Volume 10, Issue 5, May – 2025 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may185

Provision of Instant Braking of Lifting-and-Shifting Machines in Emergency Situations

Rusudan Bitsadze[1]; Simon Bitsadze[2]; Nika Damenia[3]

[1] Department of Mathematics, [2] Department of Engineering Graphics and Engineering Mechanics, [3] Faculty of Energy
[1,2,3] Georgian Technical University, Tbilisi, Georgia,

Publication Date: 2025/05/16

Abstract: The dependence of braking time on pusher's tappet rod downstroke time when using magneto hydraulic pusher as a drive gear in braking systems of lifting-and-shifting machines has been analyzed in the work. There has been offered a magneto hydraulic pusher of original design, in which the time of tappet rod lowering in emergency situations doesn't depend neither on opening of valve regulating tappet rod downstroke time, nor on attraction force caused by residual magnetism and electric power supply to the magneto hydraulic pusher. This fact makes it possible to increase tappet rod downstroke speed to the maximum. Use of the mentioned magneto hydraulic pusher as a brake actuator of lifting-and-shifting machines allows to attain both smooth braking of any degree and instant braking in emergency situation.

Keywords: *Magneto Hydraulic Pusher, Brake, Tappet Rod, Electromagnet, Piston.*

How to Cite: Rusudan Bitsadze; Simon Bitsadze; Nika Damenia (2025). Provision of Instant Braking of Lifting-and-Shifting Machines in Emergency Situations. *International Journal of Innovative Science and Research Technology*, 10(5), 408-411. https://doi.org/10.38124/ijisrt/25May185

I. INTRODUCTION

Magneto hydraulic pushers (MHP) are used in many sectors of industry, in which the transformation of electric processes into mechanical processes, in particular, rectilinear translation or backward motion is required. MHP are mainly used as a drive gear of hoisting machines [1].

Braking time of lifting-and-shifting machines depends on ratio between inertial forces of moving masses and braking torque value. The more a braking torque is and the quicker its maximum value is reached, the less is this ratio and the smaller is braking time. In its turn, braking time reduction causes dysfunction of smooth operation of the mechanism. For instance, when lowering a load, an uneven braking (by jerks) occurs during rapid deceleration, due to which heavy dynamic loads and violent fluctuations originate in the metal structures of vehicles and machinery, which in their turn, reduce strength and durability of mechanisms and metal structures. That is why for dynamic loads reduction there is recommended to increase braking time by the use of such drive gears, which provide smooth growth of braking torque when braking. Magneto hydraulic and electrohydraulic pushers, in which virtually any degree of smooth braking is obtained via adjustment of tappet rod downstroke time (speed), are used in the lifting-and-shifting machines' brakes as drive gears.

II. BASIC PART

Total time of braking of vehicles and machinery is a time from the moment of stoppage of power supply to electric drive motor and brake gear of the mechanism to the complete stop of vehicles and machinery or load to be hoisted or lowered

$$\tau_{compl} = \tau_{d.del.} + \tau_{dst.} + \tau_{br.}$$

where, $\tau_{d.del.}$ is a time of delay of tappet rod downstroke start, i.e. a time from stoppage of power supply to start of tappet rod downstroke;

$\tau_{d.st.}$ is a time, which is equal to time from start of tappet rod downstroke to start of mechanism braking, i.e. to touching of brake shoe with brake drum friction material;

$\tau_{br.}$ is a tappet rod downstroke time interval from touching of brake shoe friction material with brake drum to complete stop of brake drum and mechanism, i.e. a time, during which the braking process directly occurs.

Delay time of tappet rod downstroke start in MHP $\tau_{d.del.}$ is stipulated by armature attraction force to the core which is caused by residual magnetism of pusher's direct current electromagnet. Attraction force caused by residual magnetism implies such value of attraction force, under influence of which the armature of pusher's direct current electromagnet is attracted to the core, until it reduces down to

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may185

the value, when attraction force originated by it no more holds armature in attractive state and the armature will move away from to the core and will start downstroke, and a tappet rod will start lowering together with it. Time $\tau_{d.del.}$ caused by residual magnetism is quite significant value, especially in case of high-power pusher's electromagnet and may equal to 0,3-0,6 [1].

