Design, Simulation and Analysis Of Automatic Multifastener Device

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Abstract— **This paper deals with the design, simulation and analysis of automatic multifastener device. This device is designed by considering M22 standard metric bolt for a four wheeler tire assembly system. Assembly technology is an essential component of modern industrial production, and threaded joints are among the most common and widely used types of fasteners. Current industry demands the tools that offer One hand operation, Extended service life, Operator Comfort, Ease of serviceability to minimize the downtime, High value verses low cast. These demands can be met by the use of automatic devices. Now days the use of these type of automatic devices has gained an important role in the automobile industries, Laboratories and also in all mechanical industries Main components used in this device are motor, base stand, nut fitting and removing plate and a keypad for on/ off switches and some mechanical parts are used for driving operation. This device is operated by a DC motor. Selection of DC. Here Spur gears are used for transmitting the power. Proposed design and mechanism has been done in Pro-e wild fire.Structrual analysis of the device is carried out in Ansys at different loads.**

Keywords- fastener; Device, bolt tightner, Gear assembly, DTDP Switch, Battery, structural analysis.

I. INTRODUCTION

Assembly technology is an essential component of modern industrial production, and threaded joints are among the most common and widely used types of fasteners. The broad spectrum of assembly equipment ranges from state of the art robotics to work stations using hand-held tools. The criteria of these assembly tasks are just as varied, depending upon the application needs, the production method, quantity and the accuracy requirements.

Conventional fastening requires tools like a wrench or an electric or pneumatic tool. Industrial assembly or joining technology increasingly requires meeting long-term safety-oriented, and function oriented solutions. Historically there have been disadvantages associated with the use of conventional tools such as inaccurate tightening, high tool wear and requires more time for fastening.

Current industry demands the tools that offer One hand operation, Extended service life, Operator Comfort, Ease of serviceability to minimize the downtime, High value verses low cost. These demands can be met by the use of automatic devices. Now days the use of automatic devices has gained an important role in the automobile industries, Laboratories and also in all mechanical industries Bolted assemblies are the most commonly used connecting systems in mechanics. And although they appear to be quite simple, bolted assemblies do pose several challenges at many levels: design department, assembly workshop, on-site, and maintenance. In an assembly that contains threaded fasteners, the nut or bolt needs to be physically tightened to a specific torque. A bolted assembly quite simply means the putting together of at least two parts using one or several bolts. The design and implementation of a bolted assembly requires a very strict methodological approach, for errors can lead to costly and often disastrous failures. Several studies have shown that incidents encountered on bolted assemblies are most often due to improper design of the assembly or poor implementation like tightening method, tooling, and inspection.

Today it is known that of all the various causes of failure like overloading, design flaws, manufacturing defects, and others the most frequent is improper assembly. Tightening problems, whether insufficient tightening, excessive tightening or heterogeneous tightening, alone account for over 30% of all bolted assembly failures. More specifically, 45% of all fatigue failures are estimated to be due to improper assembly. Therefore, the importance of the design of the bolted assembly and the means used to tighten it are of utmost importance.

V.K. Zamyatin manufactured a device ie-3115a and ie 3112 electrical manual impact (chum) nut tightner for the assembly and dismantling of threaded connections at industrial firms. They used IE-3115A tightener for the calibrating the tightening of bolts size M18-M30, strength class 3.6-6.6, and bolts size M12-M20, strength class 6.8- 14.9. It consists of an electric motor, a planetary reducing gear, an impact mechanism, a handle with switch, the current-supply cable, and they found that this deviceis used for the elimination of radio interferences. They used IE-3112 nut tightener for the calibration of tightening of high-strength bolt of different sizes (M22-M30) or medium-strength bolts (35 steel) with diameters up to M42 ram. This tightener is a reversible tool and is equipped with a protective switch-off device. The IE-

3115A nut tightener is manufactured by the "Elektroinstrument" Production Association at Rostov-on-Don and the IE-3112 tightener by the "Elektroinstrument" Plant at Vyborg[1].

