ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

INVESTIGATING THE INFLUENCE OF PROCESS PARAMETERS ON THE PRECISION MACHINING OF SQUARE HOLES FOR INDUSTRIAL APPLICATIONS

Laishetty Radhakrishna[1], Dr.A.Seshu Kumar[2], Dr.A.Krishnaiah [3]
[1]Research Scholar, Osmania University, Hyd & Asst.Professor, Balaji Institute of Technology & Science, Wgl
[2] IICT Scientist, Hyderabad, 3 Professor, UCE, Osmania University, Hyderabad

Abstract:
Generally, the holes which are drilled by drilling machines are circular, it produce the circular drills in different diameters, but to produce a square have to do many operations like slotting, tapering. The main aim of the project is to produce the square in one single step without using multiple tools. The square drill is a drill bit which is designed from the Reuleaux triangle. A drill bit that produces square holes, It can a revolving edge cut for pentagonal, hexagonal, and octagonal holes, but they derive their shape from a simple geometric construction known as a Reuleaux triangle. A square hole drill having a cutterhead 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 cutterhead about its own shaft and other is the circular motion of the cutterhead as a unit about a centerline due to its eccentric mounting and drive. To achieve the opposite rotation of the unit as a whole compared to the rotation of the cutterhead about its own axis. The rotation is obtained by a flexible shaft which is designed by a series of universal joints to the drill bit.
Key words: Reuleaux triangle, Universal coupling, Drilling machine, square hole, eccentric

1. Introduction

A drill bit that produces square holes is seemingly counterintuitive, as it is commonly understood that a revolving edge can only cut a circular hole. However, there are drill bits that can produce other shapes of holes, such as pentagonal, hexagonal, and octagonal, which are derived from a geometric construction known as a Reuleaux triangle. This triangle is named after Franz Reuleaux. To construct a Reuleaux triangle, one must start with an equilateral triangle of sides with a radius equal to s and the center at one of the vertices. Then, arcs must be drawn connecting the other two vertices of the triangle, and similarly, arcs must be drawn connecting the endpoints of the other two sides. The three arcs together form the Reuleaux triangle. One of the notable properties of this triangle is its constant width, which means that the figure can be rotated entirely between two parallel lines separated by distances and always be tangent to each line.

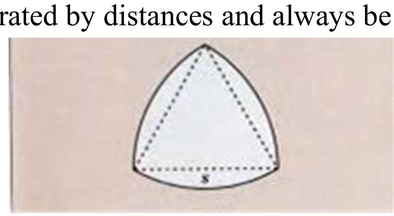


Fig: Reuleaux triangle

The property of constant width introduced the Reuleaux triangle in a sidebar of our geometry textbook. This figure, like a circle, has constant width. When I shared the idea of the Reuleaux

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

triangle as wheels on a cart, a student asked about the type of cart. I responded by saying that it was a math cart to carry my board, compass, and protractor, although this was an impulsive statement that I later admitted to being in error. My intuition had failed me completely for the first time in twenty years of teaching. The constant-width property of the Reuleaux triangle can be used to transport loads, but not by using it as wheels. If several logs had congruent Reuleaux triangles as cross sections, bulky items could be rolled on top of a base made of them. Movement would occur as logs were transferred from the back to the front, providing a movable base of constant height. It has been suggested that the Egyptians used a similar method to move the massive stone blocks for the Great Pyramids. However, the Reuleaux triangle cannot be a wheel because the only conceivable point for the axle, at the center of the triangle, is not the same distance from the Reuleaux triangle's "sides."

Holes serve various purposes in machine elements, and their shape depends on the requirement. While machines are available for round holes, methods for creating square or other shaped holes such as broaching, electro-discharge machine (E.D.M.), and electro-chemical machine are expensive and require special tools or machines. However, for drilling square holes, a Reuleaux triangle tool with a universal joint mechanism can be used. The Reuleaux triangle, based on an equilateral triangle, can be used to create a nearly square hole. The triangle rotates about an axis through its center, and the axis itself traces a curve. This curve is the Reuleaux triangle, which is a constant-width curve where all points on the sides are equidistant from the opposite vertex. To perform a square hole drilling operation on a flat plate with a straight edge, the workpiece must be placed on the workpiece holders so that the face near the cutter remains on each of the faces of the workpiece. Once the hand drill machine is switched on and starts properly, the Reuleaux casing must be slid on the sliding bars to perform the square drilling operation on the workpiece using the cutter.

