

Proper Actuator Sizing and Selection Reduces Downtime

Donald Weeks

One of the most important elements in ensuring maximum productivity is properly selecting the design and capability of the actuator and the valve. Improper selection of valves and actuators will cause premature failure resulting in high maintenance costs and lost production.

Actuators that are not properly sized and selected can significantly increase bottom line costs in a number of ways. Acquisition costs will be excessive when facilities buy a unit that is oversized and therefore more expensive. Maintenance costs will be adversely impacted because the valve or actuator will be more likely to fail. Also, safety at the facility will be reduced because the emergency shut down functions will not be properly matched to the application. A study by the *Health and Safety Executive*, a UK publication, concluded that two thirds of actuator failures resulted from the factors occurring before the actuator was first operated, with improper specification being the primary failure cause.

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Applications which require automated valve packages (valve, actuator, mounting accessories and digital positioner or solenoids with or without an integrated switchbox) demand high performance with very little downtime.



Fig.1(a). Rack and Pinion Actuator

Many chemical and petrochemical processing industries (CPI) are involved in the production of hazardous chemicals such as chlorine, phosgene and HF alkylation. These types of critical service applications require high-performance valve and actuator solutions governed by strict specifications. Within these industries the manufacturing of bulk chemicals is often a batch-controlled process using automated, frequently cycled valves.

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There are different types of actuators available to automate valves. Technologies include electric (motorized), hydraulic and pneumatic. Pneumatic designs include piston, vane, rack-and-pinion and scotch yoke. It is important to be familiar with fundamental procedures for sizing and selecting the particular actuator design being used. Rack-and-pinion and scotch yoke actuator designs [Figure 1(a) & 1(b)] for rotary on/off valves are discussed here.

Valve and Actuator Technology

The first step in properly sizing and selecting an actuator is to understand the valve product that will be automated. The three most common rotary valve designs used in the CPI are ball, plug and butterfly. Each design has a different torque profile (figure 2), which make a significant difference in choosing accurate and safe actuators.

When fluid flows through a rotary valve, static pressure does not act uniformly on the surface of the

