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Study about Tightness of the Stuffing Boxes

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Abstract

This paper presents the results of an experimental research regarding the tightness of stuffing boxes used for the shafts in rotation move. With the experimental installation that is presented in this work, it is possible to control the compression force of packing rings and the determinations of dependence between the materials of packing rings and the emission rate. Simultaneously, it is determined the dependence between the power necessary to overcome friction and the materials of packing rings.

Key words: *tightness, seals, stuffing box, packing rings*

Introduction

It is recognised that industry must reduce its impact on the environment if we are to continue global development for future generations (the so-called "sustainable development" option). A major contributory factor will be through the lowering of industrial emissions, which has been catalysed by a combination of public pressure, environmental legislation and the internal requirement to minimise the loss of valuable feed-stocks. The values of emissions will depend upon: equipment design, age and quality of the equipment, standard of installation, vapour pressure of the process fluid, process temperature and pressure, number and type of sources, method of determination, inspection and maintenance routine, rate of production. Irrespective of any environmental impact which it may cause, this is a tremendous financial burden on industry because it represents a huge loss of potentially valuable materials, and cause of plant inefficiency. Yet in most instances, the true costs are not appreciated, since many of the costs associated with emissions are invisible: labour to repair leaks, material to repair leaks, wasted energy, plant inefficiency, environmental "clean up", environmental fines, lost sales due to poor image, claims for personal injury [1, 2].

Large proportions of the emissions to atmosphere are represented by the by-products of combustion (notably the oxides of carbon, nitrogen and sulphur), along with known losses of volatile hydrocarbons and steam. A significant proportion of emissions can be losses from unsealed sources, including storage tanks, open-ended (non-blanked) lines, pressure-relief valves, vents, flares, blow-down systems, spills and evaporation from water treatment facilities. In general, these are all emissions anticipated from the industrial process, under the control of the plant operator, and will not be considered here. However, a proportion of industrial emissions occur through unanticipated or spurious leaks in process systems.

These losses may be caused by leaks in the sealing elements of particular items of equipment, such as: agitators / mixers, compressors, flanges, pumps, tank lids, valves [3, 4]. From this, it is apparent that sealing systems play a vital role in the environmental performance of industrial installations, and yet the sealing technology itself is usually given scant consideration. It must be emphasised that sealing technology can perform at its peak only after careful selection (appropriate for the specific application), correct installation, and operation according to the performance envelope, regular inspection and maintenance. The best available techniques for sealing technology must describe, together with the best practices for their selection, installation and use, in order to enable the plant operator to achieve the requirements of the UE Directives.

Theoretical Notions

The stuffing boxes are usually used to seal of circular cylindrical pieces with smooth surfaces, with rotation, translational or helical motions. The most typical examples are the seals of taps rods, the sealing devices of impellers shafts, the sealing devices of centrifugal pumps shafts, the seals of reciprocating rod pumps.

In order to ensure tightness, the seal rings are compressed with an axial force F, for the purpose of their deformation in the radial direction (fig. 1). Due to this radial deformation, the rings are compressed between shaft and the inner surface of sealing device. So, the spaces between the seal rings and these structural elements are reduced and the necessary tightness is achieved.

At the same time, due to the radial deformation, frictional forces appear which oppose the axial compression force. For this reason, the axial forces which will require sealing rings located at greater depths will be increasingly small and thus the radial pressure (tightness pressure) will decrease correspondingly. Therefore, in order to achieve the optimum tightness with a stuffing box, it is necessary to know the relation between the axial pressure applied to upper surface of packing rings and the fluid pressure which must be sealed.

On the other hand, it should be borne in mind that with increasing axial compression force to sealing rings, the power required also increases overcoming the friction from the sealing device. For this reason, for the design of the mixing device it should be taken into account the friction between the shaft and the sealing rings.

Experimental Procedure

In this paper, it is presented an experimental method for stuffing boxes tightness determination, which is used in the case of rotating shafts [7]. In order to reach this purpose, it has been used the installation which is presented in Figures 1 and 2. The packing rings 8 are disposed in the space between the shaft 1 and the exterior cylinder 3, being compressed with the hub 1 and the piston 12, which slip in the hydraulic cylinder 11. So, knowing the inner diameter of hydraulic cylinder and his inner pressure, the axial compression force and the applied pressure to surface of packing rings can be calculated.

This system assures the controlled compression of the packing rings, without else be the necessity of another system to follow the axial force, such as the use of the electrical transducers or the torque wrench. The advantage of this method consists in the fact that the compression force can be regulated easily, through the increase or decrease of the pressure from the hydraulic cylinder 11. Five packing rings with square section and the side s = 8 mm have been used. The materials of packing rings which has been tested are: a) polytetrafluoroethyl (PTFE) filament yarn with permanently added PTFE graphite dispersion, with a silicon-oil-free lubricant; b) pure graphite fibers. The space marked with A in Figure 1, which is located above the superior edge of the shaft, can be pressurized with the help of compressor 22, compensator vessel 21 and U form tube 20. On the other hand, the space A can be related with the vessel 21 through a by-pass pipe where the faucet 26is located. If the faucet 26 is closed, the linkage from space A to the vessel 21 will be realized only through U form tube 20.

