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Design and Fabrication of Drill Chuck for Making a Square Hole

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Abstract— *This paper presents design, simulation and fabrication of drill chuck for making square hole. This drill chuck is also called free floating chuck. There are many methods available to make square hole. Realeaux type drill bit is one method to make square hole. Realeaux drill bit contains three flutes. Drill bit centre point is rotated about the axis of spindle and freely movable in the plane perpendicular to the axis of 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. NX8.0 software is used for modeling, simulation and analysis of drill chuck. Drill chuck is fabricated and tested. Mild steel is used to fabricate the different components of drill chuck.*

Keywords: *Free floating drill chuck, Square hole drill, Realeaux triangle.*

1. INTRODUCTION

Making a square hole on metal solid material is not easy as making as circular hole. Earlier circular hole is made as per the side of square geometry, and then material is removed from all four corners of circular hole by using triangular file. This process does not require any drill chuck for holding a tool, instead it requires a tool post for holding cutting tool.

Square hole drill chuck:

A square hole is made directly by using square hole drill chuck. This special mechanism drill chuck contains various components like Mild steel plates, Morse taper shank, Steel round shaft, Universal couplings, Drill bit holder, realeaux triangle drill bit, Outer shell and Bolts. Above all components arranged in an assembly shown in Fig. 2. It is quite different of general chucks, because the centres of square hole and realeaux triangle drill bit would not coincide with each other, which means centre of drill bit is rotated around the square hole centre. This type of chuck is also called free floating chuck.

Realeaux triangle drill bit:

Realeaux triangle drill bit drills square holes. The shape of drill bit is derived from a simple geometric construction known as a REALEAUX triangle shown in Fig. 1.

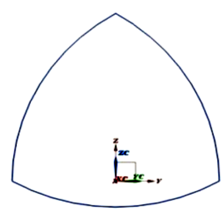
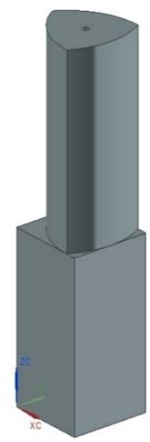


Fig. 1: Realeaux triangle



Realeaux drill bit mode

Fig. 2: Drill chuck for making a square hole.

2. DESIGN CALCULATIONS OF VARIOUS COMPONENTS

2.1 Drill bit holder

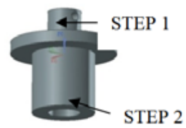


Fig. 3: Drill bit holder

Load on drill bit holder:

Axial load P N

Torque T N-mm

Material: Mild steel

Step 1:

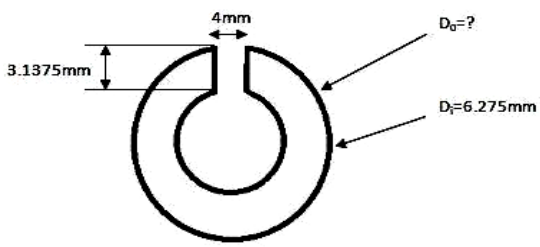


Fig. 4: minimum area cross section

Outer diameter D_0 =?

Maximum shear stress failure theory:

$\tau_{max} = \tau_{yeild}$

Where τ_{max} – maximum shear stress,

τ_{yeild}- shear stress at yield point in simple tensile test

D_0 = 11.6826~ 14 mm

Step 2:

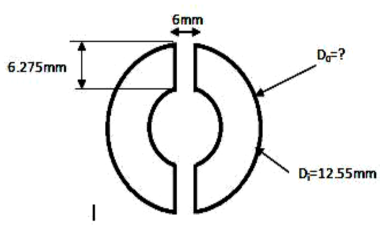


Fig. 5: minimum area cross section

D_0 = 18.6501~ 25mm

2.2 Links

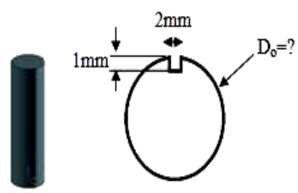


Fig. 6: Minimum area of link

Material: Stainless steel

Load acting:

