# Economic Efficiency of the Pneumatic Semi-Rotary Drives

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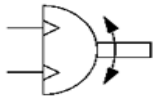
***Abstract:*** *The paper presents the study of the economic efficiency for the semi-rotary drives. In fact, semi-rotary drives are actuators used in many technical applications. The study of the semi-rotary drives is performed in the FluidSim software from Festo. In the first part, we make a pneumatic system with a single semi-rotary drive and a pneumatic circuit with two semi-rotary drives. However, we continue with simple and complex electro-pneumatic systems that contain semi-rotary drives. Pneumatic semi-rotary drives have the potential to reliable motion characteristics with large power output to weight at low benefit–cost ratios. The performance of semi-rotary drives is deeply influenced by the way in which they are actuated. Conventional semi-rotary drives are operated by compressed air supply and controlled pressure from directional valves. Thus, the semi-rotary drives can be applied to pneumatic and electro-pneumatic schemes used in real-world applications. The costs of purchasing and maintaining of the semi-rotary actuators are low.*

***Keywords****: FluidSim, pneumatic, semi-rotary, drives, actuators*

## 1. Introduction

The most commonly used actuators for pneumatic drives are cylinders (single acting and double acting). There are many applications that require a turning or twisting movement of up to 360 degrees. Only semi-rotary drives can be used for these pneumatic applications [1].
The semi-rotary are used in the following applications:

- Subsea ROV actuators;
- Submarine hatches;
- Car production automation systems;
- Door operation and security gates;
- Turn-over machines;
- Coal mining machines;
- Crane grabs;
- Ball and butterfly valve actuation;
- Rubber production;
- Mixing machines;
- Container spreader arms.

| Symbol | Description |
|---|---|
|  | The semi-rotary actuator is controlled by a reciprocal compressed air inlet from a pneumatic circuit.<br>In the end positions, the semi-rotary can activate valves or switches. |

The semi-rotary actuator is compact with high torque ratings. The force is transmitted to the drive shaft by a rotary vane. In this case, the range of angular movement is adjustable with end stops. Moreover, that angle can be adjusted between $0^0$ and $180^0$, [2].
The rotary vanes are separate from the adjustable stop system.
This allows force to be absorbed by the stop blocks. Only at the final positions, the impacts are cushioned by elastic cushioning rings, Fig. 1.


**Fig. 1.** Semi-rotary drive

The main features of a semi-rotary for an electro-pneumatic installation are:

- Cushioning angle: 43 deg.
- Swivel angle: 180 deg.
- Assembly position: any.
- Operating pressure: 0.2...1 MPa.
- Mode of operation: double-acting.
- Ambient temperature: -10...60 $^0$C.
- Product weight: 650 g.
- Pneumatic connection: M5.

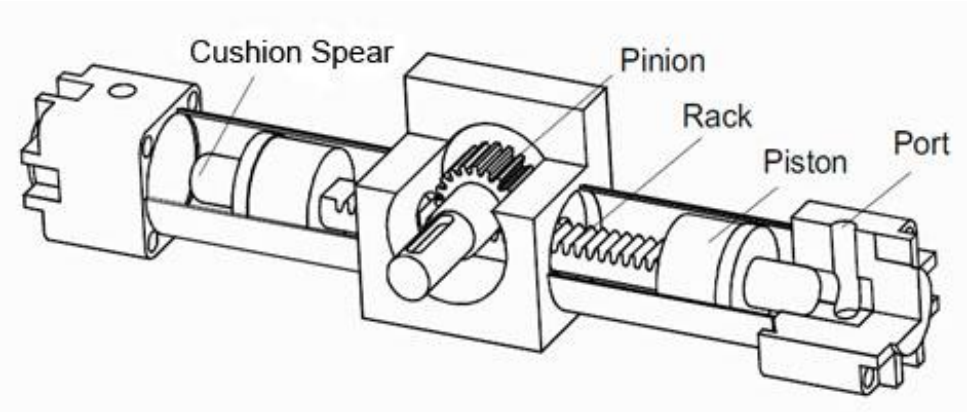



**Fig. 2.** Cut-away view of a semi-rotary actuator

Main components of a semi-rotary actuator are, Fig. 2:

- ❖ cushion spear;
- ❖ pinion;
- ❖ rack;
- ❖ port;
- ❖ piston.

