The Design of Automatic Grease Lubricator Type of the Cylindrical Cam Piston Pump

Wooseok Choi, Jinseok Yang, Hyun Soo Koo, Duck Hyun Wang, Se-Han Lee
Mechanical Engineering and Automation
Kyungnam University 449 Wolyoungdong, Masan City, Gyungnam, 631-701, South Korea
wooseok@gmail.com
leesehan@kyungnam.ac.kr

Abstract

A new piston mechanism is proposed for an automatic grease lubricator, which is able to supply equipment with grease automatically for smooth motion. The mechanism adopts a cylindrical cam system, which is able to convert rotational motion to translational motion, and is composed without any check valve for preventing back flow even though existing lubricator has two check valves. Since the mechanism has a feature of all in one, which combines piston and valves. The automatic grease lubricator includes a micro controller system, which makes feeding pressure, period, and amount of grease in accuracy.

Key Words: Grease lubricator, Cylindrical cam, Piston pump, Microcontroller, Check Valve.

1. Introduction

As the industrial technologies are developed, automation is widely spreading for product efficiency and unmanned production system. Automatic grease lubricator is equipment that provides adequate amount of fresh grease constantly to the shaft and the bearings of machines. It minimizes the friction heat and reduces the friction loss of machines. For proper operating of machinery, accurate feeding period and amount of grease is most important thing. To obtain these performances, it is required of high accuracy for feeding grease mechanism.

There are many kinds of grease lubricators such as a gas generating, a spring pre-pressurized, a pressurizing piston type for creating pressure. In case of gas generating type, chemical reaction is used for creating pressure. The gas type is subject to be affected by environmental temperature. When the chemical reaction starts, it is hard to respond to unexpected situations **[1]**.

The pressurizing piston type requires very complicated structure with check valves while it shows very good feeding performances.

In this research, we proposed a simple new mechanism for easy control. It adopts cylindrical cam piston pump and is almost similar to the pressurizing piston type lubricator. The mechanism proposed here is simple form and requires no check valves that make the mechanism complicated.

2. Design of cylindrical cam-driving mechanism of piston pump system

The piston mechanism proposed here is creating pressure for feeding grease by using special feature formed around the piston without check valve, which conventional lubricator uses for preventing back flow of grease. In order to activate the special feature formed around the piston, there needs to rotate the piston.

In order to realize rotational and reciprocal motion of the piston simultaneously, a cylindrical cam mechanism is adopted. The piston mechanism proposed here is shown in Fig. 1. It is required the bulky images of cylindrical cam for development purpose.

Fig. 1 shows an essential feature of the mechanism proposed here. As the driving motor is rotating, the piston is moving reciprocally and rotating simultaneously by guide pin and cylindrical cam formed around the piston. [2]

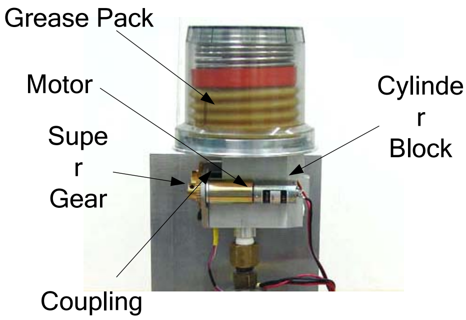


Fig. 1: Cylindrical cam mechanism prototype

The motion of the cylindrical cam is that as it rotates the piston is moving reciprocally and rotating with interaction between cylindrical cam slot and guide pin. One revolution of the motor is able to produce one cycle of reciprocal motion. The reciprocal motion of the piston is responsible for creating pressure and the rotating motion of that is responsible for closing-opening of valves. Fig. 2 and Fig. 3 show graphically view of the procedure of multi motions of the piston, respectively.