Axial load P N

Torque T N-mm

D_0 = 5.8652~ 7mm

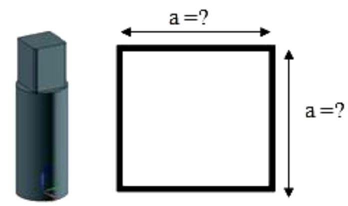


Fig. 7: Minimum area of link

a = 0.324 mm

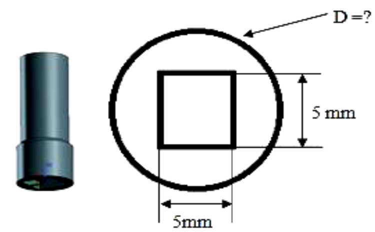


Fig. 8: Minimum area of link

Material: stainless steel

Load acting:

Axial load P N

Torque T N-mm

D_0 = 7.9954~ 10mm

2.3 Morse taper shank

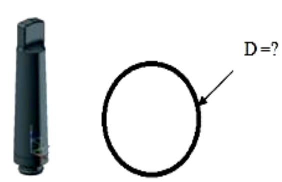


Fig. 9: Minimum area of Morse taper shank

Material: mild steel

D = 9.3821~ 14mm

2.4 Chuck partition plates

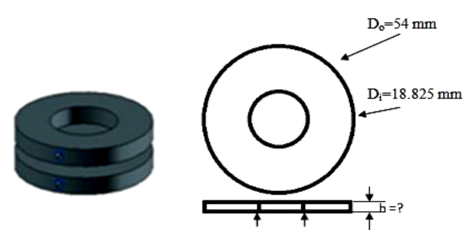


Fig. 10: Area cross section of 2nd chuck partition plate

Where D_o=54- external diameter.
D_i=18.825 – internal diameter
h= thickness (unknown)
To find 'h' of 2nd chuck partition plate

Using maximum deflection formula for thin plates, **Thickness h= 6.569 mm**

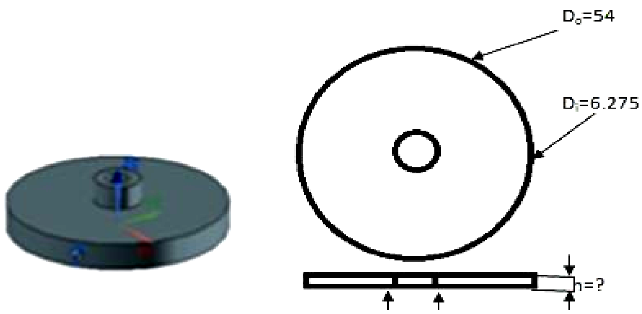


Fig. 11: Area of 1st plate

Where D_o=54- external diameter.
D_i=6.275 – internal diameter
h= thickness (unknown)
Thickness h= 6.478 mm

3. MODELLING OF DRILL CHUCK

PART MODELS**:** Morse taper shank, Drill chuck shell, Chuck partition plates, Universal coupling, Links, Drill chuck holder or Front hub, Sample drill or Model drill bit, Guide plate, and Screws