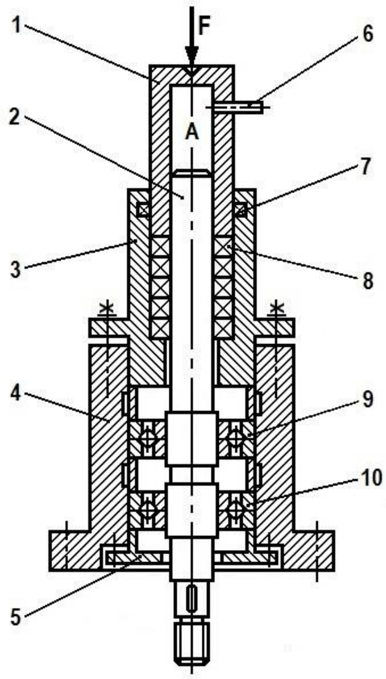

Fig. 1. Device to simulate the working of a stuffing box: 1 – gland; 2 – shaft; 3 – cylindrical housing; 4 - bearings housing; 5 – lid; 6 – connecting pipe; 7 – O-ring; 8 – packing rings; 9, 10 – bearings.

In this situation, the emission alongside of shaft will be measured with the help of the *h* difference between the initial and final levels of liquid, after a certain observation time. Knowing the inner diameter of the U form tube d = 3 mm, and the span of observation *t*, in which is produced the subside *h*, it is possible the calculation of the emissions rate *Q*, [8, 9]. The shaft have the speed n = 46 rot/min, being trained in rotation move with an electrical motor and a reducer gear.

The packing rings are compressed with the piston 12 until on the superior surface of rings it is obtained the pressure $p_e = 1.1 \div 1.6 \cdot p_i$. In the previous expression, p_i is the value of pressure which must be kept (p_i = 2 bars). During the compression operation, the shaft is rotated slowly with the hand, so that the rings are correctly settled down and fill all the space which is reserved around the shaft.

Further on, the faucet 26 is opened and the pressure is raised in the compensator vessel 21 and in the space A, until the manometer 19 will indicate a pressure equal with 2 bars. In this moment the faucet 26 is closed and the tightness of space A is verified. If some leakages are observed, the axial compression force must be increased until these leakages are canceled.

After the pressure stabilization in the compensator vessel and in the space A, by 2 bars, the faucet 26 is opened and the electrical motor is started. After five minutes, the working motor is stopped and the faucet 26 is closed. For the emissions rate determination, the evolution of subside *h* is followed in the U form tube for one minute time. If this value is little so that it cannot be measured, the observation time must be increased. If the *h* value is too high, that is the emissions rate is significant, the observation time will be decreased.

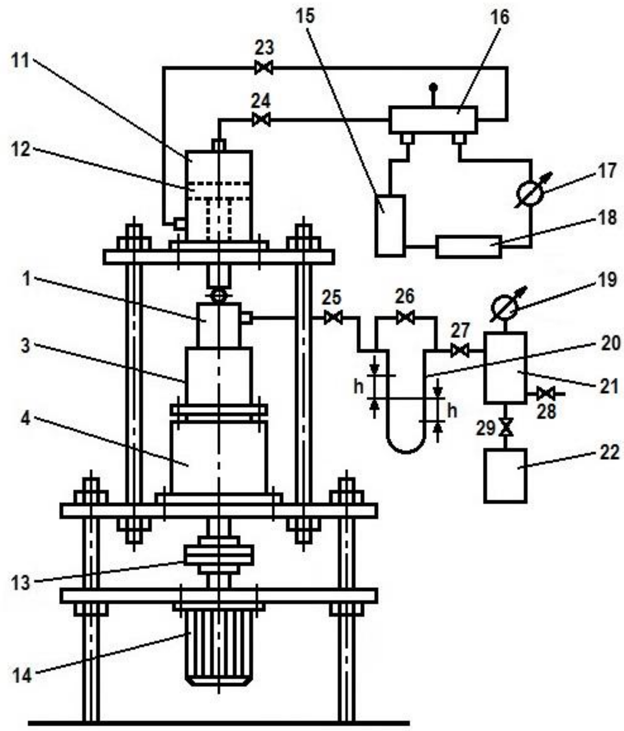

Fig. 2. Experimental set – up: 1 – gland; 3 - carcass of stuffing box; 4 - carcass of bearings; 11 - hydraulic cylinder; 12 – piston; 13 – elastic coupling; 14 – motor; 15 – reservoir for oil; 16 - hydraulic distributor; 17 – manometer; 18 - pump; 19 – manometer; 20 - U form tube; 21 - compensator vessel; 22 – compressor; 23…29 – faucets.

Further on, keeping unchanged the compression axial force and the value of pressure in the A space, is marked the difference in level *h* after every five minutes work time of electrical motor. These operations will be executed for 30 minutes duration.

