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Design and Simulation of Closed Loop Electro Mechanical Actuation System

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Abstract

An Actuator is basically a position servo control system used in industries and vehicles. A rotary electro mechanical actuation system is an angular positioning system used in aerospace applications such as control of rudder and ailerons of aero planes and control of control surfaces, jet vanes, etc. This position loop system is to steer the vehicle to move in required direction.
A servo controller is a driver to accurately control the position of the actuation system by getting the command signals from the on-board computer of the vehicle. It involves a class of DSP controller optimized for digital motor motion control and power conversion applications.
In this Paper, Closed loop Rotary Electro Mechanical Actuating system is designed for the derived specifications by using the CAD software UNIGRAPHICS, and simulated the design with the help of FEA software ANSYS and MATLAB

Keywords: *Design, Simulation, Electro mechanical system, Finite Element Analysis.*

1. Introduction

Design, inputs and specifications of the Actuation System for aerodynamic control of an Aero-vehicle. The document also describes the actuator specifications, mechanical components, BLDC motor, position sensor and the control system including simulation .

1.1 Actuator

An actuator is a mechanism that converts energy into motion. It can also be used to apply a force. An actuator typically is a mechanical device that takes energy, usually created by air, electricity, or liquid, and converts that into some kind of motion. That motion can be anything from blocking to clamping to ejecting. Actuators are typically used in manufacturing or industrial applications and may be used in things like motors, pumps, switches, and valves.

The most common type of actuator is powered by air — the pneumatic cylinder, also known as the air cylinder. Air cylinders are air-tight cylinders, typically made from metal, that use the energy of compressed air to move a piston. Air cylinders are most commonly used in manufacturing and assembly processes. Grippers, which are used in robotics, use actuators driven by compressed air to work much like human fingers.

Actuators can create a linear motion, rotary motion, or oscillatory motion. That is, they can create motion in one direction, in a circular motion, or in opposite directions at regular intervals. Hydraulic and air cylinders can be classified as single acting, meaning that the energy source causes movement in one direction and a spring is used for the other direction. Alternatively, these cylinders can be double acting cylinders, meaning the energy is used in two directions. While actuators are typically discussed in terms of mechanical implements, muscles are sometimes given as an example of an actuator. Energy (e.g., created by eating carbohydrates) is converted by the muscle (i.e., the actuator) into motion (e.g., kicking a ball).

1.2 Description and configuration of actuator

The actuator configuration is as follows….

- Prime mover is a 3 phase BLDC motor.
- Transmission by Planetary gear train.
- Position feedback element is Rotary potentiometer.
- Servo control by DSP controller.

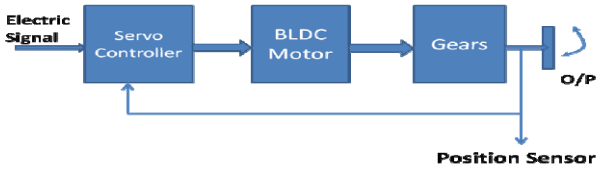

Fig 1: Block diagram of actuator

Brushless DC motor

The motor is having a three phase winding in the Stator and Rotor is composed of 8 number of samarium cobalt high-energy permanent magnet fixed to a core. The Hall Effect Sensor is used for position sensing to produce signals to control commutation electronics. Due to the absence of commutation and Brush and as there is no direct contact, the motor is maintenance free and can be operated at very high speed. However for smooth running of the motor and uniform torque generation during forward nd reverse direction drive,

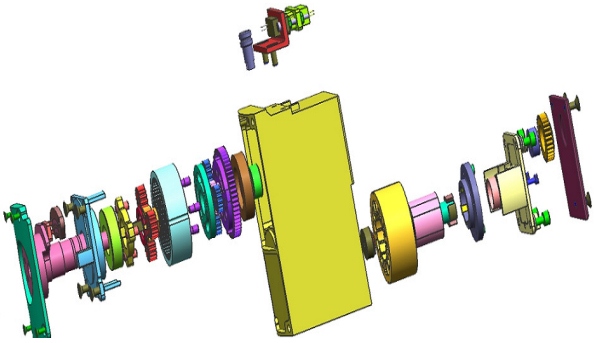

Fig 2: Exploded view of electro mechanical actuator

the Hall Effect Sensor location is very critical. As soon as electrical energy is applied the rotor starts rotating due to electro magnetic induction.