In practice, in order to reduce armature attraction force caused by residual magnetism in direct current electromagnet, a thin plate of nonmagnetic material is placed between armature and core. As far as the armature doesn't touch directly the core during attraction, i.e. there is a plate-thick air gap between them, initial attraction force caused by residual magnetism is small and the armature goes downstairs immediately after stoppage of power supply to electromagnet. At that time, an initial air gap between armature and core increases by the value of plate thickness δ_p. In this case, armature attraction force is calculated according to formula [2]

$$t_{att} = \sqrt{\frac{3m\delta_{ar}}{u \cdot \sqrt{\frac{P_{r.f.}}{2 \cdot \delta_o \cdot L_o} - R\frac{P_{r.f.}}{L_o}}}}, \quad (1)$$

Where, m – mass of moving parts of pusher's direct current electromagnet;

δ_{ar} – armature stroke value;

δ_o – value of initial air gap between armature and core;

$$\delta_o = \delta_{ar} + \delta_{pl}$$

δ_{pl} – thickness of a plate of nonmagnetic material;

u – voltage;

$P_{r.f.}$ – counteracting force acting on armature;

R – electromagnet coil resistance;

L_o – coil inductivity at initial state of armature;

Armature attraction force is calculated according to formula:

$$P_{atr} = \frac{1}{2} i^2 \frac{\mu_o S \omega^2}{(\delta_o - \delta_{ar})^2}, \ldots \quad (2)$$

Where $i -$ current force;

$\mu_o -$ air permeability;

S – armature cross-sectional area;

$\omega -$ number of turns of electromagnet coil.

It is clearly seen from analysis of formula (1) and (2) that electromagnet armature attraction time increases, and attraction force reduces in presence of plate of nonmagnetic material, so in order to obtain desirable technical characteristics of pusher the capacity of pusher's electromagnet must increase in this case, but it is undesirable, since leads to increased consumption of electricity and expensive material of electromagnet, on one hand, and MHP dimensions and weight, on the other. That is why the use of plate of nonmagnetic material in direct current electromagnet of MHP for attraction force reduction caused by residual magnetism is not reasonable.

Tappet rod downstroke time $\tau_{d.st.}$ depends on tappet rod stroke value, working fluid viscosity, pusher's hydraulic resistance, value of inertial forces of moving masses, external load acting on tappet rod and, the most important, on opening degree of regulating valve bonnet. All the above-mentioned factors have more or less action on the MHP's tappet rod downstroke time and it is impossible to avoid them. Braking time of a load to be hoisted or lowered are calculated for hoisting mechanisms according to formula [1]

$$\tau_{br.} = \frac{1}{M_{br.} \pm M_1}\left[(1{,}1 \div 1{,}2\frac{GD_1^2 n_1}{375} + \frac{QD_d^2 n_1 \eta_0}{375 i^2 a^2}\right] \quad (3)$$

where $GD_1^2 -$ flywheel moment of spinning masses (including engine rotor, clutch, engine and reducing gear connecting shaft, brake pulley and reducing gear shaft);

n – rotation frequency of brake shaft;

$a -$ pulley block multiplicity;

M_T – brake torque acting on brake pulley when decelerated;

$i -$ number of gears;

$\eta_0 -$ total efficiency factor of mechanism;

Q – nominal load weight;

$D_d -$ drum diameter;

$M_1 -$ moment generated by a load on brake shaft during deceleration process. Sign "+" placed in front of M_1 corresponds to braking of a load to be hoisted, while sign "– " correlates to braking of a load to be lowered.

It is clearly seen from analysis of formula (3) that reduction of $\tau_{br.}$ for given brake system is possible if the brake torque M_T will rapidly reach its maximum value, but rapid growth of the brake torque is limited by a speed of brake actuator tappet rod downstroke. The mentioned value is controlled by regulating valve of MHP, which provides any degree of smooth braking. In case of small $\tau_{br.}$, i.e. during abrupt deceleration, dynamic loads and violent fluctuations are originated and in brake systems and metal structures of vehicles and machinery.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may185

For reduction of total downstroke time of tappet rod, there is invented a number of designs for electrohydraulic and magneto hydraulic pushers [1, 3]. Though, both $\tau_{d.st.}$ and $\tau_{br.}$ values reduce in pushers of this construction. Based on this fact, provision of smooth braking process is excluded and their use in brake systems is not recommended. That is why, the pushers equipped with regulating valves become widely used.

