

# Study and Analysis of Torque Handling Capacity of Slot Headed Grub Screw

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**Abstract.** A Grub screw is a type of screw generally used to lock an object within or against another object. These screws are headless and mainly used in all types of gears and shaft. The following work is based on optimization of the strength of flat slotted screw head with different slot shapes. In the paper, we have considered samples of 3 different slotted flat headed grub screw profile with their corresponding screwdriver profile. The aim was to obtain the maximum torque handling capacity among the identified slot shapes. An iterative process involving design upgradation and finite element analysis was carried out. For this purpose validation of the FEA was performed by torsion testing of the specimen in the torsion testing machine. The results showed that 17° slotted angle grub screw gives better torque handling capacity than 0° slot angle. The study shows that a variation in the slot shape of a grub screw can influence the torque handling capacity.

## 1. Introduction

A screw is a sort of latch portrayed by a helical edge, known as an outer string or simply string, wrapped around a chamber. The most widely recognized employments of screws are to hold protests together and to position objects. A screw will dependably have a head, which is an extraordinarily shaped segment toward one side of the screw that enables it to be turned or driven. Regular devices for driving screws incorporate screwdrivers and wrenches. An assortment of sink head shapes are accessible the market, for instance, opened screw, hexagonal head top screw, opened grub screw and so on. With a specific end goal to drive a screw to hold protests together, its opened head is turned by giving a minute by methods for a screw driver. An assortment of space shapes with a level head is accessible for this reason. Out of which 'opened shape' is usually utilized. For a given space shape arrangement, the use of over-minute may bring about a disappointment of the head.

At the point when a minute is connected to a given opened screw through a screwdriver, it encounters ordinary and shear stresses. The transaction of these anxieties gives an Equivalent (Von-Misses) push. On differing the occasion, the weight on the example increments, with a resulting disappointment of the head area. The disappointment may come about because of typical pressure or shear pressure or probably, exchange of both.

A need to enhance the state of the space emerges for better minute transmission from screwdriver to screw. For this, screw head examples are set up with an alternate space point and subjected to minute



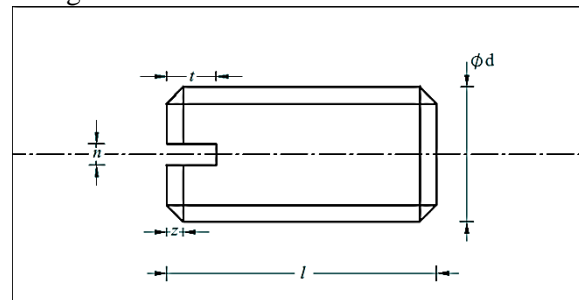
testing with their relating screw-driver profiles. The one with better minute conveying limit is considered as ideal opening shape.

Grub screws are little headless (likewise called dazzle) screws having an opening cut for a screwdriver or an attachment for a hexagon key and used to secure a question inside or against another protest. By being headless, it implies that the screw is completely strung and has no head anticipating past the significant measurement of screw string. The most widely recognized illustrations are securing a pulley or rigging to a pole in a decided position. It applies pressure or clipping power through the base tip that activity through the gap. For the analysis, brass has been recognized as the material for screw Specimen.

## 2. Literature Review

Impact Fracture of Screws for Disassembly by D. Studny et al.[1] determine the stresses developed in screws while impact testing. In this paper, the nature of fracture of a screw head has been mentioned. This has been made possible by very accurate electronic measuring devices. Controlled tightening over the Yield Point of a Screw: Based on Taylor's Series Expansions, by Goran R. Toth et al.[2] conducted experiments on screws head with different slot angle and specified the uses of snug torque. Giovanola et al.[3] carried out shear deformation and rotary inertia of a pre-cracked three-point bend specimen. Junker G H et al. [4] analysed on tightening of bolted joints of screw specimen. From the results they came to know that the tightening techniques can increase the load-carrying capacity of existing structures and permit lower weight and lower cost in new designs. Monaghan J. M. et al. [5] conducted the experiments on socket head grub screw and determined the torque distribution in the screw under lubrication condition. Toth G. R. et al.[6] carried out the simulation based on Monte-Carlo Technique, to find out the permanent elongation, maximum tightening angle, and final torque of the screw.