The semi-rotary are composed of a pinion and rack constriction providing constant torque over the total rotation.

They incorporate twin rack pistons which operate on a centrally located pinion or output shaft, [3]. Pressure applied to the piston moves the rack against the pinion creating rotary movement. Regardless of shaft angular position, positive, constant, predictable constancy, mechanically balanced torque is produced in either direction.

The pinion of the actuator drives the clamping shaft, [4].
In practice, various types of semi-rotary actuators are used. Thus, the most used semi-rotary drives are:

- Semi-rotary drive with piston DRRD

| | Advantages |
|---|---|
|  | -cushioning options: internal and space saving or externally for maximum torque in the end position;<br>-positions precisely and thus more reliably even with a long lever arm;<br>-optionally for size 16 and above: end position locking and completely sealed variant. |

- Semi-rotary vane drive DRVS

| | Advantages |
|---|---|
|  | - lightweight;<br>- simple, compact design;<br>- swivel angle infinitely adjustable;<br>- sealed for reliable use in harsh environments. |

The relationships describe the transformation from linear to rotational movement:

$$f_P = p \cdot A - f_F = i \cdot \tau_S \quad (1)$$

Where:

- $f_P$ – piston force;
- $p$− pressure;
- $A$− area;
- $f_F$ – friction forces;
- $i$− transmission ratio;
- $\tau_S$ – shaft torque.

$$i = \frac{2 \cdot \pi \cdot \varphi_{max}}{360^0 \cdot s_{max}} \quad (2)$$

Where:

- $\varphi_{max}$ - maximum angle of rotation;
- $s_{max}$ – maximum stroke.

$$S_p = \frac{\varphi}{i} \quad (3)$$

Where:

- $S_p$ – piston displacement;
- $\varphi$ – angle of rotation.

**2. The semi-rotary actuator in pneumatic circuit**

The first pneumatic circuit made in this paper is designed as a simple pneumatic scheme, Fig. 3.

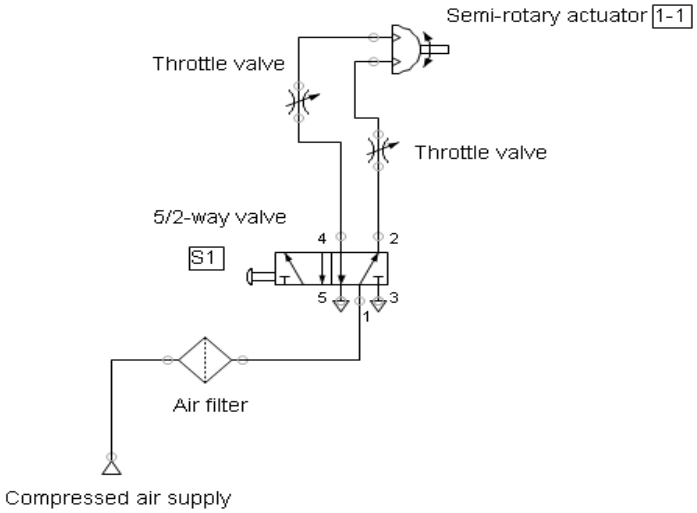



**Fig. 3.** Pneumatic system with a semi-rotary 1-1. Scheme 1.

**Table 1:** The components from scheme 1

| Description | Number of components |
|---|---|
| Semi-rotary actuator | 1 |
| Throttle valve | 2 |
| 5/2-way valve | 1 |
| Air filter | 1 |
| Compressed air supply | 1 |

The distributor 5/2 –way valve with air filter makes the connection between compressed air supply and semi-rotary 1-1, Fig. 3.

