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Design of a Novel Mechanism for Transportation of Wheelchair and Disabled People into Public Buses

[1]Rasoul Pourhassana, [1]Reza Rafieea and [1]Mahdi Pourhasana

[1]Department of Mechanical Engineering, Islamshahr Branch,Islamic Azad University, Islamshahr, Iran.

Abstract: In this paper, a new method for transporting wheelchair users and disabled people into and out of public buses is presented. This method consists of a mechanism which is mounted on two rails, one fixed, the other mobile. It has linear movement in two stages and rotary movement in one stage. The rails have vee-guideway joins so as to prevent turnover during movement. Power transition is implemented through a hydraulic system. The most important factors for design and manufacture of this mechanism are theoretically calculated. Then, system's movement mechanism is simulated with the software *Adams* and the required outputs are obtained thereof.

Key words: mechanism, wheelchair, disabled people

INTRODUCTION

Many people such as disabled people, older people, pregnant women, and wheelchair users have problem for getting on or off from a bus. They can not get on a vehicle alone and someone else should help them to get on and off. In many cases there are special vehicles that use ramp for transportation of disabled people.

Walter invented an apparatus for handling of wheelchair into vehicles which don't have any step like vanes. This system is used only for transportation of wheelchair into and out of the vehicle; so, this vehicle can not be used for transportation of ordinary people (Walter, 1970). Ricci invented a normally upstanding wheelchair ramp for minibus type vehicle (Ricci, 1976). Adamski et al proposed an elevator platform which is mounted within the entrance area at the front door of a bus. Floor and steps at the entrance of the bus are removed and a U-shaped reinforced frame forms a wall for the elevator platform (Adamski, 1977). Kinkead *et al* proposed a lift for using in a public conveyance such as bus or train, such that wheelchair can be rolled onto the lift platform at ground level and then transported into the vehicle. Its disadvantage is that steps at the entrance of bus should be removed in this structure (Kinkead, 1978).

Thorley invented a lifting device suitable for transportation of handicapped people into a vehicle or building. The platform is made up of three hinged parallel sections which can be withdrawn and folded into two steps. A hidden ramp under the stairs slides forward to allow easy access to the extended platform (Thorley, 1978). A lift is characterized by its ability to be retrofitted into a van. This lift is easily mounted on a van without requiring involved structural changes to the van]6[. Another lifting apparatus for carrying of wheelchair into a van was proposed by Williams *et al.* (1985). This apparatus has a relatable post at the front of doorway in the side of van. A carriage for the wheelchair lift platform slide along this post.

Lanier invented an apparatus for moving of wheelchair into and out of an automobile like taxi under the control of disabled person (Lanier, 1985). A lift apparatus was proposed for transferring wheelchair into trains and public transit vehicles using existing pedestrian passenger entryways. This apparatus is embedded in the station for lifting of wheelchair to the train. So, it is only used in special places for transferring of disabled people to trains or public vehicles (Williams, 1986). Gateau invented a mechanism for lifting of a wheelchair to a taxi by means of a motored mechanism comprising a component at the rear side of thereof (Gateau, 1987). In this mechanism the vehicle is provided with an upwardly opening rear door. Tauer invented a mechanism for lifting of wheelchair to an automobile (4-wheel cars). This mechanism has a single piston and cylinder for both raising and lowering of the wheelchair lift and for pushing it out to an operating configuration from underneath of the automobile (Tauer, 2000). In this paper, authors give a fundamental solution for transportation of wheelchair into a public bus. The most important factors including required force

Corresponding Author: Rasoul Pourhassana, Department of Mechanical Engineering, Islamshahr Branch, Islamic Azad University, Islamshahr, Iran.
E-mail: rpourhasan@gmail.com

for linear and rotary movements of bars, and piston diameter for both of movements are theoretically calculated. Then, system's movement mechanism is simulated with the software *Adams* and the required outputs are obtained thereof.

Mechanism Designing:

We can use many diverse mechanisms for our purpose, but all of them must have following characteristics:

- The mechanism should have sufficient security for getting on and off of disabled person.
- The wheelchair users can get on or off the bus without needing others' help.
- The mechanism should be invisible when not used.
- The mechanism should not get much space because there is limited space under the bus floor.
- Cost of manufacturing should be low.

