PERFORMANCE OF FUNCTION RELATIONSHIP WITH TRENDS BY SELECTIVE ACTUATOR

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ABSTRACT

We use an air conditioner or heater when driving a car in a hot summer or a cold winter. When you want a straight air blow or air conditioning only for the lower bottom, all these air movements are controlled by an actuator. In this thesis paper, we will look into characteristics, pros and cons of DC motor and STEP motor, actuator’s sources of energy; correlation between OPEN-LOOP SYSTEM and CLOSED-LOOP SYSTEM; type of mechanics simulation programs of actuator; and characteristics of automotive air conditioner actuator.

Keywords: Actuator, Drive, DC motor, STEP motor and Parameter.


1. INTRODUCTION

An actuator is responsible for moving mechanism and it plays an important role in mechatronics. Many types of actuators are being used in various industries, and additional researches are being conducted for low power, simplification of modules, and high efficiency [1]. It is being studied to continuously reduce size through semiconductor and increase degree of integration to include as many transistors as possible. We are moving towards the direction of low power and high performance. As actuators are being used in various industries, the trend is to make it smaller as well. Recently, actuator activated based on new fundamentals using intelligent element is being developed [2]. It is a device transforming small core energy to a big one and it is used in various areas such as aircraft wing vibration control, vehicle transmission, injector controller, air conditioning flow control, and amusement park rides. In
hydraulic control, one of the areas of actuator, actuator development such as actuator for
driving high-speed sub valve and micro mini pump is ongoing. Various researches are
required as fast reaction speed, miniaturization, effectiveness maximization through use of
diverse materials are needed [3].

Actuator exists in various areas in diverse forms. Actuator is a collaboration of
convergence technology, combining many study areas such as machinery, electrical
electronics, information, robot, materials, physics, and chemistry. In this thesis, characteristics
of each motors, simulation program, and 2 types of actuators will be introduced.

2. CHARACTERISTIC OF ACTUATOR’S ELECTRIC ENERGY

An actuator is a device that produces driving force of a machine. There are 3 main energy
sources; electric motor using electric energy; electromagnet by electromagnetic induction;
pneumatic by gas or air pressure. A device receiving many different types of energy and
transforming it into mechanical energy is an actuator. In order to interpret actuator, you must
be able to define fundamentals of various energy sources and source of mechanical energy.

How to activate actuator and control it is a very important part of managing. Actuator’s
performance may differ depending on energy sourcing method and relevant actuation circuit.
As arrangement, effectiveness, and structure may be changed, it must be designed to have
high degree of completion according to each method. For example, for the actuator shown in
Figure 1, operating method and circuit diagram change depending on DC motor, the energy
source. If it is changed to STEP motor, gear ratio and motor angle of rotation will be changed
from when it was DC motor. If actuator’s motor is changed to different sub motor or AC
motor, characteristic of actuator will change depending on characteristics of motors and
energy sources. This is why it is important to analyze each component and characteristic of
source well.

![Figure 1 Actuator configured on DC Motor](image)

2.1. Difference by Drive Motor

DC motor, compared to AC motor, is low power low noise, and lower in unit price. It is used
more generally across various industries. DC motor is mostly used in robot or various
activation systems as well as in areas where detailed control is required such as industrial
machinery. Designing detailed motor controller for robot or industrial machine is indeed
important, but providing parameters, all sorts of elements, is also necessary. However, only
expensive motors are available in motor market. Cheap motor is also used for educational
purpose or simulation, but parameters are not provided for such motors. Even if they are,
accurate data values are not provided. If you conduct a simulation with this inaccurate data
and implement it on real control object, there is a high possibility that designed controller will
be activated in a different form. In this case, you must calculate parameter by yourself. It is
possible to measure with Micro Controller unit, mostly used for motor control, and multimeter, commonly found around you. DC motor can be identified with electrometer of coil and resistance and mechanical system of mechanical elements such as rotor and bearing. Kirchhoff’s law for electrometer and Newton’s law for mechanical system can be applied to create a circuit diagram like Figure 2 [4]. Parameters possible to be calculated for DC motor’s modeling are resistance, motor rate constant, electromagnetic field, and output value and they can be described as in Table 1 [5–6].