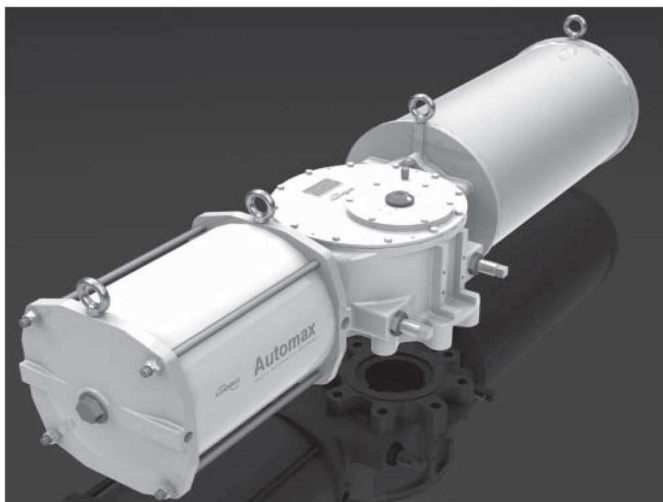


Fig 1 (b). Scotch Yoke Actuator

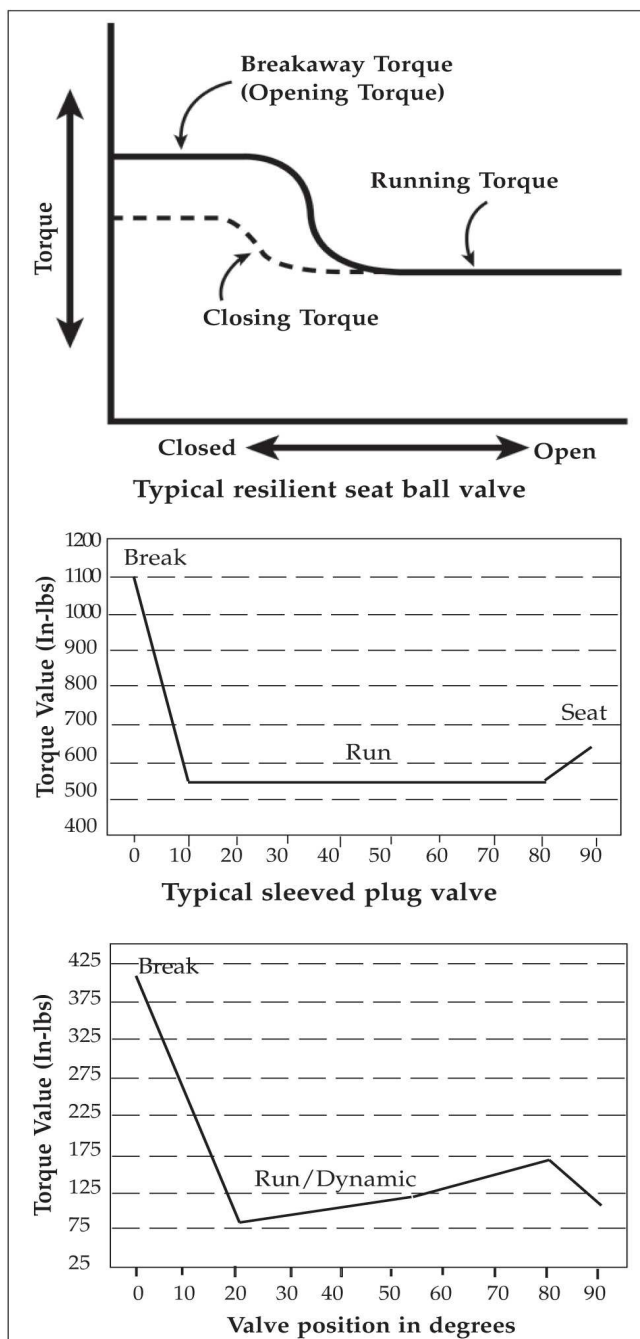


Fig 2. Torque profiles for ball, plug and butterfly valves

closure element (ball, disc or plug). Dynamic torque results from non-uniform static pressure distribution on the closure (rotating) member of a quarter-turn valve. This torque is called dynamic because it is caused by moving fluid. Figure 3 shows the possible static pressure distributions on the disc of a butterfly valve and on the port walls of a ball valve. Their

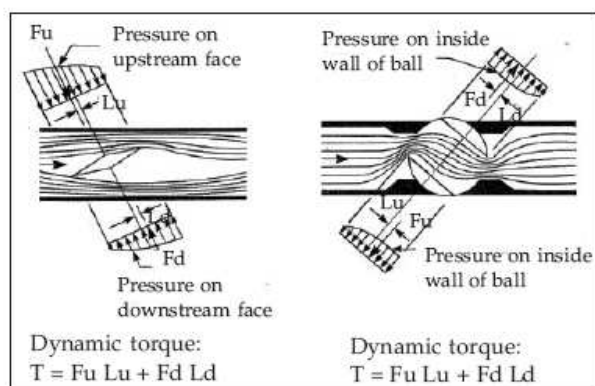


Fig 3. Non-uniform static pressure distribution resulting from fluid flow past valve closure elements causes dynamic torque.

pressure, being unevenly distributed, is equivalent to a resultant force acting at some distance from the stem axis. Dynamic torque is the sum of the product of each resultant force and its offset distance.

Because dynamic torque acts on the valve stem, it can act either with or against the valve actuator. If dynamic torque is of a magnitude that is greater than the friction torque, it will cause rotary motion if unchecked by the actuator. In conventional ball and plug valves, friction torque is usually greater than dynamic torque and is not normally a concern when sizing actuators. Small dynamic torque acts to close conventional ball valves. In butterfly valves, friction torque is generally low except when the disc engages the seat at full closure, so dynamic torque has a much stronger influence.

Dynamic torque in industrial butterfly valves with stem-centered discs with symmetric faces acts to close the valve. However, in high performance butterfly valves which have the disc offset from the stem and non-symmetric disc faces, dynamic torque acts to close the valve if the valve is installed with the seat retainer downstream (Figure 4). But they can act to close or open the valve depending on disc rotation, if the seat retainer is upstream.

