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## Importance of Bolted Joint Integrity and Types of Bolting Methods (Torqueing & Tensioning)

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**ABSTRACT**: Bolted joints are extensively used in many sectors like oil and gas, automotive, aeronautical, structural, power and heavy industries where two members are bolted together. This particular method of fastening is vastly used in many industrial disciplines because it serves as an easy and non-destructive method to join and subsequently disassemble a complex structure. Bolted joints constitute an integral part of many structural components so, it's necessary to monitor and maintain the joint integrity of a bolted joint. In order to achieve joint integrity the commonly used methods are torqueing and tensioning.

KEYWORDS:Bolted joint, Joint Integrity, Torqueing, Tensioning

#### I. INTRODUCTION

Joint integrity is a term used to define the soundness of a welded or bolted joint in a component or structure. A joint that is structurally sound may be described as having good integrity, while a joint that is compromised can be described as having poor integrity. Joint integrity is affected by several factors including bolting and welding practices, material specifications, environmental conditions and issues in the joint itself.

#### Failure of joint integrity -

Thousands of accidents happen worldwide due to joint failure, which can lead to production delays, unplanned maintenance outages and safety incidents. There could be many reasons behind joint failure such as wrong material selection of fastener, gasket failure (for flange joint), corrosion factor, environmental condition, bolting method, uneven bolting operation.



Image-1 Failure of Joint Image-2



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#### **Bolted Joint-**

The Joint that can be easily assembled and disassembled, or engagement and disengagement of a joint is known as bolted joint. The bolted joint is a non-permanent joint. It is one of the most common elements in construction, machine design and all other industries. It consist of a male threaded fastener (i.e. Bolt /stud) that captures and joins other parts, secured with a matching female screw thread (i.e. Nut).



#### Stress-strain curve

Stress-strain curve which is a graphical representation of a bolted joint, shows the ideal bolting region for fastener as per its material and grade. The general boltingstress- strain curve is as below where the green portion shows the permissible range for bolting a fastener.





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#### II. MERITS AND DEMERITS

#### Advantages of bolted joint-

Simple and Easy Operation

The bolted joint is of a simple design due to this bolting operation is easier when compared to Welded or riveted joint.

#### ✤ High Strength Joint

The strength of the bolt joint is higher than riveted joint. In comparison to riveted joint the bolted joint requires less number of bolts to achieve the same strength.

#### Low Cost

Bolted joint requires less number of equipment so, cost of equipment drops considerably.

#### ✤ Operational Noise - Low

Bolting is less noisy, as the tools are quieter in comparison to Riveting operation.

#### ✤ Less Skilled Or Semi- Skilled Labour Required

Since the bolting operation is easy, less/Semi- Skilled worker can carry out the operation, which in turn reduces the dependency on highly skilled Technician.

#### Less Man Power Required

Due to easy operation the manpower required for connection of bolted joint is comparatively lesser thanriveted joint or welded joint.

#### Non- Permanent Joint

Bolted joint is considered as a non-permanent joint because it can easily be assembled and disassembled as and when required.

#### Less risk

Bolting operation is considered as cold process. It is done with torque tool or Bolt tensioners which eliminates the need for heating of any component during bolting.

#### Replacement Is Easy

In a bolted joint, the bolts can be easily removed or replaced as per joint requirement.

#### **Disadvantages of Bolted Joint-**

#### ✤ Effect of Vibration

If the bolted joint is exposed to high vibration it will lead to loss of preload and in turn joint might fail.

#### ✤ More Weight

When two plates are joined by the bolted joint it has heavier weight in comparison to joining riveted joints.

#### Proper Lubrication Required

If proper lubrication is not carried out during bolting operation it may lead to joint failure.

#### More Space Required

The area required for bolted joint connection is more than area required for riveted joint. So the space of occupancy is more for bolted joint.



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#### III. METHODOLOGY

#### **Bolting Methods-**

The selection of proper bolting methods is one of the important parameter to maintain joint integrity. Worldwide mainly two bolting methods are preferred, these are-

#### 1. Torqueing-

In torqueing method bolting operation is done by using torque wrench. One of the basic principles for torqueing is Newton's third law i.e. every action has an equal and opposite reaction. In this method during tightening or loosing of bolt the reaction is taken by reaction arm from next adjacent bolt or from body of application. Rotation or moment of reaction is opposite to corresponding operation, for e.g. if there is requirement of tightening operation then ratchet of tool is rotated The general formula of torque is as follows.

in clockwise direction, eventually nut is rotated in clockwise direction. In this situation reaction arm gets rotated in counter clockwise direction to take reaction and bolting operation is done, vice-versa is done during loosing operation.

#### T =F x R

Where, T= Torque (Nm)

F= Force (N) R= Radial distance (m)

There is another formula for torque which is used for Torque calculation of bolted joint,

#### T= KDF/12

Where, T = Target Input Torque (ft-lb)

K = nut factor (may vary as per application)

D = nominal diameter (bolt diameter) of the fastener (in.)

