X-by-wire Vehicle Prototype: a Steer-by-Wire System with Geared PM Coreless Motors

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ABSTRACT

1. Introduction

The X-by-Wire (Steer-by-Wire, Brake-by-Wire, etc) vehicle prototype considered within this paper forms part of a multi-year research project. There have been numerous studies performed on this prototype including, an Experimental validation of a flexible MBS dynamic formulation [1] and a multi-body model for this vehicle [2]. An X-by-Wire (or instrumented) vehicle is a valuable tool for undertaking multi-body system studies. It allows for vehicle model enhancements, the design of control algorithms for autonomous maneuvers or even the improvement of vehicle stability. Although this paper focuses mainly on the Steer-by-Wire (SBW) system, the prototype has also been equipped with a Throttle-by-Wire and a Brake-by-Wire system.

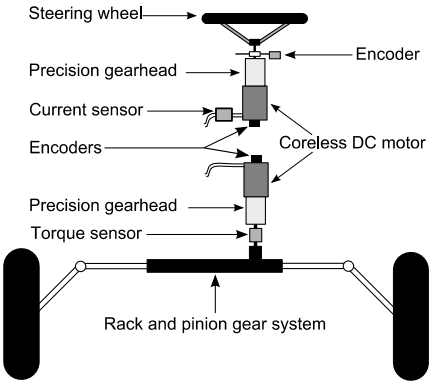

Fig 1: Steer-by-Wire

2. A Steer-by-Wire solution

SBW systems are now widely used in both vehicle prototypes and vehicle simulators. Despite SBW systems allowing for a wide range of actuator choices, the use of brushless (electronically commutated) motors, in direct drive, appears to be the most commonly used.

This wide range of actuator choices is reflected in previous research studies. For example, a brushless DC servomotor with a planetary gearhead was selected in [3], as the Road wheel Motor (RwM). Moreover the Steering wheel Motor (SwM) is a brushed DC servomotor with a timing belt drive. In [4], the SwM is a Permanent Magnet (PM) synchronous motor, in direct drive, while the interior permanent magnet (IPM) RwM was incorporated in a ball-screw actuator, directly linked to the steering rack. The SwM in [5] is a direct drive brushless actuator. Another choice of SwM actuator could be a brushless DC motor coupled with a harmonic-drive gear like in [6].

In general, brushless motors are appreciated for their high efficiency, their small size, the high heat capacity of their stators thus allowing for a longer overload time, or even for their

low maintenance. Despite their superior qualities, brushless motors are less commonly used than brushed types in motion-control applications, especially due to their higher price.

The main aim of this article is to present the design and the dynamic capability evaluation of a SBW system using low-cost geared coreless DC motors. The discussed SBW (Fig. 1) is composed of 2 geared coreless DC motors, 3 encoders, a torque sensor and a current sensor.
The coreless (or ironless) motors are PM brushed DC motors. They have no iron core, therefore no iron losses, low friction and an acceptable level of thermal dissipation. The design of a low-inertia rotor is the key here to rapid acceleration and fast reaction time. Thus, coreless motors appear to be a possible low-cost option when designing a SBW.
Two-stage planetary precision gearheads, i.e. with a low backlash angle, increases motor capabilities to reach a maximum torque of about 15 N·m. The main gearhead drawbacks are friction, additional elasticity and backlash. Nevertheless, such effects have previously been considered separately and less frequently together [7]. To avoid oversized direct drive motors, whilst maintaining good dynamic performances, compensation for friction and backlash nonlinearities should be taken into account in the SBW control.

3. Conclusions

This article presents the performance evaluation of a low-cost Steer-by-Wire. High performance geared coreless DC motors have been used. The backlash, the elasticity and the friction introduced by the gearhead are modeled for the steering wheel motor in order to improve accuracy and reliability of driver torque feedback.

References

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