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Finite Element Analysis of Impact Socket Used In Hydraulic Torque Wrench

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Abstract: **In this study, the failure of impact socket has been selected as investigation topic in Minar hydrosystems private limited, Nagpur. It essentially focuses on stress analysis. Minar Hydrosystems Private Limited is leading manufacturing and supplier of hydraulic tools. Impact socket is a tool designed to exert a torque on a fastener to achieve proper tightening or loosening of a connection. The problem identified here is the failure of male hex end of impact socket. Some of the impact socket observed wear of corners of male hex. The impact socket failed due to torsional loading which causes for shear failure. The analysis has been carried out for static loading. Finite element analysis revealed that the stresses acting at failure region are exceeding the yield stress value. A 3D modeling software Cero 1.0 is used to prepare a CAD model of impact socket and evaluate the results in the form of stresses by applying calculated loads in the finite element analysis software ANSYS 12.0.**

Index terms: Impact socket, static loading, stresses, finite element analysis.

I. INTRODUCTION

Minar Hydrosystems Pvt. Ltd. MIDC, Hingana Industrial Area, Nagpur was established in 1999 with its core strength in hydraulic cylinder technology. Products of Minar Hydrosystems Pvt. Ltd are torque wrenches, hydraulic jacks, hydraulic cylinders, hydraulic pullers and stud bolt tensioner. A hydraulic torque wrench is a tool designed to exert a 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 fastener either directly or in conjunction with an impact socket. Hydraulic torque wrenches apply control amount of torque to a properly lubricated fastener through impact socket. The purpose of impact sockets is to withstand the force applied by impact tools. Impact sockets are used in conjunction with either hand ratchet or impact tool. Impact sockets are interchangeable tools that can allow a single wrench, impact driver or breaker bar to work with a large number of fastener sizes. Problem identified in operational condition of hydraulic torque wrench TWS-100 is used to exert a torque on a fastener to achieve proper tightening in conjunction with impact socket. Male hex end of socket having across flat diameter 35.9 mm is used for tightening of M48 bolts. After tightening of 25 to 30 bolts the play occurs between the male hex of socket and screw head, which progresses and sharp corner at male hex of socket get wear out. Failure initiates at the corner of male hex of impact socket.

A. *Impact socket*

Impact socket is a tool designed to exert a torque on a fastener to achieve proper tightening or loosening of a connection. A hydraulic torque wrenches are applied to the nut or allen bolt either directly or in conjunction with an impact socket.

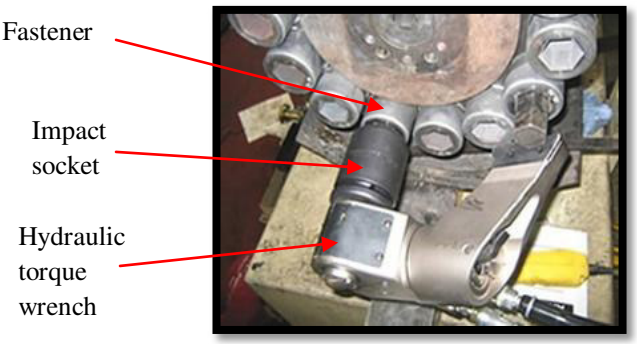

Fig. 1 Impact socket setup

Hydraulic torque wrenches apply control amount of torque to a properly lubricated fastener through impact socket. The purpose of impact sockets is to withstand the force applied by impact tools, which cause the standard sockets to failure. In their service periods, impact socket undergo heavy working stresses. As a result wearing and tearing take place in the body parts. The quality of the impact socket depends on the condition of their surfaces and on surface deterioration due to use. Impact socket having male hexagonal part at one end of 23 mm length, across flat diameter is 35.9 mm, across corner diameter is 41.45 mm and side length of face of hex is 20.73 mm. at other end of socket having female groove.

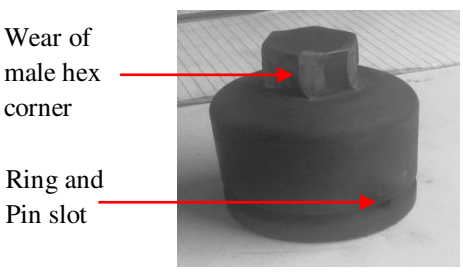

Fig. 2 schematic representation of failure of impact socket

II. FORCE ANALYSIS OF IMPACT SOCKET

As the relationship of bolt tightening force required and torque supplied by torque wrenches are as follows,

$T = k \times D \times F$

Where,

T= torque (N-mm)

D= nominal diameter of bolt or screw

F= axial tension or bolt force

k= torque factor or torque co-efficient

Bolt condition	k
Non plated, black finish	0.30
Zink plated	0.20
Lubricated	0.18
Cadmium plated	0.16
With bowman anti size	0.12
With bowman grip nut	0.09

As per processing condition, Torque =4500 Nm is supplied by hydraulic torque wrenches for tightening of properly lubricated M48 bolt.

