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Design of cam geometry for minimization of fillet radius effect in square hole drilling operation

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Abstract-Square hole found many applications in various areas like wood, marble and metal work for different purposes. There are many methods available to make square hole as discussed in this work. But making a square hole with drill operation is a different concept as in this concept reuleaux triangle type cam is used to make a square hole. But with using this type of cam we can produce almost square hole not exact square hole because there is left a fillet radius on each corner of square which required further operation. To overcome these problem different types of modified cam are introduced in this work.

Keywords: Square hole drill, fillet radius, Reuleaux triangle, Cam Geometry

I.INTRODUCTION

Hole serves various purposes in any machine element. These holes may be round, square, rectangular or any other shape depending on the requirement. For round holes, the machines are available in the market. But for square or any other type of holes, the Methods presently used are broaching, electrode-discharge machine (E.D.M.), and electro-chemical machine. These are very expensive and require special tools or machinesIn square hole drill operation we can make square hole using reuleaux triangle tool with universal joint mechanism.The shape of the reuleaux triangle can be used to drill a (nearly) square hole. The triangle rotating about an axis through its centre and the axis itself tracing a curve as shown Figure 1.

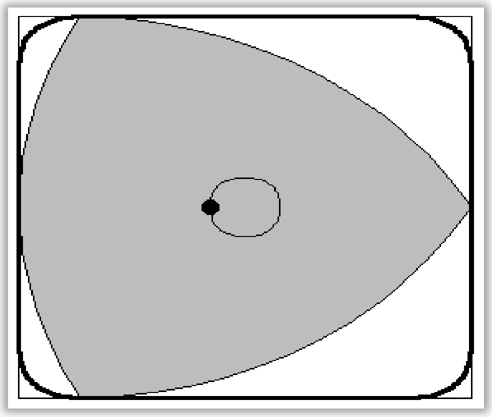


Figure 1. Reuleaux triangle [1]

The reuleaux triangle is a constant width curve based on an equilateral triangle. All points on sides are equidistance from opposite vertex and its trajectory of these points can be shown in follow (Figure 2).Suppose we want to do drilling a square hole operation on a flat plate of any straight edge, the flat side on which we want to do the square drilling operation, we have to place the work piece on the work piece holder so that the face near to that cutter remains on each of the faces of the work piece.At the time switch on the hand drill machine. When hand drill starts properly, slide the reuleaux casing on the sliding bars. Thus by cutter the square drilling operation on the work piece is to be done. (Figure 3)**.**

