Research of the force characteristics of sports and rehabilitation exercise machines loading units

Aurelijus Domeika[1], **Vytautas Grigas**[2], **Anatolijus Šulginas**[3]

[1, 2, 3] Kaunas University of Technology, A. Mickevičiaus g. 37, 44244 Kaunas, Lithuania
E-mail: [1] *aurelijus.domeika@ktu.lt,* [2] *vytautas.grigas@ktu.lt,* [3] *anatolijus.sulginas@ktu.lt*

Abstract. The aim of this research was to examine the characteristics of resistance force (force dependencies on piston displacement) generated by linear hydraulic cylinder type loading units of exercisers acting in different regimes (resistance level and piston velocities). Experimental research of six devices has been performed by means of universal computerized material properties testing machine. The research showed that hydraulic cylinder type loading units of exercise machines generate quite uneven resistance force: depending on acting regime the variation of resistance force reach up to 30% of steady force.

Keywords: hydraulic cylinder, exercise machines, resistance force, piston velocity.

Introduction

Recently hydraulic cylinder type resistance devices are used extensively in exercise machines [1]. The resistance force in these devices is obtained by forcing viscous liquid through small cross-section channels [2]. When the athlete is moving the HC piston, liquid flows from one chamber of the cylinder to another through the channels made in the piston or in the ends of the cylinder, thus hydrodynamic resistance is directly dependent on the piston speed, the diameter of the piston (area) and the viscosity of the liquid [3]. This method of resistance is widely used in sports and rehabilitation exercise machines, whereas the hydraulic resistance load adapts to the natural muscle strength and allows achieving the full muscle load during the entire cycle [4]. Such loading units, practically not requiring maintenance, are widely used in steppers, rowing machines, selectors of different muscles groups and universal force exercise machines [4]. Some of them are supplied with mechanism for setting different level of resistance (by rotating ring controlling the cross-section of the channels connecting the chambers of cylinder or simply by adjusting the arms connecting cylinder to exerciser).

The aim of this research was to examine the characteristics of resistance force (force dependencies on piston displacement) generated by linear hydro-cylinder type loading units of exercisers acting in different regimes.

Force characteristics of hydraulic cylinder type loading units

Hydraulic cylinders of six exercise machines were investigated: lever type rowing (sculling) simulators (Nr. 1, 2 and 3, adjustable force) and steppers (Nr. 4, 5 and 6). Performance of hydraulic cylinders has been measured experimentally by using a universal computerized material properties testing machine "Tinius Olsen H25KT". The change of resistance force was measured at different piston velocities (60, 300, 600, 900 mm/min) and different resistance levels (I, IV, VIII, XII), repeating each test three times at constant 20 ºC temperature.

It was obtained that force characteristics of all adjustable HC obviously differ both qualitatively and quantitatively for different exercisers (Figs 1, a and 2) and are quite uneven in the beginning of stroke while the force characteristics of stepper's cylinders are smoother (Fig. 1, b). Fig. 2 shows the characteristics of resisting force generated by HC of rowing machines Nr. 1 and Nr. 2 at different resistance levels (velocity of piston 900 mm/min). The research showed that only exercise machine Nr. 3 ensures the possibility to regulate the resistance force proportionally to the resistance level set by control ring on hydraulic cylinder.

Such instability of the force characteristics of rowing exercisers may be caused by design features of the adjusting cylinders.

Resistance force generated by hydraulic cylinders of different rowing machines (at resistance level VIII) was from 50 to 110 N at the lowest velocity of the piston to 150 to 210 N at the highest velocity of the piston, and steppers cylinders gave correspondingly 50–70 N and 270–450 N.

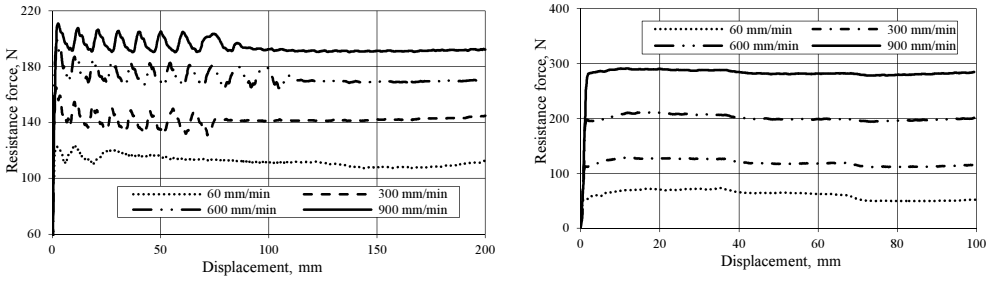

Fig. 1. Resistance force w.r.t. displacement of piston of HC:
a – rowing machine Nr. 1 (resistance level VIII); b – stepper Nr. 5

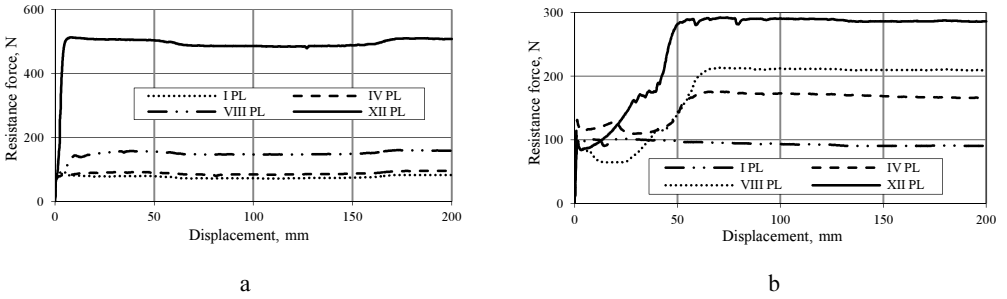

Fig. 2. Resistance force w.r.t. displacement of piston (with 900 mm/min velocity) of HC:
a – rowing machine Nr. 2; b – rowing machine Nr. 3 (at resistance levels I, IV, VIII and XII)

Conclusion

The range and character of variation of the resistance force of hydraulic cylinder type loading units of different exercise machines were obtained. The experimental research showed that resistance force generated by hydraulic cylinders of rowing simulators acting in different regimes differs for each machine and is quite uneven: the variation of resistance force is about 30% of steady force at constant velocity of the piston. Also it was obtained that setting different levels of resistance for rowing machines changes resistance force irregularly.

References

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