Redesign of Hydraulic Torque Wrench for Cost Optimization

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Abstract— This paper contains the study of optimization of hydraulic torque wrench. The hydraulic torque wrenches are designed to handle the toughest bolting jobs accurately and quickly. In this paper solution for reducing the cost of the tool has been proposed. All models provide a torque accuracy of +/3%.The study was done on square drive hydraulic torque wrench. First designing of the wrench was carried out and then the analysis. The material of the tool is Aluminum alloy T6-7075 and EN-24 for its strength and low cost. Considering the results obtained from the analysis various parts of the wrench where the stresses induced are less compared to others the part is modified and iterated until satisfactory results were achieved. This process helps in finding the optimized design for the hydraulic torque wrench without any failure and with minimum forces acting on the tool.

Key words: Optimization, Torque Wrench, Aluminum

I. Introduction

A hydraulic torque wrench is a power tool designed to exert torque on a fastener to achieve proper tightening or loosening of a connection through the use of hydraulics. A torque wrench is applied to the nut either directly or in conjunction with an impact socket. Hydraulic torque wrenches apply a predetermined, controlled amount of torque to a properly lubricated fastener. The hydraulic torque wrench was invented by George A. Sturdevant in 1968 in Houston, Texas.[6] The concept of a hydraulic powered torque wrench was first introduced on the market sometime in the early 1960s in a primitive form, and several key advances have been developed by manufacturers since that time which provided major advancements in the technology and usability of the tools far beyond the original concept tool. Today's tools offer benefits such as lighter weights, smaller nose radius dimensions for fitting into tight spaces, use of exotic alloys, actuation triggers on the tool itself, multi-position reaction members, 360° × 360° hose swivels, and the ability to run multiple tools simultaneously from a single power pack. The main characteristics of a hydraulic torque wrench which set it apart from other powered wrenches of similar function are that:

1) It must generate torque using only hydraulic means.
2) It must be self-ratcheting
3) It must include an accurate method of determining the amount of torque applied.[6]

Some manufacturers utilize a holding pawl design to keep the wrench locked in position prior to each power stroke, others use varying designs, which as in all industries have debatable faults or claimed advantages. Hydraulic torque wrenches typically offer accuracy of ±3% and have a high degree of repeatability making them well suited to applications where large bolts are involved and a high degree of accuracy is required.[2] A hydraulic torque wrench is significantly quieter, lighter weight and more accurate than pneumatic impact wrenches capable of similar torque output, making it an appealing alternative for many users to the very loud and cumbersome impact wrenches or torque multipliers which were formerly the only viable option for working with very large nuts and bolts until the hydraulic torque wrench was introduced. With pneumatic and electric wrenches, the power source is part of the tool. But with hydraulic wrenches, the power source is at the pump, so the wrench itself is able to fit into a much tighter space. When you need a tool that is small and versatile, a hydraulic torque wrench is your choice. Square drive wrenches are widely used due to their versatility and durability. They work with any industrial socket, making them a popular choice. The square drive hydraulic wrench provides low weight and high strength.[6]

II. Design

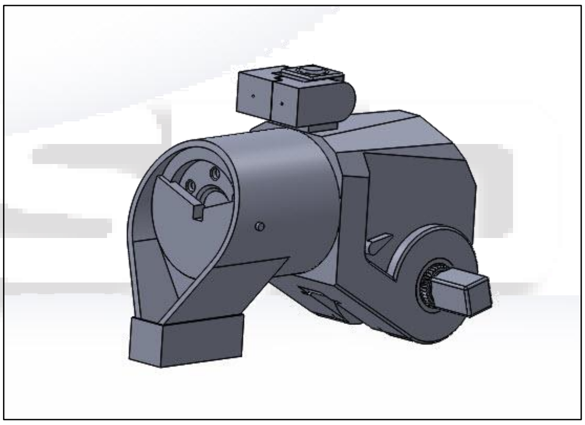

Fig. 1:

Fig. 1 shows the assembly of square drive hydraulic torque wrench.

