DIMENSIONING OF A COMPRESSION SPRING APPLIED TO A PRESSURE RELIEF VALVE

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Abstract: Pressure relief valves are safety devices widely used in industry. They are used to balance pressures between two environments and prevent damage to equipment, the environment and/or human lives. With their wide use, they have solution principles and varied projects, which makes it difficult to use calculation rules for dimensioning. In a subsea application, the need to install a pressure relief valve was identified. In this work, we present the design and experimental validation for the spring responsible for the valve operation. There are differences between the calculated and the realized due to various uncertainties or lack of previous data. In this way, the designer needs to keep the project flexible to adapt after carrying out a physical proof of concept.

Keywords: Compression Spring; Pressure Safety Valve; Subsea Equipment.

DIMENSIONAMENTO DE UMA MOLA DE COMPRESSÃO APLICADA A UMA VÁLVULA DE ALÍVIO DE PRESSÃO

Resumo: Válvulas de alívio de pressão são dispositivos de segurança muito utilizados na indústria. Elas são utilizadas para equilibrar pressões entre dois ambientes e evitar danos ao equipamento, ambiental ou a vidas humanas. Com o amplo emprego, elas possuem princípios de solução e projetos variados, o que dificulta o uso de regras de cálculo para o dimensionamento. Em uma aplicação submarina, identificou-se a necessidade de instalação de uma válvula de alívio de pressão. Neste trabalho, apresentamos o dimensionamento e validação experimental para a mola responsável pelo funcionamento da válvula. Existem diferenças entre o calculado e o realizado devido à diversas indefinições ou inexistência de dados prévios. Desta forma, o projetista precisa manter o projeto flexível de forma a adaptar após a realização de uma prova de conceito física.

Palavras-chave: Mola de Compressão, Válvula de Alívio de Pressão, Equipamento Submarino.

1. INTRODUCTION

The presence of a pressure safety valve, PSV - Pressure Safety Valve, in equipment that is subjected to pressure variation is essential to ensure the protection of the lives of operators, equipment, property and the environment during an event of pressure increase above the stipulated. The PSV is designed to open, relieve equipment pressure and close again, avoiding additional fluid release after normal operating conditions are restored.

In consideration of this, the characterization of a pressure safety valve model in the process of developing industrial products should be better elaborated to cover the various variables in which the PSV will be submitted, meeting the engineering requirements that the entire product is employed and, mainly, ensure the full operation of the subsystem so that the pre-established pressures with safety criteria are met.

The application of the PSV dimensioned in the project in question is prepared for the offshore scenario, installed in an underwater seismic data acquisition equipment. Depending on the long operating time of the underwater equipment, deposited on the seabed at a depth of 3000 metres, a state of internal overpressure may occur due to electronic equipment and on-board batteries, presenting risks of accidents during the lifting and removal of the equipment from the sea, as well as at the time of opening the lids by an operator.

Given the involvement of several variables found for the assertive performance of the pressure safety valve, the objective to be presented consists in the organization and presentation of the methodology used within the aspects of the product,since there was a need for different combinations of fundamentals up to the desired scope.