The "Uralkhimmash" Production Association produced a dual-spindle nut tightener intended for the tightening of the plates of plate heat exchangers during hydraulic testing and final assembly. This tightener has an upper and lower head, a gear box, telescopic head links, a suspension support, and a control panel. By suspension from a crane the tightener is placed on the nuts of the plate heat exchanger. The electric motor of the tightener sets the spindles into rotation through the gear box and worm reductors of the upper and lower heads. The spindles have ball inserts with an internal hexagon. The nuts of the heat exchanger bolts are located in the hexagons of the inserts. The telescopic Link compensates deviations from the distance between the bolts and nuts of the heat exchanger. The outer spherical surface of the inserts compensates the face slackness of the nuts of the heat exchanger during tightening. As the spindles rotate, the tightener travels together with the nuts in the direction of tightening until the required tightening stress is reached. This is followed by hydraulic testing of the heat exchanger[2].

SKF industries designed a standard Hydro cam tensioner. A standard Hydro cam tensioner has a hydraulic body which, using a hydraulic fluid, exerts a strong tension load on the bolt through the brace screwed on that bolt. In some tensioner types (HTC R), the body is screwed directly on the bolt to be tightened. The body also rests on the skirt in order to apply the reaction force on the assembly to be tightened. Prior to screwing the body-brace-skirt unit on the protruding end of the bolt, a socket has to be placed on the nut of the bolt. This nut can then be “turned down” (screwed until the lower surface of the nut comes into contact with the assembly bearing surface), by a tommy bar, while the tensioner applies the tension load. The turndown socket is placed over the nut and the hydraulic tensioner grasps the bolt. The brace/retraction unit is screwed onto the protruding end of the bolt. After the hydraulic connections, the tensioner is pressurized and applies the required tractive force on the bolt. While the pressure is maintained, the nut is turned down without loading, using the socket and the tommy bar. Their pressure is released and the piston is pushed back. The tightening load is now exerted through bolt tension. The tensioner and the socket can be removed[3].

A segment bolt tightener is developed by New shield machine technology.This segment bolt tightener automatically tightens fastening nuts and bolts of the primary lining segments assembled in an excavated tunnel. A movable cart equipped with tighteners is provided separate from the shield machine, so adverse affects due to shield machine backlash and vibration are eliminated, and tightening work can be performed more effectively from behind the shield. The bolt and nut tighteners are each mounted at the end of a multi-articulated manipulator, so the system can handle bolts and nuts mounted at any angle. The multi-articulated manipulators can handle segments with different inner diameters and shapes. Two tighteners are provided one on the left and one on the right, and these fasten bolts simultaneously, thereby achieving automation and labor-savings[4].Automation Industries developed a self-contained tensioner . A self-contained tensioner and tightener device is provided in accordance with this invention for a threaded stud projecting from a hole in a foundation surface. It comprises an expandable tensioning device which itself comprises a tensioning nut threadable onto the stud in spaced relation to the foundation surface and telescoping annular piston and cylinder elements defining a pressure chamber and loosely encircling the stud between the tensioning nut and the foundation surface. The expandable tensioning device also includes pressuring means communicating with the chamber for forcing the piston and cylinder elements and thus the tensioning nut and foundation surface apart to tension the stud. The invention also includes a spacer sleeve adapted to encircle the stud end portion and tensioning nut in abutting relation with the foundation surface. A locking nut is threadable onto the stud against the spacer sleeve to be tightened on the tensioned stud so that the pressuring means can be deactivated and the tensioning nut loosened. A take-up finger is fixed in relation to the tensioning device coaxial with and spaced closely adjacent the end of the stud and is threaded correspondingly to the stud so that the tensioning nut, the spacer sleeve and the locking nut necessarily move onto and are retained by the finger when removed off the end of the stud[5].