2. Literature

Annabathina Srikanth et al.[1] This paper presents design, simulation and fabrication of drill chuck for making square holes. This drill chuck is also called free floating chuck. There are many methods available to make square holes. A Reuleaux type drill bit is one method to make a square hole. The Realeaux drill bit contains three flutes. Drill bit centre point is rotated about the axis of the spindle and freely movable in the plane perpendicular to.the axis of the spindle. Drill chuck contains the components like Morse taper shank, ball joint universal couplings, rolled steel rods, mild steel plates, outer shell, and drill bit holder or front hub NX8. software is used for modelling, simulation and analysis of drill chuck. Drill chuck is fabricated and tested. Mild steel is used to fabricate the different components of drill chuck.

R.D.Gohil et al. [2] 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 holes as discussed in this work. But making a square hole with drill operation is a different concept as in this concept reuleaux triangle type drill cutter is used to make a square hole. But with this type of cutter we can produce almost a square hole, not an exact square hole, because there is a fillet radiu on each corner of the square which requires further operation. To overcome these problems

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

different types of drilling cutters are introduced in this work. Keywords: Square hole drill, fillet radius, Reuleaux triangle, floating chuck.

N. G. Lokhande et al. [3] Applications such as in the defence sector, manufacturing of grenade fuse required angular holes on fuse body, producing holes in turbine blades for the aerospace industry, generating micro-holes in diesel fuel injection nozzles etc requires angular drilling. Trepanning, gun drilling are the operations available for drilling at specific angles, but they can be useful when drilling angle should be less than 10 degree. The job having a cylindrical shape and number of holes are required on it at an angle is a challenging task for a design engineer and hence Computer Aided Fixture Design (CAFD) is incorporated in the manufacturing industry. It deals with the integration of CAD and CNC programming in CAM systems using softwares for fixture design. Except V block, no other option is available to hold cylindrical objects and hence special type of fixture is designed for this case, which can be used for angular drilling. In this paper, a literature survey of computer aided fixture design and automation over the past decade is proposed. First, an introduction is given on the fixture applications in industry. Then, significant works done in the CAFD field, including their approaches and customer requirements are discussed.

John Thomas et al.[4] The mechanical design and of a square hole producing tool based on Reuleaux Triangle.The main aim of our paper is to investigate how the circular motion can be converted into a square motion by purely a mechanical linkages; an application of which is to construct a special tool that drills exact square holes. The geometrical construction that fulfils the laid objective is Reuleaux Triangle. Additionally, for this geometry to work like a rotating drive (such as a drill press) must force the Reuleaux triangle to rotate inside a square, and that requires a square guide to constrain the Reuleaux triangle as well as a special coupling to describe the fact that the centre of rotation also in moves within in the constraint. The practical importance of this enhancement is that the driving end can be placed in a standard drill press; the other end is restricted to stay inside the fixed square, will yield a perfectly square locus and this can be turned into a working square-to-drill hole.

Rohit G. et al.[5] The main aim of this paper is to produce square holes by converting a circular motion into square by using mechanical linkages such as flexible coupling, guiding mechanism and Reuleaux triangle. Flexible coupling allows the Reuleaux triangle to rotate in an eccentric manner to produce a square hole. The Reuleaux triangle is restricted to stay inside the square guide, and that will create a perfectly square locus and this can be turned into a working square hole drill. In actual practice the driving end is connected to the vertical drilling machine and the driven end is assembled with a special drill bit. Key words: Reuleaux triangle; Flexible coupling; Special drill bit; Vertical drilling machine.

D.L.Shinde et al. [6] This paper describes producing square holes in the industry, is very common and useful and at the same time along with problems such as high cost complexity of manufacture. There are a number of machine tools producing round and taper holes. But many Engineering components require square and non-circular holes. At present square and other non-circular holes

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

are produced using CNC machines or spark erosion or slotting machines. But there is no quality machine tool to produce square and polygon holes at minimum cost.

3. Components

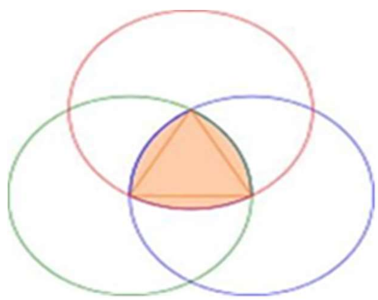
Reuleaux Triangle

The boundary of a Reuleaux triangle is a constant width curve based on an equilateral triangle. All points on a side are equidistant from the opposite vertex. The geometric centroid does not stay fixed, nor does it move along a circle. In fact, the path consists of a curve composed of four arcs of an ellipse. For a bounding square of side length, the ellipse in the lower- left quadrant has the parametric equations.

