Dynamic Analysis Of Hydraulic Rotary Actuator
By Using Planetary Gear System

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Abstract: Developing technology reveals higher force and torque requirements. In addition, it is one of the requirements of our age that these needs can be made in as small volumes as possible. For this reason, hydraulic systems are preferred instead of electrical and pneumatic systems. The fact that hydraulic systems are applicable to mobile applications is just one of the other advantages. In this study, the dynamic analysis of the hydraulic rotary actuator by using planetary gear mechanism which has been designed will perform and compared with the analytical calculations and measured how much advantaged according to existing products.

Index Term: Actuator, Dynamic Analysis, Hydraulic Rotary Actuator, Planetary Gear System, SimXpert, Actuator.

1 INTRODUCTION
In hydraulic systems, the pressurized fluid through by the pump is passed through pipes or hoses to the actuators called end users by means of flow control, directional control and pressure control valves. These actuators provide the desired movement or force. In hydraulic systems, linear motion is carried out by cylinders, and the rotation movement is carried out by hydromotors. Although hydraulic cylinders can be obtained certain angles, it is easier to make them through hydraulic rotary actuators. With the hydraulic cylinders, it is necessary to use the bar linkage mechanism shown in Fig.1 when it is desired to obtain more than 120 ° rotation movement. The use of these arm mechanisms in the system causes the construction to occupy more space.

Figure 1. Hydraulic Platform which Rotation and Equilibrium Movements provide by bar linkage mechanism

For example, the levelling movement of the basket of the hydraulic mobile aerial work platform shown in Figure 1, is provided by 270 ° and the rotation movement of the basket by 180 °. When we try to make these movements with cylinders, it is necessary to use a 5 parts mechanism in the basket levelling and a 4 parts mechanism in the rotation movement.

2 DYNAMIC ANALYSIS WITH COMPUTER AIDED ENGINEERING
The Motion Workspace environment of the MSC SimXpert software was used to perform dynamic analysis of the hydraulic rotary actuator which has a planetary gear. In order to establish the dynamic model, parts of the hydraulic rotary actuator designed in Solidworks, were transferred to the SimXpert. In the dynamic analysis established in SimXpert, while the outer body is fixed, the linear motion relation is defined between the piston which moving inside the body. The coupling relationship between the helical gears and the gears in the planetary mechanism are defined. During this relationship; how far the helical gear will rotate and the rotation of the planetary gear and the output shaft in the planetary mechanism according to linear motion; Measured from the design performed in Solidworks.

However, these movements can be provided much more easily by using the helical gear hydraulic rotary actuators shown in Figure 2.
3. COMPUTER AIDED DYNAMIC ANALYSIS RESULT AND DISCUSSION

**Figure 4.** The Dynamic Analysis Model of Hydraulic Rotary Actuator Which has Planetary Gear Mechanism

**Figure 5.** The Dynamic Analysis Model of Hydraulic Rotary Actuator Which has Planetary Gear Mechanism (Front View)

### 3.1 RIGID DYNAMIC ANALYSIS

Torque information of 2123 Nm is entered into the output shaft in order to find the force to be applied to the piston against the desired output torque. In response to this torque value entered in the analysis, the force required for the linear movement of the piston was found.

**Figure 6.** Dynamic Analysis Force-Time Curve Result

The pressure value that must act on piston area to acquire the 125420 N force that is found in dynamic analysis result, is calculated by:

\[
\text{Pressure} = \frac{\text{Force}}{\text{Area}}
\]

**Figure 7.** Piston area where pressure is applied

The area that the pressure is applied is between the outer diameter of piston and the shaft diameter of piston. This area is calculated by:

\[
A = \frac{\pi d_1^2}{4} - \frac{\pi d_2^2}{4}
\]

formula and the result is found as

\[
A = \frac{\pi \times 125^2}{4} - \frac{\pi \times 75^2}{4} = 7850 \text{ mm}^2
\]

If we put this value in the pressure formula, the pressure is calculated as:

\[
\text{Pressure} = \frac{125420}{7850} = 16 \text{ MPa}
\]

### 3.2 ANALYTICAL FORCE CALCULATION

The axial force that must act on piston area and depending on this the working pressure will be calculated for the 2123 Nm required torque of output shaft. First of all basic gear ratio of planetary gear mechanism must be calculated. The output shaft has 24 teeth, planetary gears have 10 teeth and sun gear has 44 teeth. Since the planetary gears are kept constant, they only act as a motion transfer. In this case basic gear ratio is calculated with:

\[
\text{Basic Gear Ratio} = \frac{\text{Number of Teeth on Sun Gear}}{\text{Number of Teeth on Output Shaft}}
\]

formula and basic ratio is found as

\[
\text{Basic Gear Ratio} = \frac{44}{24} = 1.833
\]

**Figure 8.** Planetary Mechanism Gear Data
The torque that the sun gear must transfer to planetary gears for the 2123 Nm required output shaft torque is calculated by:

\[ \text{Sun Gear Torque} = \text{Output Shaft Torque} \times \text{Basic Gear Ratio} \]

In this case sun gear torque is calculated as:

\[ \text{Sun Gear Torque} = 2123 \times 1.883 = 3891.5 \text{Nm}. \]

**Figure 9. Sun Gear Torque-Force Transformation**

The calculated sun gear torque is transferred to external helical gear as a force. This transformation is calculated by:

\[ \text{Torque} = F_{\text{radial}} \times \text{Pitch Radius of Helical Gear} \]

formula and the force is calculated as:

\[ F_{\text{radial}} = \frac{3891.5}{0.031} = 125532 \text{N} \]

\[ F_{\text{axial}} = F_{\text{radial}} \times \tan(\text{Helix Angle}) \]

Because of the external helical gear on the sun gear and the internal helical gear on piston are working as a couple, the radial and axial forces between these gears are equal. The axial force that must act on piston area is found by formula. Since the helix angle 45°, \( \tan(45°) = 1 \). In this case \( F_{\text{axial}} \) will be equal to \( F_{\text{radial}} \).

For the 2123 Nm required torque of output shaft, the axial force that must act on piston area is calculated as 125532 N. The pressure value that must act on piston surface to acquire this force is found by

\[ \text{Pressure} = \frac{\text{Force}}{\text{Area}} \]

Pressure is calculated as:

\[ \text{Pressure} = \frac{125532}{7850} = 15.99 \text{MPa} \]

**4 CONCLUSION**

In this study, the model which is the most real-like mathematical model of the new design of hydraulic rotary actuator by using planetary gear mechanism has been set via SimXpert software and dynamic analysis have been done by required constraints. The purpose is to show that the new design of hydraulic rotary actuator by using planetary gear mechanism provides more rotation angle and more output torque than existing hydraulic rotary actuators on less working pressure than existing hydraulic rotary actuators by verifying