Cooper Industries, Inc. Houston, TX has designed a device called Impulse or torque screw or bolt tighteners. Impulse or torque screw or bolt tighteners which are used for a number of different screwing and tightening processes are fitted with a valve with which the bolt or screw tightener is switched on and off. The valve is located along the compressed-air supply line that leads to the screw or bolt tightener. This valve can be actuated manually by the operating personnel or by an electronic measuring and control device. Prior art screw or bolt tighteners, when switched on, operate at a constant pressure throughout the screwing and tightening process. As a result, the same kinetic energy is used to fasten both an M10 screw and an M8 screw. This is undesirable. In certain cases, this constant kinetic energy that is delivered to the screw or bolt tightener may induce the tool to penetrate the material to which the screw or bolt is to be applied and cause a rupture. This may result in damage to the screwed connection. With self-tapping screws, for example, the resistance is higher at the beginning of the screwing process; however, after the sheet metal has been perforated, this resistance drops to nearly zero. Yet, the prior art bolt or screw tightener uses the same high force, and the screw is struck at full force, which may cause the screw or the screw thread to rupture[6].

Kozo Wakiyama of Osaka Sangyo University in there investigations on earthquake damage have identified that there was there was a little damage of the high strength bolted joints when compared with the welding joints of the steel frames. With this investigation they came to a conclusion that adoption of the high strength bolt joints contributes to the improvement of the safety of the steel frame buildings. adoption of the high strength bolt joints contributes to the improvement of the safety of the steel frame buildings. . If a bolt is made more high strength, the bolt number of the joint decreases. But the risk of the delayed fracture is entailed for higher strength of the high strength bolts. The development of the super high strength bolt which delay fracture doesn't occur in was begun by the research proposal of Kozo Wakiyama in Nippon Steel Corp. in 1989[7].

A.U. de Koning, T.K. Henriksen,National Aerospace Laboratory NLR, Amsterdam, The Netherlands have identified some problems on fastener joints and suggested FEA Solution for the problems. one of the most challenging problems in fracture mechanics is related to its application to fastener and joints. By nature, not only the quality such as material, manufacturing and mounting processes, of the fasteners are playing a role, but also the stiffness, surface conditions and geometry of the parts are to be considered. Moreover, a fastener cannot be considered exclusively as an individual item, but has to be seen also as a link in a multi load path design. For a reliable integrity analysis of fasteners to be performed it is of paramount importance that accurate knowledge about load distribution and stress intensity factors is available. In their study the load transfer (tension and bending) as well as stress intensity factor solutions for various crack locations and sizes have been derived by advanced 3D FE analyses including threaded bolt and nut[8].

II. SELECTION OF MOTOR,DESIGN OF PARTS AND MATERIAL SELECTION

a. Selection Of Motor

Main components used in this device are motor, base stand, nut fitting and removing plate and a keypad for on/ off switches and some mechanical parts are used for driving operation. This device is operated by a DC motor. Selection of DC motor depends upon the total torque required to fit/remove the bolt. This DC motor works on the simple principle of electromagnetism. Here Spur gears are used for transmitting the power. Proposed design and mechanism has been done in Pro-e wild fire.Structrual analysis of the device is carried out in Ansys at different loads.
An equation for estimating initial fastening load in a bolt, based on experiments is approximately

$$P = 284*d \text{ kg} \text{------------------------(1)}$$

Where d is the nominal diameter of the bolt in mm

In order to find mean torque value needed for fastening it is essential to find out the maximum torque and minimum torque required. If one uses a torque which is greater than the maximum torque required for fastening, due to excessive torque there will be a chance of application of over load on the bolt which damages the treads.

An empirical formula for finding the tightening torque is given by

$$T_{max} = C*d*p/1000 \text{-----------------------(2)}$$

Where C is a constant, depends upon lubricating condition.

Minimum torque required based on experiment

$$T_{min} = 120 \text{ N-m}$$

Mean torque is given by

$$T_{mean} = T_{max}/T_{min} \text{-------------------------------(3)}$$

Then

Work done for tightening for one bolt $w = \int_{\theta 1}^{\theta 2} T_{mean} d\theta$

$$= T_{mean} \int_{\theta 1}^{\theta 2} d\theta \text{----(4)}$$

Total Work done for tightening four bolts W =4*w N-m
Based on W value motor has been selected.

