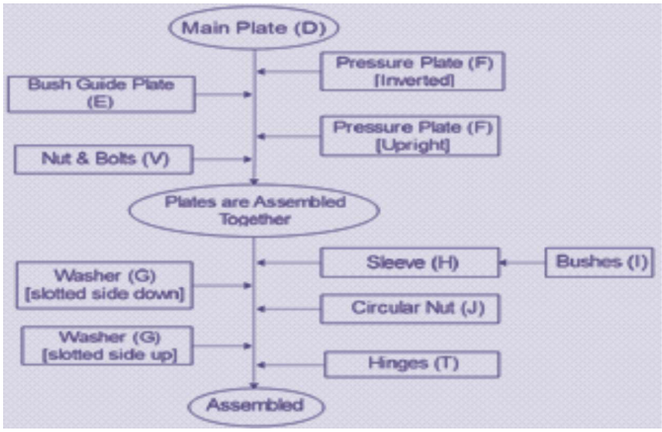


Fig.22 flowchart for the assembly of a top plate

Note: - refer to fig, 23 & 24 for the better understanding of section 4.2.

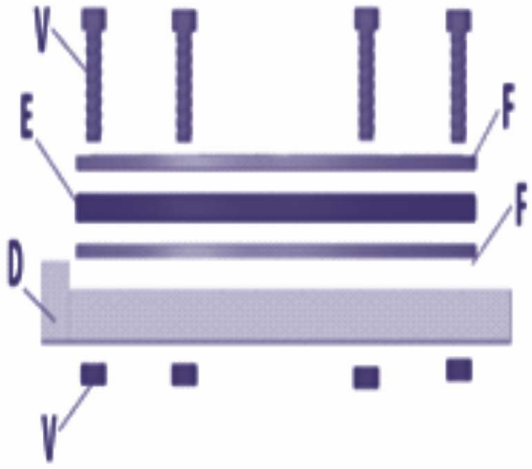


Fig.23 Top plate (Exploded view)

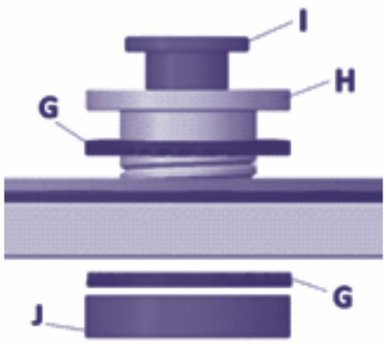


Fig.24 Sleeve (Exploded view)

5. FINAL ASSEMBLY

- Attach top plate (C), with the body (A), by screwing the hinges (T).
- Attach the cams (R), on the top plate (C), through hinges (U), to complete the assembly. [refer fig.23]
- Use vertical clamps, in the place of a central bush, in the case of plate drilling.
- Attach four adjustable locators, with collar nuts, on the work rest. And place one more rest plate, on the top of these locators, in the case of compound angle machining.

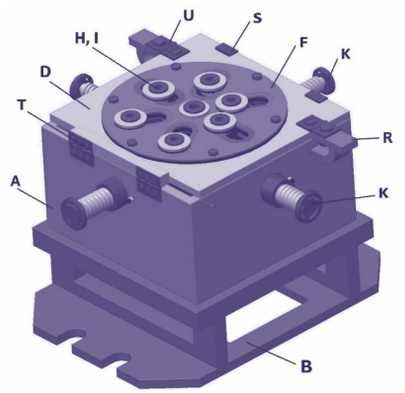


Fig.25 Jigxture (Assembled]

6. WORKPIECE LOCATING

6.1 Centre finding attachment

At the time of drilling, it is necessary to know that the center of a workpiece to reduce the chances of eccentricity (particularly for the rotational geometry). Hence hole can be drilled at intended P.C.D., or at a predefined distance from the sides. Thus, for this tool an attachment (fig.24) is suggested to find the center of a workpiece. This attachment essentially consists of two mutually perpendicular strips (Y1 & Y2) on which a scale calibrated (Y4). A vertical strip (Y1) has it's both the ends bent at 90 degrees (Y3), such a way that the distance between them is equal to the side of the body (refer fig.24 & 25). In a horizontal strip (Y2),both the bends (Y3)are on the same side. As opposite side already occupied by the top plate (whenever attached). And these two bends (of a horizontal strip), have a distance between them, equal to the wall thickness of the body (A). After the attachment and a workpiece is being mounted, the scales are observed and if workpiece has any eccentricity, then it is compensated by operating the clamps accordingly and state of zero eccentricity is attained, as demonstrated in fig.25.