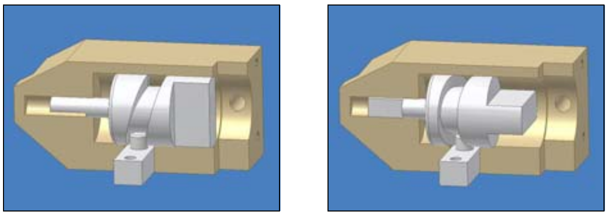
2.1 Motion of cylindrical cam and piston

Fig. 2(a) and Fig. 3(a) show initial stage of the piston motion. In this case, the piston moves close the inlet hole and outlet hole for flowing grease simultaneously. When the piston is only rotating with cam rotation the piston itself is about to open the inlet hole while the outlet hole is still closed. In succession the piston is rotating and retreating, the volume of the cylinder is increasing (becoming low pressure) and the grease is sucked. Fig. 2(b) and Fig. 3(b) show the piston reaching at 90 degrees position.

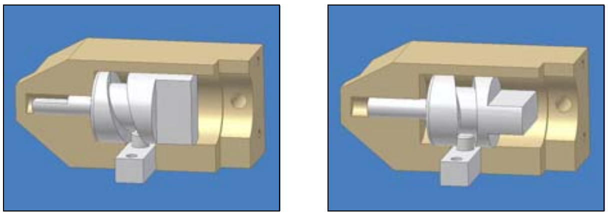
Fig. 2(c) and Fig. 3(c) show the piston reaching at 180 degrees position which is stroke of 5.5mm. At that time, the cylinder is full of grease, the inlet and outlet hole are closed simultaneously. As the piston is rotating successively, the cylinder volume is about to be decreased becoming pressurized and grease is outing. Fig. 2(d) and Fig. 3(d) show piston is outing grease and opening outlet hole while the inlet is still closed. The mechanism proposed here is feeding grease with repeating the procedure described above.

As the piston proposed here is rotating, the piston itself is closing and opening inlet and outlet hole reciprocally, while a conventional lubricator is closing and opening the holes with check valves. It is noticeable that there is position of closing the two holes while there is no position of opening the two holes.

This feature is very important. Though any unpredictable stop motion of the piston occurs, i.e. the piston stops at any position, there is no chance to open inlet and outlet hole simultaneously. It means that it never happens to flow grease by itself at any situations.

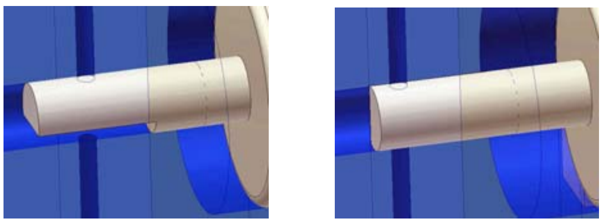


(a) Rotation angle of 0˚ (b) Rotation angle of 90˚

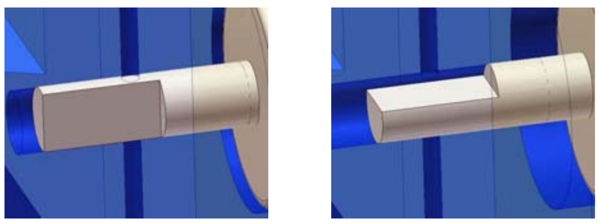


(c) Rotation angle of 180˚ (d) Rotation angle of 270˚

Fig. 2: View of Procedure of multi motions of the piston



(a) Rotation angle of 0˚ (b) Rotation angle of 90˚



(c) Rotation angle of 180˚ (d) Rotation angle of 270˚

Fig. 3: Front view of the procedure of multi motions of the piston

2.2 Design value of the grease

A required amount of grease for one stroke is about 0.125cc (0.125cc/rev.) Diameter and stroke of the piston are governed by feeding pressure and motor output torque. The government equation is following. As the piston is moving reciprocally, the created pressure is variable according to the cam feature. For practical sense, average pressure is reasonable. In order to calculate the average pressure, an energy conservation equation is needed. The input energy by rotational motion is equal to the output energy by reciprocal motion as following

$$dF = \pi\tau \qquad (1)$$

where d denotes piston stroke, F does piston thrust, τ denotes motor torque.

In order to calculate an important variable, pressure p, the both sides of (1) are divided by sectional area A.

$$\frac{dF}{A} = \frac{\pi\tau}{A} \rightarrow p = \frac{F}{A} = \frac{\pi}{V}\tau \qquad (2)$$

where $V = Ad$ denotes the volume of the cylinder.

