Design and Optimization of the Industrial Torqueing Solution

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ABSTRACT

The major objective of the following study is the design and optimization of the industrial torqueing solution for a machine known as a power tiller. It is available in two variants depending on the application, so it either has 22 or 40 bolts. Roughly 22 bolts take a fastening time of 25 mins and successively 40 bolts take 45 mins. According to the existing design, there is very less accessibility for the readily available power tools to be used in this area which drastically reduces worker ergonomics thereby reducing the productivity. Thus these fastenings are done manually by the operator using an open end spanner and the final torque is set using a manual torque wrench. The main aim of the study is to modify this existing manual system by a semi-automatic or a completely automated system thereby reducing the cycle time and improvising on user ergonomics

Keywords: ***Torque, Power tiller, Ergonomics, Automatic System, crofoot assembly etc.***

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1. INTRODUCTION

The required torque is not applied in tightening the nuts, the nuts will lose, and this will jeopardize the driver's safety. Impact wrench used to remove wheel nuts is also consuming time in automotive maintenance industry. For these reasons, to avoid time wasting and a lot of energy used to change the tyre, a special tool is designed and fabricated to allow driver or mechanic to remove four wheel nuts at once with little energy consumption

A power tiller is a revolutionary machine that combines the best of tractors and tillers. It is used to pulverise the soil and to aid in cultivation by exploiting the commercial means of agriculture thereby reducing human effort. Various design considerations need to be thought of while operating the tiller in rough and rugged environment; designing the blades to sustain impact loads and production of the roto-tiller arrangement to sustain for longevity are also some of the considerations. The power tillers are used with ground engaging tools like rotary tiller mounted on the roto-tiller shaft. Various blades are mounted on the shaft depending on the make or the variant of the tiller. The main hindrance faced in the following situation is that the cycle time of fastening of these blades to the tiller shaft is time consuming and not in harmony with the flow of the assembly line. Due to dimensional constraints, readily available market power tools are not satisfying the solution to this problem. Due to certain inaccessibility in the under belly of the shaft, user ergonomics is equally hampered and also the system is completely manual operated. The main objective is to design a system solution which will be semi or fully automatic system for the fastening of bolts on the roto shaft. As mentioned earlier that the option of market available tools is rejected, custom designed tool needs to be manufactured for this problem. The various probable solutions considered are as mentioned in the literature review.

Engineering in general, and Mechanical engineering in particular, deals with a wide spectrum of products, ranging from large and complex systems comprising of numerous elements down to a single component. Apart from being a physical object, a product can also be a service that requires the application of engineering knowledge, skills and devices to be useful to society. A service falls under the category of a system in that it is carried out with the help of personnel, facilities and procedures.

The service offered by an automobile maintenance and repair garage would be a typical example from mechanical engineering. Even computer software could be treated as an engineering product. It is also created using engineering knowledge and skills. In the following, the term product when used alone denotes the object to be designed and made with the help of engineering knowledge and skills, irrespective of whether it is a large system, a simple machine, a component or a service. A general understanding of the nature of product is a prerequisite for designing it. A complex product can be subdivided into sub-assemblies or sub system, component etc. Frequently the planning, layout and design of complex multi element product is an interdisciplinary effort, requiring the expertise and skills not only of several engineering specialization but even non engineering ones. It is always preferable that our work should be easy and fast. But easy and fast working requires some technical skills to work efficiency and properly. In a day-to-day life there are many problems where there is a need of lot of effort and time to do that specific work.

2. LITERATURE REVIEW

On the basis of the problem statement the literature survey is carried. This is survey consist of mainly two considerations

2.1 Forces Considered:

Let's discuss what happens when you turn a nut or bolt head. The threads are a form of inclined plane or wedge, the simplest type of tool. As the inclined plane is wedged (turned) into the threads, it applies a force along the bolt's length, effectively making the bolt a tension spring. This tension in the bolt shank clamps two parts together. If the clamping force is greater than the load exerted between, say, the head and the block, those two pieces will never spontaneously get loose. And the more twisting force you apply to the bolt head or nut, the more clamping force in the joint. So just tighten it until it won't come loose, right? Wrong. Differences in overall bolt length, the material of the clamped parts, the presence of a gasket between the two parts, and even the alloy of the bolt itself affect the proper torque. Also, the proper torque value takes into account the friction between the threads, which is the single biggest variable that affects the relationship between the torque applied to the bolt head and the clamping force. Friction arises from the threads as well as the rotating bolt face scrubbing along the stationary workpiece. Overcoming friction can account for as little as a few percent or as much as 50 percent of the force needed while tightening a nut or bolt. And that means that the clamping force can vary widely—not well when you're installing a cylinder head or an intake manifold.