Table 1 Standard metric bolt dimensions

Size Desig - nation	Nominal (Major) Diameter D_n	Minor Diameter D_m	Nominal Shank Area, A_n	Pitch (mm per thread) *p*	Pitch Dia-meter, d_p	Minor Dia-meter Area, A_s
M22	22	18.93	380.13	2.5	20.39	270.51

b. Design Of Gear

Spur gears have been used in this device and the material used for the manufacturing of the gears is alloy steel. The teeth project radically, and with these "straight-cut gears", the leading edges of the teeth are aligned parallel to the axis of rotation. These gears can only mesh correctly if they are fitted to parallel axles.
Dynamic load is calculated by

$$F_d = Ft + \frac{21\, v(bc+Ft)}{21v+\sqrt{(bc+Ft)}} \text{--------------------(5)}$$

where F_t is Tangential load in N
v Pitch line velocity in m/s
b face width in mm
c Deformation factor
and beam strength is calculated by

$$F_s = \pi * m * b * \sigma b * y \text{----------------------(6)}$$

where, σb bending stress in N/mm^2
m module in mm
y is a Form factor

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As the Dynamic load is less than the beam strength the gear tooth has adequate beam strength and it will not fail by breakage.

Table 2 Alloy steel properties

Properties	**Units**
Tensile Strength, psi	97,000
Brinell Hardness	201
Yield, psi	57,000
Elongation	25%
Machinability	66%

III . CONSTRUCTION AND WORKING OF AUTOMATIC MULTIFASTENER DEVICE.

The proposed device is bolt/nut fitting & removing without human help for driving. This device is designed to fit and remove bolt/nut of M22 size. Mechanical parts are used here for driving operation. Here spur gears are used for the driving operation. The different components of the device are Motor ,Battery, Gear system, DPDT switch.

Initially, make alignment of the device nut holder with the nut which we want to tight or remove. Keypad has a switch to drive the nut holder. This switch is called as DPDT Switch which stands for Double pole double through switch. Her we used the positive potential and negative potential of the motor. If we push the DPDT switch in forward direction, it helps to fix the bolt/nut, or if we push the DPDT switch in reverse direction, the given polarity will be changed oppositely and it helps to remove the bolt/nut. The efficient function of the motor has own driver unit which enables by small power.

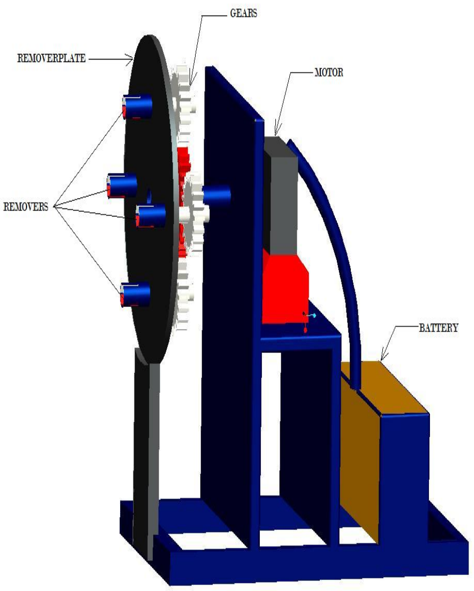

Fig 1.Design of Automatic Multi fastener Device

In this proposed device an DC electric motor of 2.5kw is used. Electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion. DC motor has six basic parts they are axle, rotor (armature), stator, commutator, field magnet(s), and brushes. In most common DC motors, the external magnetic field is produced by high-strength permanent magnets. The stator is the stationary part of the motor this includes the motor casing, as well as two or more permanent magnet pole pieces. The rotor (together with the axle and attached commutator) rotate with respect to the stator. The rotor consists of windings generally on a core, the windings being electrically connected to the commutator.

