RESEARCH ON THE VALIDITY SYSTEM OF SAFETY VALVE AND SPECIAL EQUIPMENT

by

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It is of paramount importance to accurately and promptly assess the safety of special equipment operating under high temperatures and high pressures. This paper presents an empirical and qualitative analysis of the safety of overall systems characterized by complex subsystem coupling, including the working medium, equipment operating parameters, safety valve settings value, spring property, and other pertinent variables. The paper also concludes that for a reliable safety prediction, computational fluid mechanics is necessary.

Key words: *mechanical safety valve, CFD simulation, special container*

Introduction

As a crucial safety component of pressure vessels, the primary function of safety valves is to automatically release pressure when internal pressure within the equipment exceeds the specified rating, thereby preventing equipment damage or accidents. The performance stability of the safety valve is of paramount importance in preventing excessive pressure and ensuring the safety of the system. A number of safety prediction systems have been developed [1, 2], and the safety prediction for the steam sterilization process [3] is particularly challenging due to its complex temperature response [4], and high pressure [3].

The EU has established clear requirements for the design and manufacture of simple pressure vessels in its *Simple Pressure Vessel Directive* with the objective of ensuring the reliability and performance of their safety accessories. In addition, the International Organization for Standardization (ISO) has issued a series of international standards pertaining to the safety of special equipment. These include ISO 14119, which outlines principles for risk assessment of machinery safety, and provides universal safety requirements and testing methods worldwide. It is evident that these regulations necessitate that users of special equipment should undertake regular inspections and maintenance of the safety accessories and safety protection devices of the equipment in question, and maintain records. These regulations ensure the safety and reliability of special equipment during operation, thereby reducing the risk of personal and property losses caused by equipment failure.

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Reliability and stability of the valve under extreme conditions

The ISO, American Petroleum Institute (API), European Standardization, EN, and American Aviation Administration (AD) are the general standards for safety valve verification in the world, which are applicable to different industries. Irrespective of the standard in question, a comprehensive evaluation of the performance, material, structure, and manufacturing process of the safety valve is typically conducted in order to ascertain that the valve can function stably and reliably in a variety of environments. The validation process may include pressure testing, leak testing, and cycle life testing, among other procedures. The detection of key parameters, such as opening pressure, closing pressure, and leakage of the safety valve, is also a crucial aspect of the validation process. The EN standard evaluation is concerned with the safety, durability, and environmental suitability of valves. The evaluation process may include testing the performance of valves under various environmental conditions. The AD standard calibration process is designed to assess the reliability and stability of the valve under extreme conditions.

Mechanical safety valves [5] are employed in a multitude of settings and equipment designed to prevent the build-up of excessive pressure. In the fields of steam systems and boilers, automobiles, aerospace, petroleum, and chemical industries, safety valves can prevent explosions or leakage accidents caused by excessive pressure or temperature. The operational principle of the mechanical safety valve is based on the principles of mechanics and fluid pressure control. In the absence of an incident, the safety valve is closed. The valve disc (valve core) is pressed against the valve seat by a spring or other loading mechanism to ensure that the valve is tightly closed and thus prevents medium leakage. When the pressure within the equipment or pipeline exceeds the opening pressure set by the safety valve, the pressure will act on the valve clack and produce an upward force. When the force generated by the medium pressure exceeds the force of the loading mechanism, such as the spring, the valve disc will begin to separate from the valve seat. This will result in the opening of the safety valve, allowing the medium to flow out through the gap between the valve disc and the valve seat. This will reduce the pressure in the equipment or pipeline. As the medium is discharged from the safety valve, the pressure within the equipment or pipeline gradually decreases. When the pressure drops below the closing pressure of the safety valve, the force of the spring or other loading mechanism takes over once more, pushing the valve disc back to the valve seat. This action closes the safety valve, preventing the waste of medium and the interruption of production.

The calibration process for safety valves may include testing their performance under extreme conditions, such as high pressure and low temperature, in order to ascertain their suitability for use in the aviation field in accordance with safety requirements. The fundamental objective of safety valve validation is to ascertain that the safety valve can sustain its performance and reliability in a multitude of operational settings. If the safety valve rarely explodes under normal conditions, but frequently explodes after regular inspection, it is possible that the material of the valve disc of the safety valve has exceeded the stress threshold, causing structural damage to the safety valve, which is a matter of concern.

The hydraulic device can be employed for the calibration and adjustment of the safety valve, which is typically conducted at a pressure range of 75% to 80% of the rated pressure. Verification data includes an opening pressure adjustment test, a sealing test, a repeat test, an overpressure test, a temperature test, a visual inspection, a size measurement, a material identification test, and a strength test. These tests are used to verify that the safety valve meets the specified requirements.