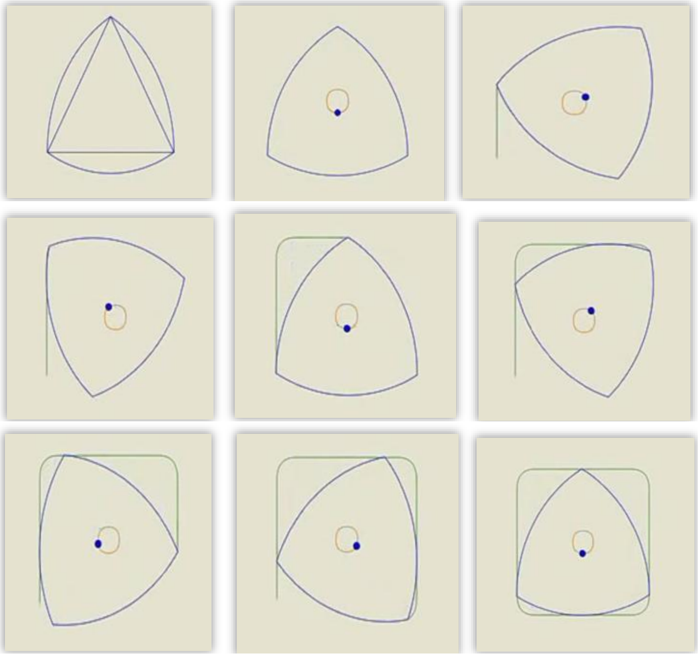


Figure 2. Trajectories of reuleaux triangle

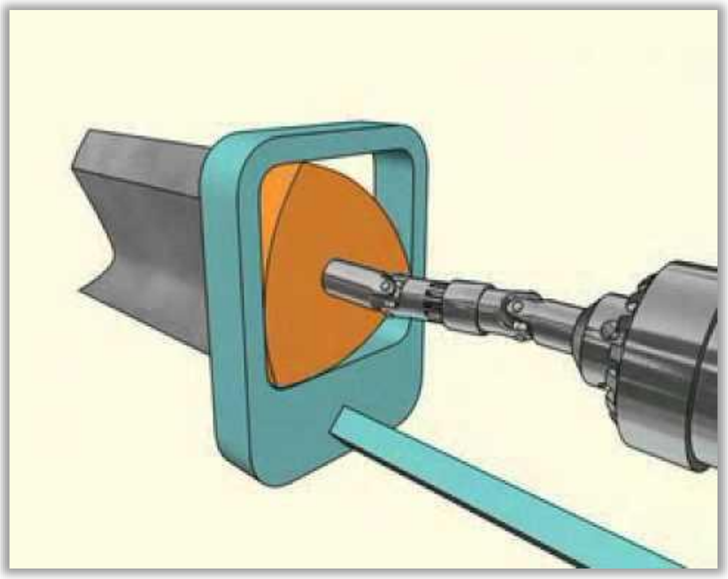


Figure 3 Square hole drilling operation

II. VARIOUS METHODS TO MAKE SQUARE HOLE

According to, the Mr. R. G. Sparber [1]there is four basic approaches to making square hole,

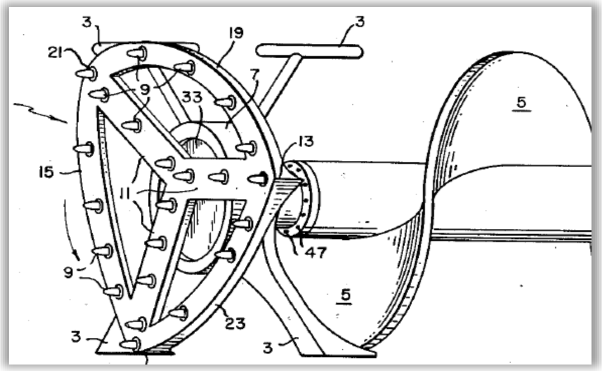
1. Only remove material (drilling then filing).
2. Only add material (Flip one bar over, and bolt or weld them together).
3. Remove and add material (bolting or welding together bits of square stock).

4. Reshape Existing Material (piece of stock having square shape on one end while taper shapeon the otherend. Then inserted it into the round hole which was made by drill previously).

While, Mr. Barry Cox and Stan Wagon[2]investigate how one can turn circular motion into square motion by a purely mechanical linkage; an application is to the construction of a drill that drills *exact* square holes. They conclude with an extension of this idea to a drill that drills hexagonal holes. They showed that A Reuleaux triangle is a shape made from arcs of circles centered at the vertices of an equilateral triangle. It has constant width. When rotated inside a square, each vertex traces a curve that is almost a square. If one makes a cutting tool at each vertex (by cutting away part of the device so as to have a sharp end at each vertex) then this shape can be used to make a working drill that drills almost-square holes. Mr.Gurpreet singh heer [3]has done design and fabrication of square hole drill machine. He makes special type mechanism that involves the use of special floating chuck, which allows the drill to wobble and a guide plate which guides the drill to make the square shape of cavity Cutting is done by the ends of the drill as with straight flutes. The rotary motion from drilling machine is transmitted to floating chuck which provides floating type motion which allows wobbling the drill and helping in making corner of square hole. cam provide exact size of the hole.The major improvement in the accuracy can be attained during manufacturing and drill point geometry, along with the shorter and stiffer drill due to which it produces accurate size of hole.According to Mr. Scott G. smith [4] reuleaux triangle is the basis of a tool that produced holes with an almost square cross-section which is most recently used. In this method, the reuleaux triangle rotates smoothly within a square housing, the three cutting bits trace out a curve that is almost, but not exactly, a square hole. He showed various mathematical formulas to represent the path of reuleaux triangle which is not circular but nearer about square. He is showed various position of reauleaux triangle in different quadrant with help of mathematics.

III. VARIOUS DRILL BITS (CUTTERS) USED TO MAKE SQUARE HOLE

Mr.Roger J. Morrell [5] introduced square hole drill having a cutter (Figure 4) head configuration whose outline is in the form of a Reuleaux triangle and which also has a planetary gear drive. Two counter revolving motions are present in the drill at the same time. One is the pure rotary motion of the drill's cutter head about its own shaft. The other is the circular motion of the cutter head as a unit about a center line due to its eccentric mounting and drive.



