Proper assembly of flange joint

SOFTWARE FOR STANDARD CALCULATION AND SIMULATION

STATIC GASKETS – For safe operation of a flange joint it is important to consider a number of parameters which have an impact on the bolts, gasket and flanges. The relatively large number of mathematical operations, the need for managing a large number of data and specific knowledge represent a highly demanding task for flange joint designers. Their work is supported by modern software programs. These programs give reliable results while providing considerable savings of time.

When calculating the flange joint according to the EN 1591-1:2001 standard the temperature and pressure of the media, additional external loads on the flanges as well as the flange, bolts and gasket dimensions should be known. Apart from that it is necessary to include in the calculation the modulus of elasticity, nominal design stress and thermal expansion coefficient for flanges and bolts at room as well as elevated temperatures. The EN 13555 standard defines the parameters of the sealing material or gasket used in flange joint calculation. There are more than 80 different parameters involved in the calculation, some of them need to be calculated iteratively (for example the gasket width and assembly bolt force).

For a faster and easier calculation of flange joints according to EN 1591-1 the DON 3.0 software includes numerous databases of standard flange, bolt and gasket dimensions as well as data on the parameters of the selected sealing materials or gaskets. The data provided this way facilitates the user in this time-consuming search for data from literature. By using the DON 3.0 software it is possible to simulate the impact of various modifying parameters acting on the joint. One of the options offered by the software is also the optimization of the joint regarding the type of the selected sealing material and the gasket width. By using the software calculation it is possible to verify if the bolts, flanges and sealing material will be able to withstand the operating conditions. The final result of the calculation is the required minimum bolting-up torque, by which the criterion for the selected tightness class is met.

Required Calculation Input

The DON 3.0 software provides a practical calculation of the most commonly used round flange joints. Currently, the software includes standard flanges made of steel. Their dimensions are defined according to the EN 1092-1:2007 standard. For standard flanges the ranges from the nominal pressure of PN 2.5 to PN 63 as well as sizes from DN 10 to DN 4000 can be selected. Regarding the nominal pressure, type and shape of surface the software provides the option of selecting the flange size. A flat gasket can be integrated into the selected flange featuring dimensions defined by the EN 1514-1:1997 standard as well as spiral wound and metal gaskets. The dimensions of the spiral wound gaskets are defined by the EN 1514-2:2005 standard while the dimensions of the metal gaskets are defined by EN 1514-6:2003. In case of non-standard flange or gasket sizes the data on the dimensions of the flanges and gasket can be entered manually.

The following types of flanges are included in the flange joint calculation:

- plate flange for welding (type 01),
- weld-neck flange with conical shell 1 (type 11),
- hubbed slip-on flange for welding (type 12) and
- blank flange (type 05).

Also the following flange surfaces are considered:

- full face (type A),
- raised face (type B),
- tongue and groove (type C/D),
- spigot and recess (type E/F).

A choice of 25 kinds of steel is available. The software provides the possibility of separate selection of material for each flange individually, as well as the selection of material of the connecting shell. The database includes data on bolt sizes from M10 to M63, for 13 different types of material. The bolt sizes are given according to the EN ISO 4014:2000 standard. Regarding the thickness of both flanges and sizes of nut and washer the software returns the minimum bolt length.

For a single flange joint 15 different combinations of operating conditions can be entered. For each combination of operating conditions the internal pressure and media temperature as well as magnitude of external forces and bending moments need to be given. The gasket parameters like Q_A and Q_{Smin} are limited for internal pressure up to 100 bar. Also the safety factor for bolts, gasket thermal expansion coefficient, friction coefficient, stiffness, tightness class and installation procedure need to be entered.

Practical approach to calculating flange joints

An important factor in calculating the result is also played by the gasket material parameters which define the thermomechanical properties of sealing materials as well as their sealing capacity. The test procedures are defined by the EN 13555:2004 standard. In order to perform the calculation the following parameters need to be known:

- modulus of the gasket – E_G,
- maximum surface pressure that can be safely imposed upon the gasket at the service tempe-rature without damage – Q_{Smax},
- gasket creep factor – P_{QR} and
- minimum gasket surface pressure required for the tightness class L after off-loading – $Q_{Smin\,(L)}$.

The correct selection of the gasket material parameters is of key importance for calculating the flange joint. It is important that the surface pressure on the gasket during the assembly is not too high since otherwise this can cause a damage of the gasket when subjected to elevated temperatures. According to the EN 13555 standard the main parameters defining the thermo-mechanical properties of the gasket are Q_{Smax} and P_{QR}. The Q_{Smax} value is defined as the maximum surface pressure at operating temperature the gasket can be exposed to without damage. The standard defines the pressure when a gasket breakdown has occurred when the set-in gasket deformation is explicitly greater than the deformation at earlier surface pressure values. Nevertheless, it can happen that with some gasket materials (for example CSF materials) the value of Q_{Smax} can not be determined easily since after the completed testing no explicit increase in gasket deformation can be assessed (Figure 1). The standard requires the confirmation of the Q_{Smax} value by a stress relaxation test. The result of this test is expressed in the form of a gasket creep factor – P_{QR}. The standard does not explicitly give the value of the P_{QR} criteria for evaluation purposes if the deformation of the gasket under operating conditions has reached such a level that it looses its functionality. Apart from that it is not clearly defined which range of the P_{QR} factor is acceptable. It is also necessary to consider that a high P_{QR} value does not ensure that the gasket at operating conditions will not be subject to a breakdown.