Slotted grub screws are available in the size ranging from M1 to M24 and in different materials such as steel, brass, etc. with 6 different shapes at the end of the screw namely, flat end (A), conical end (C), cylindrical dog point (E), tapered dog point (G), cup point (J) and oval point (K). The Dimensions for M20 grub screw are given in Figure 1 and Table 1 below.



**Figure 1:** The dimensions for M20 grub screw

**Table 1:** Dimensions for M20 screw[7]

	Size(Diameter)	M8	M10	M12	M14	M16	M18	M20	M22	M24
<b>Width of slot</b>	Nominal	1.2	1.6	2.0	2.0	2.5	3.0	3.0	4.0	4.0
	MAX	1.45	1.85	2.25	2.25	2.75	3.25	3.25	4.30	4.30
	MNI	1.20	1.60	2.00	2.00	2.50	3.00	3.00	4.00	4.00
<b>Depth of slot</b>	Nominal	2.5	3.0	4.0	4.0	4.5	5.0	5.0	6.0	6.0
	MAX	2.70	3.20	4.24	4.24	4.74	5.24	5.24	6.24	6.24
	MIN	2.30	2.80	3.76	3.76	4.26	4.76	4.76	5.76	5.76

## 3. Objectives and Methodology

The objectives of the present work are given below:

1. The primary objective is to conduct torque test on screw specimen with different slot angles.

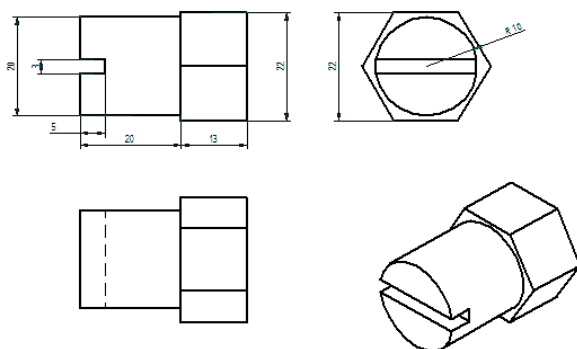
2. To identify the slot shape angle that withstands higher torque.
3. To determine the variation of torque carrying capacity with slot angles.
4. To carry out Finite Element Analysis (FEA) and validate the same with experimental results.

The main objective is to measure the torque carrying capacity of flat headed screws by varying the slot angles and identify the one that withstands higher torque. For the purpose of optimizing the slot shape design, an iterative process was carried on. Repetitive analysis on ANSYS® with a change in the design in SOLIDEDGE ST2 was conducted to make sure that failure occurs in the screw head.

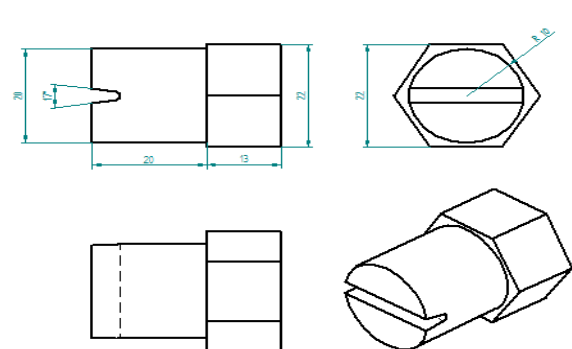
### 3.1 Identification of slot shape

For the purpose of comparison of applied torque on various specimens, the area of contact between the screw head and driver is made constant for all pairs. From the BIS standards of Grub screws\*, M20 screw specification is selected considering the practical feasibility of the project. M20 flat headed slotted screws have a depth, of 5mm and a width of as per the BIS standards. Taking the 0° flat head slotted screw as the reference [8], profiles of a screw-screw drivepair was made for 0°, 17°, 34° keeping the area of contact constant. The 34° is the limiting case for the width of 3mm.