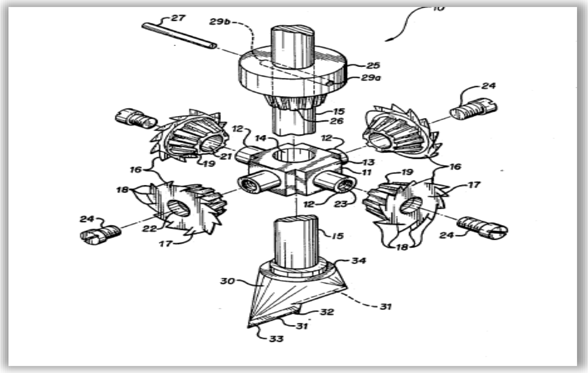


Figure4. Reuleaux type drill cutter[5]***Figure 5. Disassembled type drill cutter[6]***

Mr. Erick A. Sandoval [6] provides a square holecutter (Figure. 5) that can be completely disassembled into its individual moving parts. It is one object of this invention to provide a square hole cutter that has all the individual moving parts attach to a central hub position. It is another object of the this invention to provide a square hole cutter that has unitary one piece rotary cutters that attach directly onto the central hub. There is an additional object of the this invention to provide a square hole cutter that has a central rotation gear that is slide by disposed over the central rotating shaft.

IV. ANALYTICAL CALCULATION OF CAM GEOMETRY OF REULEAUX TRIANGLE

Consider a reuleaux triangle of equilateral sides S (Figure 6) then applying the property that the centroide is 2/3 the distance from a vertex to the opposite sides gives as follows,

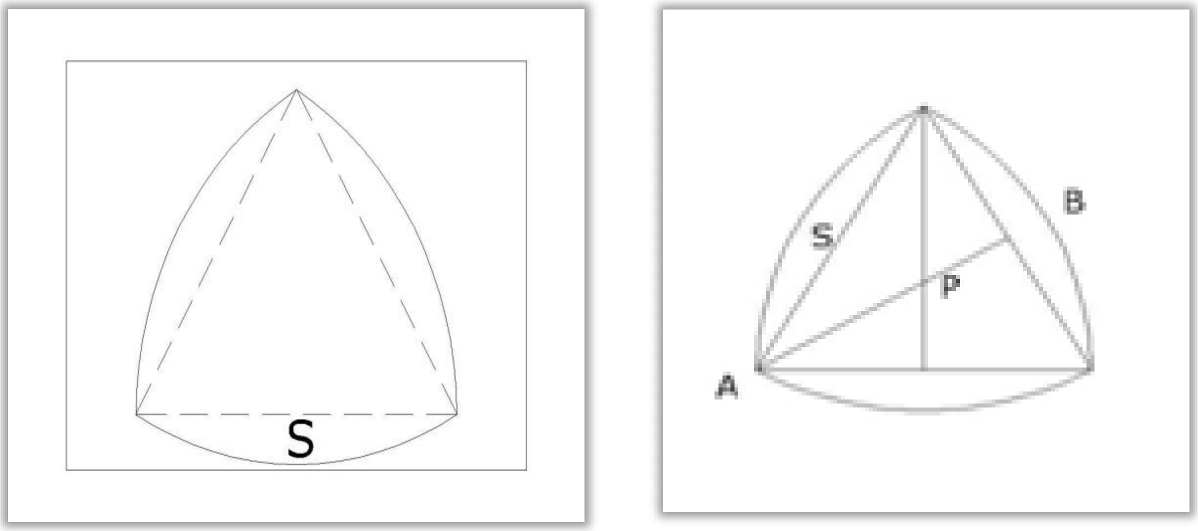


Figure 6. Centroid of reuleaux triangle

$AP = \frac{2}{3} \times \frac{S}{2} \times \sqrt{3}$

$= \frac{\sqrt{3}}{3} \times S$

$= 0.577S$ Where, S (side of reuleaux triangle)

$PB = S - \frac{\sqrt{3}}{3}S$

$= S\,(1 - \frac{\sqrt{3}}{3})$

$= 0.423S$

V. KINEMATICS OF REULEAUX TRIANGLE

The construction of a RT involves the frame of an equilateral triangle 123 of side length *s*, the sides of which are replaced by circular arcs 12, 23 and 31 of identical radius *s* that are centered on vertices 3, 1 and 2, respectively. TheRT can rotate inside a square, and as it rotates (Figure 7)