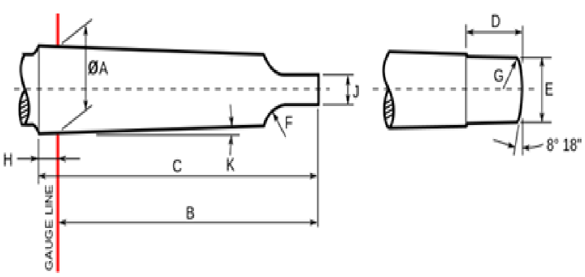


Fig. 12: Dimensions of shank

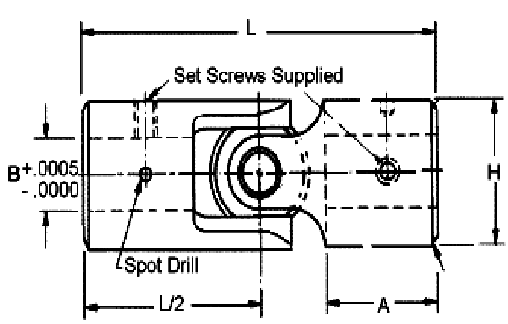


Fig. 13: Universal coupling

Fig. 14: model of universal coupling

4. MOTION SIMULATION

Motion analysis is done to check the action, whether it is in required motion path or not. Motion analysis is done with the help of UNIGRAGHICS or NX8-Recurdyn.

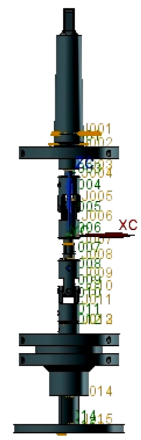


Fig. 15: links and joints

Table 1: links and joint

S. No	Links	Joint	Joint type	Snap links	Rotation initial velocity(deg)	Translation Initial velocity(mm/sec)
1	L001	J001	Cylindrical	-	800	0
2	L002	J002	Fixed	L001	-	-
3	L003	J003	Fixed	L002	-	-
4	L004	J004	Fixed	L003	-	-
5	L005	J005	Universal	L004	-	-
6	L006	J006	Fixed	L005	-	-
7	L007	J007	Fixed	L006	-	-
8	L008	J008	sliding	L007	-	-
9	L009	J009	Fixed	L008	-	-
10	L010	J010	Universal	L009	-	-
11	L011	J011	Fixed	L010	-	-
12	L012	J012	Fixed	L011	-	-
13	L013	J013	Fixed	L012	-	-
14	L014	J014	Fixed	L013	-	-
15	L015	J015	Fixed	-	-	-

16	L014	J016	Point on curve	-	-	-
17	L014	J017	Point on curve	-	-	-

5. ANALYSIS

Analysis is done on the drill chuck components like Morse taper shank, drill chuck cover, and chuck partition plates. Analysis is done with the help of NX8- NX Nastran.

5.1 DRILL BIT HOLDER:

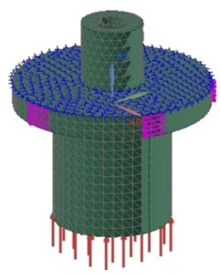


Fig. 16: Force and torque acting on the component.

5.1.1 Stress deformed images:

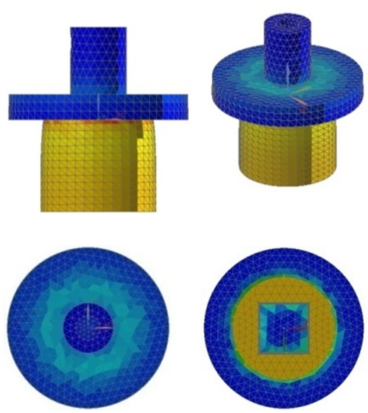
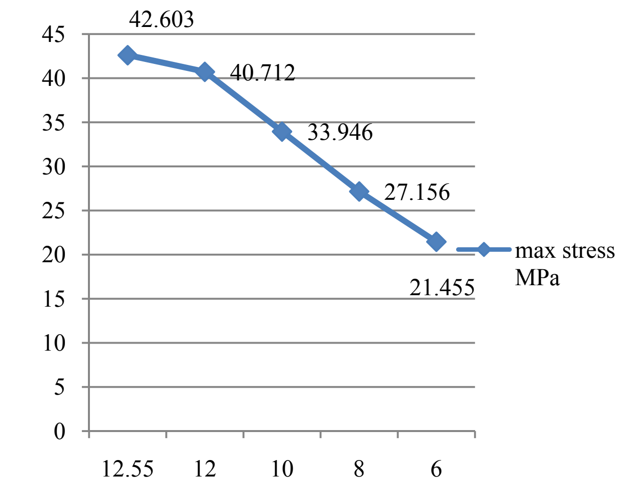


Fig. 17: Deformed image various views.

