Chapter 62
Human-Friendly Mechatronics Systems with Functional Fluids and Elastomers

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ABSTRACT

Safety for humans is one of the most important issues for systems in which humans and machines coexist. Man has developed human-friendly devices using functional materials (electrorheological fluids (ERF), magnetorheological fluids (MRF), and magnetic-field sensitive elastomers (MSE)) and applied them to several types of robots and mechatronics devices for health care, life support, and the evaluation of human functioning. In this chapter, projects related to human-machine coexistent systems and functional materials are presented and classified according to their applications.

INTRODUCTION

The aging population is a major concern for many countries. Several types of robots or mechatronics devices for use in health care, life support, and the evaluation of human functioning have been researched and developed. Such a device, which works very closely with humans, is called a human-machine coexistent system (HMCS). In terms of designing HMCSs, safety for humans is one of the most important issues. Because of the different sized distance between machines and humans, there is a large gap between the design of conventional mechatronics systems and that of the HMCS. One of the major strategies for safety in conventional robot systems is a physical barrier that separates human from the robots. However, it is impossible to create physical barriers between human and machines for many of the applications of the HMCS. Therefore, human-friendly devices are required for feasible mechatronics systems that work alongside humans within the same environment.

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The human-friendly actuator has recently become a "hot topic" in robotics. The ultimate goal of this research is the artificial realization of a soft-yet-powerful human muscle. Many of the new actuators that aim to produce artificial muscle have been studied, but a perfect artificial muscle that has the same (or even nearly the same) characteristics of a real muscle (e.g., has a wide range of force and bandwidth, is lightweight, has long-term durability) has not been realized.

In our research, clutch-driven mechanisms with functional fluid clutches (Kikuchi, et al., 2010) have been developed and applied to an educational robot designed for physical therapists (Kikuchi, Oda, Yamaguchi & Furusho, 2010; Kikuchi, Oda & Furusho, 2010), as a rehabilitation system for the upper limbs (Kikuchi, Jin, Fukushima, Akai & Furusho, 2008). The clutch-driven mechanism has a powerful force (torque) output in the on-state of the clutch. In addition, the mechanism also has very low inertia and good backdrivability in the off-state. We also used functional fluid (i.e., electrorheological fluids (ERF) (Bossis, 2002) and magnetorheological fluid (MRF) (Carlson & Jolly, 2000; Noma, Abe, Kikuchi, Furusho, & Naito, 2010) to operate the clutches. The ERF and the MRF show dramatic changes in their rheological properties, especially given their apparent viscosity upon the application of an electric/magnetic field. Because the response times for the changes in viscosity are very fast, our actuators responded more rapidly than any of the conventional clutches. These functional fluids can be used as working materials in various types of mechatronics devices, which are classified into two types (flow type and shear type, in Figure 1) depending on the relative motion of the fluid and input parts of devices. Figure 1 illustrates this principle using the example of MRF devices. If one side is fixed, it becomes a brake. Conversely, if both sides move, it becomes a clutch. In the case of the MRF, we used electromagnets or permanent magnets to apply a magnetic field to the MRF. In Figure 1, the dashed lines represent the magnetic flux. The change in viscosity or resistance of the MRF is transformed into a controllable force in the piston or torque in the rotational devices. Regarding ERF, we used electrodes to apply electric field to the ERF instead.

Figure 1. Types of MRF devices