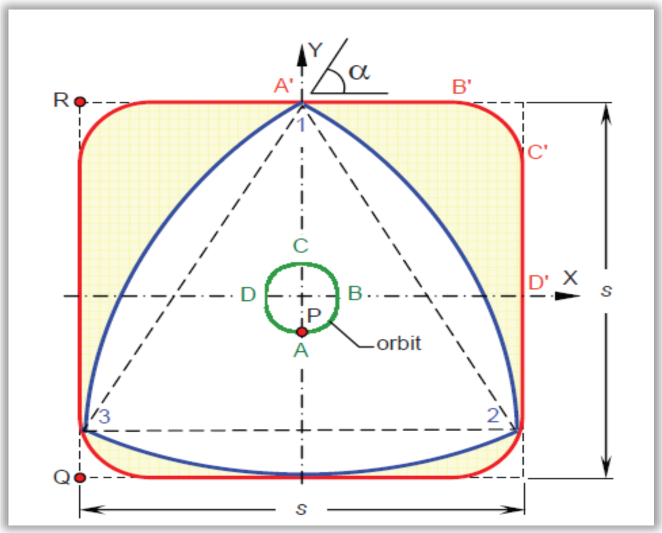


Figure 7 Construction of reuleaux triangle

Clockwise such that vertex 1 traverses the first quadrant, it traces the path A,B,C,D. Segments A,B and C,D are linear while segment B,C is part of an ellipse with its major axis oriented at 45° to the X-axis and centered at point Q in the third quadrant is located at A. The clockwise motion of vertex 1 along A, B, C and C, D corresponds to the counter clockwise motion of P along AB, BC and CD, respectively. Each of these segments that constitute the orbit is part of an ellipse; for instance, path AB is part of an ellipse with its major axis oriented at 135° to the X-axis and centered at point R in the fourth quadrant. Path AB of centroid P is defined by the parametric equations

$$\text{Xp}=S*\frac{-3+\sqrt{3}COS\,\alpha+3\text{SIN}\,\alpha}{6}\text{Yp}=\text{S}*\frac{3-3COS\,\alpha-\sqrt{3}\text{SIN}\,\alpha}{6}$$

where α is the angle between the side of the equilateral triangle and the linear segment traced ,which varies from 60° to 30° as P moves from A to B,corresponding to vertex 1 translating from A to B.Segments BC and CD of the orbit can be obtained by symmetry. For every complete rotation of the RT inside the square, its centroid therefore orbits thrice in the opposite direction.

VI. DESIGN AND SELECTION OF CAM GEOMETRY OF REULEAUX TRIANGLE

Design and selection of cam geometry of reuleaux triangle and compared with existing one and the alternative or modified cam geometry of reuleaux triangle are chosen for best result.

4.1 Existing cam geometry of reuleaux triangle

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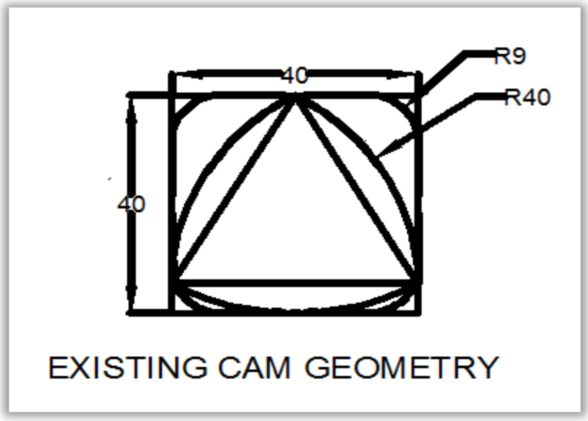

Figure 8. AutoCAD drawing of existing cam geometry *Figure 9. Actual existing cam geometry*

Figure 10. Contact between cam and follower *Figure 11. Square hole with existing cam geometry*

4.2 Modified cam geometry of Reuleaux triangle

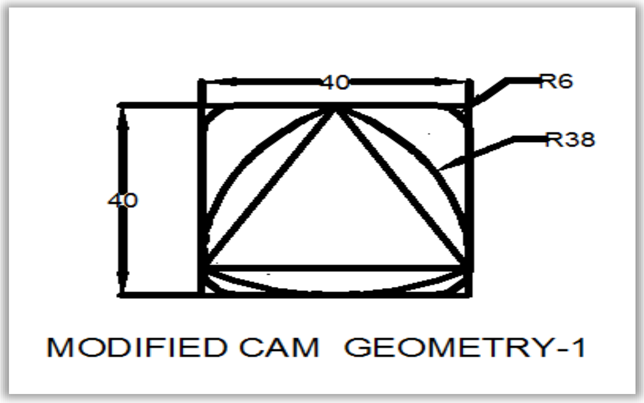

Figure 12. AutoCAD drawing of modified cam geometry *Figure 13. Actual modified cam geometry*