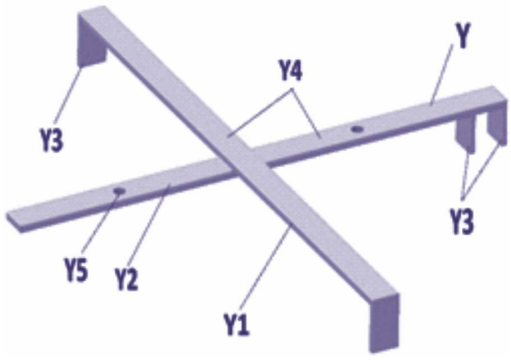


Fig.26 Center finding attachment

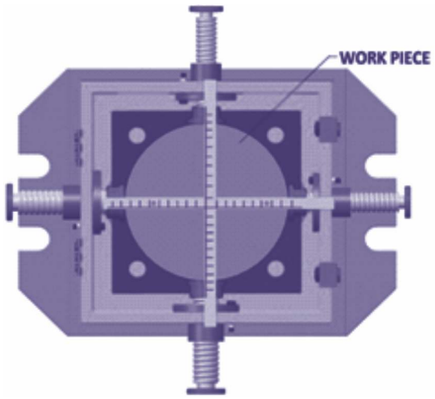


Fig.27 Application of center finding attachment

6.2 Angle finding attachment

In this tool, to drill a hole at a required angle or to machine a surface at an intended inclination, mandates the knowledge of inclination or a tilt angle of work rest to ensure the obtained angle is as per the requirement (or not). For that autocollimator or micrometer collimator gives best results. But, it is assumed that this tool would be used by small production units, where resources are scare. Thus, a procedure is suggested (below), which can give approximate results.

To find the angle, symmetric holes (at a known distance) are cut on the horizontal strip (Y2) of center finding attachment. Few more things like Two additional rods (Z2), with scale (Z3) engraved on them (either a simple millimeter scale or directly in terms of angle) and rod guides (Z1), with locking screws (Z4) are incorporated in the center finding attachment (refer fig26). These rod guides (Z1) are attached, at the hole (Y5) given in horizontal strip through nut and bolts. Then rods (Z2) are passed from the guides (Z1) and allowed to touch the top surface of work rest as illustrated in fig.27. Then finally locking screws (Z4) are tightened and readings shown by the scales (Z3)is observed. The difference in the readings (indicated) is the inclination achieved.