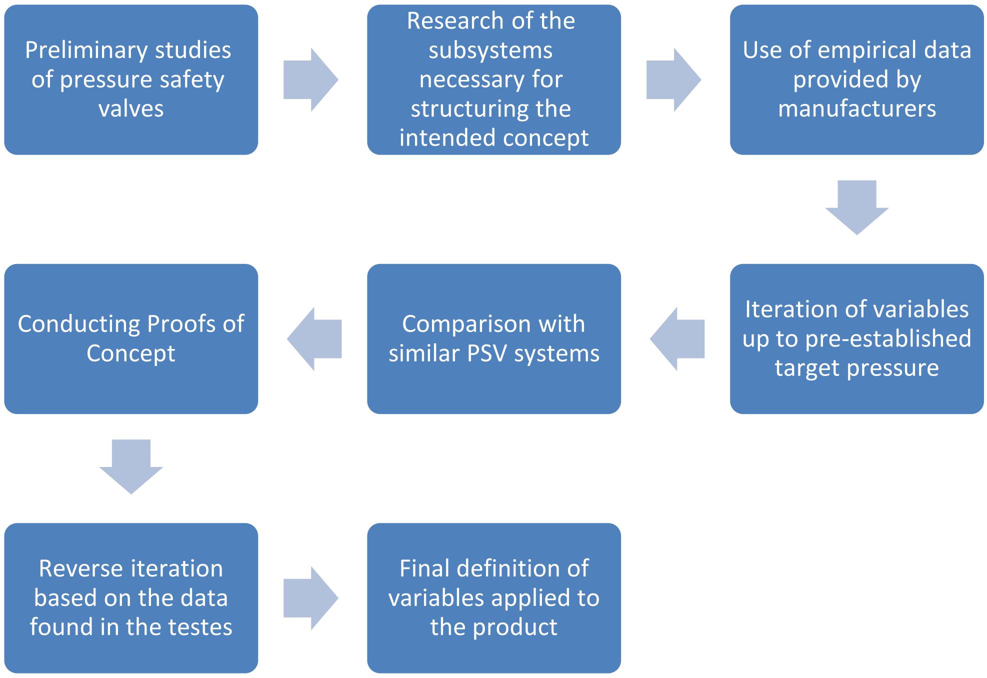
2. METHODOLOGY

In view of the above, exploratory research was necessary, since in addition to a bibliographic survey, it was necessary to communicate with project teams that had experience in carrying out the dimensioning, as well as comparisons with other existing models.

The bibliography used consisted of engineering textbooks, given that, for the final design of the valve, there is an arrangement with several themes, where they are studied separately, only then to carry out the structuring and application of all the knowledge obtained. Allied to this, it was also necessary to consult technical manuals made available by manufacturers of the applied machine elements, in which quantitative data were presented from preliminarily realized empirical models.

In Figure 1, it is possible to follow the work process carried out until the conception of the PSV in its final design, to be installed in an underwater seismic data acquisition equipment.

Figure 1. Work process used for the conception and elaboration of the PSV.

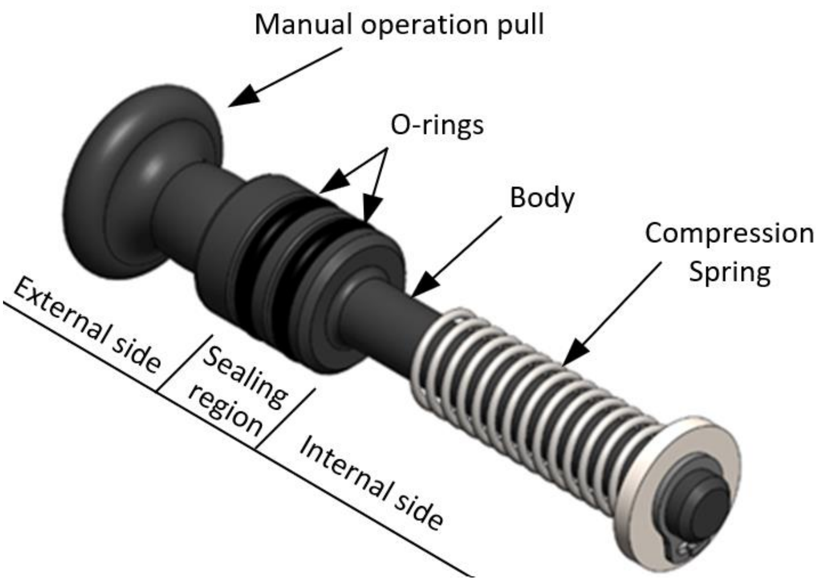


Source: Authors, 2023.

3. RESULTS AND DISCUSSION

The final concept chosen of the PSV, presented in Figure 2, is composed of: a valve body, which already acts as a guide for the spring employed; a spring; a washer; an elastic ring, in order to ensure the correct initial deflection of the spring; and two o-rings in the region with the largest diameter of the valve.

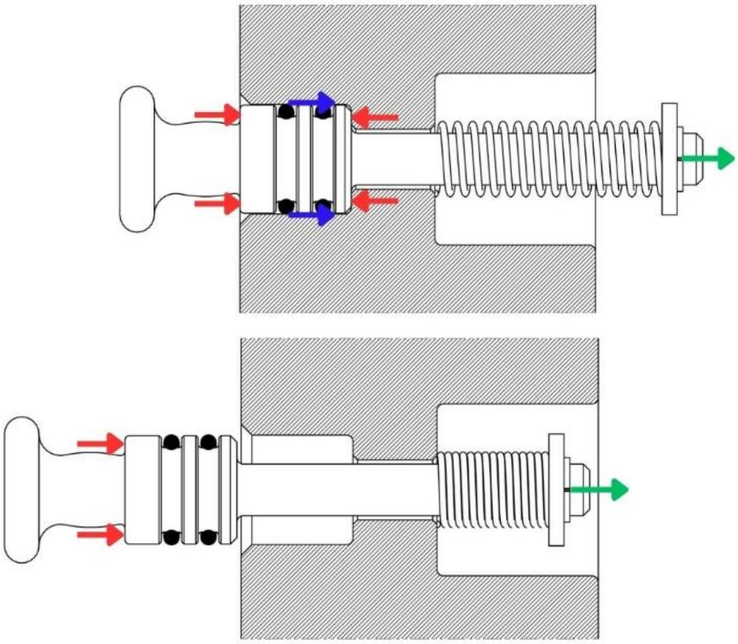
Figure 2. The pressure relief valve and its elements.



