Design and Evaluation of Enhanced Handheld Hydraulic Wrench

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Abstract—This document gives information about design, evaluation and fabrication of a portable wrench powered by fluid power system. The wrench is designed to be a substitute to a conventional wrench for opening wheel nuts. The design of the portable wrench has gone through three stage of design process; initial, intermediate and final. A prototype to test the mechanism was built with some limitations. The design was modeled using modeling tool and a structural analysis has been done using a simulation tool. Torque of 120 Nm was taken as the baseline for the amount of tightening torque of wheel nuts. The safety factor of the assembly is 1.35 based on the lowest safety factor of the part in the assembly.

Keywords—Hydraulic, Portable Wrench, Torque Wrench, Fluid Power System, ANSYS Static Structural Analysis

1. Introduction

Wrench comes in different sizes and designs. For conventional wrench, the bigger the size of the wrench, the greater the torque it can produce due to having longer arm to apply force. However, in the case where size is the limiting factor, the amount of torque can be increased by increasing the applied force.

Based on car owner’s manual, the value of tightening torque of wheel nuts for sedan-type vehicles is in the range of 100 Nm to 110 Nm. The baseline output torque for the final product was set at 120 Nm, which is higher than the average value.

This project focuses on the idea of a compact and portable wrench powered by hydraulic which minimizes human effort to open wheel nuts of sedan-type vehicles. The wrench which is called as Enhanced Handheld Hydraulic Wrench (EHHW) was designed to be user friendly, compact and portable.

2. Fluid Power System (FPS)

There are seven basic components in FPS; a tank, pump, power source to drive the pump, control valves, actuators, hose line and the working fluids. Fluids can be categorized as gases and liquids. Because EHHW uses hydraulic fluid, the working fluid here refers to the hydraulic fluid.

The work is carried out by the pump that sends pressurized fluids into hydraulic actuators which drive the final mechanism to perform useful work. The system could produce very high horsepower and have tolerances up to one tenth-thousands of a centimeter at the same time, making it a very versatile system [1]. In addition, the force multiplication can be done without the use of gears, pulleys and levers. With less moving parts in the system, the chance of failure is minimal. Not only that, it is also capable of producing constant output torque regardless of speed changes [2].

3. Research Methodology

The design of EHHW has been through three phases of design stages; initial, intermediate and final stage. A stress analysis using ANSYS has been done on the final design. A prototype to test the workability of the mechanism was built.

3.1 Design Stages (Initial, Intermediate and Final)

The design of EHHW in the initial stage was inspired from the most basic shape of a bell crank which is a triangle. The main frame was designed in triangular shape which has two mounting points; one for the wrench and the other for the hydraulic cylinder. Two design constraints were introduced to ensure the final product to be compact in size; the length of the handle must not exceed 200 mm and the height of the triangle must not be higher than 90 mm.

In the intermediate stage, important design parameters which have great effect on the output torque were identified and a new design was drawn. It was found that the length of the handle has the least effect to the output torque produced. However, some of the parts were found in interference of each other. Therefore, to avoid complications, the design has been changed.

With the changes made, the EHHW has now entered the final stage of the design process. As a whole, EHHW has all the seven components of FPS. The pump and tank come together with a manual hydraulic pump. Hydraulic cylinder as the actuator is linked to the wrench that will do the opening of wheel nuts. The whole components are connected together with hydraulic hoses and human force will be used to power the pump which drives the whole system. A single mounting frame will hold the entire parts together as shown in Fig. 1. EHHW has user friendly features like adjustable stopper which its position can be adjusted and multiple size sockets can be used on the same wrench to accommodate different sizes of wheels.

Fig. 1 Complete EHHW assembly without hydraulic pump

3.2 Stress Analysis of EHHW in ANSYS Simulation

The stress analysis of the design has been done in ANSYS Workbench. A free body diagram was drawn to determine all the forces acted on the EHHW during operation. The loadings were configured as Fig. 2 to copy the actual operation. The direction of the forces from the hydraulic are labeled as D and E while C is pretension bolt loading of 60000 N. The bolt pretension load resembles a nut that has been tightened with 120 Nm of torque. The magnitude of loads D and E are
833 N. The stopper is fixed at the bottom (A) because in the real operation, it will rest in between the gap inside the wheel. Fixed points B and F resemble the wheel and wheel bolt.

The method used for the meshing was automatic. The size of the meshing for the stopper, wrench, main frame and holding bolt was controlled. A total of four simulations were done and the size of the meshing was different for every run. The size of the meshing was set to be default for the first run followed by 5 mm, 4 mm, and 3 mm for second, third and fourth run respectively.

Figure 2 EHHW Loadings and Supports Setup in ANSYS

### 3.3 EHHW Prototype

A prototype of EHHW has been made to test out the workability of the opening mechanism (Fig. 3). The design, materials and equipment used for the prototype are altered due to limited material and apparatus. However, the alterations are acceptable because the prototype is only tested on its mechanism only. The prototype was not tested for actual operation.

![Fig. 3 EHHW Prototype](image)

### 4. Results

The results of the simulations for the wrench, main frame, stopper and holding bolt are tabulated according to the different meshing size in Table 2.

The opening mechanism tested using the prototype worked finely as there is no parts interference. The wrench turns accordingly as the piston extends. However, because the prototype uses pneumatic cylinder as oppose to hydraulic cylinder, the wrench turns with high speed.

### 5. Discussion

Based on Table 1, the highest value of stress can be seen on the wrench. Compared to the wrench, the other parts experienced significantly lower stress. The material selection process was done based on the result of the stress analysis with more attention towards the wrench.

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<table>
<thead>
<tr>
<th>Parts</th>
<th>Max. Stress according to mesh size (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Default</td>
</tr>
<tr>
<td>Wrench</td>
<td>154.0</td>
</tr>
<tr>
<td>Main frame</td>
<td>65.0</td>
</tr>
<tr>
<td>Stopper</td>
<td>40.5</td>
</tr>
<tr>
<td>Holding Bolt</td>
<td>10.6</td>
</tr>
</tbody>
</table>

Factor of Safety (FOS) is another important factor that needs to be taken into consideration while designing. FOS is defined as, given the YSOTM, the ratio of maximum load over operational load [3].

For EHHW, the FOS of the wrench is 1.35. That means the wrench can take up to 35 percent more load. Because the value of FOS for the wrench is the lowest for the EHHW, it can be said that the FOS of the whole assembly to be 1.35. It is important to consider having FOS to be more than one so that the assembly would not fail when overload.

When fully retract, EHHW is 200 mm in length, 150 mm in height and 100 mm width and becomes longer by 30 mm when it fully extend. Pressurized hydraulic fluid is supplied to the hydraulic cylinder by hydraulic pump which is manually operated by human. The wrench turns as the hydraulic piston extends. For a 32 mm diameter piston, a pressure of 1.1 MPa is needed to provide the required force to produce 120 Nm of output torque. Given the stroke of 125 mm, the volume of hydraulic fluids required is 0.1 litre. Therefore, any hydraulic pump that can provide the required pressure and any reservoir that has a capacity of at least 0.1 litre can be used for EHHW. However, a small hydraulic pump is preferred for portability purpose.

### 5. Conclusion

Aiming to minimize human effort to open wheel nuts, EHHW was designed to be user friendly, compact and portable. The human force is amplified with the use of the hydraulic pump. Aluminum alloy was chosen over steel so that the final product will be lightweight. The stopper which its position can be changed can accommodate different size of wheels. With minimum FOS of 1.35, EHHW could withstand 35 percent more loads which means it can also open over tightened wheel nuts.

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### References