F = target preload (lbs)

Also torque value of any application may vary as per lubrication, bolt grade, corrosion factor etc.

#### Types of Torque Wrench-

There are various type of torque wrenches available. Usability of these wrenches depends upon application, industry demand, environmental condition, etc.



Battery Torque Wrench



Hydraulic Torque Wrench



Pneumatic Torque Wrench



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#### Pinch point and safety issue-

Pinch points are points where there is a chance of a body part getting caught between a stationary part of application or the adjacent nut and a reaction arm of torque tool.

Pinching under this circumstances is very dangerous and can cause severe injury. It can crush the fingers of the operator. Using conventional torque tightening and extremely high reaction forces impacts the equipment. These reaction forces can be extremely hazardous and may damage equipment, if not used properly.



Pinch point can be averted by avoiding the use of reaction arm but, it is not possible with conventional torque tools. This pinching issue may occur on both the sides. Active side, where bolting is done and passive side, which is the opposite tightening side. Back up spanner is generally used on the passive site to arrest the rotation of the nut or Bolt head during torqueing.

The reaction arm forces on the front and backup wrench forces on the rear



Reaction arm pinch hazard

Backup wrench pinch hazard



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To avoid this HYTORC, a well-known bolting OEM, has introduced a solution which is very simple yet very effective. HYTORC's washer system, consisting of Reaction washer or J- washer and a backup washer.



**HYTORC J- washer** can solve two major issues of bolting i.e. pinch point (which causes safety issue) and self-loosening of bolt during dynamic load condition (which causes joint to fail).

This particular washer is specially design to work with HYTORC's torque tool to eliminate the need of reaction arm. This in turns make the job safer. Backup washer is used on the passive side, this eliminate the need of Back up wrench and safety hazard associated with it. Also, use of this washer system (J-washer and backup washer) drastically reduces bolting time.



Reaction arm free Bolting

Standard pre-loaded fasteners can loosen as a result of relative motion between surfaces due to vibration. The J-Washer's knurled surface locks the nut when torque is applied so that loosening does not occur. The locking design has been verified by the industry standard Junker test, which simulates the transverse forces that loosen the assembly.



Anti-loosening test of HYTORC J-washer

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#### 2. Tensioning

Tensioning is a method in which preload is achieved by direct axial stretching of the bolt. Hydraulic bolt tensioning tools tighten bolts quickly and easily to high and accurate pre-loads. Unlike conventional methods, it does not use torque. The forceful turning of the nut or bolt, with impact wrenches, flogging spanners or hydraulic torque wrenches is not required. All of these methods have one common enemy, FRICTION. Overcoming thread friction and head friction uses up over 80% to 90% of torque energy applied to the nut or bolt, leaving around 10% to 20% of the energy to produce useful tension or elongation in the bolt. Variations in this friction loss from bolt to bolt causes non-uniform tension in bolts that have been tightened to the same torque setting.



The tensioner capacity is defined by load (in KN). The formula for applied load to bolted joint by tensioner is as follows.

#### $\mathbf{F} = \mathbf{P}/\mathbf{A}$

Where, F = Applied load (N)

P = Pressure (N/sq. Meter)

A = Hydraulic pressure area (sq. meter)

In many situations, technicians/operators get confused with the terms preload and applied load. Both terminologies are different from each other.

Applied load- The load that is applied by bolt tensioner to the bolt.

But Load loss is caused due to the bolt thread deflections, nut embedment into the flange. It is also dependents on the bolt diameter and the grip length.

**Preload/ Residual load-** the actual load transfer to bolted joint after losses is called preload or residual load. Mathematically preload is defined by the following formula.

#### Preload (residual load) = Applied Load - Load Losses

#### Pre- requisite for Bolt Tensioning-

An extra length of the thread must extend beyond through the nut for the tensioning to screw onto and apply the bolt tension. The length of the bolt is very important. Minimum 1D (1x Diameter of Bolt) bolt protrusion is required over the nut. Good quality bolts and nuts will make the tensioning operation quicker and more accurate. You need not use washers under the nut when using a bolt tensioner as friction is not a variable factor here. However, it is up to the design engineer.



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Like a torque wrench there are various types of bolt tensioner. Their usage depends upon various parameters like types of industry where tensioning is done, Joint type, etc. In some cases, special tensioning tools are designed to cater to non-standard flanges. Some type of bolt tensioners are as follows.



Standard Tensioner

Foundation Tensioner



Multi-stage Tensioner

#### **IV. CONCLUSION**

Bolted joints have an integral and vital role to maintain joint integrity. The loss of joint integrity may cause safety and economic damages. The selection of proper bolting method is also important to sustain and maintain joint integrity. Therefore, for a bolted joint, tensioning or torqueing is commonly used to tighten or loosen nuts in order to achieve joint closure with desired Load/Torque. With conventional torqueing method 'Pinch point' is one of the concerns which can be resolved using the HYTORC washer system. There are various type of tools available to carry out the bolting process.

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