We can use electrical or mechanical mechanisms for our purpose but electrical mechanism such as lifting is costly and mechanical mechanism such as chain sprocket needs a lot of space. So, in this paper; we propose four parallel bars mechanism. Four parallel bars mechanism is a mechanism that bars move in a parallel manner. A plate can be put above these four parallel bars for carrying the wheelchair. Thus, seat plate remains horizontal during all of the stages, and provides higher security for the user. This mechanism is mounted on two rails, one fixed, the other mobile. It has linear movement in two stages and rotary movement in one stage. The rails have vee-guideway joins so as to prevent turnover during movement. The mobile rails are connected to each other with a bar, so they have coordinated movement. Power transition is implemented through a hydraulic system. This mechanism has one piston for linear movement of mobile rails and two pistons for rotary movement of L- shape bars.

Performance Stages of Mechanism:

1. The mechanism is under the bus so as not to make any trouble for normal people to get on or off.
2. The mechanism moves linearly on the mobile rail to be placed on the first stair, so that the wheelchair user can move on it to get off the bus.
3. The mechanism protrudes from the bus to a certain extent to be prepared for rotation without hitting the body of the bus.
4. In the final stage, the L-shaped bars start rotating in the section where they join the mobile rail.

Following the last stage the plate is completely on the ground so that the wheelchair user can easily get off the bus. The foregoing stages apply to getting off the bus; obviously, the reverse applies to getting on the bus. Figure 1 show these stages for getting off the bus.

We should select a special bus for precise designing of bars length, so we chose 0457 Mercedes Benz bus. We can use this mechanism for other kind of buses with only a little dimensional variations in rails and L- shaped bars length. Figure 2 shows schematically final mechanism with dimension of bars.

Modeling of Mechanism with Solidworks Software:

The mechanism is modeled with *Solidworks* software for provision of drawing from parts and devices. Figure 3 shows the mechanism when it is hidden under the bus floor, so passengers do not see it and can get on or off without any problem. In this situation all of pistons are closed.

Figure 4 shows mechanism situation after two linear movements. First, the mechanism linearly moves outward with magnitude 800 mm on the mobile rail to be placed above the second stair, so wheelchair user can move on it to get off the bus. If the mechanism rotates in this stage, it will collide with the first stair of the bus. Thus, the mechanism protrudes from the bus with magnitude 390 mm in outward direction to be prepared for rotation without hitting the body of the bus.

Figure 5 shows mechanism situation after the final stage. In this stage, the L-shaped bars start rotating with magnitude 150 degree in clockwise direction in the section where they join the mobile rail. Following the last stage the plate is completely on the ground so that the wheelchair user can easily get off the bus.

Calculation of Required Force for Rotary Movement:

Required force for rotary movement of L-shape bars should be calculated. So, we calculate uplifting and lowering forces of wheelchair because these forces are needed for calculation of hydraulic piston diameter. Figure 6 shows extension of uplifting and lowering forces on bars. Also, four bars free diagram has been shown in Figure 7.

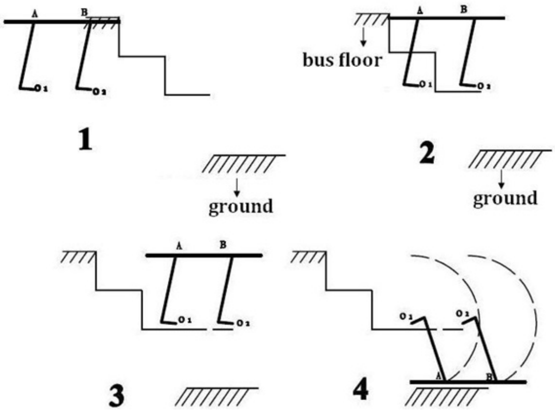

Fig. 1: Performance stages of mechanism when wheelchair user gets off the bus.

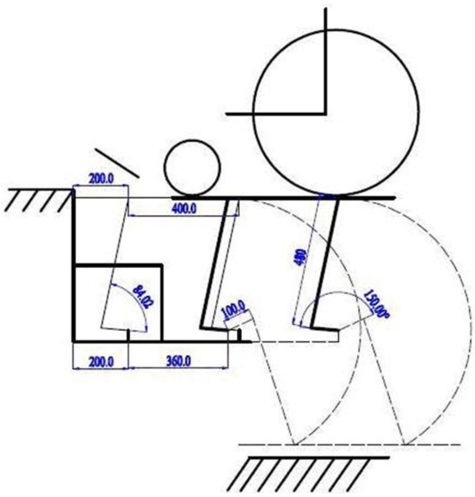

Fig. 2: Schematic of mechanism with dimensional information.