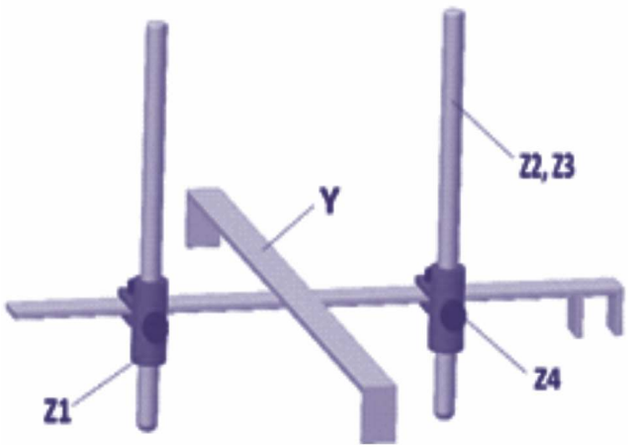


Fig.28 Angle finding attachment

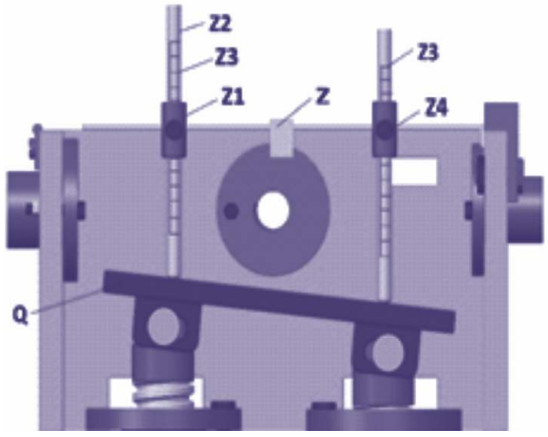


Fig.29 Application of angle finding attachment

7. SETUP PREPARATION

- Achieve proper height and/or inclination of work rest, by operating lifting screws with the help of angle measuring attachment. (refer fig.27)
- Advance all four horizontal clamps, towards the workpiece, and coincide geometric center of the workpiece with the geometric center of a tool with the help of center finding attachment. (refer fig.25)
- Locate bushes at desired P.C.D. by the altering center distance (radius) of sleeves from the center of the tool.
- Use special gauges or use special colour code, if that P.C.D.s were used frequently.

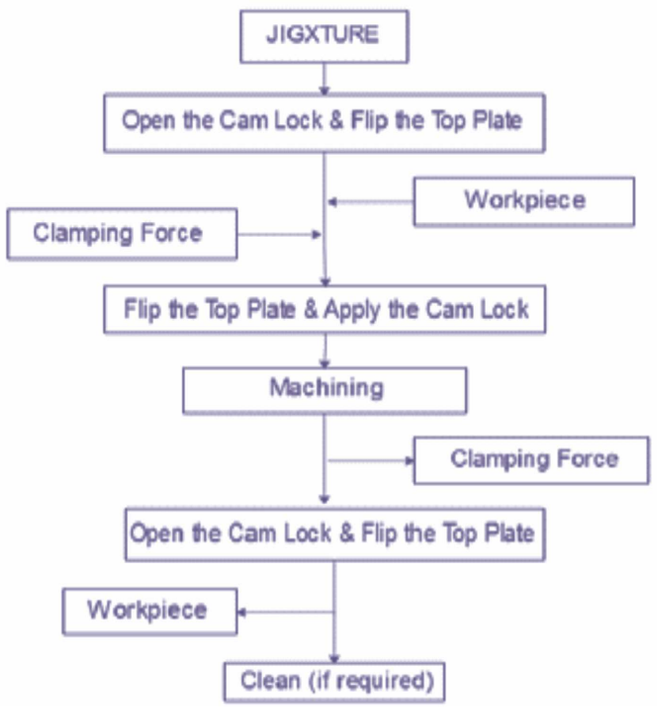
8. PRINCIPLE OF CLAMPING / LOCATING

When this tool is utilized, for the purpose of drilling [only] particularly when the jig aspect is put in to use. It is necessary to locate/clamp the part properly. To reduce the degree of freedom equals to zero. As well as to reduce vibration and deformation due to cutting forces. Traditionally the principle called "principle of 3:2:1" is used, for proper locating. Where 3, 2 and 1 no's of locators were placed at three mutually perpendicular surfaces. [6] But, in our case a new approach is implemented, which might work the same as the principle of 3:2:1 does. In this tool at two [mutually] perpendicular surfaces (at two sides of body, where small horizontal clamps were supposed to be) 2 and 1 (say 2:1) locators are being substituted by two plain locators (each at one surface), which are termed as clamp heads, in this paper. And for the third plane at bottom surface of the part (top surface of work rest) few solid locators (either a pin type or a button type) are mounted.

Number of locators and distance between the (considering all three P.C.D.s where holes are cut) (refer section 3.6) are chosen in such a manner that, an operator could place the workpiece on at least three or more locators. In order to embrace the center of gravity for stability. [25]

9. FLOW OF OPERATION

Since the top plate is removed in the case of milling shaping and grinding processes. Only follow the clamping/unclamping and loading/unloading operations. But in case of drilling refer to fig.30 for the flow of operation.



10. DIMENSIONS OF WORKPIECE

This tool is designed in such a manner that, the final assembly can clamp/locate/machine workpiece which has dimensions shown below.

- Outer most [maximum] dimension: 150 mm
- Lowermost [minimum]dimensions: 50 mm
- Maximum height/thickness of workpiece: 80 mm
- Range of P.C.D.: 80 mm to 120 mm
- Maximum permissible inclination: 30 degrees
- Maximum size of a central hole: 10 mm
- Maximum size of holes at the P.C.D.: 8 mm

11. DIMENSIONS OF THE TOOL "JIGXTURE"

Note: As the grade of material is not specified, due to the difference in the area of application for different users. Prescribed dimensions may alter a bit. Though one can use them for the purpose of reference.