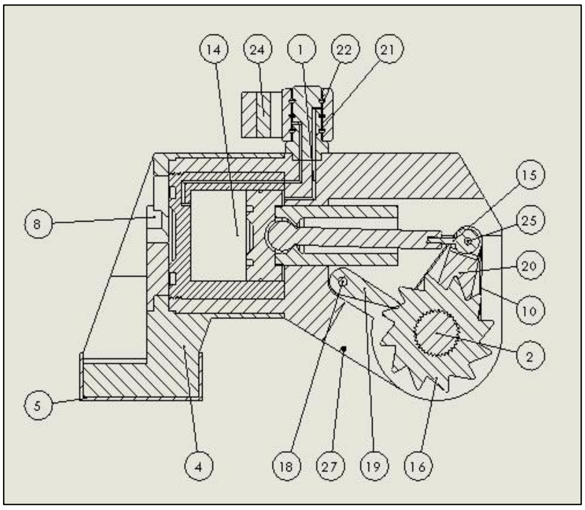

Fig. 2:

Fig.2 shows the sectional view of the square drive hydraulic torque wrench.

A hydraulic torque wrench having a separate ratchet unit and hydraulic cylinder drive unit connectable by an overlapping cylindrical connection at selected angles of rotation providing clearance in use. The hydraulic cylinder actuates the ratchet mechanism by a connecting rod traveling through the overlapping cylindrical connection and engaging a drive plate. The ratchet may have a male drive shaft for driving a socket, or a female driver such a hex or spline wrench. The ratchet unit case may be integral, or split for removable accesses to the ratchet mechanisms. The cylinder unit hydraulic connections may be separate rotatable connections or a single connection and collar, allowing three-way rotation. Attachments for the hydraulic unit include a pipe flange spreader, a nut splitter, scissor action shears, and a lift/spreader for lifting an object from a flat surface or spreading surfaces apart. A reaction bar affixes to the drive unit body.[1]The process starts from the oil under pressure in the cylinder from the pump through the swivel assembly. It forces the piston to move forward which in turn rotates the drive plate. The drive plate also makes the ratchet to rotate and which in turn rotates the drive shaft. The socket of suitable is mounted on the drive shaft to tight or loosen the nut and bolts. The reverse motion of the ratchet is prevented by a reaction pin as shown in the fig.3.

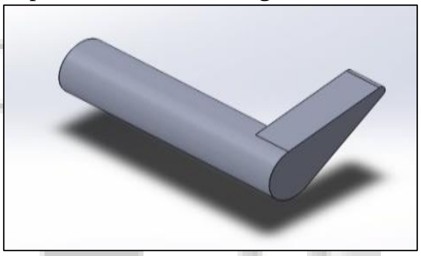

Fig. 3:

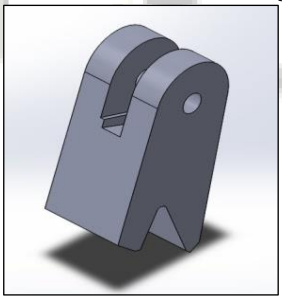

Fig. 4:

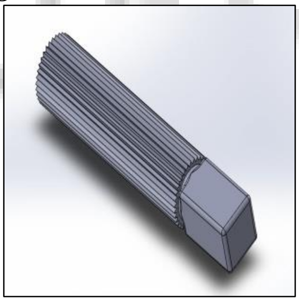

Fig. 5:

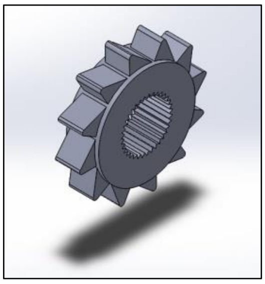

Fig. 6:

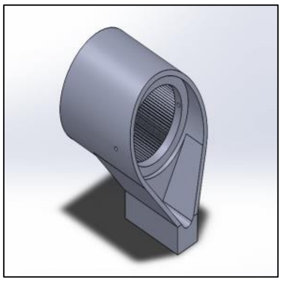

Fig. 7:

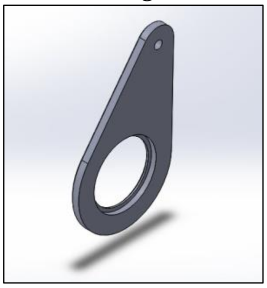

Fig. 8:

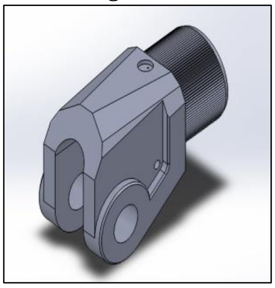

Fig. 9:

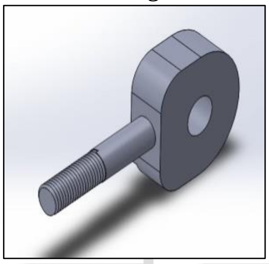

Fig. 10:

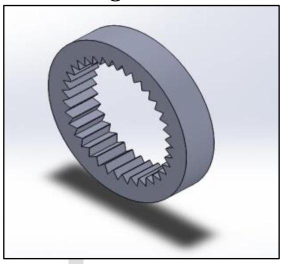

Fig. 11:

Fig. 4,5,6,7,8,9,10,11 are the components of the Square Drive Hydraulic Torque wrench.

III. ANALYSIS

Part Name	Material	Yield Stress MPa	Young modulus GPa	Density Kg/m^3
Side Plate	SS	207	81	7750
Cylinder	T6-7075	480	70	2810
Ratchet	EN-24	950	207	7840
Piston	T6-7075	480	70	2810
Drive Plate	EN-24	950	207	7840
Lock Pin	EN-24	950	207	7840

Object Name	Equivalent Stress	Total Deformation	Equivalent Stress 2	Total Deformation 2	Strain Energy	Total Deformation 3	Equivalent Stress 3
State	Solved						
Scope							
Scoping Method	Geometry Selection						
Geometry	All Bodies		1 Body		All Bodies	1 Body	All Bodies
Definition							

Type	Equivalent (von-Mises) Stress	Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	Strain Energy	Total Deformation	Equivalent (von-Mises) Stress
By	Time						
Display Time	Last						
Calculate Time History	Yes						
Identifier							
Suppressed	No						
Integration Point Results							
Display Option	Averaged		Averaged				Averaged
Average Across Bodies	No		No				No
Results							
Minimum	1.5079e-008 MPa	0. mm	3.8226e-004 MPa	8.1297e-006 mm	1.7619e-021 mJ	0. mm	1.5079e-008 MPa
Maximum	6.8513e-002 MPa	1.2799e-005 mm	2.0707e-002 MPa	9.3454e-006 mm	1.6977e-007 mJ	7.5174e-006 mm	6.8513e-002 MPa
Minimum Occurs On	Part 4	Part 22			Part 4		Part 4
Maximum Occurs On	Part 27	Part 1			Part 24		Part 27
Minimum Value Over Time							
Minimum	1.5079e-008 MPa	0. mm	3.8226e-004 MPa	8.1297e-006 mm	1.7619e-021 mJ	0. mm	1.5079e-008 MPa
Maximum	1.5079e-008 MPa	0. mm	3.8226e-004 MPa	8.1297e-006 mm	1.7619e-021 mJ	0. mm	1.5079e-008 MPa
Maximum Value Over Time							
Minimum	6.8513e-002 MPa	1.2799e-005 mm	2.0707e-002 MPa	9.3454e-006 mm	1.6977e-007 mJ	7.5174e-006 mm	6.8513e-002 MPa
Maximum	6.8513e-002 MPa	1.2799e-005 mm	2.0707e-002 MPa	9.3454e-006 mm	1.6977e-007 mJ	7.5174e-006 mm	6.8513e-002 MPa

The above table 1 shows the stresses developed at various parts of the tool. It also shows the part where stresses developed is minimum and the part where stresses is maximum.