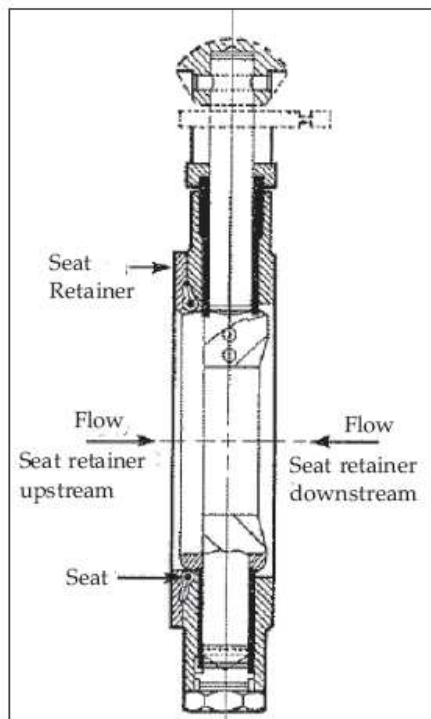


Fig 4. High performance butterfly valve and flow direction rotation

Valve manufacturers have the responsibility to properly test and publish valve torque data. Torque charts are often based on calculating multiple variables, with one peak value published. Most testing is performed using a clean environmentally friendly media. Therefore, additional application factor charts are provided to better match the installed torque conditions specific to the end user's application. Subsequently, the actuator manufacturer is responsible to report accurately its output torque data. This process is simplified and becomes more reliable when both valve and actuator are made by the same manufacturer.

Actuator Sizing

Pneumatic actuators require two external influences to operate: a signal and a power source.

The signal is typically a discrete voltage supply of 120/240 VAC or 12/24 VDC, which will energize a solenoid valve. When using a positioner to control actuator rotation, the signal is typically analog (4-20 mA) or digital. The solenoid valve or digital positioner controls the supply of air entering and exhausting from the actuator cylinder, which in turn controls the position of the valve. A solenoid valve

is used to provide open or closed position rotation. Positioners can support the same function but are designed to provide modulating control or support in advanced applications such as partial stroke testing for safety instrumented systems. As the cost of digital positioners decreases over time, their usage continues to increase. The typical power source for pneumatic actuators is compressed air, normally ranging from 60 to 100 psig.

Each actuator type has a normal mode of failure when the actuator power is removed. A double-acting (air to open, air to close) design will fail in its last position without actuating power. If dynamic valve torque exceeds valve frictional torque, rotation may occur. A spring-return design will return to its initial position without actuating

power; accordingly, this design is often selected for fail-safe critical requirements.

Once the torque requirements of the valve have been determined, the actuator can be properly sized. Before sizing the actuator for the valve, specific information is necessary. The customer should provide the minimum air supply pressure available and the type of operation (i.e., double-acting or spring-return) that the actuator is to perform. If the actuator is to be spring-return, the failure mode (i.e., fail closed or fail open) must also be determined, using the following guidelines:

1. Double-acting operation: Select the actuator whose torque output at the minimum air supply pressure exceeds the calculated torque requirements of the valve.
2. Spring-return operation, Fail closed: Select the actuator whose torque output at the minimum air supply pressure at the end of spring stroke exceeds the torque required to close the valve.
3. Spring-return operation, Fail open: Select the actuator whose torque output at the minimum air supply pressure at the end of air stroke exceeds the torque required to open the valve.

While using sizing rack-and-pinion and scotch yoke actuators on valves and dampers, engineers should look to provide a margin of safety between the estimated valve operating torque and the actual actuator output torque. In the absence of end-user direction, the following guidelines may be used to de-

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termine if a safety factor should be added to a stated or published torque value:

1. Safety factors should be added to the valve torque, not the actuator torque.
2. If the end user advises, or the valve catalog torque data states “sizing torque” or “actuator sizing torque,” then no additional safety factor is added.
3. If the end user does not advise, or the valve catalog torque states “valve torque,” then the following safety factors are added to the valve torque:
 - a. Stated “valve torque” plus 10% for double-acting actuators.
 - b. Stated “valve torque” plus 15% for spring-return actuators.

