Variable stiffness element based on rheology characteristics of shear thickening fluid

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ABSTRACT

The unique rheological properties of discontinuous shear thickening fluids (STF) have been employed in various engineering applications in recent years. These have most notably been body armors and protective equipment, but also in specialized smart structures in damping and force-coupling applications [1]. This work focuses on the application of STF in a lower extremity Energy Storage and Return (ESR) prosthetic foot, with the objective of achieving variable stiffness in the ankle joint. Previous work has indicated that an active (functional) translational joint, connected in series and parallel with a spring system, can be used to affect the force transfer within the system and thereby influence the stiffness of the ankle dynamically over the gait cycle [2].

The device described in this work is a STF filled piston/cylinder design. The objective is a velocity dependent force response over the translational motion. Ranging from dampened, compliant deflection at low velocity, to efficient force transfer (coupling) for energy storage and return in the spring system at higher speed. The rapid viscosity increase in the STF at a critical shear rate is used to create an element that has a stepwise force response, thereby enabling adaptive response of the foot for different walking speeds and eventual different tasks, such as standing up from a seated position. The adaptive response results in a greater range of motion with easier rollover through stance phase for slow movement without sacrificing the energy return needed in faster walking. Restrictions in weight and size of the element call for compromises in the design, which are considered in the context of the characteristics of the foot during the gait cycle.

The results show that by manipulating both the properties of the STF and the geometry of the piston, the critical velocity can be adjusted. Hence, adjusting the velocity at which the device will rapidly increase the force coupling as the reaction in the STF goes from viscose friction to a near solid state. This is achieved without compromising the capacity of coupling a force over the joint that exceeds three-fold bodyweight of the user.

REFERENCES

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