Supporting Member

HP Motor

Horsepower (hp) is a unit of measurement of power, or the rate at which work is done, usually in reference to the output of engines or motors.

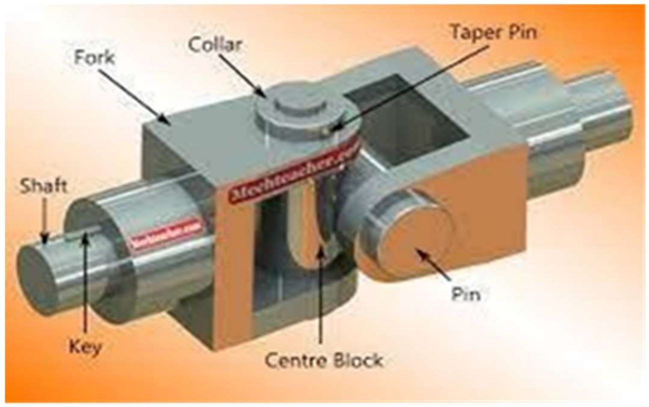


Reuleaux Triangle

Universal Joint

A universal joint (also called a universal coupling or U-joint) is a joint or coupling connecting rigid shafts whose axes are inclined to each other. It is commonly used in shafts that transmit rotary motion. It consists of a pair of hinges located close together, oriented at 90° to each other, connected by a cross shaft. The universal joint is not a constant velocity joint.

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)



Universal Joint

It is required that the Reuleaux triangular shape of the drill bit to be rotated in the square guide by touching its side. It will cause the drill bit to rotate in the same motion as of the Reuleaux triangle and as a result a square hole can be drilled on the work piece. The square guide is required to navigate or guide the drill bit in square shape motion with the help of Reuleaux triangle and universal coupling. The square guide is as shown in the following figure.

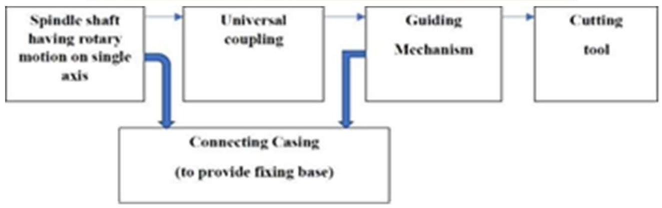
Fig:HP Motor

4. Working Principle

The square hole drilling machine operates on the principle of the Reuleaux triangle. According to this principle, when a Reuleaux-shaped cam is rotated within a square guide, it can convert the rotational motion of the shaft and rotor into a guided square motion. The rotary motion is typically imparted by a motor or hand drill. To achieve the necessary eccentric rotation of the shaft, a universal coupling is employed. This coupling ensures that the shaft rotates at a distance from the center of the motor chuck.

The eccentric motion of the shaft enables the Reuleaux triangle-shaped cam to rotate within the square guide. This arrangement allows the drill bit to reliably rotate within the guide, facilitating the drilling of a square-shaped hole on the workpiece. In summary, the Reuleaux triangle principle, coupled with the eccentric rotation provided by the universal coupling, enables precise and controlled drilling of square holes using the square hole machine.

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)



Block diagram of square Hole drilling machine

5.Mathematical Model for developing tool

Drill bit

Where (h) is perpendicular line tangent to trajectory curve, (k) is a constant and (ϕ) is the angle between horizontal axis and (h) line. Family of tangents be given

$$F(x, y, \phi) = x.\cos\phi + y.\sin\phi - h(\phi)$$

To different forms by choosing h(ϕ), equations are obtained of the assortment curves of constant width. Where h(ϕ), , by choosing h (ϕ) =1, equation is obtained for the simplest curves of constant width, the circle. By

choosing $h(\phi) = a.\cos2(3\phi) + b$, the curve width would be equal to a+2b

"Equation can be written":

$(\phi) = (a/2\cos3\phi + a/2 + b) . \cos\phi + 3a/2 \sin3\phi. \sin\phi$

$(\phi) = (a/2\cos3\phi + a/2 + b). \sin\phi - 3a/2\sin3\phi. \cos\phi$

By using above equation varying a & b value getting the tool drill bit profile

Figure: Tool drill bit

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

Determine residual area:

The following process parameters to effect on the exact geometry of square shape

1. Side length of drill bit
2. outer radius of drill bit
3. Angle between the two axes of coupling

The determination of the cutting area percentage involves establishing a ratio between the effective cutting area and the total area encompassed by the given form. In this scenario, the envisaged form is a square. However, achieving a complete cut is hindered by minute areas located at the four corners of the square. These particular zones fall beyond the operational reach of the cutting tool and necessitate precise calculation.