Table 2: Stress element nodal values for drill bit holder.

S. No	Diameter(mm)	Von-mises stress (MPa)		Element id	Node id
1	12.55	MIN	0.012	3331	1860
		MAX	42.603	2424	635
2	12	MIN	0.011	3331	1860
		MAX	40.712	2424	635
3	10	MIN	0.010	3331	1860
		MAX	33.946	2424	635
4	8	MIN	0.008	3331	1860
		MIN	27.156	2424	635
5	6	MIN	0.006	3331	1860
		MAX	21.455	2424	635

Maximum displacement = 0.005 mm(node id-2675)



Graph 1: Max stresses obtained Vs diameter of various drill bits

5.2 PARTITION PLATE

5.2.1 Stress deformed images

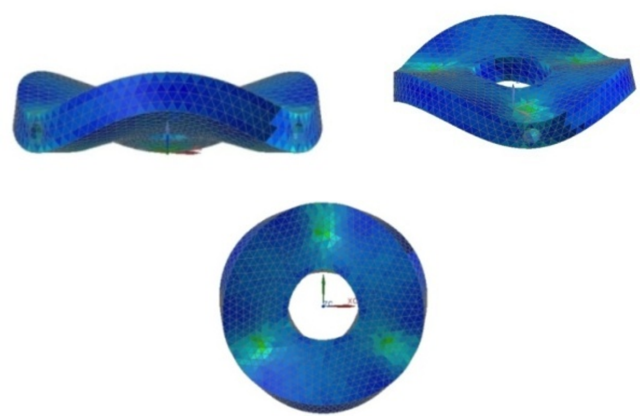
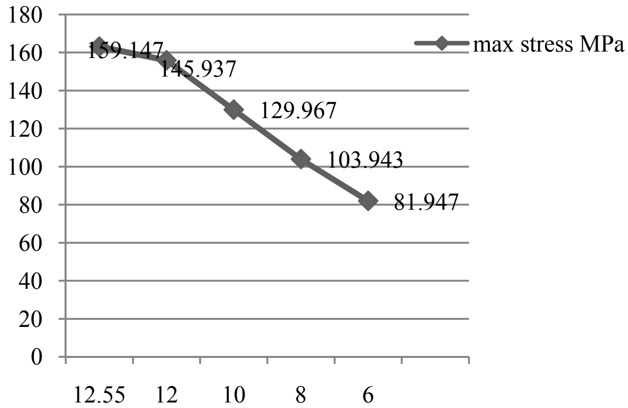


Fig. 19: Stress element nodal deform images.

Table 3: Stress element nodal values for second plate.

S. No	DIAMETER (mm)	VON-MISES STRESS (MPa)		ELEMENT ID	NODE ID
1	12.55	MIN	2.107	1092	215
		MAX	159.037	8974	124
2	12	MIN	2.014	1092	215
		MAX	146.353	8974	124
3	10	MIN	1.679	1092	215
		MAX	138.672	8974	124
4	8	MIN	1.343	1092	215
		MAX	110.934	8974	124
5	6	MIN	1.058	1092	215
		MAX	87.638	8974	124

Maximum displacement = 0.013 mm (node id-2350)