11.1 Body

Fig.30 flow of operation

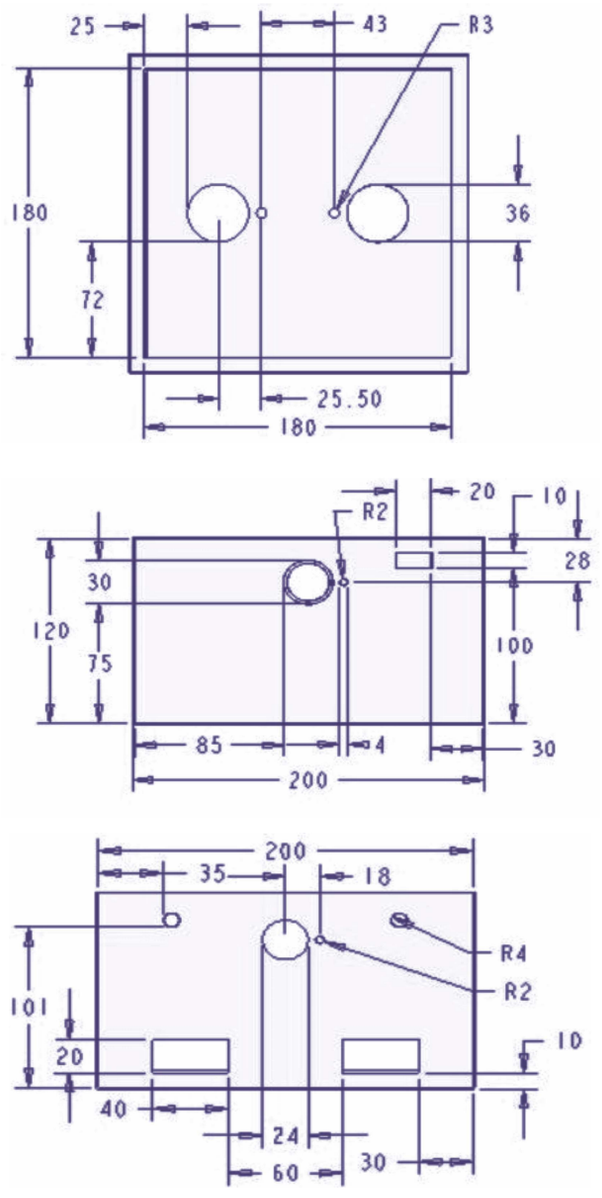


Fig.31 Body

11.2 Main plate

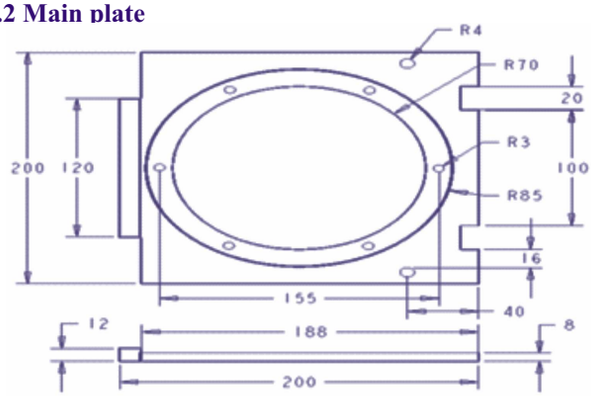


Fig.32 Main plate

11.3 Pressure plate

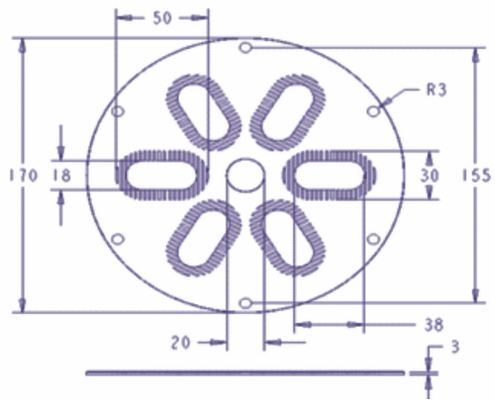


Fig.33 Pressure plate

11.4 Bush guide plate

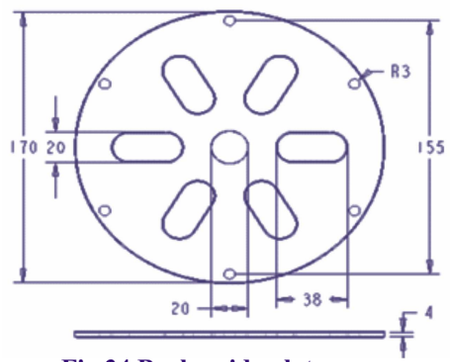


Fig.34 Bush guide plate