The cutting area percentage=(area of square shape − 4 * residual area at the corner) divide by area of square shape* 100

The entire mechanism lies a pivotal component, upon which the entire functionality depends. This particular element is tasked with the precise tracing of a square and executing material cuts in accordance with its orchestrated movements. The foundational geometry of the cutting tool aligns with the guiding Reuleaux shape, yet it undergoes subsequent modifications to incorporate a safety margin for specific cutting parameters.

S.no	Side length	Outer radius	Angle	Residual Area
1	30	17.4372	45^0	2.6678
2	30	17.942	30^0	2.8562
3	30	18.3528	15^0	2.9673
4	31	17.4372	30^0	2.8543
5	31	17.942	15^0	2.9678
6	31	18.3528	45^0	2.9463
7	32	17.4372	15^0	2.8563
8	32	17.942	45^0	2.7987
9	32	18.3528	30^0	2.8003

Table: Residual Area of various parameters

For different area side length, Angle between two axes between the two axes of universal coupling then the finding residual area by using design software shown in table.

6. Fabrication and Assembly

As per the design calculations, the various parts are selected and assembled together to get the final product.

The mail parts of assembling

1. Universal Couplings 2. Guide ways
3. Tool profile 4. Shaft 5. Motor
6. Supporting elements

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

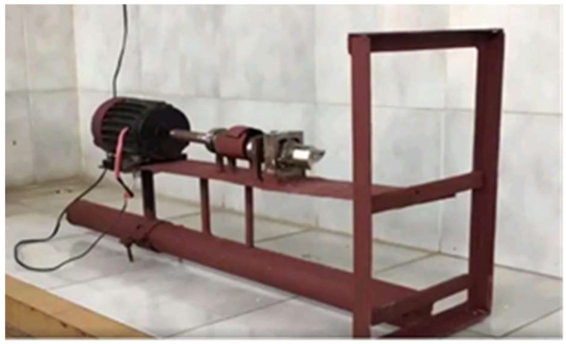


Fig: Model of square drilling machine

7. Result

- The drilled hole obtained is 98 % square geometry shape
- The Reuleux triangle principle is successfully implemented to obtain square hole on a drilling machine.
- Due to excess vibrations the tool runs a little out of the predefined path which resulted into 2 to 3% error in the drilled hole size.
- As the foundation of the machine is not fixed the vibrations occurred are more

.

8. Conclusion

After conducting a series of illustrations and trial runs on the work piece, we have determined that drilling a square hole using a vertical drilling machine arrangement is indeed feasible. The circular motion generated by the motor or hand drill machine can be effectively converted into a square action through the use of a flexible coupling. This conversion process has resulted in achieving an impressive 98% square shape hole. However, through consecutive trials, we have identified certain modifications that are essential to achieve a 100% success rate in implementing this concept.

Found that a preliminary drilling of a circular shape on the work piece is necessary before shaping it into a square. Additionally, due to the considerable vibrations produced during the drilling process, it is imperative to ensure a robust and secure fixation of the machine base.

Improvements in the tool design can contribute to better results. Specifically, extending the length of the Reuleux triangle-shaped shank of the tool could prove beneficial. Moreover, incorporating a guide support that restricts the motion of the tool within the guide can prevent it from running out of alignment. To address this, we have introduced another guide plate to effectively constrain the motion of the tool, enhancing the overall stability and precision of the drilling process.

9. References:

1.Annabathina Srikanth, S. Sreekrishna and VBS. Rajendraprasad, “Design and Fabrication of Drill Chuck for Making a Square Hole”, Journal of Material Science and Mechanical Engineering (JMSME), Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 5; pp. 375-380,April-June 2015

2.R.D.Gohil, M.S.Kagathara, “Review on Design of Cam Geometry for Minimization of Fillet Radius Effect in Square Hole Drilling Operations”, International Journal for Research in

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

Technological Studies| Vol. 1, Issue 5, | ISSN (online): 2348-1439, April 2014

3. Prof.D.L.Shinde, Sagar Mhaisagar, Ganesh Nagare, Sagar Mergal, Suraj Nalawade, "Design And Fabrication Of Square Hole Drilling Machine", Volume 2, Issue 6, IJSRD | ISSN: 2455-2631, June 2017

4. N. G. Lokhande, C.K. Tembhurkar, "International Journal of Engineering Research and Applications (IJERA)" ISSN: 2248-9622, www.ijera.com Vol. 2, Issue 3, 2, pp.1100--1104 1100 | P a ge e,Advanced Fixture for Angular Drilling on Cylindrical Objects, May-June 2012