Equation (2) says that feeding pressure is dependent on motor output torque and displacement which is volume per revolution. Details of the piston diameter and stroke are determined by manufacturing conditions. There exists a minimum dimension to form cam and valve feature around piston.

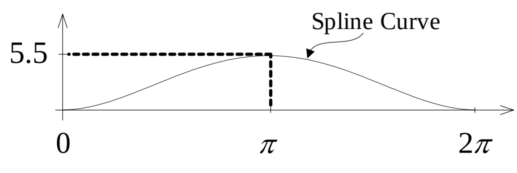


Fig. 4: Displacement of cam

Fig. 4 shows a cylindrical cam trajectory candidate that stands for piston stroke versus motor rotation. The cylindrical cam trajectory is generally formed by spline curve. It is noticeable that the cylindrical cam trajectory is adjusted not to occur only rotational motion without reciprocal motion at stage of opening or closing the holes, since the grease fluid is incompressible. At the first and end stage of the piston stroke, the following condition should be met.

$$\frac{\Delta d}{\Delta\theta} = 0 \qquad (3)$$

where Δd denotes infinitesimal stroke of the piston, $\Delta\theta$ does infinitesimal angle of the piston rotation. A candidate of the piston dimensions is listed in Table 1.

Table 1. Dimensions for Piston

Require Flux (cc)	Piston Diameter (mm)	Require Displacement (mm)
0.125	5.40	5.4580

Important dimensions of the piston, diameter and stroke are determined based on manufacturing. The reason is that difficulty of manufacturing is not free from productivity. A diameter and stroke of the piston should be more than 5mm and 5.5mm, respectively. Dimensions listed in Table 1 are nearly met the above conditions.

A high performance automatic grease lubricator should be able not only to out proper pressure but also to supply destinations regularly with proper amount of grease. These conditions for an automatic grease lubricator are able to be met by implementing micro controller and its peripherals.

In this research, there is introduced an 8-bit micro controller, AT89C2051 [3](manufactured by Atmel) and peripherals, LB1630[4] for driving motor and SG2BC[5] for detecting motor ration state.

In order to program software for the micro controller, we use C-language, which is very familiar for user to use. In order to control the motor precisely, the main part of the software consists of an internal timer and interrupts. Fig. 5 shows a flow chart of the software.

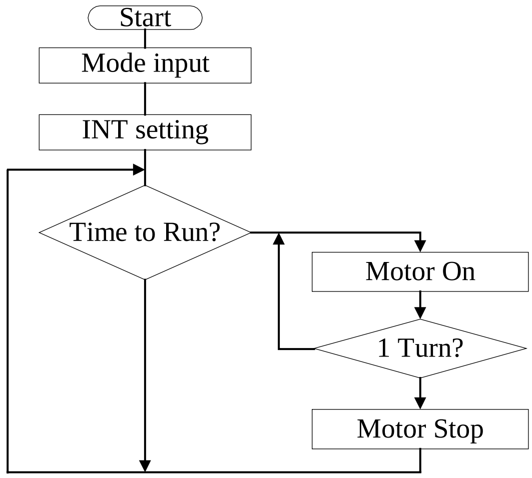


Fig. 5: Flow chart of the software

In order to verify the mechanism proposed here, a micro controller board is constructed. Fig 6 shows the test board

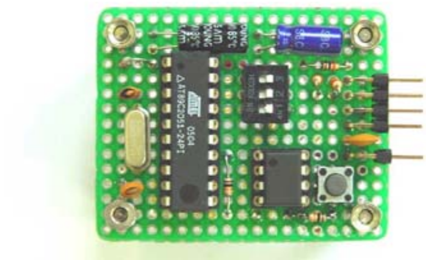


Fig. 6: Micro controller for the mechanism test

3. Experimental result

A lubrication mechanism test was conducted, Fig. 7 shows the photo of the experimental set-up (left) and essential parts of the piston system (right). [6][7]