Figure 14. Contact between cam and follower

Figure 15.Square hole with modified cam geometry

4.2 Construction of Modified cam geometry of Reuleaux triangle

The modified shape comprises three circular arcs (Figure 16) that replace the sides of an equilateral triangle of side *s*, but the arcs are of radius *ks* rather than *s* in the case of the reuleaux triangle, where *k* is a constant that works out to be 1.93 for the included angle to be 90°.This is not a shape of constant width but can rotate within a square and generate sharp corners

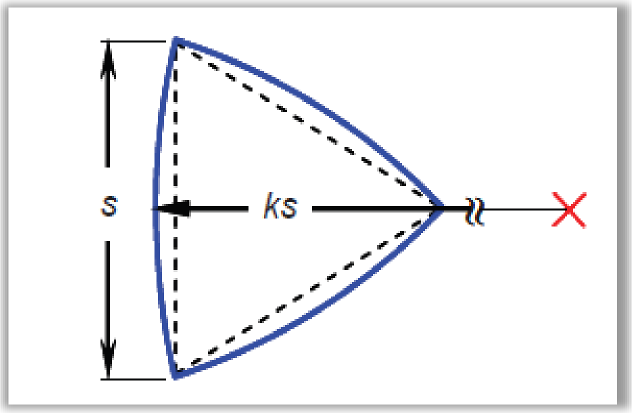

Figure 16 Construction of modified cam geometry of reuleaux triangle

4.3 Comparison between existing andmodified cam geometry of Reuleaux triangle

Square hole done by existing cam geometry

Each equilateral side of reuleaux triangle = 40 mm

Radius opposite to each vertex of reuleaux triangle = 40 mm

Fillet radius on each corner = 9 mm

Total radius of each corner = 9*4 =36 mm

Square hole done by modified cam geometry

Each equilateral side of reuleaux triangle = 40 mm

Radius opposite to each vertex of reuleaux triangle = 38 mm

Left fillet radius on each corner = 6 mm

Total radius of each corner = 6*4 =24 mm

So, that total minimization of radius = 12 mm

V. CAM AND FOLLOWER DISPLACEMENT DIAGRAM

With allocating different point on cam geometry of reuleaux triangle we can get its co-ordinate of X and Y axis from the center of reuleaux triangle. We can also get the position of follower on different point on cam geometry of reuleaux triangle. Table no.1 to 2 shows the various position of point on X and Y axis, follower height distance of existing, modified cam.

Table 1 Various position of point on X and Y axis, follower height distance of existing cam geometry of reuleaux triangle

Point on cam profile	X-coordinate	Y-coordinate	Follower height
1	0	23.17	23.40
2	6.73	18.27	19.75
3	11.34	13.44	17.75
4	14.66	8.46	17.12
5	17.19	2.87	17.75
6	19.02	3.43	19.75

Table 6.2 Various position of point on X and Y axis, follower height distance of modified cam geometry of reuleaux triangle.

Point on cam profile	X-coordinate	Y-coordinate	Follower height
1	0	23.17	21.40
2	6.73	18.27	17.75
3	11.34	13.44	15.75
4	14.66	8.46	15.12
5	17.19	2.87	15.75
6	19.02	3.43	17.75

By using data of above table displacement diagram of cam and follower for existing, modified can draw as follows.