Source: Authors, 2023.

To perform the initial analysis of the variables involved, a forces diagram was elaborated in two different scenarios, as shown in Figure 3.

Figure 3. Diagrams of valve forces in two different scenarios.



Source: Authors, 2023.

Above, the first scenario is presented, in which the valve is completely retracted and there are four forces acting on the system: the friction force F_{at}, represented in blue, caused by the contact between the two o-rings and the wall in which the PSV is housed. The force of friction always acts contrary to motion; the force of the spring F_M, represented in the color green, which varies as a function of the initial pre-tightening force of the spring, the initial force being greater than F_{at}. Once the initial displacement occurs, the F_M varies depending on the product of the constant stiffness of the material and the displacement exerted; finally, there is the force resulting from the variation of pressures in relation to the external and internal area of the valve body, represented by ΔF_P, where from the variation as a function of time, it will result in the movement of the PSV, in the direction from the inside out, causing compression in the spring.

$$\Delta F_P = F_{at} + F_M$$

In the second scenario, positioned below, the increase in internal pressure was already enough to cause the PSV to be opened. At the instant shown in Figure 3, the compression of the spring and, consequently, the F_M reach their maximum values. In view of this, the spring force will be sufficient for the return of the PSV to the initial positioning as soon as the internal pressure of the equipment is relieved.

Initially, the equation was determined to find the friction force F_{at}, performed in an iterative way, fixing the thickness and internal diameter values of the o-rings - because they are commercial values - until a result consistent with the product in question is found. In the scenario where the o-ring and spring are employed, the calculations were carried out according to the dynamic operation of the system, generating the following equations that represent the frictional forces arising from the compression of the o-rings and acting pressures:

$$F_C = f_C \times L_P$$

Where f_C represents the load distributed on the perimeter of the inner diameter and is found in Parker's manual, this being an empirical value. The L_P represents the perimeter of the contact region, also in the region of the inner diameter. Thus, Fc represents the frictional force by compression of the o-ring. The equation below is also used with the objection of finding the frictional force F_{at}:

$$F_H = f_h \times A_P$$

In which f_h represents the friction force arising from the pressures under the o-rings, a value also found in the manufacturer's manual, obtained empirically. And finally, A_P which is the area of friction obtained from the inner and outer diameters of the o-rings, thus, it F_H represents the friction force due to the seal coming from the compression. Finally, the friction force is F_{at} found from the sum of the two and, in the particular case of the project, two o-rings are assigned.

$$F_{at} = 2 \times (F_C + F_H)$$

Given the sequential use of the equations presented, and the commercial values used of 9.26 mm of internal diameter and thickness of 1.78 mm, the value of 20.03 N was obtained and replaced in Equation 1. As the generation of the concept was carried out according to the scenario in which the underwater equipment will be submitted, there was a search for similar, in order to predefine dimensions of the diameter and consequently area of the valve body.

The ΔF_P is the force as a function of the internal and external pressures of the vessel, so it is necessary to use the area of the PSV that after several concepts, was established in the value of 124.69 mm² and a target of 3 bar for the opening of the PSV, so the F_P has the value of 37.41 N. From the necessary replacements, the minimum required F_M found for the opening is 16.30 N.

Em sequência, houve o planejamento e realização da POC - prova de conceito, a fim de testar e validar a deflexão inicial, sendo assim a montagem do sistema da PSV estaria devidamente dimensionado. Para a realização da POC, as peças apresentadas na Figura 4 foram fabricadas e montadas, como mostrado abaixo:

In sequence, there was the planning and realization of the POC - proof of concept, in order to test and validate the initial deflection, so the assembly of the PSV system would be properly dimensioned. To perform the POC, the parts presented in Figure 4 were manufactured and assembled, as shown below:

Figure 4. PSV proof of concept.

Source: Autores, 2023.

Figure 4 shows the execution of the proof of concept, where a small-scale pressure vessel is used and is connected to a hose used to power the system with compressed air. In addition, there is a pressure gauge in order to identify the pressure internal to the vessel and the entire valve mounted. During the tests performed at the POC, the spring deflection was adjusted until the length of 26.5 mm was defined and inserted in the last concept that will be manufactured.

4. CONCLUSION

It can be concluded that the sizing of the valve is in accordance with the expected for its operation, with an internal pressure difference of 3 bar, having a safety ranger of 1.5 bar to 5 bar of actuation, since there are other variables not considered in its dimensioning, understanding the need for simplification. In addition, in order to ensure the safety of the operator to perform the handling of the opening of the equipment, It is up to the orientation to perform previously the manual opening that was also elaborated in the conception phase.

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