Operating Effort in **Manual Valves**

A Valve Manufacturer's Perspective

Operating effort is the force an operator exerts by pushing or pulling on a lever or turning a handwheel on a valve. Valves can be opened or closed either manually (handwheel, lever or gearbox) or automatically (actuator) and in a typical plant, 60% of the valves are manual valves while automated and control valves constitute the remaining 40%. Workers in process plants manually open and close 1000's of valves with handwheels that require high torque and this makes the task physically strenuous.

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Triple offset butterfly valve

Background

According to a study, 56%, more than half of the back injuries acquired by operators in refineries were associated with valve tasks. Furthermore, it was also reported that 75% of head, neck, and face injuries and 64% of lower back injuries reported by the process operators were attributed to industrial valve hand wheel actuation [1]. Hence, there's a lot of focus to reduce operating effort to open to close manual valves and end-users and valve manufacturers thus have adopted an approach to ergonomically design valves for ease of access, operating and maintaining valves.

The main considerations during selection of manual operators are the effort and the number of turns required to operate the valve. In addition, there a host of other hygiene factors that determine the ability of operators to apply the required force such as space available, position of the handwheel or lever, operator's physical strength, nature of force such as momentary or uniform, environmental conditions and finally frequency and urgency of operations [2].

Guidelines and benchmarks for valve operating effort

It is commonplace in the valve industry for end-users to specify the operating effort requirements for a specific project based on local statutory laws or incorporate specifications/standards that provide guidelines for valve operation. Figure 1 lists the operating effort requirements of end-users around the world and the trend is conspicuously leaning towards alleviating the burden of operators.

- MSS SP-91:2009, Guidelines for manual operation of valves, provides guidelines for operation of manually actuated valves as affected by valve operator's input. Apart from momentary input forces for different handwheel diameters/lever lengths, this standard practice provides input factor multipliers based on position of the operator, use of manual impact devices, space available, short-term, uniform and long-term forces.
- EN 12570:2000, Industrial valves - Method for sizing the operating element [3], specifies the requirements for establishing the minimum size of the operating element supplied with an industrial valve having regard for the force applied by one person to operate the valve under specified working conditions. This standard applies to manual operating elements of sizes from 100 mm to 1000 mm. Though both EN 12570 and MSS SP-91 cover operating effort guidelines for manual valves, there are minor differences in the way the momentary operating forces are specified (Table 1).

Need for higher momentary force

Certain valves by virtue of their design need a higher seating and/or unseating torque. In addition, with ageing, the unseating/seating torque tends to increase when compared with the design values.

- Flexible wedge gate valves in power plants go through closed hot/opened cold or closed cold/opened hot conditions that may lead to higher momentary unseating or seating forces.
- Globe valves with "flow under the disc" require a high seating force while those with "flow over the disc" require a high unseating force.
- Though trunnion ball valves are position seated, 'break to open' torque values when the valve is opened against differential pressure are significantly higher than the other torque values.
- In triple offset butterfly valves, a greater amount of closing torque is required for the valve to seal in the non-preferred direction as the pressure does not aid in the sealing process.