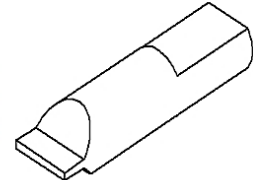
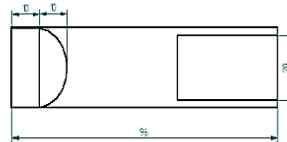
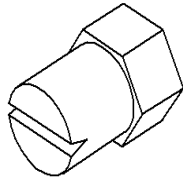
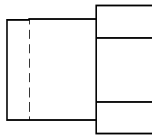
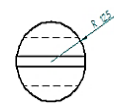
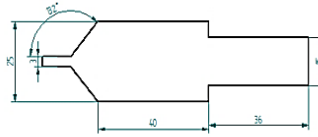
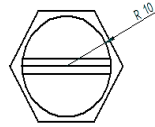
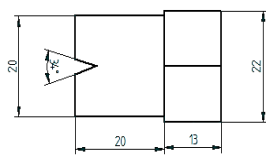
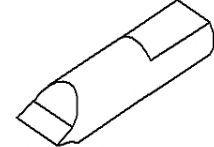
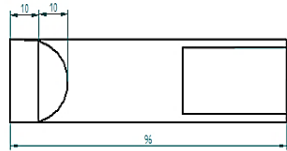
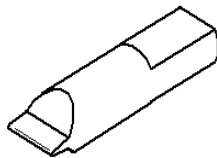
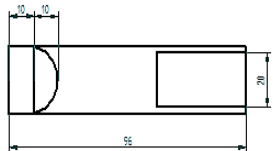
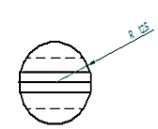
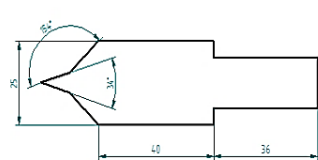
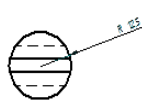
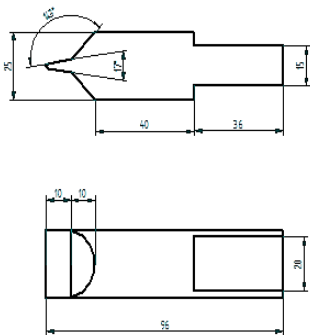
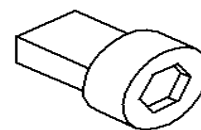
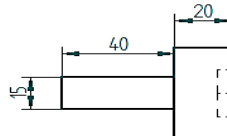
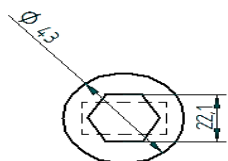
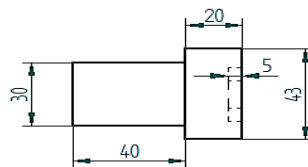
- 1) Design on identification of the slot angles: the design of the screws was finalized based upon the standard dimensions mentioned in Indian standard specifications for grub screws [Ref: Doc: EDC 27 (1662)]. Brass was selected as the material based upon its applicability as a fastener in the market.
- 2) A holder profile was required for holding the brass specimen while conducting the torsion test. For this purpose, the brass specimen should snugly fit inside the holder. Based upon a survey in the market, a hexagonal brass bar of (22mm opposite edge length) was chosen for making the screw specimens. Subsequently, a holder profile with a hexagonal pocket of 5mm depth was designed.
- 3) A single point HSS tool was designed for the purpose of slot cutting in the brass specimen with angular with angular slot of 17° and 34°.
- 4) The screwdriver profile for each of the screws was designed with appropriate tip angles. The design of the screwdriver and holder were in accordance with the shape of the chuck on the Torsion Testing Machine.
- 5) The final design of various specimens was arrived after a number of iterations. The drafts of these designs are as follows.