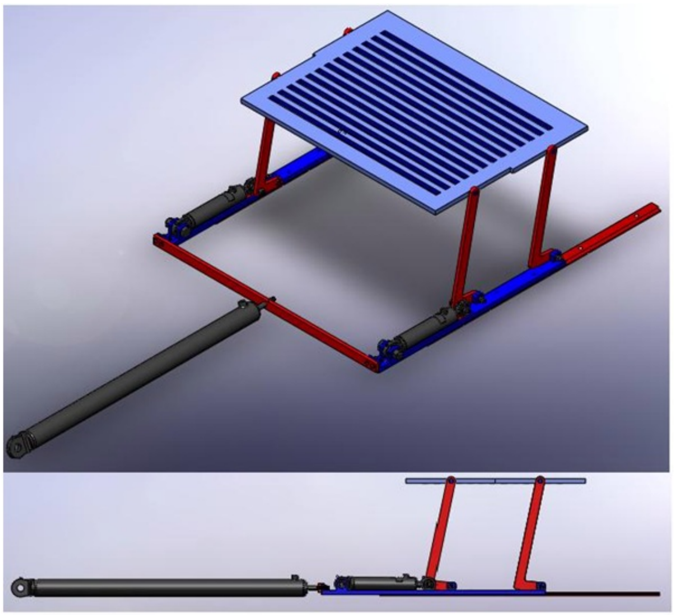

Fig. 3: Mechanism situation before movement.

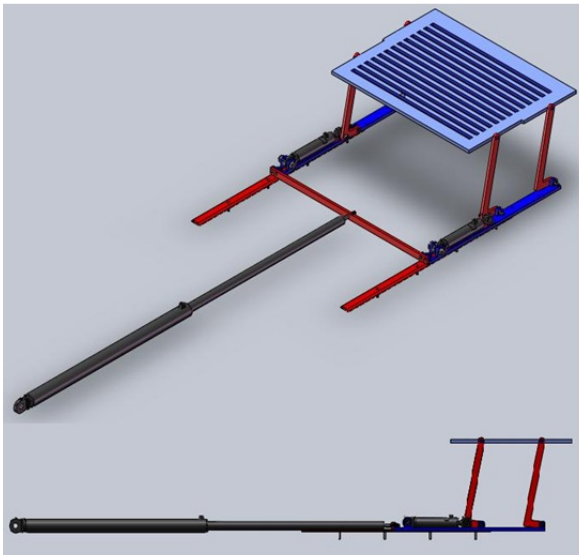

Fig. 4: Mechanism situation after two linear movements

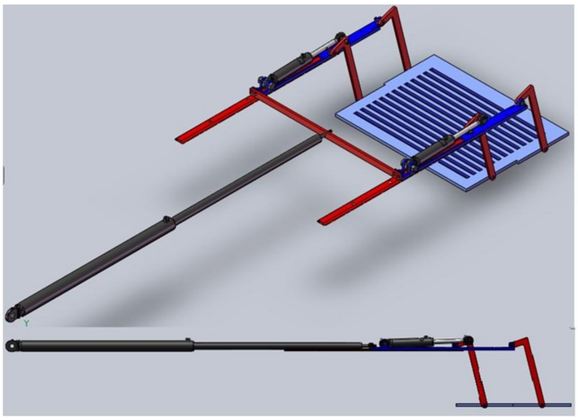

Fig. 5: Mechanism situation after rotary movement.

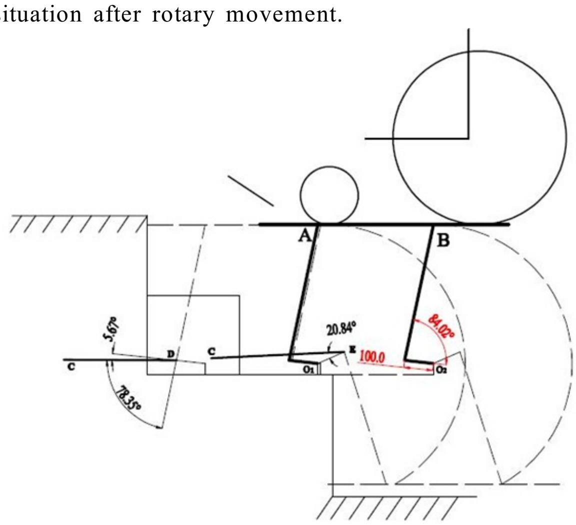

Fig. 6: Extension of uplifting and lowering forces.