In order to avoid the earlier described non-defined condition two additional criteria are considered when determining the Q_{Smax} and P_{QR} parameters: visual look and deformation of the gasket. Due to the temperature impact on the flanges, bolts and gasket as well as due to the internal pressure and external forces a release of those elements can occur. If such an impact needs to be compensated during installation, the gasket has to be exposed to an adequate level of surface pressure. This pressure can exceed Q_{Smax} value. Accordingly, the values of the P_{QR} factor at different initial surface pressures (even larger as Q_{Smax} at given temperatures) are integrated in the DON 3.0 software. The calculation considers a P_{QR}, which meets the operating temperature and assembly surface pressure. The

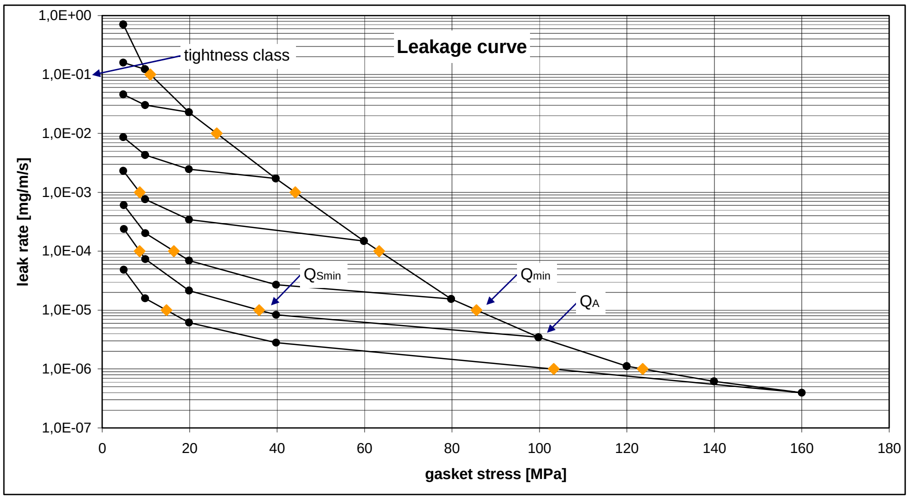

Figure 2: Leak rate as a function of gasket stress for an internal pressure

sealing specification of the gasket material is determined by a sealing test. During such a test the gasket is subjected to the selected initial surface pressure and the gasket leak rate is measured. Then the gasket is slowly released and at each release the actual leak rate is determined (Figure 2). The minimum surface pressure the gasket needs to be exposed to for a particular tightness class after release represents the Q_{Smin} value which depends on the gasket overload (Q_A). Regarding the requirements of the (EN 1591-1:2001/prA1:2005) standard the DON 3.0 software has been modified in such a way that the calculation of the minimum required gasket surface pressure at assembly depends on Q_A and not on Q_{min}. Practice has shown that, when the calculation of the minimum required assembly gasket surface pressure is based on the Q_{min} parameter, the level of the resulting surface pressure (Q_{Smin}) will be inadequate in the case of joint release.

Calculation and Simulation

The calculated values by considering the software modifications are shown in the form of diagrams and tables (Figure 3).

The calculation result is the required bolting-up torque by which the bolts need to be tightened for the selected tightness class. The software algorithm is designed in such a way that the software during the calculating process continuously informs the user if the bolts are overloaded or if the gasket is unable to withstand the operating conditions. The deviation of the bolt torque or the deviation of the gasket surface pressure depends on the selection of the bolting-up method. The software therefore includes a safety mechanism for checking the magnitude of the gasket surface pressure. The software algorithm compares the minimum surface pressure on the gasket (Q_{Gmin}) against the minimum required pressure (Q_{Smin}) and in case of an insufficient surface pressure informs that this pressure is insufficient for attaining the required tightness class. The comparison of the maximum surface pressure on the gasket (Q_{Gmax}) and the maximum acceptable surface pressure at operating temperature (Q_{Smax}) is performed the same way.