<table>
<thead>
<tr>
<th>Name</th>
<th>Remarks</th>
<th>Unit</th>
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<tbody>
<tr>
<td>R</td>
<td>Coil resistance</td>
<td>Ohm</td>
</tr>
<tr>
<td>K</td>
<td>EMF constant or Torque constant</td>
<td>V/(rad/s) or Nm/A</td>
</tr>
<tr>
<td>B</td>
<td>Viscosity friction constant</td>
<td>Nm/A (rad/s)</td>
</tr>
<tr>
<td>J</td>
<td>Inertia moment</td>
<td>Kg · m</td>
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Figure 2 DC Motor system

STEP motor, different from DC motor, has different types such as single phase, 1 phase, and 2 phase depending on number of poles, which shows different motor STEP characteristics. Number of poles and STEP motor type must be decided depending on required performance and purpose of use [7]. Fundamentally HB type for detailed location control and PM type for simple control system are being used. Not like DC motor, STEP motor does not need rotor location control hardware like encoder. It only rotates to the fixed angle by number of poles within STEP motor, and stops to the angle of rotation with high accuracy. Therefore, encoder’s Feedback system is not required and it is possible to form a trustable system. However, STEP motor requires rectifier circuit and its weakness is unstable speed and location response caused by resonance and vibration from low speed or high speed driving. In order to supplement this weakness, microstep control is being used currently [8].

The big system difference between DC motor and STEP motor is use of Feedback system. They are controlled through opposite system as DC motor uses Closed-loop, using Feedback system, and STEP motor uses Open-loop. There are differences in power consumption section for two motors. Each motors’ power consumptions for motor motion completion time when activating or controlling differs, but STEP motor’s consumption is comparably more when compared from overall power consumption. From cost perspective, DC motor, even with encoder, the Feedback system, is cheaper than STEP motor [9]. You can choose one of two motors and design the controller you want [10].

2.2. Simulation Programs

There are many sources of energy for actuator. There are motor using electric energy, one using electromagnet through electromagnetic induction, and pneumatic actuator using gas or air pressure. For verification of each device, problems and causes are understood by inputting each parameter through program before production. The various tests include mathematical interpretation, mechanical interpretation through simulation program, 3D, vibration analysis,
and etc. if parameters of cheaper components are not provided as mentioned earlier, it may cause difficulty and require additional calculation of parameter. Because of input value of simulation and many variables, there may be difference between simulation outcome and actual activation.

There are various mechanical simulation programs such as Ansys program, Catia series, ADAMS, ABAQUS, Recurdyn V7, and etc. As each program have different functions and different program usages, selection of the program should be done after understanding managing elements of actuator [11–12].

3. ACTUATOR CATEGORY

3.1. Automobile Actuator

Automobile, a consolidation of many technologies, consists of many different components. Out of those components, many are operated by actuators. Power steering drive transforms from oil pressure into electric motor. Gear and clutch of transmission are activated by oil pressure and motor operated actuator. It is also used for engine drive. For environmental issue, less fuel should be used but on the contrary, people seek for high fuel efficiency and power. Fuel efficiency is achieved by actuator’s detailed control of fuel injector. Actually, diesel engines, using common rail type of high pressure fuel injection, have achieved fuel efficiency improvement and cleaner exhaust through detailed electronic control system. This fuel injection system actuator used piezoelectric element actuator. Even with all these efforts, environmental issue is still being strongly highlighted and electric vehicles and hydrogen fuel cells are being raised. As per this matter, the source is electric energy, so actuator favorable to low current and light weighted wires using high pressure voltage will be in use [13–14].

3.2. Piezoelectric Stack Actuator

It is variously distributed in electronic industry where piezoelectric element is applied. There are HDD, optical precision instrument, biomedical industry, ultrasonic instrument, communication device and etc. using characteristics of piezoelectric element such as undersize, virtual displacement, and high response. Micro actuator’s vibration control is expanding in these areas. In hydro controlling area, safer than solenoid method, it is applied to high speed electron ON-OFF valve, super speed sub valve, and driving part of micro mini pump [15].

Piezoelectric actuator can be divided into stack and bimorph depending on the structure. Stack has an advantage of less displacement but strong power. Bimorph actuator has a structure of thin plate connected to metal elastic plate pole using electrically conductive glue. If voltage is given to bimorph actuator, characteristic of actuator shows in a form of one side being expanded and the other side contracting. A technology development of actuator reducing vibration and noise by applying piezoelectric actuator to displacement amplification device is ongoing at the moment [16].

4. CONCLUSION

An actuator, in charge of mechanism movement and energy status transformation, is being used as controller in many areas. Actuator performance is decided by how to activate, how to control, and balance of its components, so characteristics of the components must be understood. (The controller’s actuation circuit changes depending on energy source and this may influence the performance.) It is expected that there will be a lot of researches for simplification and miniaturization of actuator, and applied to many areas and industries.
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