Reduction gear train

High Speed and low torque is developed at the motor; it is required to be modified for torque amplification with reduction in speed. Reduction Gear train serves speed reduction and the amplification in the torque. The gear train is having one simple gear train and two-stage planetary gear train reduction and the planetary gear train is connected to the output shaft. The gear train is designed for minimum backlash. The total reduction gear ratio is 49.25:1.

Rotary potentiometer

Rotary conductive plastic film potentiometer with infinite resolution is used on the output shaft as a feedback sensor for closed loop control of the Actuator.

Servo electronics

The electronics control the position of the output shaft according to the input signal. The voltage applied to the motor is proportional to the error between the command and the actual position of the output shaft sensed by the potentiometer.

2.1 conceptual design

Based on the available space, torque and speed specifications, the rated torque of the motor is taken as 0.075Nm. To get a rated torque of 2.5Nm, the gear ratio of the gear box is taken as aprox.50:1. To meet this gear ratio at output shaft, the gear train taken is one simple gear train and two stage planetary gear train. Keeping in view of available space and above consideration that is taken, the conceptual design and final modelling is done in CAD software unigraphics.

3. Design and Analysis of Actuator

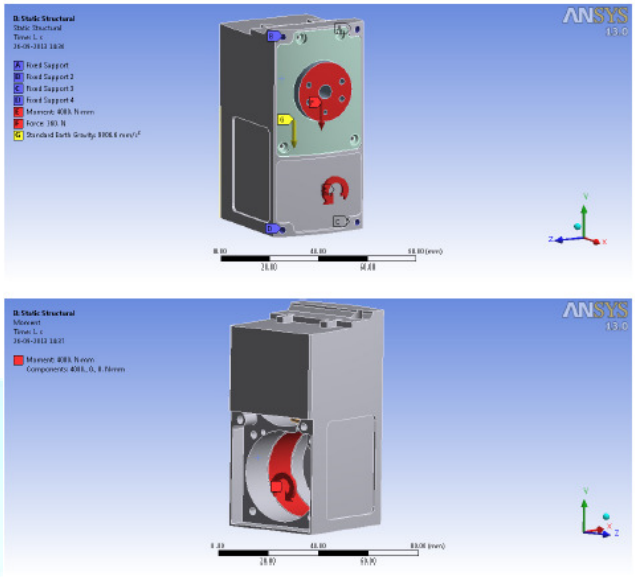

Fig 3 Design of Housing

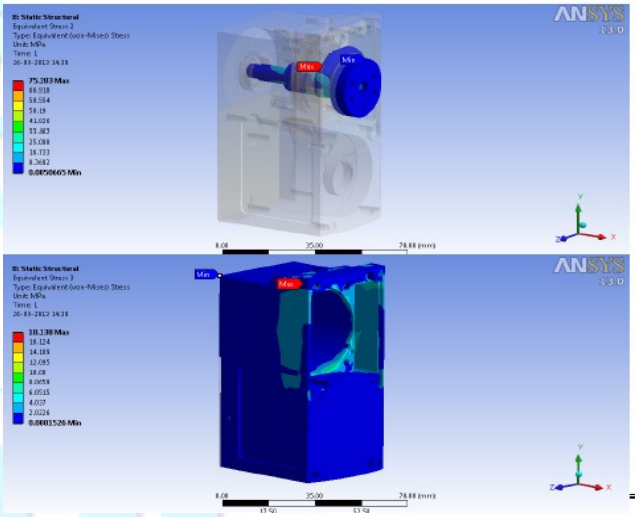

Fig 4 Equivalent stress on Housing

Part	Allowable stress(N/mm^2)	Results in ANSYS(N/mm^2),MAX
Output shaft	448	75.283
Housing	37.5	18.138

Table 1 Fea Results

4.Design and analysis of Servo controller

Servo controller System is a sub-system of Rotary Electro Mechanical Actuator. Based on the command from On Board Computer it examines series of functions and drives the BLDC Motor.