Nominal diameter= 48 mm

K= 0.18

$T = 4.5 \times 10^6$ Nmm

$F = T/(k \times D)$

$F = 4.5 \times 10^6 / (0.18 \times 48)$

F= 520.833 KN.

As area of hexagonal bit which exert a force of 520.866 KN on bolt is

$A = 6 \times b \times (a + h)$

Where,

A= area of hexagonal bit

b=side length of hexagonal face= 20.73 mm

a= apothem height of hex= 17.95 mm

h= height of hex =23 mm

Because of clearance present in the assembly of male hex of impact socket and hex hub of fastener very small area of male hex come in contact with hex hub depend on the side length of male hex.

So, contact length of male hex after rotation in hub b=3.2 mm

So contact surface area of hex bit

$A = 6 \times b \times (a + h)$

$A = 6 \times 3.2 \times (17.95+23)$

$A = 786.24$ mm^2

Now stress acting on the male hex is 662.43 MPa. This is maximum shear stress acting on male hex of impact socket due to torque transmission to the fastener or bolt hex hub.

Maximum shear stress= 662.42 MPa

Material properties of impact socket are as follows

Tensile yield strength (S_{yt}) = 1105MPa, tensile ultimate strength (S_{us}) = 1240 MPa

As Yield stress in shear (S_{ys}) = S_{yt} / 2

S_{ys} = 1105 i2

S_{ys} = 552.5 MPa

Maximum permissible shear stress

= S_{ys} / factor of safety

Considering FOS=1

Maximum permissible shear stress = S_{ys} /1

= 552.5 MPa

As maximum shear stress for torsional loading is more than permissible stress calculated by taking factor of safety is one. This will lead to socket failure.

III. MODELING OF IMPACT SOCKET

Creo is a computer graphics system for modeling various mechanical designs and for performing related design and manufacturing operation. The material properties of Impact socket (SAE 9840) is inserted in software for the analysis are as fallows.

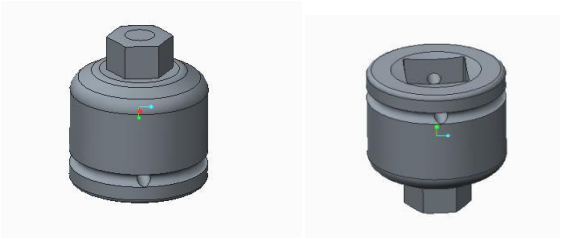

Fig. 3 Creo model of impact socket.

Table 1 Material properties of impact socket (SAE 9840)

Properties	Unit	Value
Density	Kg/m^3	7700
Young's modulus	MPa	200E3
Poisson's ratio	-	0.29
Tensile yield strength	MPa	1105
Tensile ultimate strength	MPa	1240

Table 2 Material properties of fastener (ASTM A574M).

Properties	Unit	Value
Density	Kg/m^3	7135
Young's modulus	MPa	200E3
Poisson's ratio	-	0.3
Tensile yield Strength	MPa	1170
Tensile ultimate strength	MPa	1300

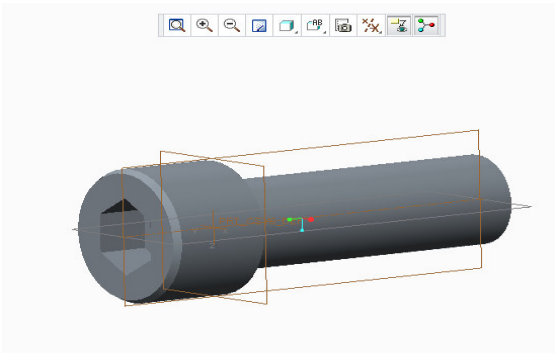

Fig. 4 Creo model of M48 fastener.

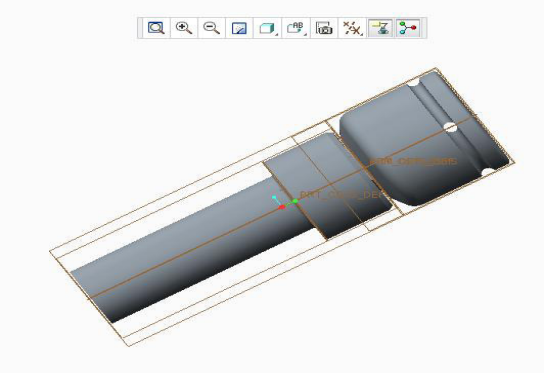

Fig. 5 Creo model of assembly of impact socket and fastener.