**Figure 2:** Draft of Zero degree Screw Specimen



**Figure 3:** Draft of 17° degree screw specimen

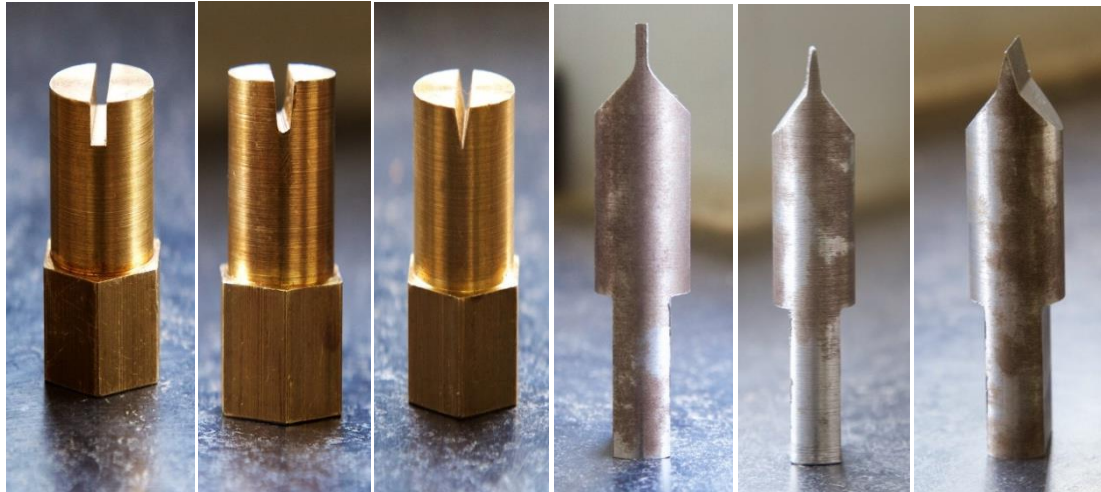
**Figure 4:** Draft of 34° screw Specimen**Figure 5:** Draft of Zero degree Driver**Figure 6:** Draft of 17° Driver**Figure 7:** Draft of 34° Driver**Figure 8:** Draft of holder

### 3.2 Fabrication of specimen

A shaper tool of HSS (S-500) grade was used for making the angular slots of 17° & 34° on the brass specimen. The tool specifications are as follows.

- 3/8" square \* 4" long.
- Face angle of 17° and 34° on the two ends.
- A positive back rake angle of 2°.
- Side clearance angle of 6°.
- A nose radius of 0.2 mm.
- Front clearance (for single point cutting tool) as 6°.

The hexagonal brass rod was machined on the lathe to make the diameter as 20mm on one end. After this, the slot shape was made using shaper machine and grinding was done to obtain edge fillet. The photographic view of the sample screws are shown in figure 9.



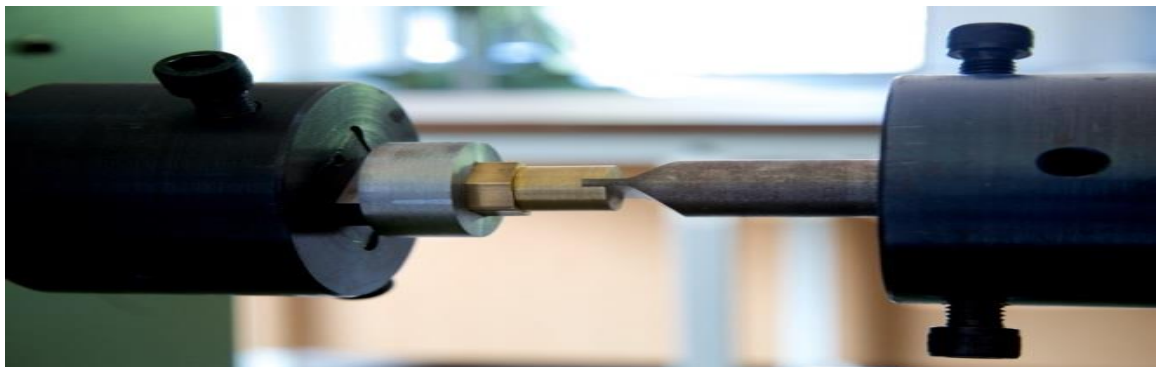
**Figure 9:** Slotted screw specimensFigure 10: Drivers