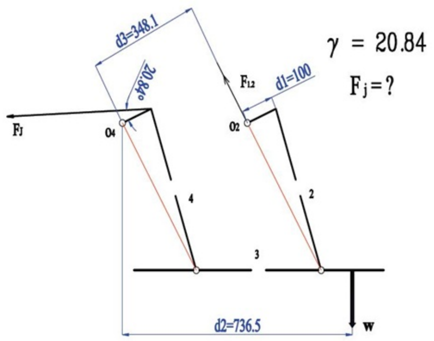

Fig. 7: Four bars free diagram.

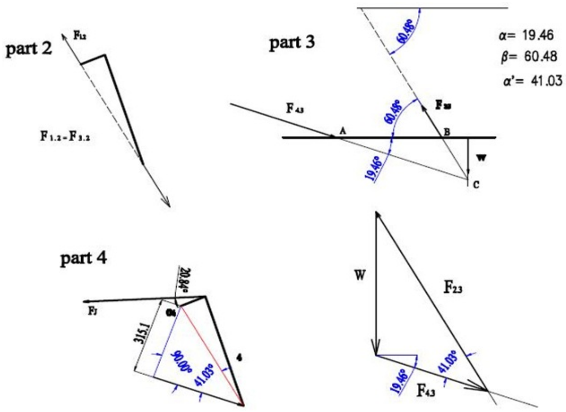

Fig. 8: Free diagram of all bars.

CE (Fj) : uplifting force, CD: lowering force, γ: angular between forces

$$\sum MO_4 = 0$$

$$Fj \times \sin\gamma \times d_1 - W \times d_2 + F_{1.2} \times d_3 = 0$$

For calculation Fj we need to calculate $F_{1.2}$. So, we will draw free diagram of all bars and calculate internal forces (Figure 8).

Unknown forces can be calculated from above diagrams:

$$\frac{W}{\sin\alpha'} = \frac{F_{2.3}}{\sin\alpha + 90} = \frac{F_{4.3}}{\sin 90 - \beta}$$

$$\frac{1500}{\sin 41.03} = \frac{F_{2.3}}{\sin 19.46 + 90} = \frac{F_{4.3}}{\sin 90 - 60.48}$$

$$F_{1.2} = F_{3.2} \quad F_{4.3} = 1125.883N \quad F_{2.3} = 2154.471N$$

$$Fj \times \sin\gamma \times d_1 - W \times d_2 + F_{1.2} \times d_3 = 0$$

$$F_j \times \sin 20.84 \times 0.1 - 1500 \times 0.7365 + 2154.471 \times 0.3481 = 0$$

$$F_j = 9972.429 \cong 10000N$$

We attained uplifting force (Fj) and since amount of this force is more than lowering force, we do not mention required calculation for lowering force of wheelchair. Piston diameter for rotary movement can be calculated with uplifting force because it is maximum force on bars.

Calculation of Required Force for Linear Movement:

It is obvious that required force for linear movement is low, but we should calculate it for selection of desired piston for linear movement.

$$\tau = \mu \frac{u}{y}$$

$$\tau = 0.35 \times \frac{0.05}{2 \times 10^{-5}} = 875\,Pa$$

$$\tau = \frac{F}{A} \Rightarrow 875 = \frac{F}{9 \times 10^{-4}} \Rightarrow F = 7875 \times 10^{-4}\,N$$

τ: Shear stress, μ: dynamic viscosity factor, *u*: linear movement velocity, *y*: Oil thickness between two surfaces

Calculation of Hydraulic Piston Diameter:

Hydraulic piston diameter is calculated for applying force during linear and rotary movements. First, piston diameter (D) and rod piston diameter (d) for linear movement is calculated by following equations. Since calculated linear force is very low (F= 0.787 N), so we use higher force for increasing safety factor.