The calculation of a flange joint by using the DON 3.0 software has been verified by checking the calculated parameter values obtained on actual flange joints. For illustration purposes the calculation of a flange joint by using a gasket made of CSF material is shown, with the initial surface pressure during installation being higher than Q_{Smax}. For the selected gasket material the gasket parameters have been assessed according to the EN 13555 standard and the bolting-up tightening torque by the DON 3.0 software. The joint data are as follows:

- flange: PN40/DN40,
- flange surface: raised face,

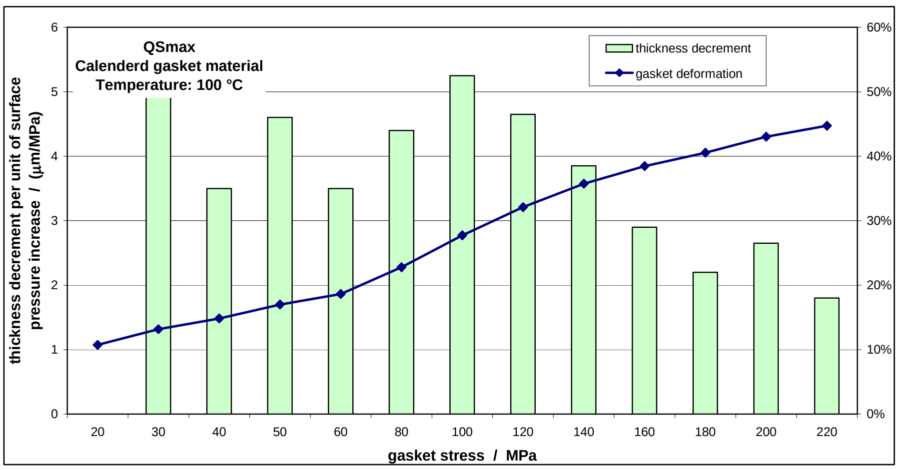

Figure 1: Comparison of results of the Q_{Smax} test for calandered material

- tightness class: 0.001 mg/(m s),
- operating temperature: 200 °C,
- internal pressure: 40 bar,
- bolts. quality 12.9,
- gasket width: 2 mm,
- joint stiffness: 500 kN/mm,
- friction factor: 0.14,
- bolting-up tightening method: torque wrench.

By using the DON 3.0 software the resulting bolting up torque is 178 Nm by which the maximum surface pressure of 61.5 MPa is applied on the gasket. The calculated gasket surface pressures under operating conditions are as follows:
- maximum (Q_{Gmax}) – 47.4 MPa,
- average (Q_G) – 39.9 MPa,
- minimum (Q_{Gmin}) – 32.4 MPa.

Based on data from the database the software defines the value of Q_{Smin}, which under pre-stress of 61.5 MPa results in 10 MPa and the value of Q_{Smax}, which is 50 MPa at a temperature of 200 °C. From the calculated, minimum and maximum values of surface pressure it can be deducted that the gasket will be able to withstand the defined operating conditions. To confirm this calculation a test has been carried out under equal condition on an actual flange joint as part of a testing steam supply. After 24 hours of operation the residual surface pressure on the gasket has been assessed and the look of the gasket (Figure 4) has been checked. The measured surface pressure was 34.7 MPa. The resulting values are a proof of the calculation of the flange joint since they lie within the interval between the calculated maximum and minimum surface pressure. At the same time a visual inspection shows that at the defined operating conditions no damage of the gasket appears.

Figure 4: Gasket after 24 hours of operation

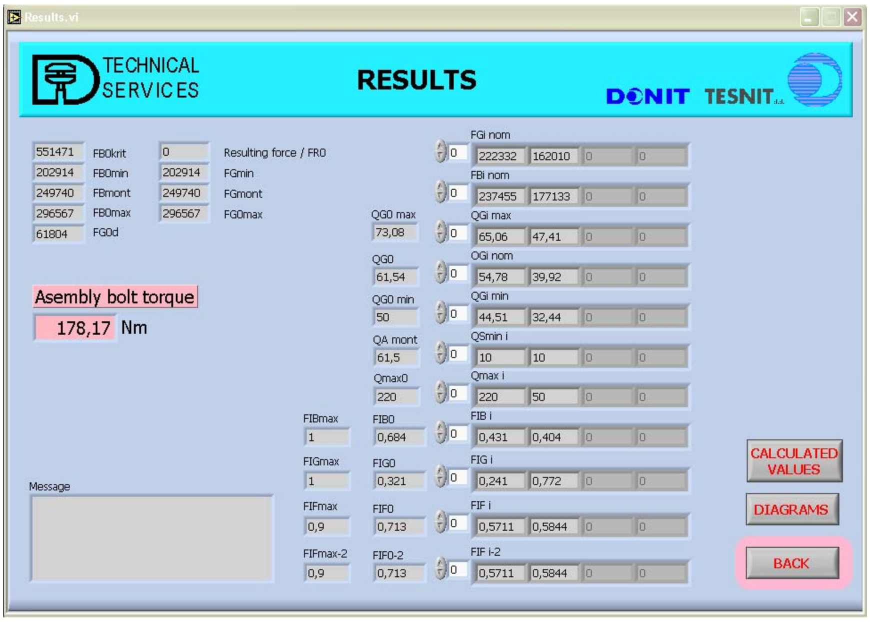

Figure 3: Dialogue window – overview of calculated values

Literature

EN 1591-1:2001: Flanges and their joints – Rules for designing flange joints featuring round flanges and gaskets – Part 1: Calculation method

EN 1591-1:2001 / prA1:2005: Flanges and their joints – Rules for designing flange joints featuring round flanges and gaskets – Part 1: Calculation method – Amendment 1

EN 13555:2004: Flanges and their joints – gasket specifications and test procedures for the application of rules for the design of flange joints featuring round flanges and gaskets

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