2.2 Torque Basics:

At some time, we have all had difficulty in removing the lid from a jar. The reason we have this trouble is simply that we are unable to supply adequate torque to the lid to break it loose. The solution to our dilemma may be to:

- Grit our teeth and try harder,
- Use a rubber pad, or cloth, to increase the ability to transmit torque without slippage, or
- Use a mechanical device to help multiply our torque producing capability.

Failing on all of the above, we may pass the jar to someone stronger who can produce more torque. If we were to wrap a cord around the lid and supply a force to the end of the cord through a scale, we could get the exact measurement of the torque it takes to loosen the lid. The torque required would be the force as indicated on the scale, multiplied by the radius of the lid.

3. PROBLEM STATEMENT:

The power tiller has a series of blades bolted on a shaft which is chained to the main drive shaft and it is located below the frame of the tiller. It is available in two variants depending on the application. So it either has 22 or 40 bolts depending on the variant. Roughly 22 bolts take a fastening time of 25 mins and 40 bolts take 45 mins. These fastenings are done manually by the operator using an open end spanner and the final torque is set using a torque wrench. As the bolt spacing is very less, it is very difficult to access them during its assembly. It affects the ergonomics thereby reducing productivity.

4. METHODOLOGY:

While tightening of bolt by crofoot assembly the bolt will give a reaction in the opposite direction at the ending of thread. This reaction is because of the Torque which are applied by the tool and opposite angular force given by the bolt. This Reaction force may hamper the worker's health in actual practice.

Hence in order to perform all the above things a design should be proposed which should be more convenient, cheaper and easy access. Therefore Design of Reaction Arm which will sustain the reactions coming from the tool and so that reducing chances of harm to the worker.

4.1 Tool to be used:

As per Company guide views we decided to use a Pneumatic Fastener which is manufactured by Atlas Copco. This is the schematic CAD model of the tool;

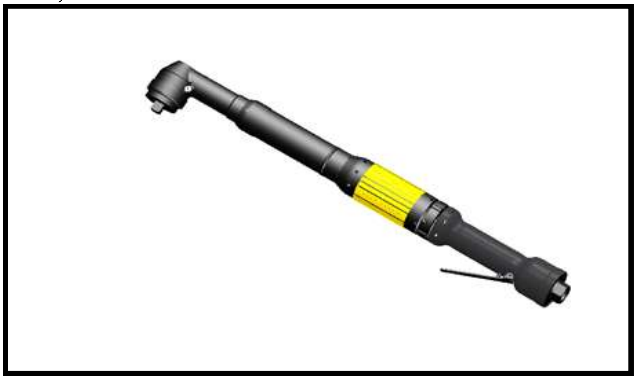

Fig. No. 1 Cad Model of Tool

If we thing of using this tool directly on the tiller shaft, by considering the thickness of head of tool is not fitting in the shaft tolerances as per the iterations taken. There is some sort of interference of tool and shaft/tool. So we come up with the solution of using a mechanism called Crofoot.

Crowfoot is a device which converts torque applied in axially to the direction normal to the axis of torque applied. Crowfoot contains several bevel gears mounted linearly to transfer torque. Crowfoot is a product of German company called Lubbering. Internal view of crowfoot is as shown below.