The EN 19 Alloy Steel was machined on lathe to obtain a diameter of 16 mm on one end and 25 mm on the other end. This was followed by shaping the standard holding dimension for the chuck. Further machining of the tip was done on 4 axis CNC lathe at Government tool room and Training centre (GT&TC) . The photographic view of the drivers is shown in figure 10.

## 4. Simulations and Experimental Results

### 4.1 Experimental results

The experimental setup for torsion testing of the specimen screws are shown in figure 11. Based on the experiments and analysis performed readings were obtained for maximum torque carrying capacity of different screw specimens. The test data for  $0^\circ$ ,  $17^\circ$  and  $34^\circ$  slot angles are given in table 2, 3 and 4 respectively.



**Figure 11:** Experimental setup of Torsion machine

**Tabel 2:** Data of Zero degree screw

$\phi$ =Angle of twist in Degree	Torque in Kg-cm Specimen 1	Torque in N-m Specimen 1	Torque in Kg-cm Specimen 2	Torque in N-m Specimen 2
0.5	40	3.94	60	5.88
1.0	100	9.81	110	10.79
1.5	200	19.62	220	21.58
2.0	280	27.46	280	27.46
2.5	380	37.27	360	35.31
3.0	480	47.08	470	46.10
3.5	560	54.93	580	56.89
4.0	640	62.78	640	62.78
4.5	710	69.65	720	70.63
5.0	790	77.49	780	76.51
5.5	800	78.48	810	79.46
6.0	860	84.36	840	82.40
6.5	900	88.29	900	88.29
7.0	940	92.21	950	93.19
7.5	1000	98.10	990	97.11
8.0	1020	100.06	1020	100.0

**Table 3:** Data of 17° screw

$\phi$ =Angle of twist in Degree	Torque in Kg-cm Specimen 1	Torque in N-m Specimen 1	Torque in Kg-cm Specimen 2	Torque in N-m Specimen 2
0	0	0	0	0
0.5	60	5.88	40	3.92
1.0	180	17.65	120	11.77
1.5	310	30.41	210	20.60
2.0	450	44.14	300	29.43
2.5	600	58.86	410	40.22
3.0	760	74.55	620	60.82
3.5	930	91.23	780	76.51
4.0	1060	103.98	900	88.29
4.5	1170	114.77	980	96.13
5.0	1260	123.60	1160	113.79
5.5	1350	132.43	1220	119.68
6.0	1430	140.28	1310	128.51
6.5	1500	147.15	1390	136.35
7.0	1560	153.03	1460	143.22
7.5	1630	159.90	1530	150.09
8.0	1670	163.82	1570	154.01
8.5	1700	166.77	1620	158.92
9.0	1720	168.73	1660	162.84
9.5	1735	170.20	1680	164.80
10.0	1745	171.18	1690	165.78
11	1755	172.16	1700	166.77

**Table 4:** Data of 34° screws

$\phi$ =Angle of twist in Degree	Torque in Kg-cm Specimen 1	Torque in N-m Specimen 1	Torque in Kg-cm Specimen 2	Torque in N-m Specimen 2
0.5	60	5.886	50	4.905
1.0	90	8.829	80	7.848
1.5	140	13.734	150	14.715
2.0	190	18.639	180	17.658
2.5	220	21.582	190	18.639
3.0	240	23.544	200	19.62
4.0	245	24.034	270	26.487
5.0	Slippage occurred	Slippage occurred	Slippage occurred	Slippage occurred