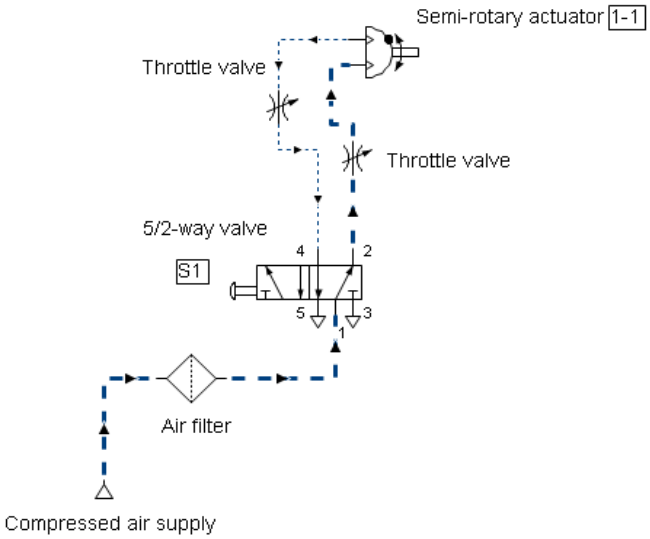



**Fig. 4.** Pneumatic system with a semi-rotary. Simulation

The pneumatic system with a single semi-rotary actuator opens if we press S1 button from 5/2-way valve, Fig. 4.

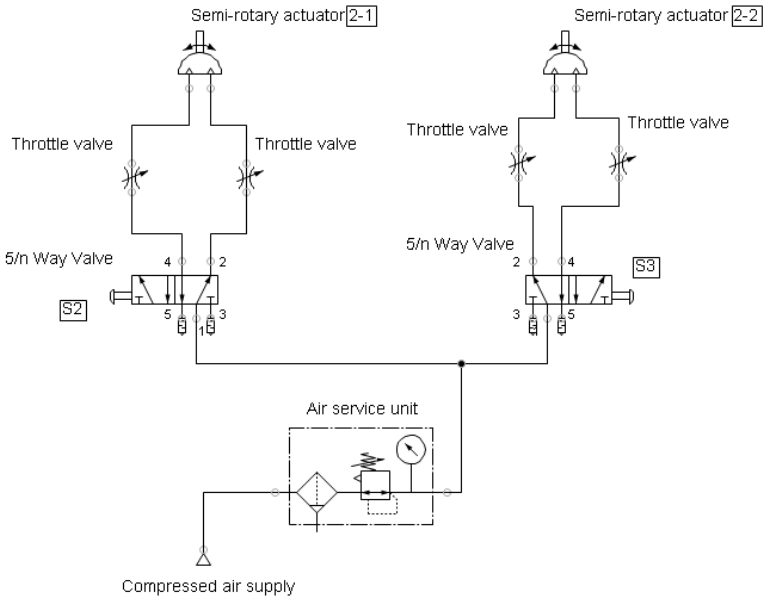



**Fig. 5.** Pneumatic system with two air motors. Scheme 2.

**Table 2:** The components from scheme 2

| **Description** | **Number of components** |
|---|---|
| Semi-rotary actuator | 2 |
| Throttle valve | 4 |
| 5/2-way valve | 2 |
| Air service unit | 1 |
| Compressed air supply | 1 |

Those two semi-rotary actuators are independent of each other. They can start at the same time or in turn, Fig. 6.