11.5 Lifting screw head

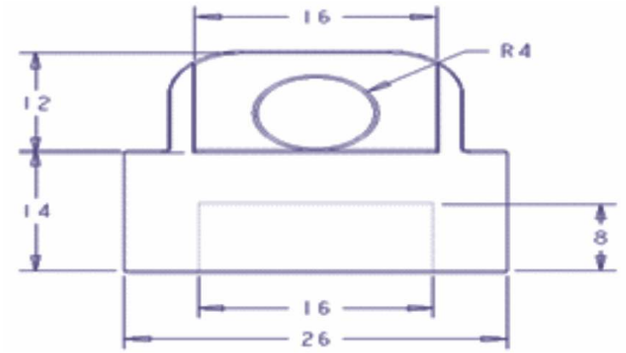


Fig.35 Lifting screw head

11.6 Collar nuts

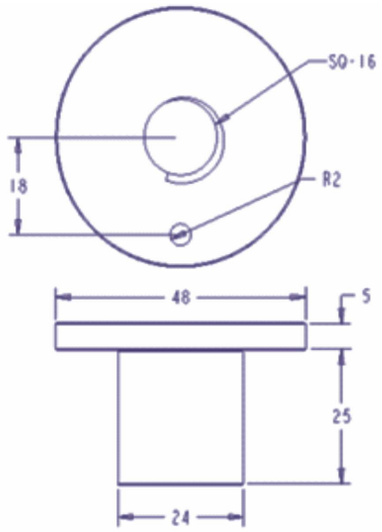


Fig.36 Collar nut [for smaller

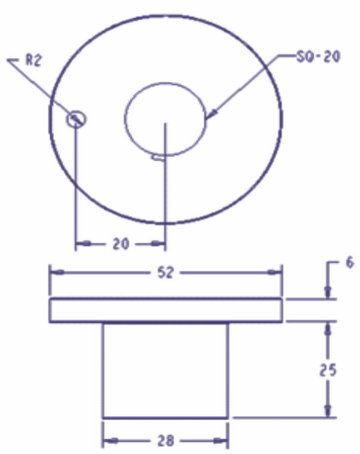


Fig.37 Collar nut [for larger clamps]

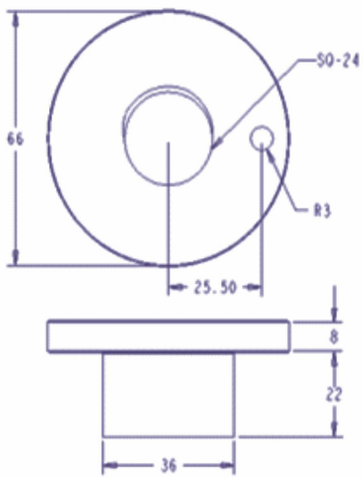


Fig.38 Collar nut [for lifting screws]

