Advantages of Rotary to Linear Transmission in Axial Valves

By Alberto Argilés, SAMSON Ringo

For regulating processes the most common valves in all applications are globe valves, due to their high performance for medium and high pressure drops. However, the axial-type regulating valves have advantages over globe valves in terms of capacity. This article presents a unique system of rotary-to-linear movement transmission for SAMSON Ringo axial control valves, so that with a minimum torque it is possible to shut off against high pressures, reducing the weight and cost of the assembly.

1. INTRODUCTION.

In modern control processes, most of the valves used are Globe valves: straight, step or angle. The main advantage of these valves is good control working with high pressure drops. The pressure drop is related to the geometry of the valve that dissipates energy in the flow of the fluid circulating through it. Part of the lost energy dissipates in reducing pressure and increasing velocity but some dissipates in vibration, noise and fluid turbulence.

Globe valves have different designs and solutions to prevent the energy from dissipating in the form of vibration and noise, which can become harmful to the process or material. However, regarding turbulence and loss of energy, they are not very efficient because of their complex geometry and lack or "aerodynamic" design (Figure 1).

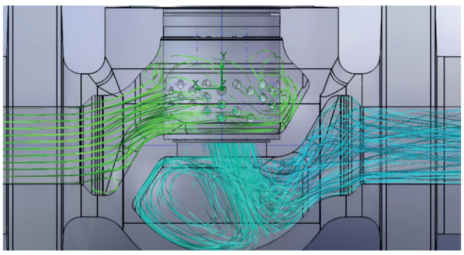


Figure 1. Fluid trajectories in a CFD simulation of a globe valve, where you can see the turbulence.

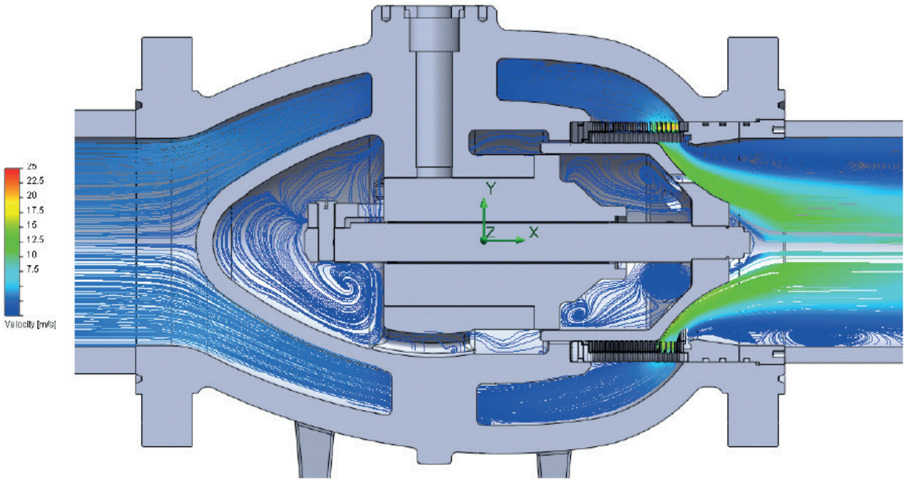


Figure 2. Trajectories of the fluid in a CFD simulation of an axial valve. It is observed in the High speed zone (green) that the trajectory of the fluid is uniform and without turbulence.

The axial valve has a more "aerodynamic" geometry (Figure 2) with the main objective of reducing energy loss through turbulence, so that for the equivalent size globe valve, the axial valve can obtain greater flow for the same pressure drop. This results in a reduction in weight, size and cost of product.

The main complication of the axial valve is the movement transmission system from the actuator to the closing member. The simplest designs use linear to linear transmission systems by means of gearing, in which all the necessary force to move the closing member is generated by the linear actuator. This paper presents a rotary to linear design alternative that provides a mechanical advantage, thus reducing the force required by the actuator with a consequent reduction of actuator size and cost.

2. BRIEF DESCRIPTION OF THE AXIAL VALVE

Before analyzing the rotary to linear transmission system, it is worth briefly presenting the characteristics of the axial valve, since this type of valve is not well known in industry.

The axial valve's regulating function, other than the axial movement of the closing member, is identical to globe control valves with a multi-orifice cage. In this type of control valve, the flow control to create the required pressure drop is obtained by opening a series of holes with a specific area.