The opening pressure adjustment test verifies that the opening pressure of the safety valve meets the set value. The sealing test verifies that the sealing performance meets the requirements. The repeat test verifies that the performance is stable. The overpressure test verifies that the safety valve can be opened in time when the set value is exceeded. The temperature test verifies that the performance is stable under different temperature conditions. The visual inspection verifies that the aging of the safety valve is within acceptable limits. The size measurement verifies that the dimensions of the safety valve are in accordance with the design requirements. The material identification test verifies that the material used to manufacture the safety valve meets the specified requirements. The strength test verifies that the bearing time under rated pressure meets the specified requirements.

The spring material standard for a mechanical safety valve is typically determined by a number of factors, including the specific application scenario, operating pressure, temperature range, and medium characteristics. The spring vibration properties are also an important factor in ensuring safety. A fractal buffer [6] is therefore essential for the spring optimization. The frequency-amplitude relationship of the spring vibration can be elucidated by the nonlinear oscillation theory [7-9].

In the process of designing and manufacturing a spring safety valve, the appropriate spring material is typically selected based on several factors, including the working pressure, temperature range, medium characteristics, size, and structure of the safety valve. Concurrently, in order to guarantee the quality and dependability of the spring, it is imperative to conduct rigorous inspection and testing to ascertain that it complies with the pertinent standards and specifications. Alloy steel springs exhibit high strength and elasticity, rendering them suitable for deployment in high pressure and high temperature environments. The mechanical properties and stability of the valve disc material are of paramount importance in determining the opening and closing action of the safety valve. During the course of periodic inspections, safety valves may undergo multiple openings and closings, which can have a detrimental effect on the material and reduce the service life of the valve. In conclusion, the establishment of a coupling model for the mechanical safety valve and a special equipment system for the verification of the mechanical safety valve can enhance the safety inspection coefficient and mitigate the loss of the mechanical safety valve resulting from verification.

Computational fluid dynamics

In accordance with the specific application scenarios and requirements, it may be necessary to conduct special performance tests, simulation models, and safety tests.

The CFD is a contemporary computer simulation technology that employs computational techniques to resolve intricate control equations in fluid mechanics, thereby enabling the analysis of fluid-flow and heat transfer [10, 11]. The variational-based finite element method necessitates the establishment of a variational formulation [12], which is a relatively challenging undertaking. In the simulation process, the Galerkin technology is widely employed.

The field of CFD primarily concerns itself with the resolution of the governing equations of fluid mechanics through the application of computer and numerical methods. Additionally, it encompasses the simulation and analysis of fluid mechanics-related issues. The fundamental principle underlying CFD is the Navier-Stokes equation.

In the context of the safety valve test, it is essential to define the fluid-flow within the safety valve and to create a geometric model. Firstly, the 3-D geometric model is established by using CAD software, taking into account the structural characteristics (size and shape) of the safety valve. In the FEA software, the appropriate material properties, such as modulus of elasticity, yield strength, and so forth, are defined for each component of the safety valve. The geometric model is subdivided into a finite number of elements (grids) for numerical calculation. In accordance with the operational parameters of the safety valve, the appropriate boundary conditions and loads are applied, including inlet velocity, outlet pressure, wall conditions, and so forth. The FEA solver is then employed to calculate the physical quantities, including stress, strain, deformation, and displacement, of the safety valve under the specified conditions. Subsequently, the simulation results pertaining to fluid-flow, including velocity field, pressure field, and temperature field, should be analyzed in order to evaluate the structural strength and reliability of the safety valve.

The CFD is a widely utilized technique for the prediction and analysis of gas-flow. In the context of gas simulation, it is essential to consider the distinctive properties of gas, adjust the standard model in an appropriate manner, and construct a digital model to optimize the setting value of the safety valve and the operational performance of the safety valve. This is done in order to guarantee that the safety valve can function stably under high temperature and high pressure conditions.

Conclusion

When calibrating safety valves for special equipment working under high temperature and high pressure, it is essential to consider a multitude of factors, including the working medium, equipment working parameters, safety valve settings value, spring materials, and other pertinent variables. The combination of parameters, such as different spring materials, spring preload, and safety valve settings, should be carefully evaluated to ensure optimal performance. Computational fluid mechanics and other methods are employed to develop a digital model for the purpose of optimizing the fixed value of the safety valve, optimizing the working performance of the safety valve, and ensuring that the safety valve of the special equipment system can operate stably under high temperature and high pressure conditions.

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