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Investigating the Influence of Geometry on Performance Characteristics of Mounted Cushions in Hydraulic Cylinders

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ABSTRACT: In this research, design, fabrication and evaluation of 5 different hydraulic cushions have been considered in order to optimize the stopping mechanism of pistons at the end of the course. The comparison of 5 cushion spears including Cylindrical, Conical, Sagittal, Double conical and Parabolic cushion have been studied with reviewing the motion behavior of piston and measuring displacement, speed, acceleration, flow rate and hydraulic pressure in an one way hydraulic cylinder. Results showed that the sagittal cushion with maximum pressure increasing of 1.98% for 200 kg load and 0.35% for 350 kg load had the lowest percentage of hydraulic pressure rise and cylindrical cushion with maximum pressure increasing of 11.98% for 200 kg load and 3.92% for 350 kg load had highest percentage of hydraulic pressure rise. Also operational time of sagittal cushion in experiments with 350 kg load was respectively 33.8 and 63.9 percent lower than that of conical and cylindrical cushion. Also double conical cushion has the nearest performance to the sagittal cushion. As a concluding result with tacking into account the low response time, steady speed reduction and steady rate of hydraulic oil discharge, sagittal cushion is recommended to be used in industries.

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1. Introduction

The word "Cushioning" has an extended use in industry, especially in hydraulic and pneumatic cylinders. The usage of cushions is widespread from big excavator to precise robotics [1,2]. In a perspective view, the cushion spear mounted in hydraulic and pneumatic cylinders would control the speed of the moving piston by entering to cushion sleeve at the end of the cylinder course, see e.g., [3-16]. This process would happen due to the limitation of the outgoing oil flow.

2. Methodology

In the experiments, comparison of 5 cushion spears including Cylindrical, Conical, Sagittal, Double conical and Parabolic cushion have been studied with reviewing the motion behavior of piston and measuring the parameters such as displacement, speed, acceleration, flow rate and hydraulic pressure.

To pump the hydraulic oil inside the cylinder, a 120 bar power package has been used. In order to measure the mechanical movement of piston and the effect of weight and the cushion geometry on the piston motion, cushions have been tested under two separate load of 200 and 350 kg. Cylinder movements have been recorded by a 30 frames/s CANON video camera mounted on the stand in a fixed distance of 2 meter from the cylinder. Recorded videos have been converted to separate frames using Video-to-Picture software made by Watermark Software Company. Then the location of the loading plate have been calculated from the separated frames by accuracy of the 0.1 mm. Also oil pressure has been measured using PS-100 pressure transmitter made by Lutron Company with ±0.002 bar tolerance, recorded with RS-9302 logger and transferred to computer using RS-232 serial cable.

Fig. 1. The examined cushions (from right-to-left): cylindrical, conical, sagittal, parabolic and double conical.

3. Results and Discussion

The results of the pressure changes with two weights of 200 and 350 kg showed that before entering the cushion spear inside the cushion sleeve, the pressure changes are constant

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due to the lack of resistance. When the cushion spear receives to the cylinder block, the flow pressure would increase slowly due to the decrease of the discharging effective area. This point is the beginning of the cushioning process and shown with *R1, R2, R3, R4* and *R*5 in Fig. 2. With reducing the effective area, the oil pressure would increase due to the restriction of passing the flow from a 2 mm orifice, located inside the cushioning system. With comparison of the maximum pressure at the moment of entering the cushion spear to the cushion sleeve with the pressure at the start of the cushion movement, it can be concluded that the sagittal cushion has the lowest amount of the pressure increase with maximum increase of 1.98% (200 kg) and 0.35% (350 kg) and cylindrical cushion has the highest amount of the pressure increase with 11.32% (200 kg) and 3.92% (350 kg).

On the other hand, with reviewing the time difference between examined cushions, it can be concluded that the sagittal cushion had the lowest operational time, see Fig. 3.

The results of reviewing the deceleration rate of the piston movement in test with 200 and 350 kg load showed that the first level of the deceleration would happen at the moment of receiving of the cushion spear to cylinder block. The other point is that the deceleration diagram slope in all of the 5 cushions and in both of the test weights which was stepwise. Lack of resistance in the way of oil discharge before entering

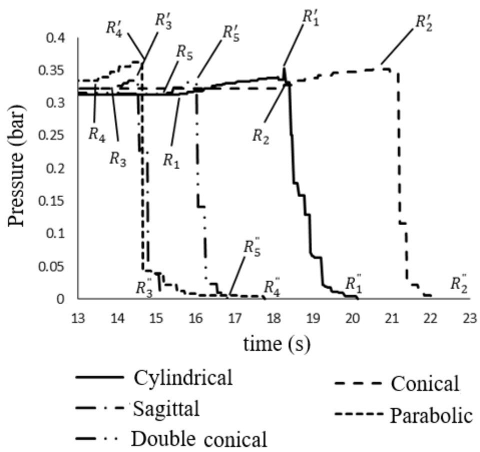

Fig. 2. Variation of the oil pressure for different cushions.

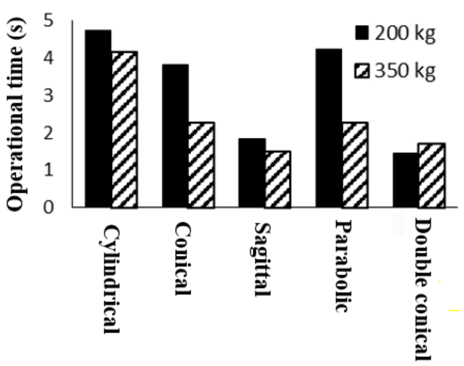

Fig. 3. Comparison between operational times of different cushions

the cushion and sudden effective area reduction at the moment of receiving the cushion spear to the cushion sleeve was the main reason of this effect. So the deceleration at the beginning of the cushioning process happens with the steep slope. With fully closing of the cushion sleeve, the trapped high pressure oil between cylinder and the cylinder block would discharge through a 2 mm orifice. According to the limitation of orifice area, the deceleration in this level happens slowly and in the end, with vanishing the volume of the hydraulic oil, the piston movement velocity would be zero. The other point is the similar performance of the double conical cushion in compare to the sagittal cushion.

4. Conclusion

In this research the performance of the 5 cushions (cylindrical, conical, sagittal, parabolic and double conical) mounted in a one-way hydraulic cylinder have been examined. The obtained results showed that the cushion geometry has the most important role in cushioning process. Also it has been proven that the cylindrical cushion had the highest amount of the pressure increase and longest operation time, while the sagittal cushion with lowering the performing time to 1.5 s has the lowest operational time and lowest amount of the pressure increase. On this basis and according to the higher discharge rate of the sagittal cushion in comparison to the other cushions, it can be concluded that the sagittal cushion had the lowest operational time, lowest possible amount of pressure increase and lowest amount of hydraulic shock. It can be concluded that in contrast to the suggestion of lay *et al*. (2016) on the usage of conical cushion, we suggest to use the sagittal cushion in industries. After sagittal cushion, double conical cushion has shown the best performance in case of operational time and pressure increase.

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