The energy in the cage is dissipated in the same way as in globe valves, by varying the number of holes, their diameter, and in some cases, by labyrinth or multi-stage systems. The latter are characterized by dividing the total pressure drop of the process into steps or "stages", in such a way that the total energy to dissipate is attenuated, thus avoiding noise phenomena and high velocity. For general control services, single-cage (one-stage) designs are used (Figure 3)

Due to the valve's construction, and unlike globe valves, the axial valve closure is guided by the valve stem and not by the cage. In this way an axial valve can be used for fluids with particulates since there is no risk of blocking the clearance between plug and the cage. In addition, it is possible to suit applications without a cage where it is intended to maximize the already greater flow capacity of the axial valve.

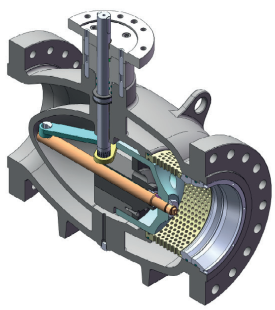


Figure 3. A section of a single-stage axial regulating valve.

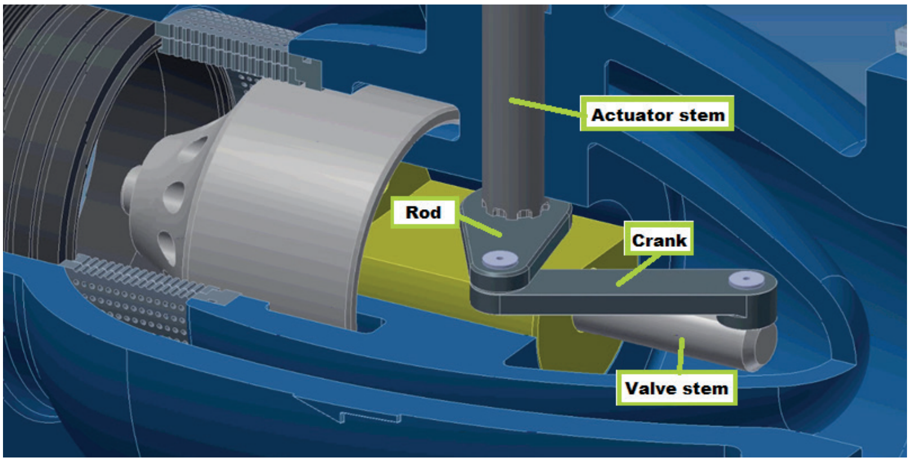


Figure 4. Main components of the rod-crank system of the axial valve.

3. MOTION TRANSMISSION SYSTEM

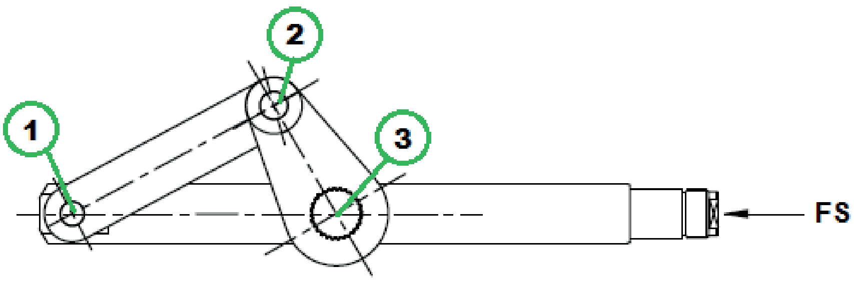
The unique transmission system presented in this article by SAMSON Ringo, is composed of a crank system (Figure 4) that connects the shaft of the closing member of the valve with the axis of rotation associated with the actuating element. The valve shaft has a linear movement in the direction of flow while the actuation shaft has a rotating, quarter turn (90 º) movement. This rotary movement is commonly used for other types of valves such as ball or butterfly valves.

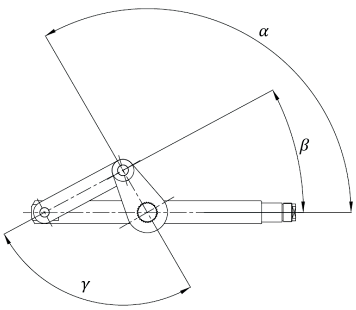
The main advantage of this transmission system is the reduction of the torque required by the actuator when the force generated by the fluid is at its maximum and to also obtain a distribution of required forces across the elements of the linear transmission system so that the resultant force generated by fluid is reduced - this results in a lower force/torque required by the actuator.

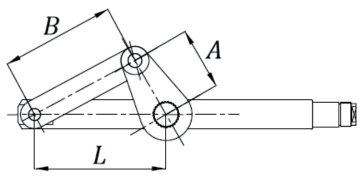
To determine the equation that provides this reduction of effort, we need to calculate the force in the joints of the mechanism (Figure 5) based on its geometry (Figure 6). First, it is considered that the fluid only produces an axial force (FS) in the center of the valve stem, which is fully transmitted to the joint No.1. For this calculation, friction produced by the linear movement is not included as it has not been found to directly affect the force value of the fluid (FS).