Results and Discussions

The results presented in Figure 3 put in evidence a very similar behavior of the two materials tested. Yet, it can be said that in the case of the packing rings from PTFE with graphite, impregnated with lubricant, the emissions were with approximation 5÷10% less. This result is owed, likely, to the fact that the braid from pure fibers of graphite has a less compact structure and requires for sealing off an elder axial force than one necessary of the braid from PTFE with graphite, impregnated with lubricant.

Afterwards, it is put in evidence the behavior of the two types of rings in the presence of a bigger axial forces than one used in the frame of previous determinations. With this end in view, it is measured the power necessary to overcome the friction forces from the stuffing box, in the gradually increasing axial force conditions.

As is can be seen in Figure 4, in the case of the packing rings from PTFE with graphite, impregnated with lubricant, after a slow increase, the value of power remained constant to the value of 100 W, however it was amplified afterwards the axial force. On the other hand, for the packing rings from pure fibers of graphite, with the increase of axial force, we remarked a big increase of power necessary to overcome the friction. Finally, the shaft is blocked for a value of the axial force of about 4000 N.

After the looseness of the stuffing box, on the shaft we noticed a very deposit adherence of material composed from fine particles of graphite, resulting from friction between the shaft and the packing rings. This behave drives to the recommendation as this material to be used, in particular, in the case of static sealing-off (faucets), when it shall assure a very good tightness in the presence of great pressures and temperatures. In this situation, the material of packing rings can be compressed with big axial forces, without being considered the problem of blockage of installation.

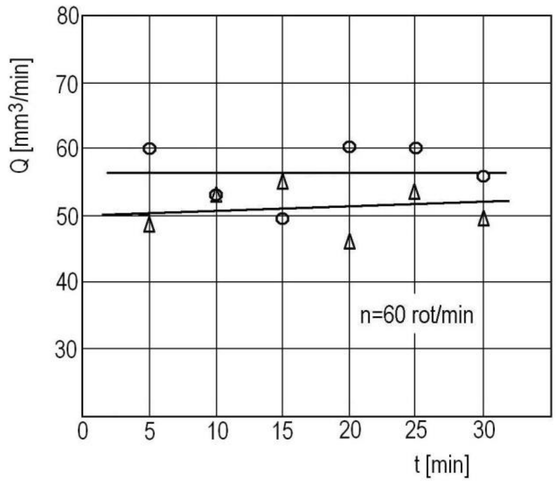

Fig. 3. Dependence between the materials of packing rings and the emission rate: Δ - braid from PTFE filament yarn with graphite, impregnated with lubricant; O - braid from pure graphite fibers.

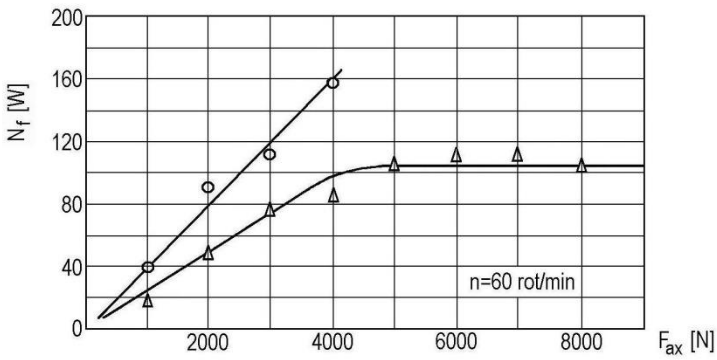

Fig. 4. The dependence between the materials of packing rings and the power necessary to overcome the friction: Δ - braid from PTFE filament yarn with graphite, impregnated with lubricant; O - braid from pure graphite fibers.

Conclusions

The experimental researches presented in this work had as an aim the determination of the emission rate of stuffing boxes used for the shafts in rotation move. It is noticeable the fact that the suggested method permits the controlled compression of the packing rings, as well as the exact determination of amount of substance lost alongside of shaft. The reaches is directed to the material behavior of the packing ring in the initial period of stuffing box operate, up to the stabilization of the emission rate. The results put in evidence the fact that in the case of little pressures, the tested materials do not presented significant differences in what looks the assurance of tightness of shaft in rotation move.

On the other hand, it results the superiority of the packing rings from PTFE filament yarn with graphite, impregnated with lubricant, in what it looks the power necessary to overcome the friction with the shaft. In the frame of subsequent long-time researches, it can be followed afterwards the evolution of the emission rate, in order to put in evidence the influence of the wear shaft and the packing rings material relaxation upon the emission rate. Also, with help of the installation presented, it can be studied the influence of rugosity and eccentricity of the shaft upon the emission rate.

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Studiu privind etanșeitatea dispozitivelor de etanșare cu inele de umplutură moale

Rezumat

În cadrul acestui articol sunt prezentate rezultatele unei cercetări experimentale privind etanșeitatea dispozitivelor de etanșare cu inele de umplutură moale, folosite în cazul arborilor cu mișcare de rotație. Instalația experimentală care este folosită în această lucrare oferă posibilitatea de a se controla forța de comprimare a pachetului de inele de umplutură și de a se determina dependența dintre materialele inelelor de etanșare și debitul de scăpări. În același timp este determinată dependența dintre puterea necesară învingerii frecării și materialul umpluturii.