The data obtained in above tables is based upon the gradual increase in the Torque testing machine and values of torque were recorded on the Kg-cm scale. While applying the torque, the screw specimens were carefully observed for any deformations or cracks near the slot as inferred from the ANSYS results. The experimental analysis was carried out for 3 different slot angle screw specimen. From the results of experimental analysis it is observed that 0° slot angle screw was deformed at a torque of 100 N-m. Similarly, 17° slot angle was deformed at 172 N-m. But the 34° slot angle screw slippage occurred at a torque of 26 N-m. From the experimental analysis, we concluded that 17° slot



angle screws are better than other two samples. Deformation of the screw specimen we are validated with Ansys Tool.

#### 4.2 Analytical(Static Structural Analysis) Results

Analysis done on ANSYS fetched a lot of data regarding the stress concentration on the screw-screwdriver profile which gave an estimate of failure. For this purpose, Equivalent Stress(Von-Mises) was taken into consideration since the stresses acting on the specimens were not purely Normal or Shear in nature, but a combination of two. In this way, on increasing the moment, the stresses on the specimen increases which, consequently gives the failure torque.

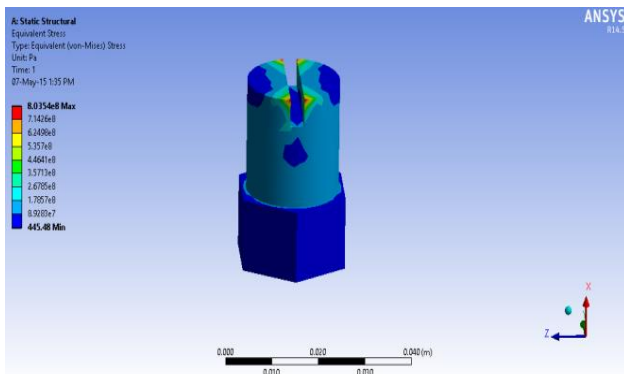


Figure 12: Equivalent stress of zero degree screw

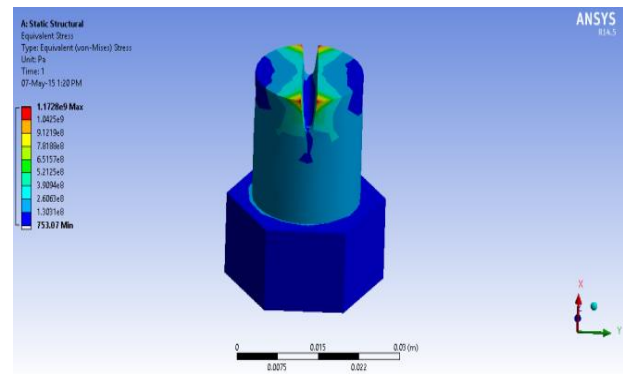


Figure 13: Equivalent stress of 17° screw

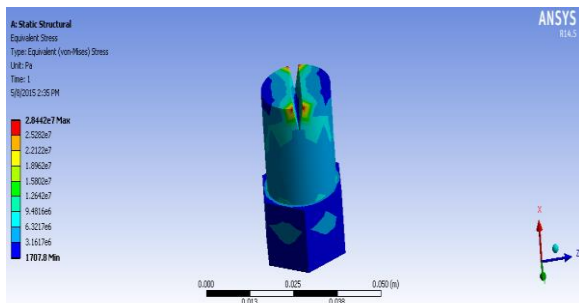


Figure 14: Equivalent stress of 34° screw