The result of the following calculation is the distribution of the torque in joint No. 3 related to the thrust of the FS fluid and the main pivot angle (α). The result of this equation is that the torque value of the fully open valve (α = 120 º) to fully closed (α = 30 º) will be reduced.

Figure 5. (below) Mechanism joints used in the calculation, the force of the fluid (FS) is transmitted in full to the joint No. 1







$$\gamma = \alpha + \beta$$

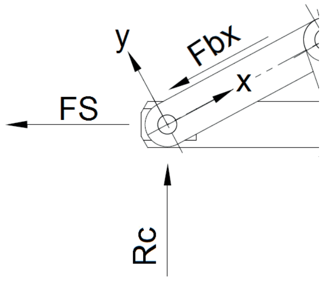
$$L^2 = A^2 + B^2 - 2AB\cos\gamma$$

$$sen\,\beta = \frac{A}{B} * sen\,(180 - \alpha)$$

Figure 6. Angles and lengths used and their trigonometric relationships

3.1. Balance of forces joint No. 1.

In the balance of forces on the first joint, we note that the axial force of the valve stem is transmitted by the connecting rod proportionately to the angle, the rest of the effort is conveyed in the Reaction Force (RC) which is transferred to the guiding of the valve stem



$\sum Fx = 0\ Rc * sin\beta - Fbx - FS * cos\beta$ (1)

$\sum Fy = 0 = Rc * cos\beta + FS * sin\beta$ (2)

Combining (1) and (2):

$Fbx = FS/cos\beta$ (3)

3.2. Balance of forces joint No. 2

From the second balance of forces we can obtain the reaction force produced in the crank by the connecting rod (Rby ‘).

$\sum Fx = 0 = Fbx + Fax' * cos\gamma - Rby' * sin\gamma$ (4)

$\sum Fy = 0 = Rby' * cos\gamma + Fax' * sin\gamma$ (5)

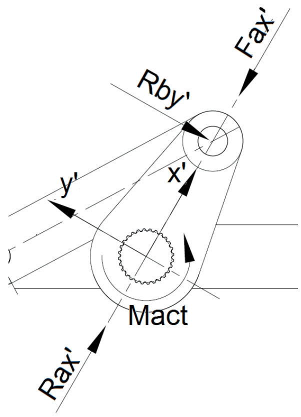
Combining (4) and (5):

$Fax' = -Fbx * cos\gamma$ (6)

$Rby' = Fbx * sin\gamma$ (7)

3.3. Balance of forces joint No. 3.

In the last joint, all forces that are not perpendicular to the axis of rotation do not increase the torque requirement of the actuator, so the required torque is directly proportional to the reaction force in joint No. 2 (Rby’).



3.2. Balance of forces joint No. 2

From the second balance of forces we can obtain the reaction force produced in the crank by the connecting rod (Rby ‘).

$\sum Fx' = 0 = Rax' - Fax'$ (8)

$\sum M = 0 = Mact - A * Rby'$ (9)

From the balances in the three joints we obtain the following formula, which together with the trigonometric relationships of the angles, determine the rotational-linear relation of forces according to the angles of each element of the mechanism.

$$Mact = Fs * A * \sin\gamma / \cos\beta \quad (10)$$

4. CONCLUSIONS.

From the equation and trigonometric relationships in Figure 5, we can derive a torque curve depending on the angle of rotation of the crank (α). When we narrow the curve to the actual torque values of this element, these are: valve fully open (α = 120º) fully closed (α = 30º). (Figure 7).

The main conclusion that we can obtain from Figure 7 is that the rotary to linear transmission system studied in this article have lower torque values when the valve is in the closed position.

It is known that the distribution of load generated by the fluid (FS) is not linear or constant but has a maximum value in the closed position to ensure the metal contact and sealing of the valve. As the axial valve is balanced by the pressure of the fluid, the forces in the rest of the stroke are reduced to the friction of the different mechanical components.

In order to compare the reduction of force required by the rotary-to-linear mechanism to that of a linear-to-linear mechanism, we can consider the example of a Quarter Turn actuator with a 85mm lever – Figure 8 shows the force required by a rotary-linear system (green curve) compared with that of a linear-linear system (red curve), that would require the same force as that generated by the fluid (ignoring friction).