Crowfoot nut runners from Atlas Copco are certified for accuracy and durability by major car manufacturers. They are easy to choose, easy to set, and easy to operate Accurate every time. You don't need to think about it. The tool gives the torque you install, independent of joint variations and variations in air pressure and lubrication. The clutch shuts off at the same torque. Highest productivity: Instant disengagement of the clutch keeps torque over-shoot to a minimum even on the fastest tools. Our new models were developed to meet the most extreme requirements on operational speeds. As always, we kept operator comfort in mind. The tools are well balanced, slim and comfortable to handle. Reaction forces are extremely low. Job verification: For remote indication of clutch release function the tools can be equipped with air signal outlet – RE. This is often used for counting the number of fasteners in a tightening cycle.

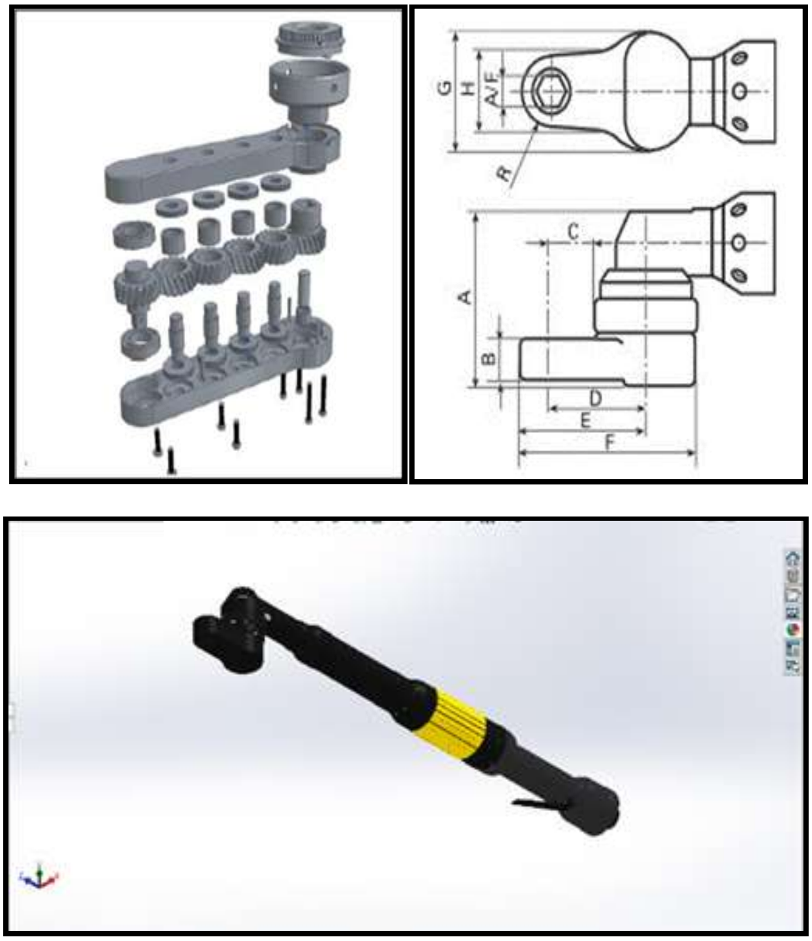

Fig. 2 Crofoot detailed drawing

4.2 DESIGN OF REACTION ARM

When operating torque tools for high torque and high speed applications, it is extremely important to consider the issue of torque reaction of the tools being used. For torque tools such as torque multipliers, pneumatic screwdrivers, non-runners, DC control tools and other tools that will be used for the torque application, you need to consider both how the tool will be supported and how the torque reaction and high speed will be dealt with in order to protect the operator. Selecting the right torque tool for the job is crucial, but operator safety is key priority when operating a high torque or high speed tool. Below you will find an overview of the different types of safety solutions available for protecting the operator.

Reaction coming from tool is considered as 1000N.

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S_{yt}=450N/mm2, S_{ut}=750N/mm2

Diameter of reaction arm, d = 10(2)1/2=14.14mm

Bending moment = F X L = 1000x110 = 110000Nmm

Assumptions,

The process is completely reversed cycle.