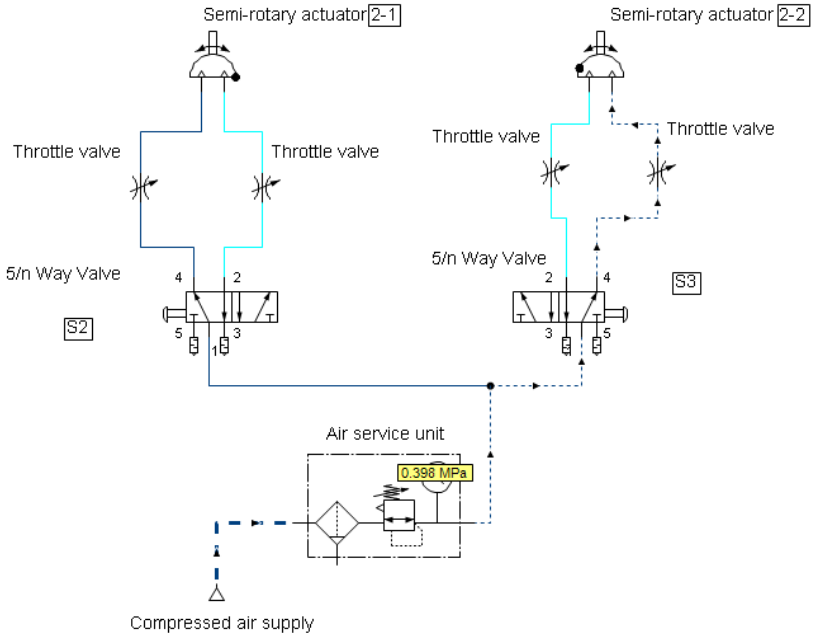



**Fig. 6.** Pneumatic system with two semi-rotary actuators.

### 3. Electro-pneumatic system using semi-rotary

Pneumatic circuit can be controlled by electric circuits. The interface between these two circuits is a solenoid valves. Solenoid valves perform the same function as normal pneumatic valves but there are operated electrically [5].

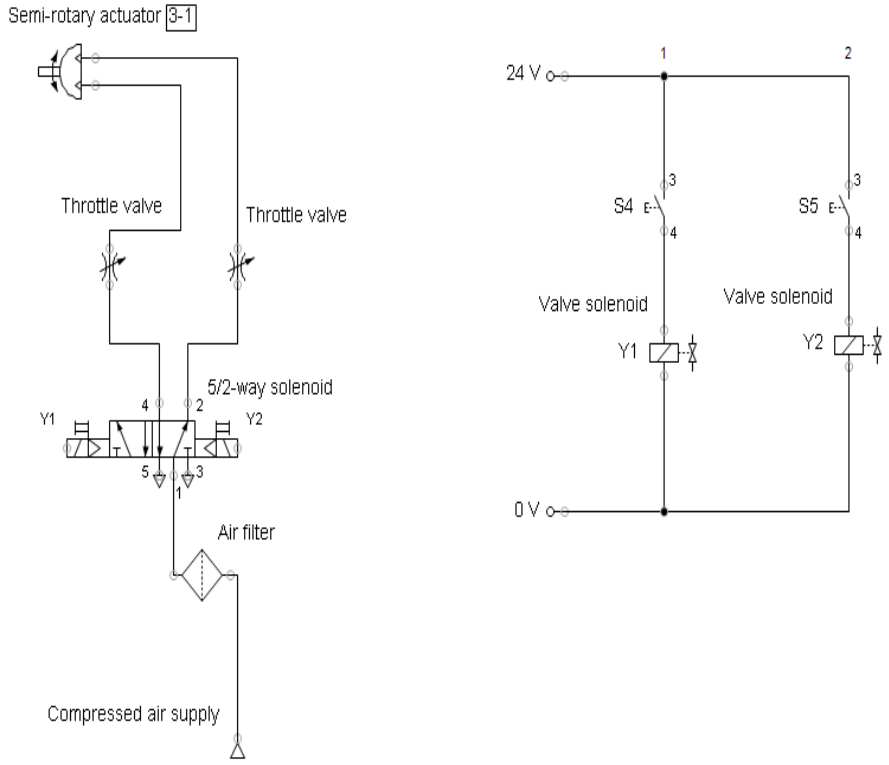



**Fig. 7.** Electro-pneumatic circuit with a semi-rotary actuator. Scheme 3.

The electro-pneumatic system with semi-rotary drive 3-1 has the following devices:

**Table 3:** The pneumatic components from scheme 3

| Description | Number of components |
|---|---|
| Semi-rotary actuator | 2 |
| Throttle valve | 4 |
| 5/2-way valve | 2 |
| Air filter | 1 |
| Compressed air supply | 1 |

**Table 4:** The electrical components from scheme 3

| Description | Number of components |
|---|---|
| Valve solenoid | 2 |
| Pushbutton | 2 |

To start the electro-pneumatic circuit we must press the S4 button. Then the semi-rotary pinion rotates clockwise, Fig. 8.