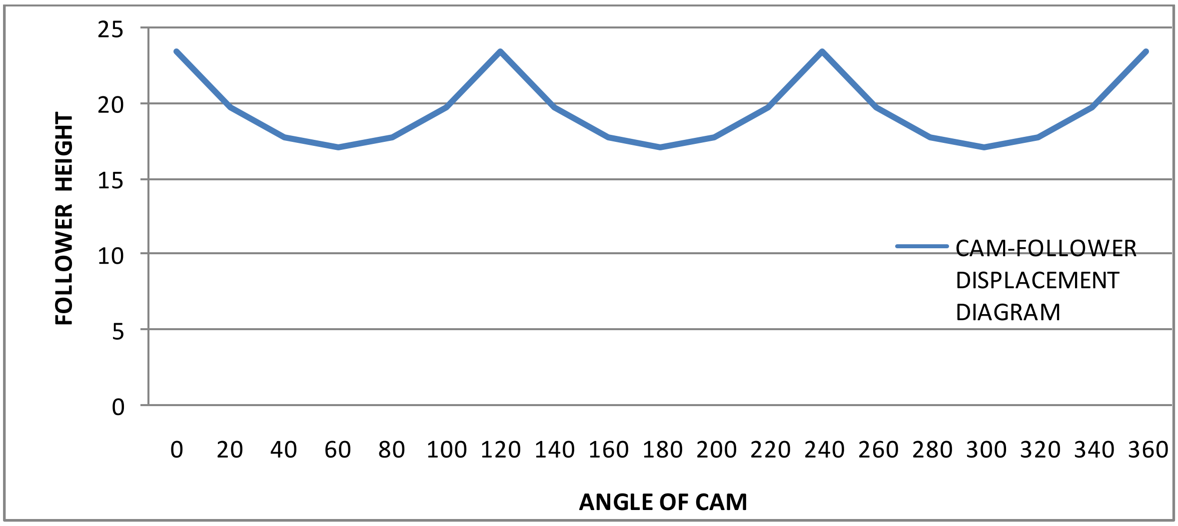

Figure 17.Cam –follower displacement diagram of existing cam.

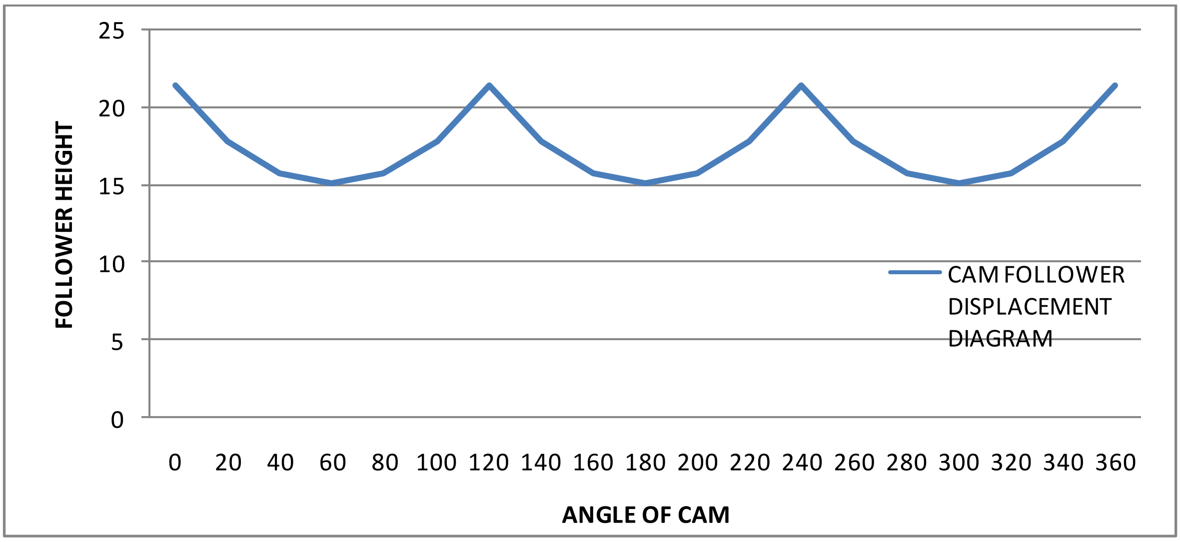

Figure 18.Cam –follower displacement diagram of modified cam.

From the above diagram it can show that, displacement diagram of modified cam differs compare to existing cam as it is shows that cam rotation is more nearer to the follower its result in more contact of cam and follower in corner .so that, tool will travel more nearer to the corner and cut the fillet radius of corner of square hole.so that it will decrease the distance betwwen cam and follower in corner esult in improve sharpness of corner compae to above two cam.

VI.CONCLUSION AND FUTURE SCOPE

From above work, we can conclude that with minimizing radius of reuleaux triangle will improve the contact between cam and follower which result in reduce fillet radius in work piece. With reference to the above data it shows that with using above modified cam geometry of reuleaux triangle reduced radius about 12 mm (33.33%) compare to existing cam geometry of reuleaux triangle. With this background, further explorations into this work might include studying other figures of constant width, identifying further the curve of the Reuleaux triangle's centers it cuts a square; and noting the shape of bits for pentagonal, hexagonal, and octagonal holes.

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