5. Rohit G, Kamble Manoj Y, Chougule Rohan K, Churi Sanjay R, "Design and Development of Special Tool to Produce Square Hole" International Journal for Scientific Research & Development| Vol. 4, Issue 01, | ISSN (online): 2321-0613, 2016

6.John Thomas, Ronald Pauly, Sachin Peter, Vasyan K S, Bezaleel Sebastian, Anto Zacharias, "Design and Fabrication of Square Hole Drilling Machine", Journal of Engineering Research and Application, www.ijera.com ISSN : 2248-9622, Vol. 6, Issue 11, (Part -1) November 2016, pp.75-79,

7. Chawla A, Sharma A, "Advancements in square hole drilling machines", International Journal of Advanced Research in Mechanical Engineering and Technology, 2(2), 25-34, (2015)

8. Garg R, Rana M, "A review of the drilling processes in square hole drilling machines".International Journal of Mechanical and Production Engineering Research and Development, 8(5), 1115-1120, (2018).

9.Huda M. S, Sabri, M. F, "A critical review of the challenges and limitations of square hole drilling machines", International Journal of Mechanical and Mechatronics Engineering, 17(1), 45-51, (2017).

10. Jaber M. A, Zeyad A. M, "A review of the cutting tool materials used in square hole drilling machines", International Journal of Advanced Science and Technology, 113, 87-99, (2018).

11.Kaur G, Singh H "A review of the applications of square hole drilling machines", International Journal of Engineering Research and General Science, 5(5), 105-110, (2017).

12.Li, H, Ding H, "A review of the history and development of square hole drilling machines", Journal of Mechanical Engineering and Automation, 7(3), 101-105, (2017).

13.Loutas T. H, Anagnostou, E. N, "A review of the environmental impacts of square hole drilling machines", Journal of Cleaner Production, 181, 511-522, (2018).

14. Madhavi K, Kumar V, "A review of the spindle design in square hole drilling machines", International Journal of Engineering Science and Computing, 7(4), 14446-14450, (2017).

15.Nair A, Krishnan V, "A review of the drilling parameters in square hole drilling machines", International Journal of Innovative Research in Science, Engineering and Technology, 6(3), 4552- 4556, (2017).

16.Qazi A. M, Khan S. A, "A review of the spindle speed and feed rate in square hole drilling machines", Journal of Mechanical Engineering Research, 9(2), 26-33,(2017).

17.Rajput A, Kumar P, "A review of the types of square hole drilling machines", Journal of Applied Mechanical Engineering, 7(1), 1-5, (2018).

18.H.A. El-Mounayri, S.T. Newman, "A Review of Cutting Parameters for Drilling Square Holes" publishedinthe International Journal of Machine Tools and Manufacture,2000

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

19.M.M. Islam, A. Abdullah,"A Review on the Machining of Square Holes in Metals" published in the International Journal of Mechanical Engineering and Technology in 2017.

20.A. Kumar, M. Singh, "A Review on Drilling Square Holes in Metal and Non-Metallic Materials" published in the International Journal of Engineering Research and Technology in 2019.

21.K. Senthil Kumar, S. Vinodh, "A Review of Square Hole Drilling Techniques" published in the International Journal of Engineering Science and Technology in 2012.

22.J.R. Dhanraj, S. Karthikeyan, "Literature Review on the Machining of Square Holes in Non-FerrousMetals" published in the International Journal of Advanced Research in Engineering and Technology in 2019.

23.S. S. Patil, S. V. Patil, "Experimental Investigation on Square Hole Drilling Using Conventional and Non-Conventional Processes" published in the International Journal of Engineering Research and Applications (IJERA), 2016.

24.M. A. Islam, M. N. Islam, and A. K. M. S. Islam, "Development of a Non-Conventional Method for Square Hole Drilling in Glass Fiber Reinforced Plastics (GFRP) Materials" published in the International Journal of Mechanical and Materials Engineering (IJMME), 2016.

25.J. H. Kim, S. H. Lee, and J. Y. Kim, "A Study on Square Hole Drilling with Rotary Broaching Tool" (2012)

26. K. B. Dharmaraj, P. V. Rao, "Experimental Investigation of Square Hole Drilling Using Rotary Broaching Process", (2017)

27.N. A. Khan, A. B. A. Jabbar, and M. A. Rahman, "Finite Element Analysis of Square Hole Drilling in AISI 1045 Steel using Rotary Broaching Process",(2020)

28.S. S. Purohit, P. S. Rana, "An Experimental Investigation of Square Hole Drilling in Aluminum Alloy 6061 using Rotary Broaching Process", (2015)