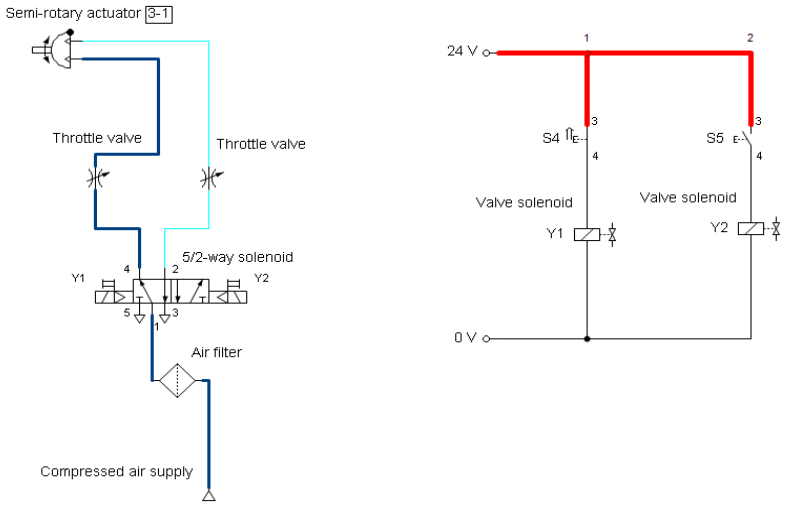



**Fig. 8.** Pinion clockwise rotation

After that, we press the S5 button. In this case, the pinion rotates counterclockwise, Fig. 9.

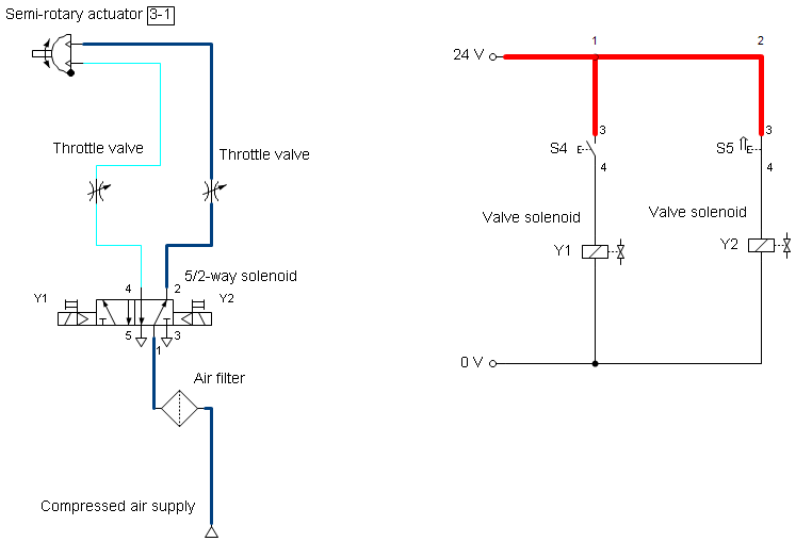



**Fig. 9.** Pinion counterclockwise rotation. Scheme 4.

**Table 5:** The pneumatic components from scheme 4

| Description | Number of components |
|---|---|
| Semi-rotary actuator | 1 |
| Throttle check valve | 2 |
| 5/2-way solenoid valve | 1 |
| Air service unit | 1 |
| Compressed air supply | 1 |

**Table 6:** The electrical components from scheme 4

| Description | Number of components |
|---|---|
| Valve solenoid | 1 |
| Pushbutton | 2 |
| Logic module | 1 |