We have elaborated the MHP of original design [4], which makes it possible to reduce the tappet rod downstroke time $\tau_{d.st.}$ to any desirable value and afterwards to smoothly adjust by any degree the speed of its lowering at any necessary point of time (e.g. at the onset of braking). Use of the mentioned pusher provides significant effect in case of high values of its tappet rod stroke, when it is desirable to rapidly run a process first and then to adjust the smoothness of its speed. For example, use of this pusher as a brake actuator makes it possible to attain rapid onset of braking and to smoothly run a braking process afterwards.

Based on the above-mentioned one may make a conclusion that it is necessary to provide a smooth braking process in brake systems (especially in case of deceleration of large masses), which is attained through increase of tappet rod downstroke time in pushers used as a brake actuator of MHPs.

Operation of such machinery and equipment, when pushers are used as a drive gear, may create such emergency situations, during which a rapid stop of working machinery and equipment or quick termination of any engineering process will be required, despite the fact that this stoppage may cause its breakdown (incapacitation). But it may be excluded when using the available pushers with regulating valves. It should be especially noted that in available electromagnetic and magneto hydraulic pushers the tappet rod downstroke is impossible without cutoff of electric power supply to pushers.

Based on analysis of operation principles of MHP discussed above, one may draw conclusion that no one of available pushers can provide rapid downstroke (and respectively, fast braking) of tappet rod in case of emergency situations. That is why our goal is to invent such design of MHP, which being used in brake system, will provide any degree of smooth braking, while in case of emergency situation will enable rapid downstroke of pushrod and attainment of fast braking.

We have elaborated the original design of MHP based on already available MHP (Fig. 1). It consists of the body 1, in lower part of which a direct current electromagnet coil 2 is disposed. In coil 2 the nonmagnetic material cylinder 3 is disposed, which performs the role of hydrocylinder. It contains a large-diameter piston 4, which represents direct current electromagnet armature. Upper part of MHP body 1 is an oil tank 5, inside of which the second hydraulic cylinder 6 is disposed, in which a small-diameter piston 7 shifts together with a tappet rod 8. This rod is also connected by its second end with executing mechanism. Small-diameter under-piston area 7 of hydrocylinder 6 is connected with oil tank 5 by a hole 9, which is plugged by electromagnetic valve 10. This valve 10 is connected by means of stem 11 with direct current electromagnet armature 13 of valve 12, while spring 14 is disposed on stem 11. Upper area of piston 4 by means of hole 15 is connected with under-piston area, and through single-action valve 16 and hole 17 – with oil tank 5. Oil tank 5, also by means of tube 18 and regulating valve 19 is connected with under-piston area.