In this device we used secondary type battery. A battery is one or more electrochemical cells, which store chemical energy and make it available as electric current. There are two types of batteries, primary batteries and secondary batteries, both of which convert chemical energy to electrical energy. Primary batteries are also called as disposable batteries. Secondary batteries are also called as rechargeable batteries. Primary batteries can only be used once because they use up their chemicals in an irreversible reaction. Secondary batteries can be recharged because the chemical reactions they use are reversible; they are recharged by running a charging current through the battery, but in the opposite direction of the discharge current. Secondary, also called rechargeable batteries can be charged and discharged many times before wearing out.

In this Automatic Multi fastener Device spur gears are used for the driving operation. Design of the spur gears has been done according to the design conditions. Dynamic load and beam strength has been calculated, As the Dynamic load is less than the beam strength it has been concluded that gear tooth has adequate beam strength and it will not fail by breakage. Therefore the design is satisfactory. Spur gears have teeth parallel to the axis of rotation are used to transmit motion from one shaft to another shaft. Spur gears are the simplest and most common type of gear. Their general form is a cylinder or disk. The teeth project radically, and with these "straight-cut gears", the leading edges of the teeth are aligned parallel to the axis of rotation. These gears can only mesh correctly if they are fitted to parallel axles. Modeling and assembly of the gears is done in ProE software. Simulation of the Automatic Multi fastener Device is performed in Pro E software .One driver gear with four driven gears will form a gear assembly unit this is shown in fig 2. This entire gear assembly unit is attached to the base plate of the Automatic Multi fastener Device. Fig 3 describes the design of a bas plate. Power to drive the driver gears will be given from the batter. When driver gear completes one rotation, driven gears completes two rotations and the gear ratio is 2.

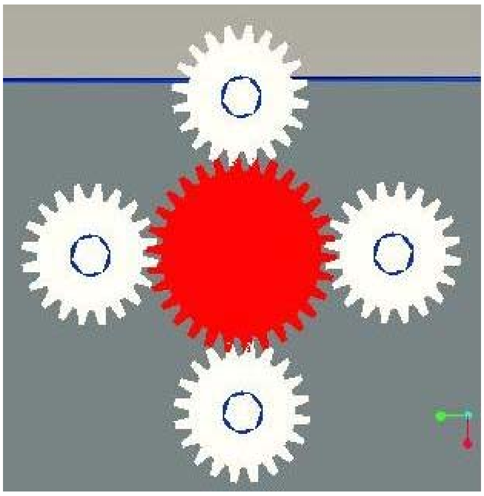

Fig 2.Gears Assembly

In order to have clock wise and anti clock wise rotation of the removers a DTDP switch is used. DPDT Switch stands for Double Pole Double Through Switch. In electronics, a switch is an electrical component which can break an electrical circuit , interrupting the current or diverting it from one conductor to another. The most familiar form of switch is a manually operated electromechanical device with one or more sets of electrical contacts. Each set of contacts can be in one of two states: either 'closed' meaning the contacts are touching and electricity can flow between them, or 'open', meaning the contacts are separated and nonconducting.

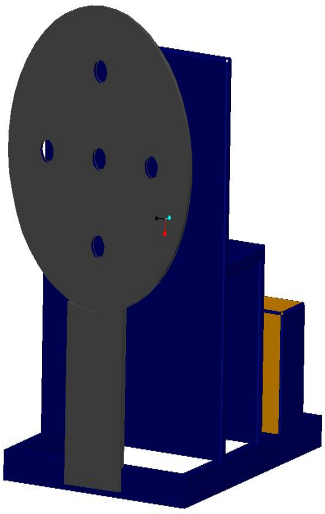

Fig .3 Base Stand

IV ANALYSIS AND RESULTS

structural analysis of the Automatic multi fastener device is done in Ansys. Automatic multi fastener device is modeled in Proe. This model is saved in IGS format and it is exported to Ansys for performing analysis. Analysis is performed at three different load conditions. In the preprocessing element type, material properties, meshing and loads have been defined. In the post processing deformed shapes and the displacements have been identified.

structural analysis of the Automatic multi fastener device is carried out at different load conditions. Three different loads have been considered L1 as 800 N,L2 as 1600 N and L3 as 2400 N.