Reliability = 90% = 0.9

For steel, Se′=0.5Sut = 0.5x750 = 375N/mm2

Surface finish factor,

K_a=a(Sut)b

For cold drawn steel, a=4.51, b= -0.265

K_a = 4.51(375)(-0.265)

= 0.93

As 7.5<d<50mm, size factor, K_b = 0.85

For 90% reliability, K_c=0.897

Assuming, modifying factor, K_d = 1

$S_e = K_a K_b K_c K_d S_{e'}$

= 0.93x0.85x0.897x1x375

= 265.9 N/mm^2

0.9Sut = 0.9x750

= 675 N/mm^2

Log_{10} (0.9Sut) = 2.82

Log_{10} (Se) = 2.42

Cross sectional area, A = $(\pi/4)d^2$

= 157mm^2

Bending strength, $\sigma_b = M_b y / I$

= $(32 \times M_b)/(\pi x d^3)$

= 396.13N/mm^2

σb=Sf

Log_{10} (Sf) = 2.59

From the graph,

$$\frac{BC}{AB} = \frac{DE}{AD}$$

$$BC = \frac{(6-3)(2.82-2.59)}{(2.82-2.42)}$$

BC = 1.725

N = 10(3+1.725)

=104.725=53088.44 cycles

The design is safe having factor of safety of 4-5.

5. SIMULATION AND ANALYSIS:

This crofoot assembly is to be checked for interference with blasé or shaft with all 20 lugs so that it perfectly fits in given tolerances. By considering the workers condition and position while tightening of bolts the tool must be in between 0 to 45 degrees to the axis of lug. The designing of the internal parts of the crowfoot assembly was neglected previously to check for its feasibility for external dimensions and available space on the roto-tiller arrangement. The testing was done using the designing software. The crowfoot mechanism was tested on the complete shaft having 20 blades. All the 20 blades gave a successful fit. The only hindrance to make this as the system solution and to implement it was the economics of the entire crowfoot arrangement. As this is a completely custom-made tool and only manufactured by the international companies, it is very costly ($10000-$12000 USD). This was the only factor to think about in the successful implementation of the solution on the assembly line of the power tiller.

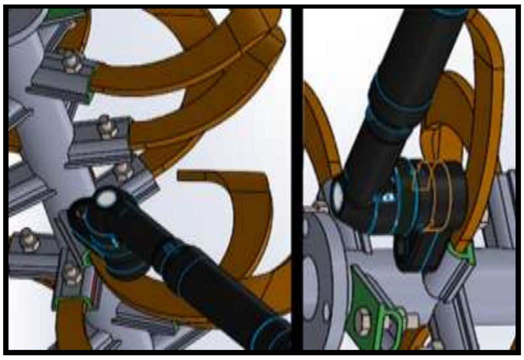


Fig. No.3 Power Tiller with Crofoot Arrangement

Lug number (blade no)	Result
1	No Foul
2	No Foul
3	No Foul
4	No Foul
5	No Foul
6	No Foul
7	No Foul
8	No Foul
9	No Foul
10	No Foul
11	No Foul
12	No Foul
13	No Foul
14	No Foul
15	No Foul
16	No Foul
17	No Foul
18	No Foul
19	No Foul
20	No Foul

Table No.1 Result table of Tightning the boot

By the result of simuation and literature review use crowfoot assembly is finalized. For the analysis of reaction arm, the Arm is considered as cantilever beam. By above considerations Static analysis is carried out in Ansys Workbench.

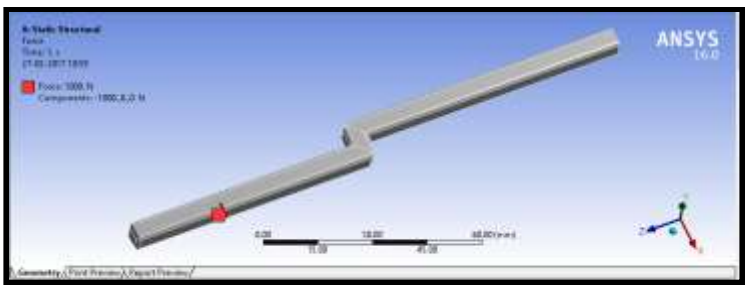


Fig. No. 4 Loading Condition:

A cantilever is a beam supported on only one end. The beam transfers the load to the support where it has managed the moment of force and shear stress. Moment of force is the tendency of a force to twist or rotate an object. Shear stress is defined as a stress which is applied parallel to the face of a material. In other words, the beam bears a specific weight on its open end as a result of the support on its enclosed end, in addition to not breaking down as a result of the shear stress the weight would generate on the beam's structure. Cantilever construction allows for overhanging structures without external bracing / support pillars. Cantilevers can also be constructed with *trusses* or slabs. Cantilever construction is famous in many kinds of architectural design and in other kinds of engineering, where professionals use terms like end load, intermediate load and end moment to find out how much a cantilever will hold.

