Load Control by Active Materials at Arm Exercising

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Abstract. Up-to-date training facilities are developed which are able to control loading in order to adapt to the trainee physical abilities, the aim of exercises and make the loading as close as possible to specific sports movements. The arm exercising is simple and effective, thus widely used in practice. Its disadvantage is instability of the arm loading due to inertia forces acting on the lifted mass and changing the arm geometry when exercising. The paper deals with the analysis of possibilities to control the law of loading during the exercising cycle by means of magnetorheological fluid damper.

Keywords: arm exercising, loading, magnetorheological fluid, control.

Introduction

In the present society, sports, active leisure, healthy aging and rehabilitation are in the focus of rapidly growing interest. A wide variety of equipment exists and continues to be developed for such activities. The modern facilities are equipped with feedback between the human input and generated loading, which is used to control the latter in order to achieve the law of its exchange adequate to training aims and workload units, whose action is based on very different principles, are developed to accomplish the task [1, 2].

Active materials have now revealed themselves as extremely perspective for exploiting them in adaptive mechanical devices. A lot of new devices and their composite structures are being created in addition to “classical” ones (rheological fluids, piezomaterials, shape memory alloys). Magnetorheological fluids (MRF) have found application in sports engineering products due to their ability to change rapidly their viscous resistance force using magnetic field as control [3].

The paper discusses the analytical investigation of MRF damper application possibilities to control the load in any training device where muscle loading is created by lifting the mass.

Dynamics of arm loading in the system with MRF damper

Hand motion *y(t)*, when exercising by lifting mass, was measured experimentally, and thus proved it could be quite exactly approximated by fourth degree polynomial. The MRF, approached as Bingham plastic fluid, movement in the damper has been described by equation

$$\rho\frac{\vartheta^2 u}{\partial t^2}=\eta\frac{\vartheta^3 u}{\vartheta x^2\vartheta t}; \tag{1.1}$$

where ρ is MRF density; η – MRF viscosity; u – MRF fluid particle coordinate,

with initial

$$u(x=h,t)=s; \qquad \dot{u}(x=h,t)=\dot{s}, \text{ when } t=0, \tag{1.2}$$

and boundary

$$u(x,t)=s; \quad \dot{u}(x,t)=\dot{s}, \text{ when } x=h \text{ and } u(x,t)=0 \quad \dot{u}(x,t)=0, \text{ when } x=0, \tag{1.3}$$

conditions, which corresponds to the dynamic model of arm exercising, given in the Fig. 1, in which the elastic and damping properties of rope are evaluated as well.

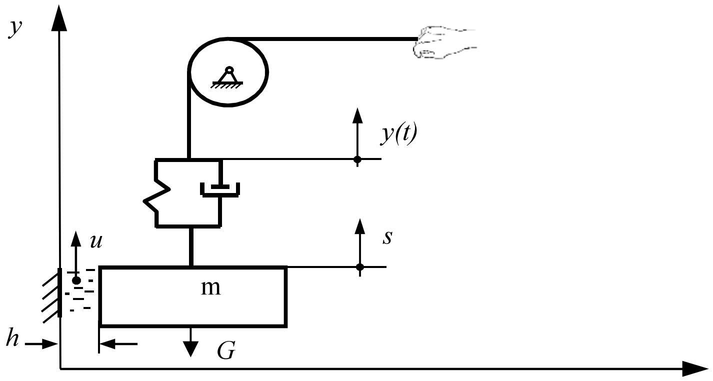

Fig. 1. Dynamic model of arm exercising

The viscous resistance force of MRF has been derived as

$$F_{vr}\left(\dot{s}\right)=\sum_{k=1}^{\infty}\left(\lambda_k \eta ctgh\right)\dot{s}; \quad \text{where} \quad \lambda_k=\frac{\left(2k+1\right)}{2h}\pi, \qquad (1.4)$$

which was substituted into the equation describing the given above dynamic model and its solution allowed us to define the law of motion of the lifted mass evaluating MRF damper dynamical properties.

Conclusions

The performed analysis of the training facility with a MRF damper for arm exercising, allowing to evaluate the of MRF viscous resistance influence on the trainee's arm loading, provides a possibility to organize the control satisfying the given requirements on the arm and its muscle loading on the base of the findings.

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