$$P = \frac{F}{A} \Rightarrow A = \frac{F}{P} = \frac{7875 \times 10^{-4}}{70 \times 10^{5}} = 11.25 \times 10^{-8}\,m^2$$

$$A = \frac{\pi}{4} d^2 \Rightarrow d = \sqrt{\frac{A}{\frac{\pi}{4}}} \qquad D = 3.78 \times 10^{-4} \approx 4 \times 10^{-4}\,m = 0.4\,mm$$

If we use higher force:

$$P = \frac{F}{A} \Rightarrow A = \frac{F}{P} = \frac{6000}{120 \times 10^{5}} = 5 \times 10^{-4}\,m^2 \qquad D = 0.0252\,m = 25.2\,mm$$

Thus, we can choose D=32 mm and d=14 mm from standard piston diameter table. Then, piston diameter for rotary movement is calculated with safety factor 2:

$$P = \frac{F}{A} \Rightarrow A = \frac{F_j}{P} = \frac{20000}{120 \times 10^{5}} = 166.66 \times 10^{-5}$$

D=46 mm piston diameter
p: work pressure of pump

Thus we can choose D=50 mm and d=22 mm for required piston for rotary movement of bars from standard piston diameter table

Simulation of Mechanism's Movement with the Software Adams:

The system's movement mechanism was simulated with the software *Adams* and required outputs were obtained thereof. We first used step equations for showing displacement of linear motors in simulation of mechanism's movement. Mentioned equations in this mechanism are:

$$Step(time, x_0, h_0, x_1, h_1)$$

Step (time, 0, 0, 10, 800)	first linear movement
Step (time, 10, 0, 20, 390)	second linear movement
Step (time, 20, 0, 30, 192)	rotary movement

$x_0, x_1 : time$

$h_0, h_1 : displacement$

Figure 9 shows modeled mechanism with the software *Adams*. Required outputs including angular variations (Figure 10), angular variations of mechanism to stroke length of piston (Figure 11), and force variations (Figure 12) were obtained after modeling of mechanism in the *Adams* software. It is clear that obtained results from this software conform to theoretical calculations.

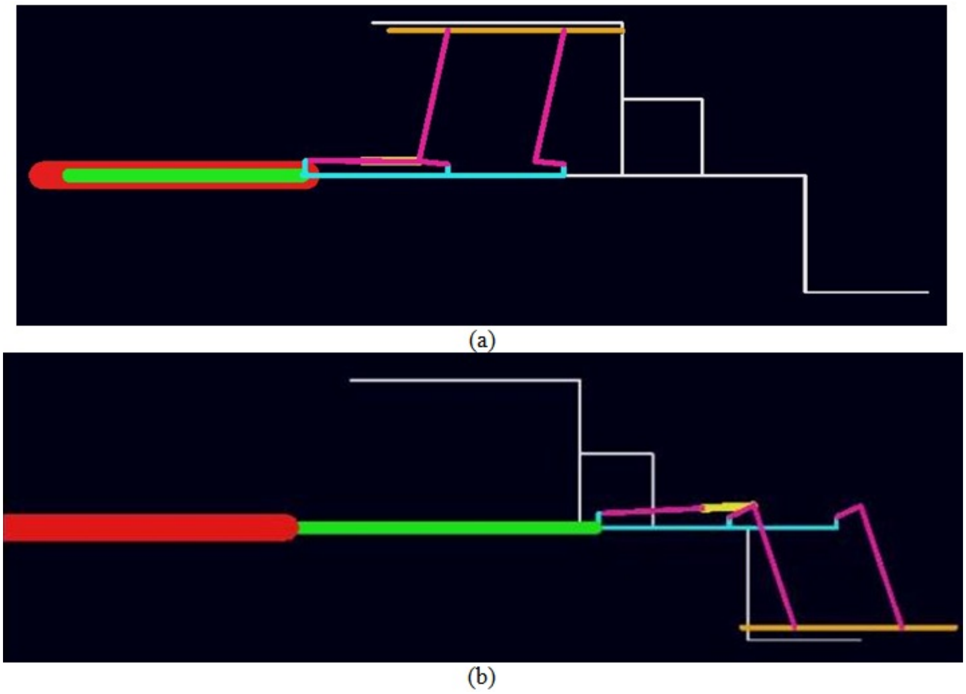

Fig. 9: Modeled mechanism with the software *Adams* a) before performance b) after performance.

