PIPEDLINE VALVES AND FITTINGS

PROSPECTS FOR IMPROVING THE SERVICE DURABILITY OF GAS SHUTOFF VALVES

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The current trends in development of valve and fitting manufacture for the oil and gas industry provide evidence that specialists have given their continuous attention to problems in the service durability of pipeline shutoff and control valves. In many of the pipelines used for natural gas production, transportation, and storage, abrasives are constantly and inevitably present in the flow through the line. The presence of solid contaminants in streams of the working medium is one of the problems that must be solved from time to time by the operators.

The sand-jet effect of a flow of natural gas through a shutoff valve, on the background of corrosion processes, is such a serious factor that failure in the form of leakage through the shutoff will occur long before expiration of the time-before-failure guaranteed by the manufacturer. Here we should note that in this sort of failure, the metal body of the shutoff valve remains in good condition and fully functional.

Let us examine the development of modern technical solutions aimed at improving the service durability, in the example of Christmas tree gate valves. The gate valve is designed to operate with a constant, tight contact between the sealing surfaces of the valve parts while it is operating, thus minimizing the probability that abrasive particles will penetrate between the rubbing surfaces of the gate and seat.

Major attention has been given to the improvement of the gate/seat components. At the present time, the primary advances in this direction have been demonstrated by firms in Japan and the USA.

The design of the shutoff assembly of a gate valve that is described in [1] provides for a compound gate, the halves of which form an expanding wedge. With rigid seats, this design gives the contact pressure on the working surfaces of the valve parts that is necessary for sealing. In the course of opening, with a reversal of the direction of force on the valve stem, the halves of the wedge shift, and the contact pressure on the working surfaces of the gate and seat decreases; with this design, wear can be reduced.

With the aim of protecting parts of the shutoff assembly of a gate valve from abrasive erosion, an original technical solution was proposed in [2] under the name "dual seat." The essential feature of this design is the presence of a concentric seat consisting of two seats with smaller and larger diameters—a rigid seat and a spring-loaded seat, respectively. The large seat, in the closed position of the gate, is outside the zone of gate damage, thus ensuring tight shutoff.

The gate valve designs that we have considered thus far have the obvious disadvantage of complexity, which makes them more trouble-prone. The most widely used gate valve designs [3-5] are those in which the gate and seat are spring-loaded against each other, and the working stroke of the gate is equal to the diameter of the flow opening plus the width of the contact annular surface of the seat.

Over the course of several years, the Resurs Gas Institute of the I. M. Gubkin State Academy of Oil and Gas has worked on the design and technological improvement of shutoff and control valves, with the aim of improving the service durability of these items in applications where they are exposed to flows of abrasives-containing, corrosive working media (primarily natural gas). These developments have been based on a systems approach in application to investigation of the physics of failure, along with the development of a design principle for separating the functions of the various elements in the mechanical system [6].

Modernized gate valves with spring-loaded seats were manufactured at two locations: Rising-stem gate valves at the joint stock company Rybinsk Design Bureau of Engine Construction, and nonrising-stem valves at the Voronezh Mechanical Plant [7].

In the course of operation, a gate valve performs two functions: It blocks the flow (cuts down the flow rate until the flow stops), and it seals off the line (with leakage less than the specification level). In this connection, the gates were designed with separate sections for these two purposes. The length of the blocking section, theoretically equal to the diameter of the through-opening, was reduced in the new design to $1/3$ the diameter of the through-opening (with a slight increase of the overall size of the housing used in the regularly produced gate valve), or was even reduced to match the width of the contact annular surface of the seat (while keeping the same overall dimensions of the gate valve). The sealing section of the gate was sized to be equal to the diameter of the through-opening, plus twice the width of the contact annular surface of the seat.

In the process of opening and closing the valve, the blocking section of the gate is subjected to attack by the flow of the working medium. In contrast, the sealing function is performed after the gate has already blocked the flow; therefore, the sealing section is not damaged by the flow. A tight seal is effected by the action of pressure drop. The blocking and sealing sections are separated by transverse grooves on both sides of the gate, which serve to unseal the gate artificially in the concluding stage of blocking the flow, i.e., at the moment at which the flow becomes most aggressive. As a consequence of leakage of the working medium through the gate grooves, from the inlet to the outlet fittings during the stage of sealing, the pressure drop and unit pressure in the contact zone of the rubbing surfaces are reduced, thus leveling out the peak torque on the drive. The grooves perform the function of removing abrasive particles that have adhered to the working surfaces of the seat, and also the function of self-cleaning by purging with a flow of the working medium.

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For the protection of seats against attack by the working flow, it is also possible to realize the principle of separation of functions: One surface of the seat should perform the blocking function, the other the sealing function, so as to eliminate the effect of abrasive erosion on the tightness of shutoff of a Christmas-tree gate valve.

In the construction of the proposed valve [8], between each seat and the corresponding side of the gate, additional protective, mobile gates are located, performing the function of blocking the seat, the surfaces of which are subjected during the time of the working stroke to aggressive attack by the flow of the medium being shut off. In the closed position, the protective gates are moved alternately in the direction of the working stroke of the main gate until damaged contact surfaces are removed from the sealing zone; the undamaged contact surfaces of the main seats, the protective gates, and the main gate perform the sealing of the valve.

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For the protection of gate valve parts against abrasive wear in a corrosive medium, whether the damage is by particles in the stream or by sliding friction, it is considered today that the most effective method is plasma-arc facing of the contact surfaces with self-fluxing nickel-chrome alloys of the PR-NKh16SR3 type (specification TU 14-22-33-90) or by hard-facing with Stellites (in other countries).

The main disadvantages of these methods are the high cost of the hard-facing materials (particularly those containing tungsten) and the high energy costs of the hard-facing processes.

Cases have been reported in which elements of the flow section and shutoff assembly in low-pressure gate valves have been faced with ceramic plates [9], or all-ceramic parts have been used in shutoff valves [10]. However, nothing has been reported on any regular production or service of such items in the gas industry; even more importantly, no information has been published on the use of such valves in high-pressure service.

Under conditions such that the slightest leak through a valve is a basis for preventive maintenance work, the protective methods we have described are highly recommended. If preventive maintenance is not performed, or is performed less frequently than is required by the actual condition of the valve (as is characteristic in operating practice in our country), the damaged gate valve will fail quite rapidly, most often in the closed position.

In this connection, the Resurs Gas Institute has investigated the feasibility of using ceramic materials in fabricating shutoff valves; these studies were performed within the framework of a systems approach [11]. Preference was given to the most widely used structural ceramic based on Al$_2$O$_3$, which is chemically inert and highly resistant to abrasive wear and erosion when exposed to either grazing or acute angles of attack of the flow containing the abrasives. In the original designs