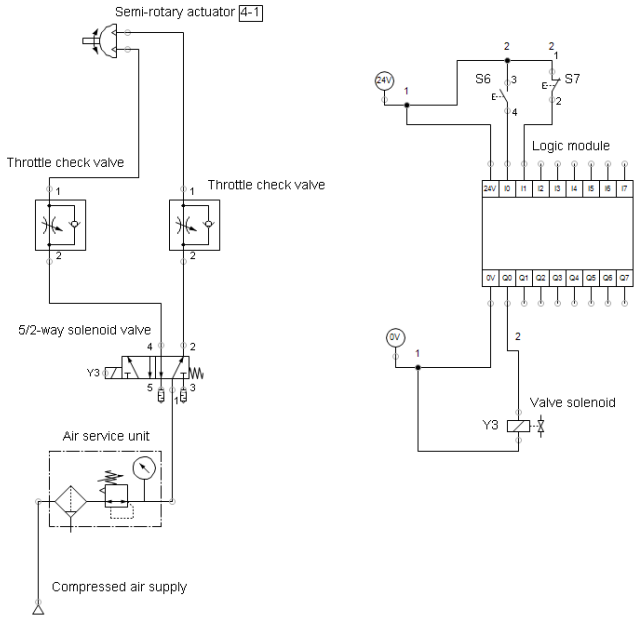



**Fig. 10.** Electro-pneumatic system with a semi-rotary and logic module

In logic module, there are two components in digital technology: Off delay and NOT, Fig. 11.

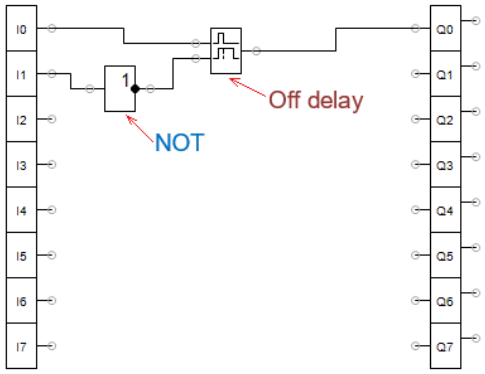



**Fig. 11.** Components of logic module

The electro-pneumatic system with semi-rotary 4-1 actuator starts if the S6 button is pressed. In this case, the pinion from semi-rotary 4-1 are clockwise rotation, Fig. 12.

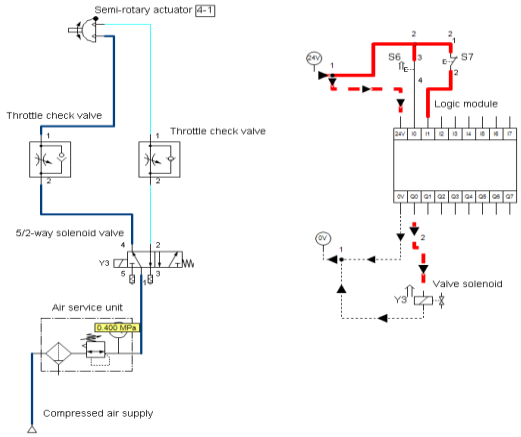



**Fig. 12.** Pinion clockwise rotation with logic module

However, to change the direction of rotation from semi-rotary actuator 4-1, the S7 button must be pressed in electrical circuit, Fig. 13.

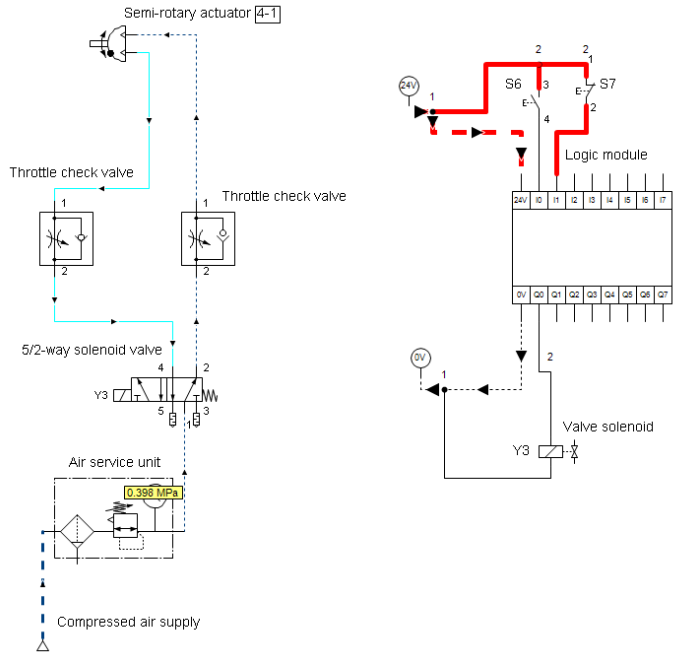



**Fig. 13.** Pinion counterclockwise rotation with logic module

Diagram of the semi-rotary actuator depends on rotational angle [deg], Fig. 14.