Special performance requirements usually exist when sizing actuators for Safety Shut Off Valves (SSOV) and Emergency Shut Down (ESD) requirements. For valves that cycle less than once per month, the recommended safety factor is two times calculated valve torque. Most SSOV are required to close in a specific – normally fast – timeframe. It is not uncommon for a customer to specify one second close time for an automated four-inch SSOV. To ensure this requirement is met, the actuator manufacturer will



Fig 5. Guide rod support systems

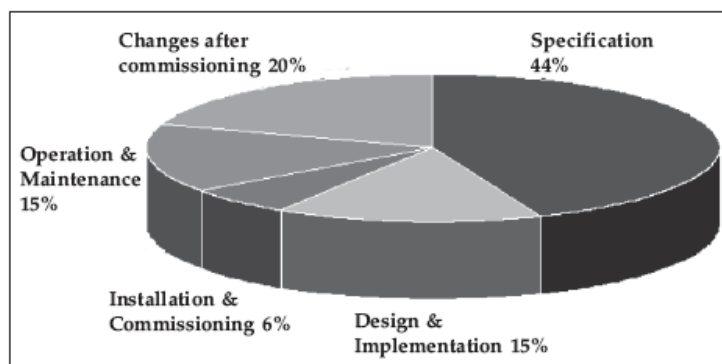


Fig 6. Causes of hazardous failures

perform advanced speed of operation calculations. Documented calculations are often required to confirm compliance and properly selected actuator controls.

Many automated valve specifications (above four inch) require manual-gear overrides, and it is important to specify advanced actuator controls to accommodate this accessory. To ensure safe and proper operation, pneumatic actuators must be equipped with pneumatic lock-out and vent (LOV) controls. The LOV evacuates trapped air in the cylinder that could oppose piston travel and cause equipment damage. More importantly, it safeguards against inadvertent, typically remote operation.

Protect your plant, people and investment

The proper selection of valve automation will increase production uptime, reduce maintenance costs and increase plant safety. Selecting the appropriate actuator design is often based on torque requirement, valve application and price.

Rack-and-pinion technology is normally selected to automate valve sizes which are six inches and smaller. The performance and reliability of a quality designed twin piston, double rack-and-pinion actuator is unequalled. For high-cycle/high-performance applications, advanced designs add internal support rods (Figure 5) to eliminate piston canting to increase cycle life.

Above six inches, the scotch yoke actuator is predominantly used, as this design is better suited to handle higher torque and thrust loads requiring up to millions of inch-pounds actuator torque. Advanced designs include internal guide rods (Figure 5) for

yoke support and advanced piston seal designs that clean the advancing surface to enhance sealing. Quality designs offer improved corrosion resistance by surface treating critical internal components (i.e., cylinder walls, guide rods) as well as external surfaces for harsh environments.

Among properly specified and installed actuators, the number one cause of actuator failure is poor air quality as defined by ANSI/ISA-7.0.01. Almost all valve actuators arrive permanently lubricated and will operate best with instru-

ment-quality air (environmental air ingress applies as well). Actuator cylinders are designed to vent during piston travel. As the pistons move inward, they draw in the surrounding environmental air via vent ports. If the local environment is harsh, special controls (i.e., rebreather blocks) must be included to prevent contamination and premature failure. If the air is kept clean, actuators can last for a long period of time.

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The subjects of Functional Safety (IEC 61508) and safety integrity level (SIL) ratings are becoming high profile in the CPI. The study by *Health and Safety Executive* concluded that two-thirds of failures were the result of factors that occur before the operator even started to use a product or system (Figure 6). Specification errors were the main cause of failures. The now globally embraced standard emphasizes that the quality and reliability of the equipment forming a safety system are key to the prevention of failure.

The selection and procurement of valve actuators require thorough evaluation by qualified people and is the responsibility of the user and his/her contracted support to create a well-defined product specification. The performance of a plant and the safety of employees depend on it.