Table 3 Structrual Analasys

Load(N)	Deformation(mm)	Max VonMises(N/mm^2)
(L1) 800	.390e-4	.134143
(L2) 1600	.489e-4	.330091
(L3) 2400	.702e-4	.726869

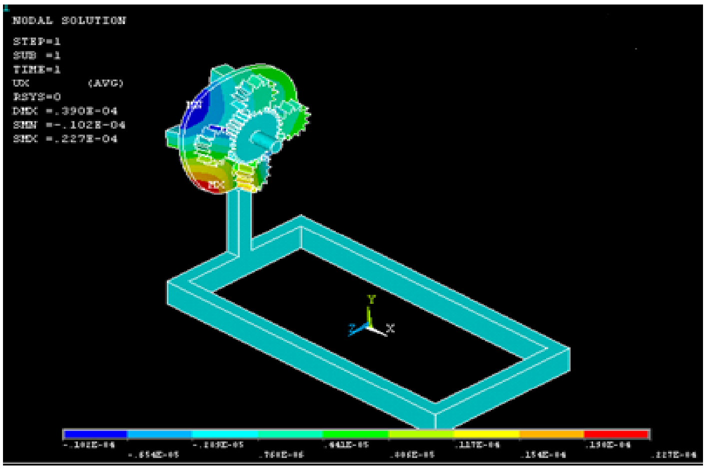

Fig 4 Nodal solution dof x with load L1

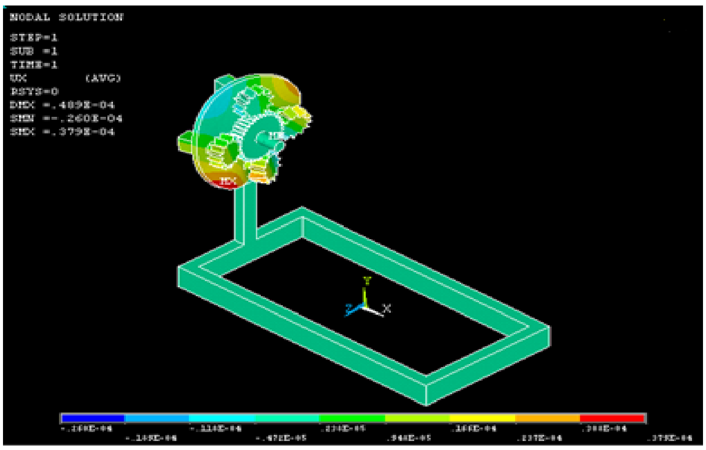

Fig 5 Nodal solution dof x with load L2

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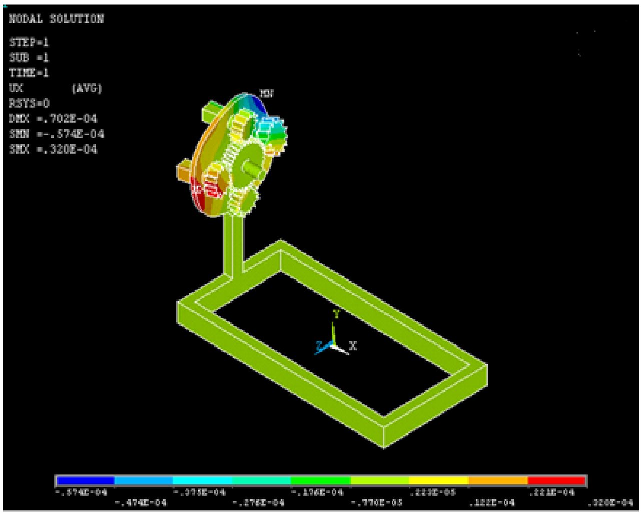

Fig 6 Nodal solution dof x with load L3

Nodal solutions for the different loads is given in Fig4,Fig 5,Fig 6.From the structural analysis of the Automatic multi fastener device it is found that the structure will fail if the applied load is beyond the designed value.

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