Graph 2: Max stress obtained Vs diameter of various drill bits

5.3 OUTER SHELL

5.3.1 stress deformed images

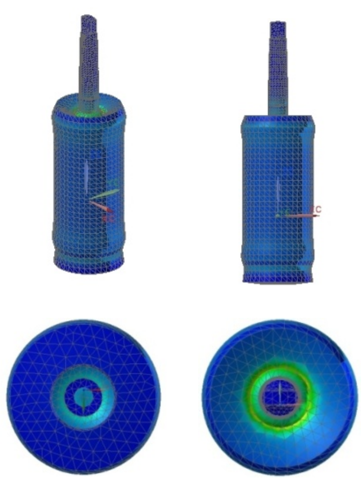
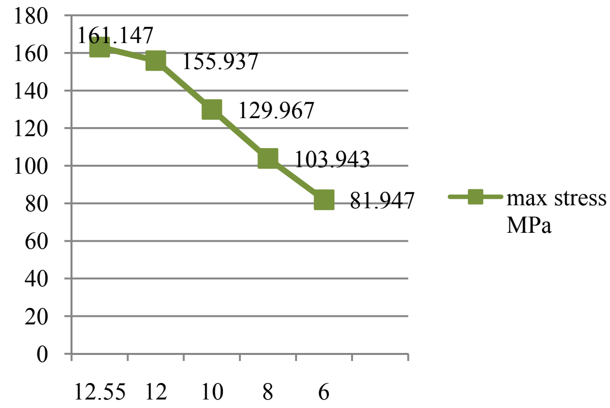


Fig. 20: Stress deformed images of outer shell.

Table 4: Stress element nodal values for outer shell.

S. No	DRILL BIT DIAMETER (mm)	VON-MISES STRESS (MPa)		ELEMENT ID	NODE ID
1	12.55	MIN	36.589E-12	8105	22692
		MAX	161.147	11923	28059
1	12	MIN	34.966E-12	8105	22692
		MAX	155.937	11923	28059
2	10	MIN	27.122E-12	8105	22692
		MAX	129.967	11923	28059
3	8	MIN	23.265E-12	8105	22692
		MAX	103.943	11923	28059
4	6	MIN	18.348E-12	8105	22692
		MAX	81.947	11923	28059
5	4	MIN	12.178e-12	8105	22692
		MAX	54.581	11923	28059



Graph 3: Max stress obtained on the outer shell

6. FABRICATION

Fig. 21: Final assembly

7. TESTED ON WORK PIECES

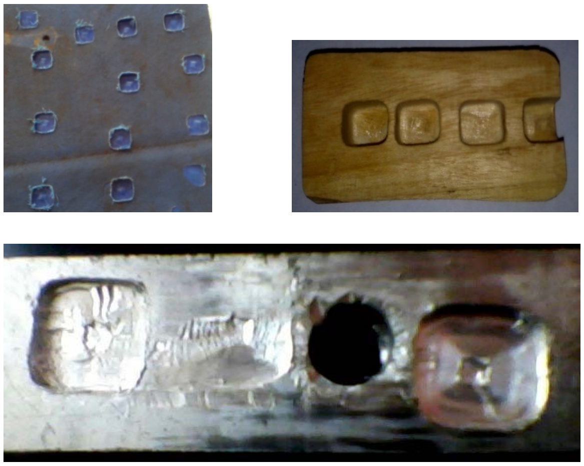


Fig. 22: Square holes made on plates

8. RESULTS

8.1 Design Calculations

Part Name	Dimensions of the part
Drill bit holder	Step 1: diameter=14mm Step 2: diameter=25mm
Links	Link1: diameter=7mm Link2: side= 5mm Link3: diameter=10mm
Morse taper shank	Bigger diameter=14mm
Chuck partion plates	Inner diameter=18.825mm External diameter=54mm Thickness=7mm

9. CONCLUSIONS

- Square hole drill chuck has been designed and fabricated.
- All the analysis results are within the permissible limits
- Square hole can be produced with realeaux type of drill bit. The realeaux type drill bits are more effective compared to other operations.
- Machining process time for making square hole is very less. It may equal to reaming operation in drilling press. It is quick and faster than slotting and shaper machine.
- The work piece changing setup time is completely zero as compared to other process like slotting and shaper machines.

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