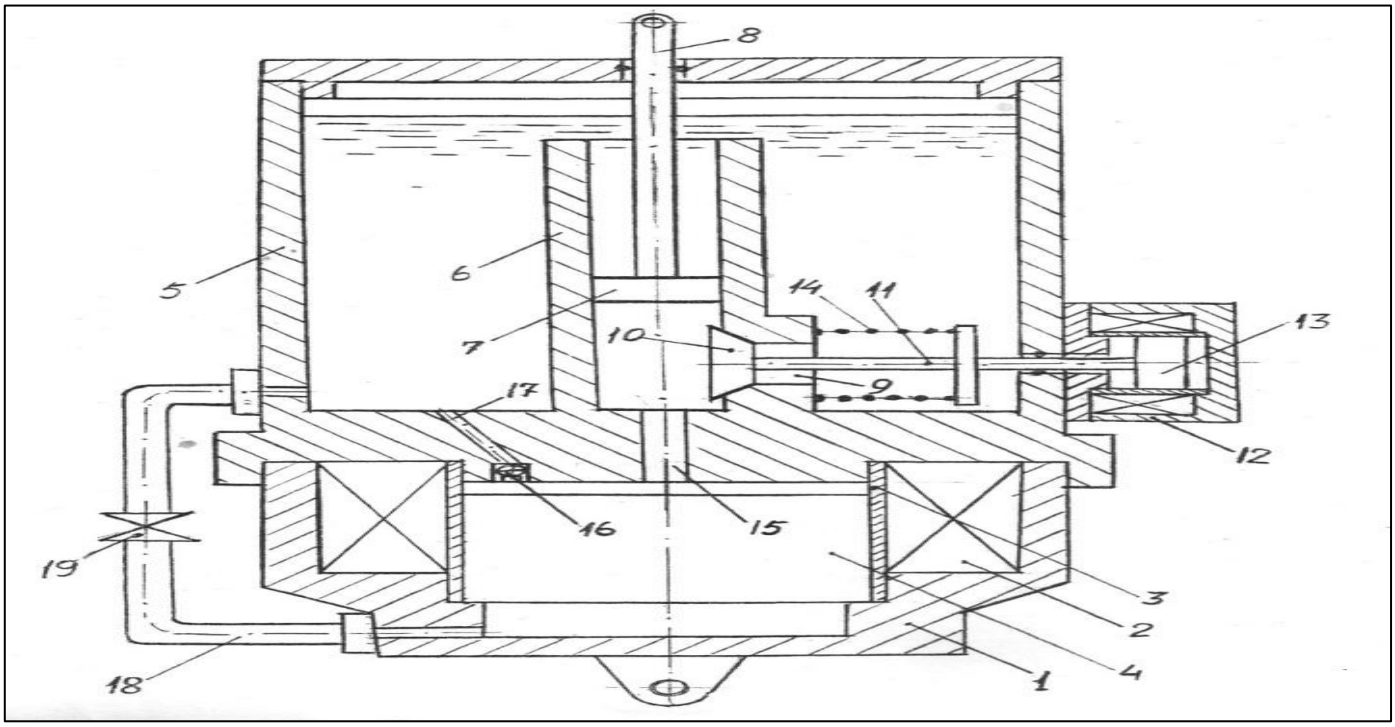

Fig 1 Magneto Hydraulic Pusher

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may185

When emergency situation is originated in the process of machinery and equipment operation, pressing the emergency button for rapid downstroke of tappet rod induces switching on of direct current electromagnet of pusher's electromagnetic valve, armature of which is attracted to the core. The armature by means of spring stem opens up by a valve a hole in small-diameter under-piston cylinder. The tappet rod, while being in uppermost working position, by means of small-diameter piston permanently pressures a working fluid under influence of external force acting on it and own weight and creates excessive pressure, which is much more than a pressure in the working fluid tank. Due to this, a working fluid flows from small-diameter under-piston area to working fluid tank through a hole in the small-diameter cylinder, without any resistance, and a tappet rod together with small-diameter piston rapidly comes down to the lower initial position. Tappet rod downstroke is no more opposed neither by attraction force caused by residual magnetism and, the more important, nor by any degree of regulating valve opening.

When a tappet rod reaches the lowermost position, the electromagnet of electromagnetic valve switches off and the valve plugs a hole connecting small-diameter cylinder and working fluid tank. Right after the rod reaches the lowermost position, MHP's electromagnet switches off by the last cut-off device. Armature-piston, while pulled away from electromagnet core, under influence of its own weight pressures a working fluid placed under and through a tube and regulating valve pumps a working fluid into tank. Armature-piston during downstroke sucks a working fluid to its upper area from working fluid tank by means of single-action valve, and when armature-piston reaches an initial lowermost position, electromagnetic valve switches off as well and a hole connecting small-diameter cylinder with working fluid tank plugs. After that, the pusher is ready to be switched on again, when emergency situation is eliminated.

III. CONCLUSIONS

Thus, the tappet rod downstroke speed of MHP of original design elaborated by us, in case of emergency situations doesn't depend neither on opening rate of valve adjusting the rod downstroke speed, nor on attraction force caused by residual magnetism as well as on electric power supply to MHP electromagnet. That is why it is possible to increase tappet rod downstroke speed to the maximum, selecting a diameter of hole connecting small-diameter hydrocylinder and working fluid tank. Proceeding from this fact, application of the mentioned MHP as a brake gear of lifting-and-shifting machines provides any degree of smooth braking, as well as instant braking in case of emergency situations.

REFERENCES

[1]. M.P. Aleksandrov. «Brakes of lifting-and-shifting machines», Moscow, «Mechanical Engineering», 1976, 383 p. (in Russian)
[2]. A.K. Ter-Akopov. «Dynamics of fast-acting electro-magnets». Moscow, «Energy», 1965, 166 p. (in Russian)
[3]. E.M. Guselnikov. «Electrohydraulic pushers». Moscow, «Energy», 1968, 111 p. (in Russian)
[4]. S.G. Bitsadze. «Magneto hydraulic pusher». A.C. №1331817, Bulleting of inventions №31. Moscow. 1987.