Fig. 7: Experimental set-up and its exploded parts

First, for identifying only transmission load (reduction gear train, etc.), no-load current of the driving motor was measured and it was 95mA. At the maximum nominal torque (2770g·cm) produced by the reduction motor, the corresponding pressure is obtained as following by using eq. (2)

$$p = \frac{\pi}{V}\tau = \frac{\pi \times 2.77 \times 9.8 \times 10^{-2}}{2.29 \times 10^{-5} \times 5.5 \times 10^{-3}} = 6.2 \times 10^{6}(\mathrm{N/m^2}) = 62.0(\mathrm{kg_f/cm^2}) \quad (4)$$

The maximum nominal torque is performed at a nominal current of 300mA. On the other hand, the manometer as shown in Fig. 8 actually shows pressure of about 5Mpa (=50kgf/cm^2). Fig. 9 shows produced pressure with respect to applied motor input current. The discrepancy (about 22.5%) is supposed to be caused by mechanical friction force between the prototype cylindrical cam and guide pin.

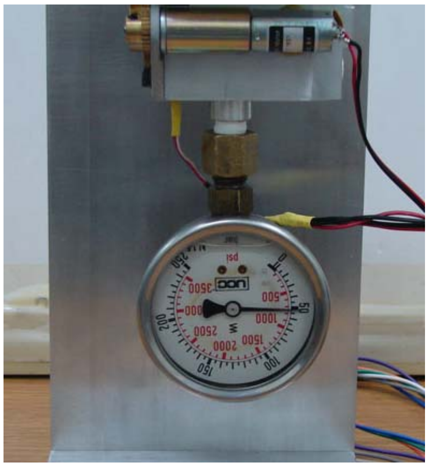


Fig. 8: Pressure value of 50kg$_f$/cm^2 measured by manometer

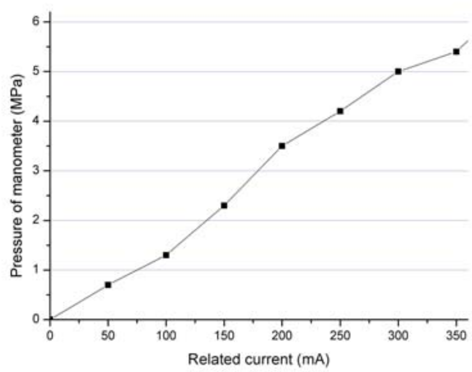


Fig. 9: Diagram of comparative theoretical and experimental Data

We can be detecting the defect on the first experimental test, which is frictional wear in the piston. Fig 10 shows wear of piston feature.

Fig. 10: Frictional wears of piston

This is important defect while the driven cylindrical cam piston mechanism. We settle the defect after changing the material of piston.

4. Conclusion

An automatic grease lubricator using cylindrical cam mechanism of piston pump was developed. The mechanism proposed here is simple as it eliminates a check valve, which is able to prevent back flow. Eliminating a check valve is helpful for cheaper product. Additionally, Cylindrical Cam Mechanism performs high force at instantaneous stop range where Coulomb friction force may be maximized.

As closing and opening the valve is synchronized to the rotation of the piston automatically, a micro controller needs to control only the driving motor and has no burden to control the flow valves.

The discrepancy between theoretical and actual pressure is supposed to be caused by mechanical friction force between the prototype cylindrical cam and guide pin. And also find the defect about the same material problem which is occurred frictional wear between the piston and cylinder.

Acknowledgment

This research was supported by the New University for Regional Innovation program of the Ministry of Education & Human Resources Development (NURI MECHANO21)

References

[1] P. I. Cherednichenko, Lubricator Design as A factor in the Yarn Quality, pp. 68-69

[2] Robert L. Norton, Design of Machinery, New York, 2004, Chap. 8, pp. 378-384.

[3] AT89C2051 datasheet from http://www.atmel.com

[4] LB1630 datasheet from http://www.sanyo.co.jp

[5] SG2BC datasheet from http://kodenshi.co.jp

[6] Teale. J. L., Lebeek, A. O., "An Evaluation of the Average Flow Model for Surface Roughness Effects in Lubrication Technology", 1980, Vol. 102. July, pp. 360-367.

[7] D. H. Wang, K. Y. Lee and S. H. Lee, "The Development of Automatic Grease Lubricator Driven by Gear Mechanism with Controlled Operation Time", J. of KSPE, 2006, Vol. 23, No. 2, pp. 199-206.