This system is designed to drive the 3-Ø Brush Less DC (BLDC) Motors. It receives position and current limit signals from Rotary potentiometer and current sensors respectively. The Hall effect sensors provide rotor position information required for electronic commutation. Based on the above sensors information, position loop is executed to deliver the power to the motor. Current sensor info available at controller is used for switching OFF PWM signals to motor for safety.

It is a digital process based system. It receives the I/P Command from the OBC and executes series of functions like sensing, position and current limiting from the Potentiometer and Current sensor respectively and commutates the motor based on hall sensor signals.

The input power supply to the system is 28V DC. A DC-DC converter derives the required voltages of +15V,-15V,5V and regulator derives 3.3V,1.8V for electronics which resides inside the controller Box. An EMI filter is provided in the front end to the DC-DC converter to take care of the possible EMI threats. Servo Electronics system generates PWM signals required for controlling the speed of the motor based on the error calculated by the control loop.

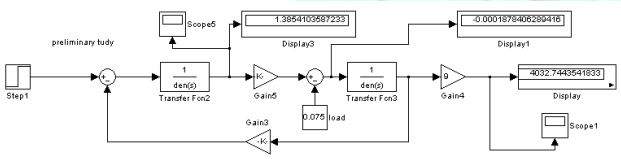

Fig 5 Motor simulation model at load

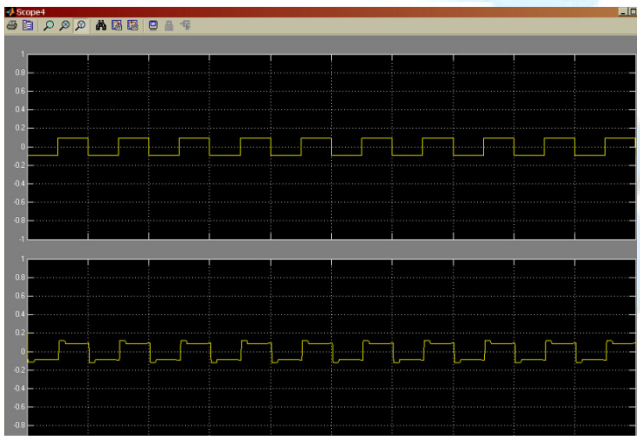

Fig 6 Dead band frequency response 9mV

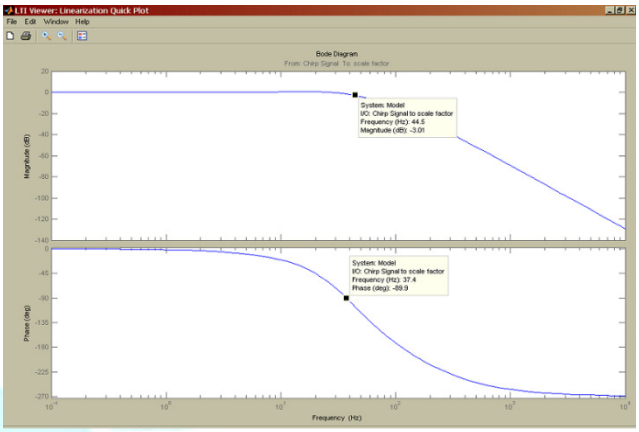

Fig 7 Frequency response at 1V

5.0 Conclusion

Based on the results achieved in ANSYS and MATLAB we conclude that the closed loop electro mechanical actuation system will meet the required design specification.

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