Fig. 10: Angular variations of mechanism.

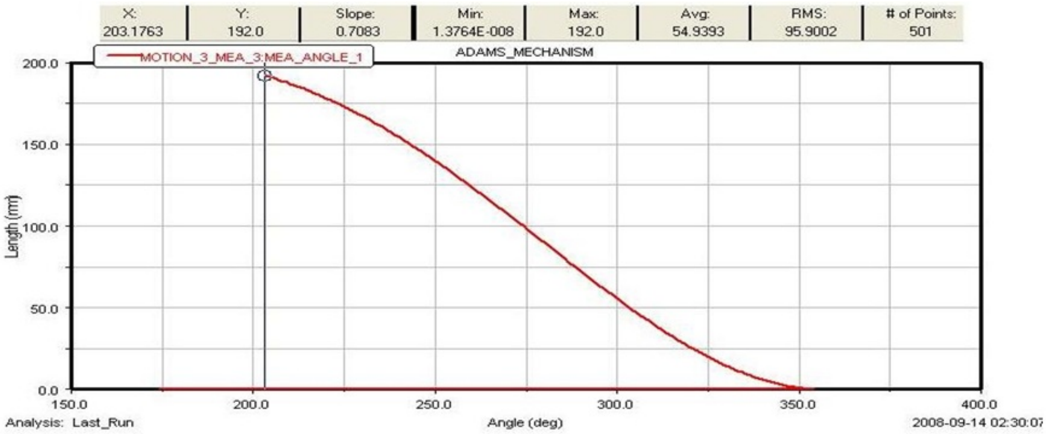

Fig. 11: Angular variations of mechanism to stroke length of piston.

Fig. 12: Force variation of piston in rotary movement.

Simulation of Hydraulic Circuit with the Software Automation Studio:

Hydraulic circuit of mechanism was designed with the software Automation Studio (Figure 13). Next, the designed hydraulic circuit was tested with the simulation facility of that software.

Conclusion:

In this paper, a new method for transportation of wheelchair user and disabled person into and out of public buses was presented. The most important factors for design of this mechanism such as required force for linear and rotary movements of mechanism were theoretically calculated. Also, piston diameter for linear and rotary movements was calculated. Then, system's movement mechanism was simulated with the software *Adams* and required outputs including angular variations, displacement variations, and force variations during rotary movement were obtained thereof. Obtained results from this software conformed to theoretical calculations.

This novel mechanism has following advantages:

1. The wheelchair user can get on or off the bus without needing others' help.
2. The mechanism is invisible when not used, so the bus can use for ordinary people.
3. The plate which carries the wheelchair remains horizontal during all the stages, providing higher security for the user.
4. The rails have vee-guideway joins so as to prevent turnover during movement.

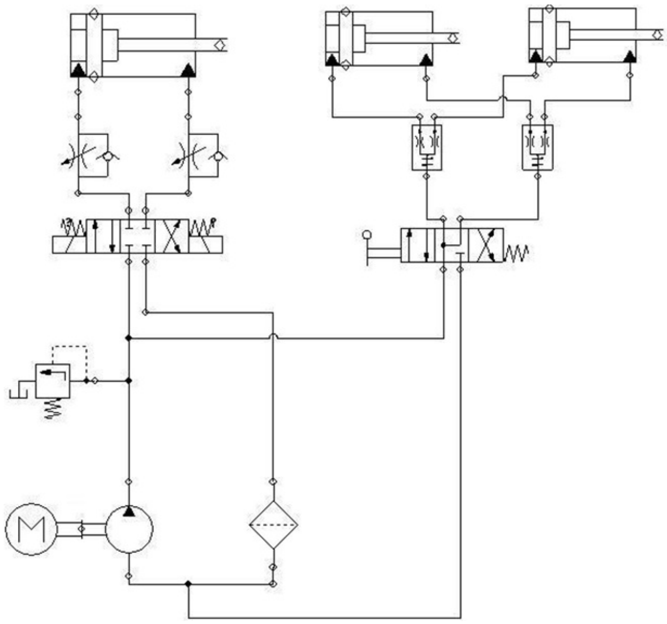

Fig. 13: Applied hydraulic circuit in mechanism.

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