As shown in Figure 8, the maximum force for a linear-rotary mechanism is reduced to values less than half those required by a linear-linear mechanism. Thanks to this unique transmission system it is possible to select a smaller actuator for the valve than with alternative systems, with resulting technological and economic benefit in the final assembly of axial valve and actuator. •

For further information please contact **SAMSON Controls Ltd.**
sales-uk@samsongroup.com or +44 (0) 1737 766391

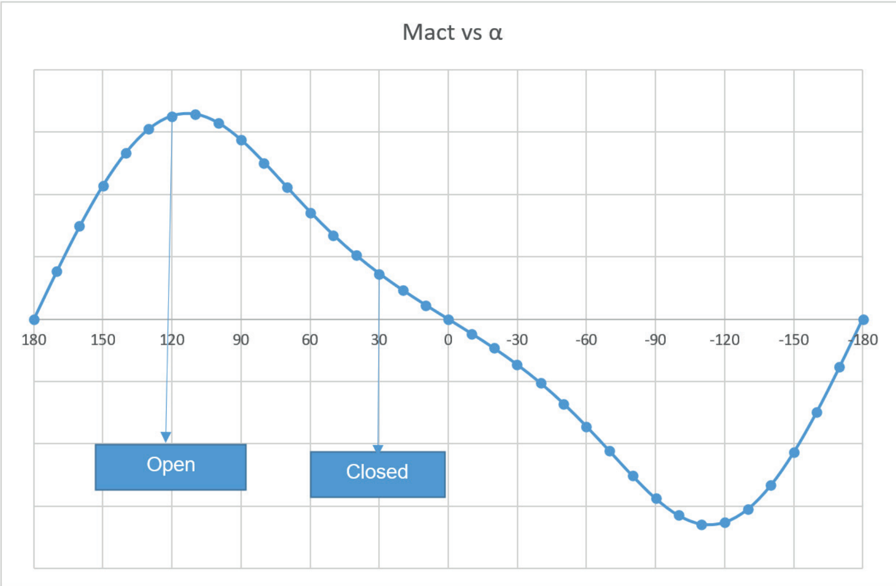


Figure 7. Graphical representation of the results of equation No. 10 and the trigonometric ratios of Figure 5, for the turning angle of the crank at 360 º (blue) and marked with the opening and closing positions of the valve.

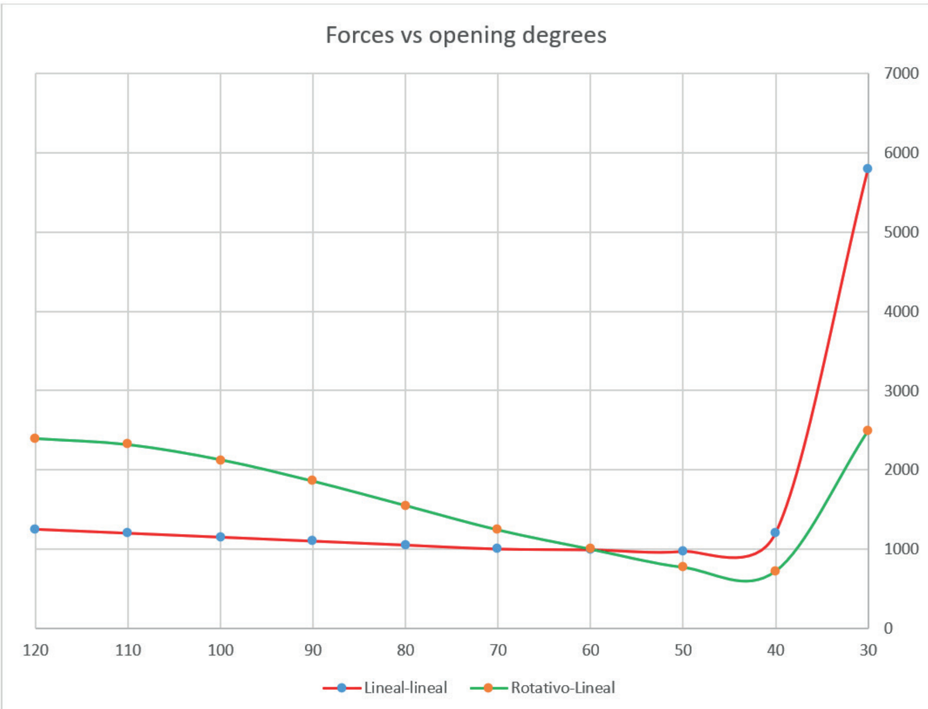


Figure 8. The force generated by the fluid for a specific example, fully transmitted to the actuator in a linear-linear system (red) compared with that of a rotary-linear system (green) showing that the point of maximum force is reduced by almost 50%, in favour of the rotary-linear system.