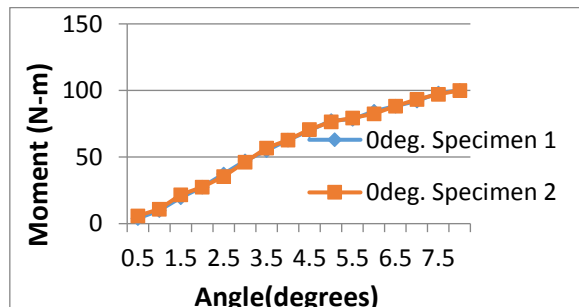


Figure 15: Moment for zero degree slot angle

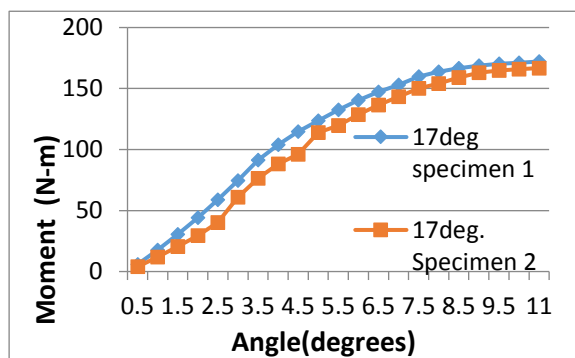


Figure 16: Moment for 17° slot angle

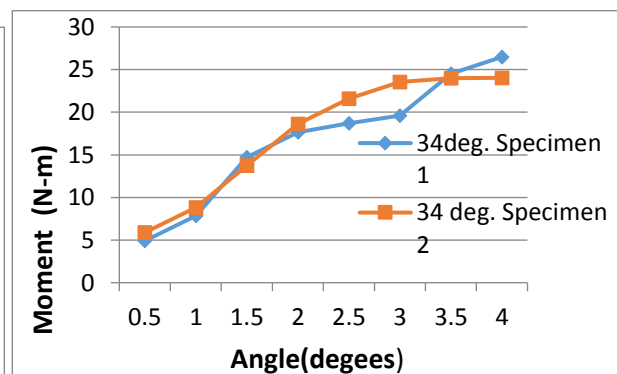
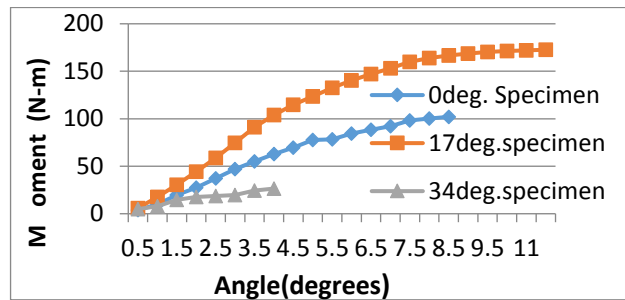


Figure 17: Moment for 34° slot angle

**Figure 19:** Deformation of 3 different specimens**Figure 18:** Comparison of moment for 3 specimens**Table 5** Comparison result of experimental and Analytical work

Sl.No.	Type of Specimen	Experimental Torque(N-m)	Max. Equivalent Stress Obtained Analytically (N/m <sup>2</sup> )
1	0°	100.062	8.0354*10 <sup>8</sup>
2	17°	172.1655	1.1728*10 <sup>9</sup>
3	34°	26.487	2.8442*10 <sup>7</sup>

## 5. Conclusions

1. Torque carrying capacity of 3 specimen brass screws of 0°, 17° and 34° has been evaluated.
2. The torque carrying capacity of the grub screw with slot angle of 17° is found to be higher than 0° slot angle.
3. The torque carrying capacity of the grub screw with slot angle 17° is found to be 1.72 times more than of 0° slot angle.
4. The maximum torque carrying capacity of the grubscrew with slot angle 34° could not be evaluated since the screw and screw driver pair underwent slip at 4° of rotation at an applied torque of 26.487N-m because of non-supportive grip angle. Hence this slot shape for a screw is not recommendable as slipping will occur while tightening for an insufficient screwdriver axial force.
5. From the FEM analysis, it is been noted that equivalent stress of 17° slot angle is 1.45 times that of a screw with 0° slot angle.

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