Primary flange forces – Part 2

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In Part 1 we saw how flange forces directly affect gasket stresses. In Part 2 we point to criteria that assures the correct flange forces are considered, discuss two of the most common sources of uncontrolled forces, and what can be done to ensure they're maintained with an acceptable of values.

The problems with uncontrolled flange forces

Fundamentally there are three problems that can result from uncontrolled flange forces.

1. Gasket stress drops below what is required to seal the connection.
2. Gasket stress increases to a value that damages the gasket.
3. Flange forces increase to a value that damages the flanges and/or bolts.

Any combination of these conditions can result unless the sum of the value of flange forces is maintained within acceptable limits. Acceptable limits will depend on the *particular* combination of bolt, flange and gasket as all three components interact together to determine the resulting value of flange rotation, and therefore, the pattern of gasket stress on the face of the gasket. The reader is cautioned that specifying bolt loads based only on average gasket stress and allowable bolt stress can result in gasket leakage. For instance, a value of bolt load that targets a high value of average gasket stress may be well within the limits of successful sealing for a welding neck flange, but may be excessive for a lap joint flange. Lap Joint flanges are significantly more susceptible to excessive rotation, given high bolt loads. The first step in targeting a successful value of bolt load is to simultaneously consider the sealing properties of the gasket with the mechanical characteristics of the connection.

Accounting for flange forces in flange design – EN 1591-1

Always the intention of specifying a bolt load for a particular flange pair is to develop and maintain the level of tightness required. The evolution of gasket testing constants such as Q_{smax}, $Q_{min(L)}$, $Q_{smin(L)}$, P_{QR} and E_G in Europe, and G_s, a, G_b, T_{Pmax}, S_l, and S_c in the USA has allowed the level of tightness to be predictive, provided the effect of forces are properly accounted for in the mechanical design of the connection. Specifically, components should neither be over stressed or strained (rotation).

In the USA, development is still in progress to incorporate the concept of leak-tightness into design of flange components. In Europe though, the Standard EN 1591-1 has been available since 2001 to include flange forces, in conjunction with gasket properties, to derive leak-tight bolt loads. In this calculation procedure the mechanical properties of each component is simultaneously reconciled against the forces and temperature effects inherent in the bolted flange connection.

The components become suitably proportioned to avoid damage, or excessive flange rotation. As such, the extent of gasket stress and therefore, leak-tightness becomes predictive. Finite element analysis also incorporates the material properties of all three flange components in deriving a targeted value of gasket stress. However, except in the most challenging of conditions, the resources required to create and evaluate these models are rarely productive.

In any case, a reliable gasket solution always begins with proper consideration of the interaction of all three components of a bolted flange joint; bolts, gasket and flanges.

Good bolting practices

Good bolting practices are not only encouraged, they're *necessary*. The targeted bolt load will only be created when the components are in good condition and the bolt load has been evenly applied. The EN 1591-4 Standard provides the qualification and technical requirements necessary for successful torque control during gasket installation. ASME PCC-1, Appendix A outlines qualification and training requirements, and ASME has recently announced the availability of its own qualification and training course entitled, Bolting Specialist Qualification program. These standards and this training program provide specific guidance on the conditional assessment of bolting components as well as details for recommended tightening procedures. Gasket stress, and therefore sealing is predictive when components are in good condition and the bolt load is evenly distributed around the flange. The single most common cause of BFC leakage is failure to follow an approved tightening sequence. Stated otherwise, this means the most important thing that can be done to preventing leakage is faithfully following all details of an approved tightening sequence. There is also another very important consideration to be addressed – flange alignment.

Flange alignment

As noted in Part 1 the intended bolt-up force can only be predicted if alignment of the mating flanges is within allowable limits. This can be a considerable challenge as it's very difficult to accurately predict the amount of preload force loss to misalignment, rather than goes into tightening the gasket. Fortunately, guidance exists to determine if a particular instance of misalignment is expected to be problematic.

ASME has published recommended limits on flange misalignment in ASME PCC-1-2013, Appendix E. The limits are based on the particular type of misalignment. The types are categorized as follows:

Centerline High/Low – Result of the difference in alignment of the axial centers of connected flanges.

Parallelism – Results when the face of the connecting flanges are not parallel.

Rotational Two-Hole – Results when the centers of the bolt holes of each flange do not coincide with one another.

Excessive Spacing, or Gap – Result when there is excessive distance between the face of each flange.