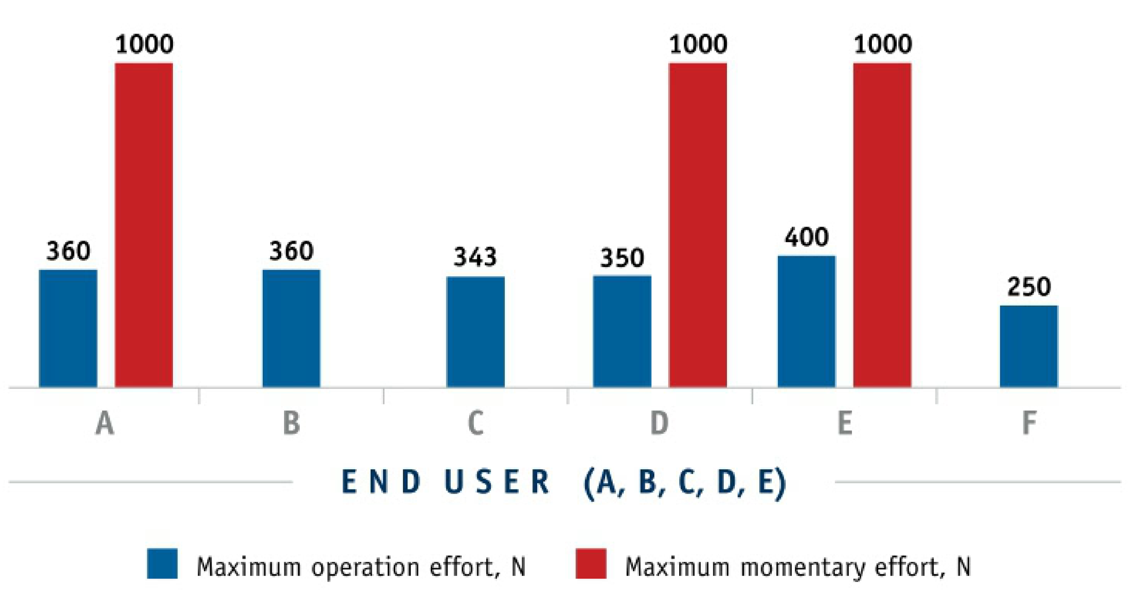

Figure 1: Industry benchmarks for operating effort

Table 1: Example of a linear valve with a 16" (400 mm) Handwheel

MSS SP-91		EN 12570	
Momentary input force (f)	1000 N	Momentary input force (Fs)	1000 N
Uniform force (0.7 x f)	700 N	Assumed manual force (F) for the conditions:	
Long term force (0.25 x f)	250 N	• Operator standing • Operating element at waist level • Operating time <5 minute	400 N
Position: Below the hip level (0.5 x f)	500 N		
Position: Shoulder to hip level (1 x f)	1000 N		

Ways to reduce operating effort in valves

Reducing frictional forces:

Valve torque is proportional to the line pressure and the frictional force. Though force due to line pressure is fixed for a particular size and pressure rating and hence reduction is not possible, frictional force in a valve tends to increase with use owing to factors such as accumulation of dirt, greater packing friction and evaporation of drive train lubricants. With improved workmanship, good maintenance practices and periodic lubrication, frictional force can be controlled and not allowed to increase when the valve is in-service.

Using larger diameter handwheels

By increasing the handwheel diameter or lever lengths, the operating effort can be reduced as F = 2 x T/D (where F is the operating effort, T is the torque and D is the diameter). However, there is a limitation to the maximum handwheel diameter that can be specified as an over-sized handwheel can hinder with other equipment in a plant layout. Certain end-users restrict the maximum handwheel diameter to 800 mm or the face to face dimension of the valve.

Using high efficiency gearbox

Gearbox with a high mechanical advantage can be used to reduce the operating effort to acceptable limits. For a linear valve, bevel gearboxes are commonly used and in special cases, double stage reduction gearboxes or gearboxes with spur attachments are used when the valve torque is high or the operating effort has to be restricted below a certain value.

Implications of using a high efficiency gearbox

Higher operating time

Adding a gearbox increases the number of turns required to operate the valve thereby increasing the operating time. The number of turns to operate the valve increases proportionally with the mechanical advantage of the gearbox where mechanical advantage (MA) is gear ratio multiplied by efficiency of the device. It is common practice to limit the number of turns to open or close the valve to less than 100 turns. In cases where the number of turns exceeds 100, either a hand-held power (pneumatic or hydraulic) tool can be used to drive the handwheel or a dual input shaft/speed gearbox can be used.

Stem failure

When using a high efficiency gearbox, additional care should be taken to prevent damage to the drive train of the valve. Let's take a case of a regulating globe valve that has to be sized to comply with the end-user specification which is <250 N operating effort. While sizing, the designer was left with no choice but to choose a gearbox with spur attachment as the standard gear failed to meet the operating effort requirements. With a mechanical advantage of 10.9, the operating effort was brought under 250 N and while this sounds like an easy fix, there was more to this than met the eye.

The mechanical advantage of the gearbox selected reduced the maximum acceptable stem torque (MAST) appreciably to ~ 140 Nm. Despite the operating effort being less than 250 N, the failure of the stem is imminent as the torque applied would exceed the MAST if the operator applied a force > 350 N. It is common knowledge that an operator can, in most cases, apply an effort exceeding 350 N in real life conditions and MSS SP-91 specifies that a typical operator is one who is capable of exerting approximately 670 N (150 lbf) on a lever with an effective length of 12 inches at waist level. The problem was finally solved using a higher strength stem material which is a deviation to the end-user specification for the said valve.

Table 2: Case – Sizing details of a regulating globe valve

Parameters	Direct Handwheel	Gear unit	Gear unit with Spur attachment
Valve torque, Nm	1079	1079	1079
Mechanical advantage of GU	NA	4.5	10.9
Operating effort for the Valve torque, N	2697	599	247
Maximum allowable stem torque or MAST (Stem YS: 30,000 psi), Nm	1535	1535	1535
Maximum allowable torque at the Gear unit shaft, Nm	NA	341	141
Maximum allowable operating effort based on MAST, N	3838	853	350

Way forward

- In sum, maximum operating effort considerations should be based on critical factors such as location of the valve, position of the handwheel, space available, frequency of operation, environmental conditions while acknowledging that the momentary effort would be higher during seating/unseating of the valve obturator.
- Current industry standards such as EN 12570 and MSS SP-91 specify that seating and unseating an obturator would require a higher momentary force. MSS SP-91 is also referenced in API 598 for guidance on applied forces during closure testing of valves.

REFERENCES

[1] The effects of valve wheel size, operation position and in-line pressures on required torque for gate valves, Sean C. Parks, Lawrence J. H. Schulze, December 1998

[2] MSS SP-91:2009, Guidelines for manual operation of valves

[3] EN 12570:2000, Industrial valves - Method for sizing the operating element

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