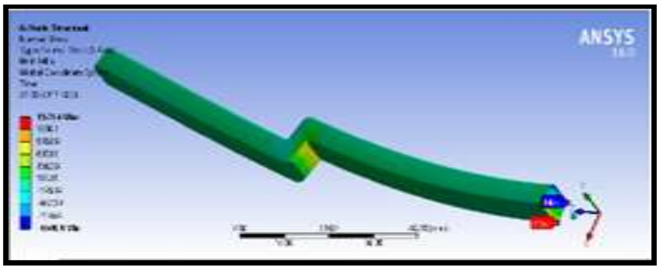
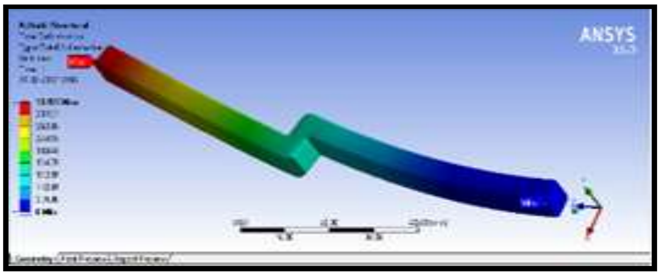


Fig. No. 5 Total Von Misses Stress



Fig, No. 6 Total Deformation

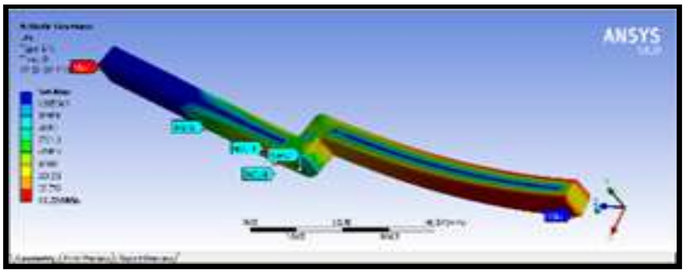


Fig. No. 7 Result for Fatigue Life condition

5.1 Optimization of Cross Reaction Arm:

Optimization of cross section of reaction arm is done with the help of Ansys workbench. Basically we decided the range I.e. 5x5 to 12x12 square cross section or preferably rectangular section. Company suggested to keep factor of safety between 4-5.so keeping the relation between stress , area and FOS, stress and deformation must be lesser to get max FOS. Also for min stress we need max area. For finding this we need to take the iterations ranging between 5x5 and 12x12 c/software took total 1000 samples and converged these samples to get top 3 candidates. The 3 Starred candidates denoted best solution therefore selecting cross-section 12x11 having min stress and deformation thereby having max FOS.

After checking the feasibility conditions, (i.e. economic feasibility, operational feasibility and technical feasibility) it is checked experimentally. It worked well in Experimentation. Finally the output was received as desired. It showed that cycle time required for tightening of bolts on tiller shaft is 19-20 min. Which is 5 min lesser than previous method.

6. CONCLUSION:

According to the problem statement, the existing time of fastening 20 bolts is roughly 23-25 mins. The projected result is to reduce this fastening time to 17-19 mins. All of the above is to be implemented without hampering operator safety. Proper care and designing is more over important for the successful modification in the assembly line which can aid to maximize profits and minimize dangerous or unavoidable incidences. With respect to the original shaft design, it was in compliance to the tools and available modes of fastening the blades. With the updating of the system, we have recommended to change the orientation of the blade mounting lug number 01 in the similar direction as the rest of the other blades.

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