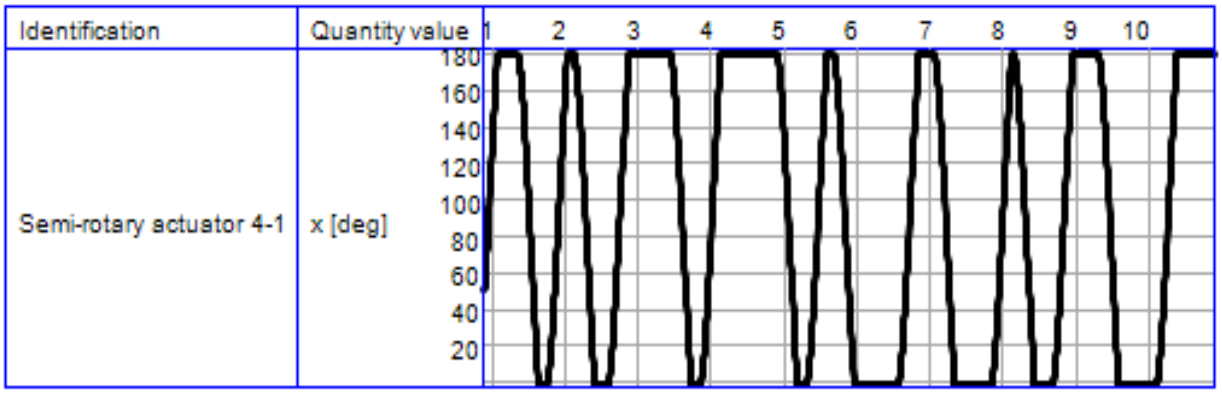



**Fig. 14.** Diagram of the semi-rotary actuator 4-1

## 3. Conclusions

The semi-rotary actuators are rugged and versatile with multiple streamlined sizes that keep operations simple and cost-effective. This actuator construction ensures the pinion bearing by each rack under pressure. The torque of pinion can be varied by adjusting the hydraulic pressure.
Cushioning from semi-rotary is available as an optional extra to slow down operation at the end of stroke. It is normally effective over the last 10 to 15 degrees of stroke in each direction.
However, the semi-rotary is more compact than a hydraulic cylinder with crank arm, more reliable than gearbox and an electric motor. These actuators rated for continuous industrial duty are ideal for continuous automation requirements, subject to speed of suitability and operation of the electro-hydraulic circuit control system and inertial loads.
In the future, electro-hydraulic circuits will be developed with semi-rotary actuators.

**References**

[1] Panaitescu, Mariana, Gabriela Simona Dumitrescu, and Andrei Alexandru Scupi. "Sustainable pneumatic transport systems of cereals." *International Journal of Energy and Environment* 15 (2021): 21-26.

[2] www.festo.com.

[3] Rădoi, Radu, Marian Blejan, Iulian Duțu, Gheorghe Șovăială, and I. Pavel. "Determining the step response for a pneumatic cylinder positioning system." *Hidraulica Magazine*, no. 2 (June 2014): 25-31.

[4] Dagdelen, M., and M.I. Sarigecili. "Friction torque estimation of vane type semi-rotary pneumatic actuators in the form of combined coulomb-viscous model." Paper presented at The 5th International Conference on Advances in Mechanical Engineering ICAME 2019, Istanbul, Turkey, December 17-19, 2019.

[5] Dumitrache, Constantin, Ioan Calimanescu, and Corneliu Comandar. "Naval standard safety valve design using CAD solutions." *Applied Mechanics and Materials* 658 (October 2014): 65-70. https://doi.org/10.4028/www.scientific.net/amm.658.65.