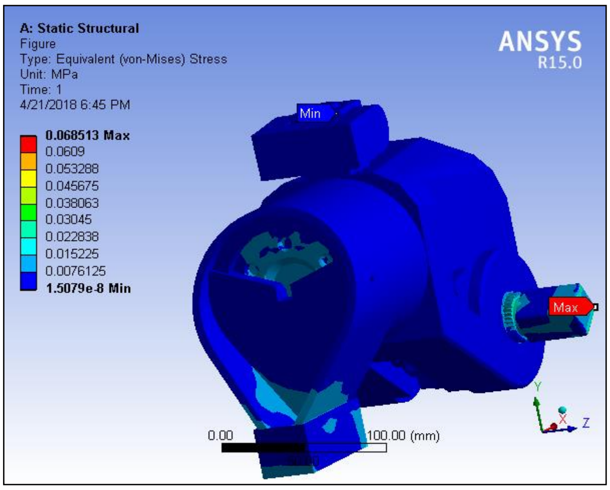

Fig. 12: Equivalent Stress

Fig 12 shows the Von-Mises stress analysis of drive shaft where maximum stress is developed at the drive shaft which will be in contact with the socket and minimum stress is developed at the swivel assembly.

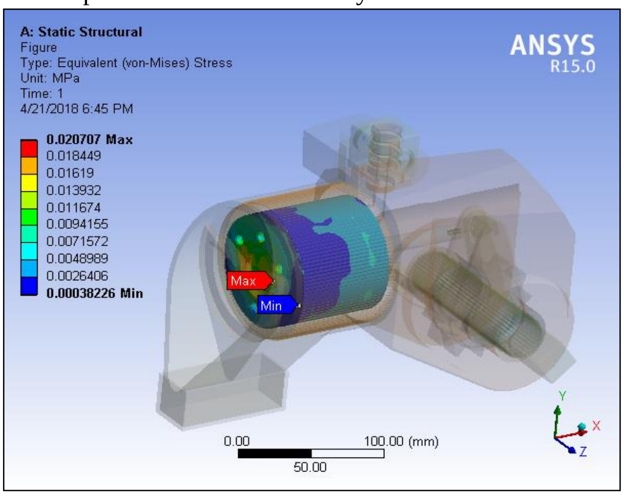

Fig. 13: Static Analysis of Cylinder

Fig 13 is stress analysis of the cylinder where maximum stress is developed at the end of cylinder where reaction arm is attached.

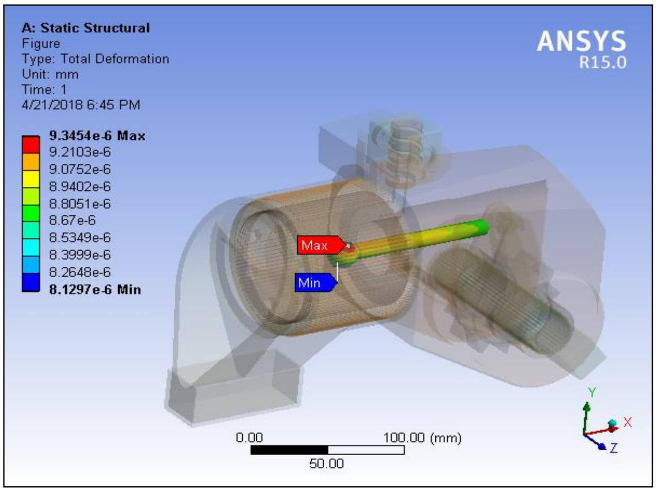

Fig. 14: Analysis of piston rod

The Fig.14 shows the stress concentration of the piston rod that occurs at the point where hydraulic fluid under pressure enters in the cylinder. The deformation is very less as compared with stresses occurred.