11.7 Work rest

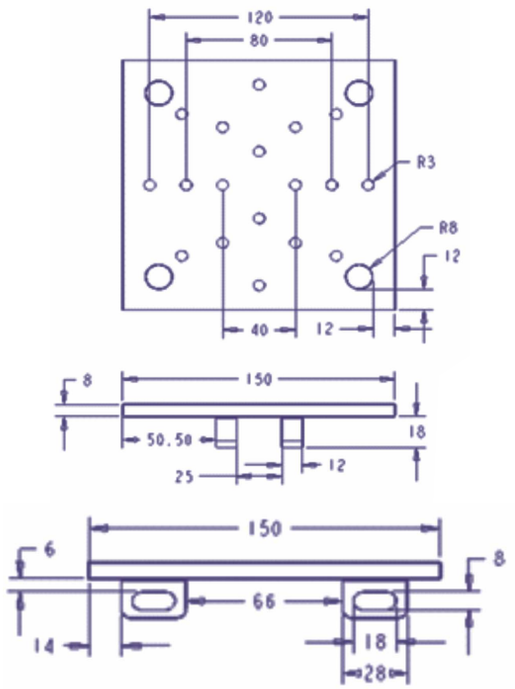


Fig.39 work rest

12. CONCLUSION

In this paper, the aim of our work is, to suggest an alternative option of standard jigs and fixtures. Which can eliminate their limitations like, no or less flexibility and smaller working range. After studying this paper, it can be observed that by the use of a top plate (section 3.3)the P.C.D. can be varied in the range of 80 mm to 120 mm. And use of work rest (section 3.6) along with clamping panel (section 3.4 & 3.5), enables this tool to clamp/locate parts, having maximum inclination of 30 degrees, and outer most dimension in the range of 50 mm to 150 mm (provided, the tool is manufactured as per the dimensions which are shown in fig28 to fig. 36). Thus having a working capacity, as shown by fig.37 (a) & (b).

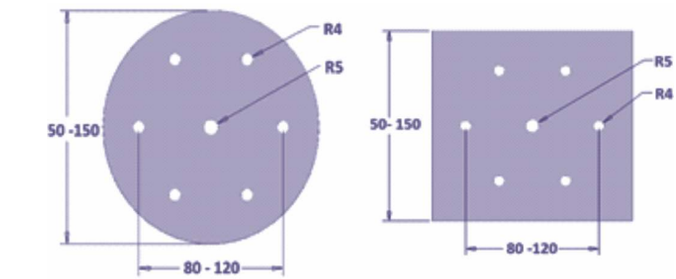


Fig.40 (a) & (b) working capacity

Hereby, it can be concluded that, the use of a proposed tool "jigxture" can reduce the tooling cost of a small production unit. And it is capable to make their production process more efficient and economical. As it eliminates the need to design and manufacture a unique fixturing system for each variety. And fulfils their almost every requirement within the single tool.

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APPENDIX 1

Table 1.Shorthand notations

A	Body	N	Lifting screw
B	Stand	O	Lifting screw head
C	Top plate [assembly]	P	Collar nut
D	Main plate	Q	Work rest [top plate]
E	Bush guide plate	R	Cam
F	Pressure plate	S	Top plate guide
G	Washer	T	Hinge 1 [top plate]
H	Sleeve/liner	U	Hinge 2 [cam lock]
I	Bush	V	Nut & bolts
J	Circular nut	W	Screw
K	Clamp	X	Pin
L	Clamp head [plain]	Y	Center finder attachment
M	Clamp head [swivel head]	Z	Angle finder attachment

Table 2. Detailed nomenclature

A1	Space for swarf removal	K1	External threads
A2	Space for cam adaptation	K2	Hand wheel
A3	Bigger hole for collar nut	L1	Internal threads
A4	Smaller hole for collar nut fixing	L2	Pressure pad
A5	Hole for top plate guide attachment	M1	Internal threads
A6	Threaded holes for hinge attachment	M2	Hemisphere
B1	Space for body attachment	M3	Pressure pad
B2	Bigger hole for collar nut	N1	External threads
B3	Smaller hole for nut & bolt attachment	N2	Hand wheel
B4	Material removed to reduce weight	N3	Projection
B5	Space for fastening with table	O1	Projection
D1	Central recess	O2	Hole [for pin]
D2	Annular recess	O3	Hole [for lifting screw]
D3	Space for top plate guide projection	Q1	Throughout holes
D4	Threaded hole for hinge 1 attachment	Q2	Holes for solid locators
D5	Threaded hole for hinge 2 attachment	Q3	Projections
D6	Hole for nut and bolt attachment	Q4	Recess in projection
E1	Hole for nut & bolts	R1	Short handle
E2	Profile for bush guiding	R2	Cam profile
E3	Central hole	Y1	Strip 1 [vertical]
F1	Hole for nut & bolts	Y2	Strip 2 [horizontal]
F2	Profile for bush guiding	Y3	Bended ends
F3	Central hole	Y4	Calibrations [both strips]
F4	Indentations	Y5	Symmetrical holes
G1	Projections	Z1	Rod guides
H1	External threads	Z2	Rods
H2	Sleeve bore	Z3	Calibrations [rod]
H3	Collar/head	Z4	Locking screws

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