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Review paper On Design Methods for Mechatronics Servo Motor

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1 Abstract

The number of electric powered sub-systems in road-vehicles is increasing fast. This development is primarily driven by the new and improved functionality that can be implemented with electromechanical sub-systems, but it is also necessary for the transition to electric and hybrid-electric drive trains. An electromechanical sub-system can be implemented as a physically integrated mechatronic module: controller, power electronics, electric motor, transmission and sensors, all integrated into one component. A mechatronic module, spans, as all mechatronic systems, over several closely coupled engineering disciplines: mechanics, electronics, electro-mechanics, control theory and computer science. In order to design and optimize a mechatronic system it is therefore desirable to design the system within all domains concurrently. Optimizing each domain or component separately will not result in the optimal system design. Furthermore the very large production volumes of automotive sub-systems increase the freedom in the mechatronics design process. Instead of being limited to the selection from off-the shelf components, application specific components may be designed.

Keywords:
Mechatronics Design Methodology; Servo Systems; Electric Motors; Gears; Auxiliary Systems

2 Introduction

A **servomotor** is a rotary actuator that allows for precise control of angular position, velocity and acceleration.[1] It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.Servomotors are not a specific class of motor although the term *servomotor* is often used to refer to a motor suitable for use in a closed-loop control system.Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing. **Servo motors** (or servos) are self-contained electric devices that rotate or push parts of a machine with great precision. Servos are found in many places: from toys to home electronics to cars and airplanes. If you have a radio-controlled model car, airplane, or helicopter, you are using at least a few servos. In a model car or aircraft, servos move levers back and forth to control steering or adjust wing surfaces. By rotating a shaft connected to the engine throttle, a servo regulates the speed of a fuel-powered car or aircraft. Servos also appear behind the scenes in devices we use every day. Electronic devices such as DVD and Blu-ray Disc™ players use servos to extend or retract the disc trays. In 21st-century automobiles, servos manage the car's speed: The gas pedal, similar to the volume control on a radio, sends an electrical signal that tells the car's computer how far down it is pressed. The car's computer calculates that information and other data from other sensors and sends a signal to the servo attached to the throttle to adjust the engine speed. Commercial aircraft use servos and a related hydraulic technology to push and pull just about everything in the plane.

3 Goal

The goal with this review paper is to develop a design and optimization methodology for mechatronic modules. The aim is to treat all important phenomena from all involved engineering domains in one single process. This is however only possible for a relatively small number of design parameters, therefore the target of this methodology is concept evaluation, early in the design process. In later stages of the development process, the number of design parameters may be huge; also the number of involved design engineers may be large. Hence, it is very hard to apply any analytical design or optimization method on the system level during the later stages of the design process.

4 Mechatronics Design Methodology

A mechatronic system spans over several engineering disciplines: mechanical engineering, electrical engineering, control engineering and computer science (Figure 1). Separately applying the available domain specific design and optimization methods to a mechatronic system will not result in an optimal system design. For example, parameters like inertia and motor torque depend on the system's size and geometry and can only be optimized in common. The drawbacks with the traditional methodologies for mechatronic design mostly appear in the interfaces between the different domains, for example: The design of the controller and the structure to be controlled (plant) is often separated. Therefore the control engineers have to design a controller for an already existing physical system. Hence, few aspects from a control perspective have been considered in the design process of the mechanical system, resulting in a system with non-optimal dynamic performance.

5 Servomotors vs. stepper motors

A servomotor consumes power as it rotates to the commanded position but then the servomotor rests. Stepper motors run warm to the touch because they continue to consume power to lock in and hold the commanded position.Servomotors are generally used as a high performance alternative to the stepper motor. Stepper motors have some inherent ability to control position, as they have built-in output steps. This often allows them to be used as an open-loop position control, without any feedback encoder, as their drive signal specifies the number of steps of movement to rotate, but for this the controller needs to 'know' the position of the stepper motor on power up. Therefore, on first power up, the controller will have to activate the stepper motor and turn it to a known position, e.g. until it activates an end limit switch. This can be observed when switching on an inkjet printer; the controller will move the ink jet carrier to the extreme left and right to establish the end positions. A servomotor will immediately turn to whatever angle the controller instructs it to, regardless of the initial position at power up.The lack of feedback of a stepper motor limits its performance, as the stepper motor can only drive a load that is well within its capacity, otherwise missed steps under load may lead to positioning errors and the system may have to be restarted or recalibrated. The encoder and controller of a servomotor are an additional cost, but they optimise the performance of the overall system (for all of speed, power and accuracy) relative to the capacity of the basic motor. With larger systems, where a powerful motor represents an increasing proportion of the system cost, servomotors have the advantage.

6 control

Most modern servomotors are designed and supplied around a dedicated controller module from the same manufacturer. Controllers may also be developed around microcontrollers in order to reduce cost for large volume applications.

Conclusions The research has so far mainly considered the structural properties of an actuation module. Dynamic and control properties have not yet been considered. The plan is however to include the system dynamics and control later on, as discussed in section 4 below. From the structural design point of view, a number of conclusions can be made, the main ones are: The gear ratio has a great impact on the necessary motor size, regardless of load type. Paper B shows that the choice of gear ratio to minimize the motor size is rather complicated and not always intuitive. However, the proposed method can, for any given load, find the smallest possible motor/gear ratio combination. The results from report C indicate that three-wheel planetary gears can transmit more torque and has significantly less inertia than conventional pinion and gear-wheel pairs. The derived equations for the necessary gear sizes are rather complicated and include many parameters. However, as stated in the report, it is generally the flank pressure that limits the gear size, and the flank pressure is almost independent of the number of teeth. This makes it possible to use simplified versions of the gear models in future research.

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