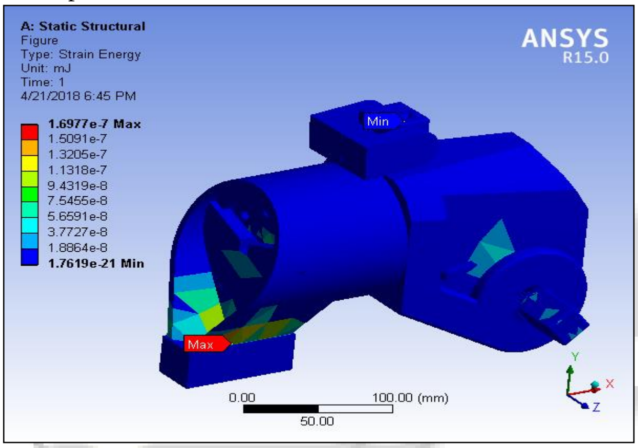

Fig. 15: Strain Energy

Fig. 15 shows the strain energy developed at the various part of the tool. Maximum strain energy is seen at the base of reaction arm.

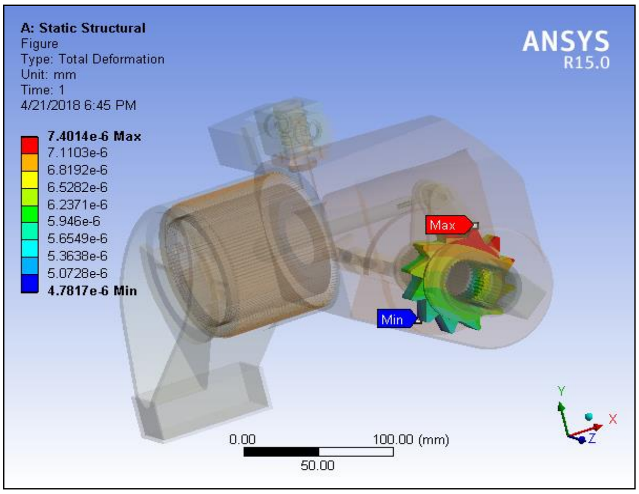

Fig. 16: Total Deformation

Fig. 16 is the total deformation in the ratchet developed. The analysis show maximum deformation at point which is in contact with the drive pawl.

Aluminum Alloy > Alternating Stress R-Ratio

Alternating Stress MPa	Cycles	R-Ratio
275.8	1700	-1
241.3	5000	-1
206.8	34000	-1
172.4	1.4e+005	-1
137.9	8.e+005	-1
117.2	2.4e+006	-1
89.63	5.5e+007	-1
82.74	1.e+008	-1
170.6	50000	-0.5
139.6	3.5e+005	-0.5
108.6	3.7e+006	-0.5
87.91	1.4e+007	-0.5
77.57	5.e+007	-0.5
72.39	1.e+008	-0.5
144.8	50000	0
120.7	1.9e+005	0
103.4	1.3e+006	0
93.08	4.4e+006	0
86.18	1.2e+007	0
72.39	1.e+008	0
74.12	3.e+005	0.5
70.67	1.5e+006	0.5
66.36	1.2e+007	0.5
62.05	1.e+008	0.5

Table 2:

The above table 2 shows the alternating stresses induced in the part having aluminum alloy property after every cycle. After each cycle the bearing capacity of the part reduces.

IV. CONCLUSION

1) From above results of the analysis from ANSYS it is evident that the proposed design of the tool is safe and can be optimized for cost and performance.
2) The tool cost is reduced by reducing the part material from area where stress concentration is low. As solved above most of the contact region has lower stresses, thus the cost can reduced by reducing the area.
3) The result shows less reactive forces developed on the reaction arm, hence it can be eliminated or minimized.
4) The use of reaction washer in place of reaction arm reduces the cost and weight of the tool.
5) High quality oil rings will minimize the chance of leakage, and hence a proper functioning torque wrench is obtained.

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