IV. FINITE ELEMENT ANALYSIS OF IMPACT SOCKET

Using the technical specification of impact socket the FE analysis has been carried out in ANSYS 12.0. A higher order 3-D, 10-node element having three degree of freedom at each node, translations in the nodal x, y and z directions SOLID187 were used. In this analysis, the moment of 4500 Nm is applied at the end of impact socket and remote displacement is given in y-direction. The boundary condition and FE results in Ansys for moment and remote displacement at static and dynamic are as below.

Mesh model:
Number of nodes- 22312
Number of element-12853
Type of element-Tetrahedral (SOLID187)
Behavior of element-DOF-3

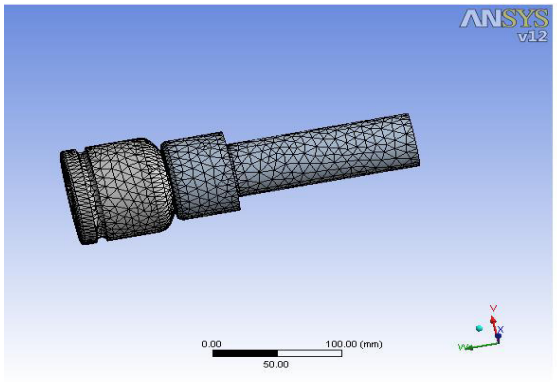

Fig. 6 Mesh model of impact socket and fastener assembly.

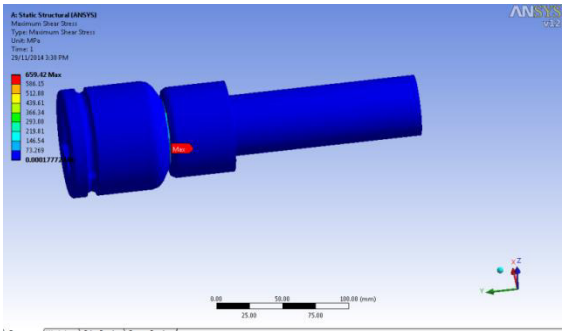

Fig. 7 Shear stress distribution in assembly.

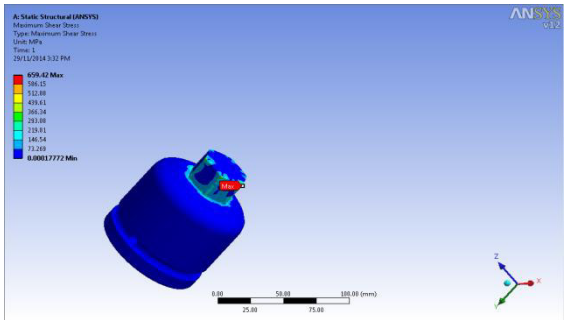

Fig. 8 Shear stress distribution in impact socket

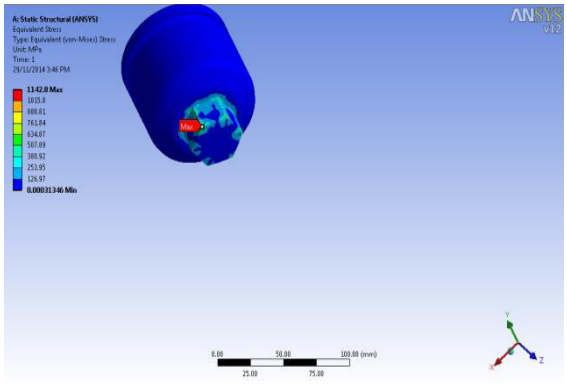

Fig. 9 Equivalent Von- Mises stress distribution on impact socket

Table 3 Analytical and FEM Result comparison.

Stresses	Analytical result	Ansys result	Allowable limit
Maximum shear stress (MPa)	662.42	659.43	552.5

V. CONCLUSION

This study was conducted on an impact socket used in hydraulic torque wrench. Structural analysis revealed that the failed impact socket material is SAE 9840 alloy steel. Stress analysis performed by both analytical and Ansys 12.0 software show that maximum stresses generated at corner of male hex of impact socket. This indicates that wear failure initiate at that area. The component to be preventing wear failure, maximum shear stresses should be less than allowable stress of material. In this case it is greater than the allowable shear stress of material. For static loading maximum shear stress 659.43 MPa is develop which exceeding the allowable stress of 552.5 MPa. Equivalent (von-mises) stress is 1142.8 MPa which is also exceeding the allowable equivalent (von-mises) stress of 1105 MPa. This results in shear failure of impact socket. The failure of the impact socket is taking place at the corner of male hex.

VI. ACKNOWLEDGMENT

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