ASME PCC-1-2013

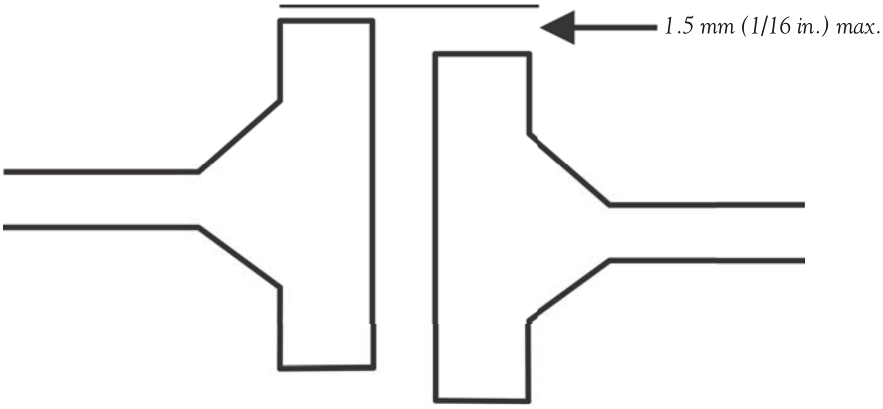

Fig. E-1 Centerline High/Low

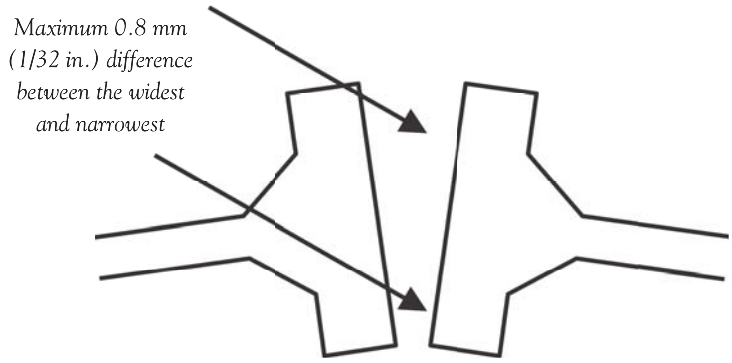

Fig. E-2 Parallelism

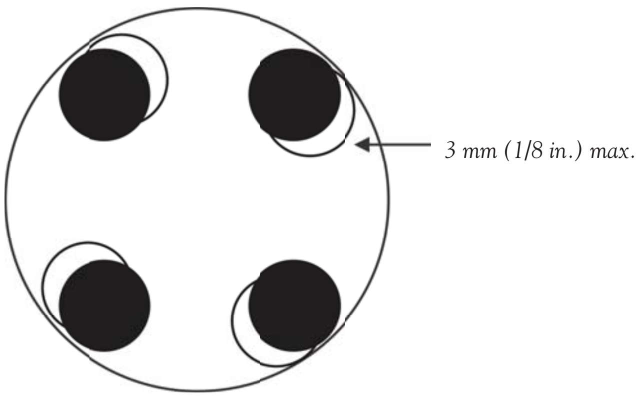

Fig. E-3 Rotational-Two Hole

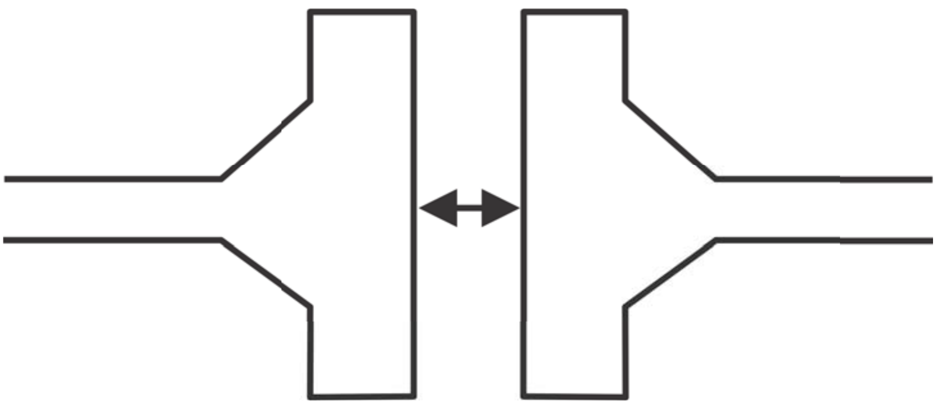

Fig. E-4 Excessive Spacing or Gap

Copied below[1] from this standard are graphics showing how the extent of the various misalignments can be measured. Again, each of these misalignment categories can introduce some measure of force into the connection. Worse still, their combined effect results in creating a confliction of forces on the flanges, none of which are usually accounted for in the target torque for the gasket. Following these guidelines will be helpful to judge whether misalignment may be excessive. Repairing, or re-supporting piping is often required to correct these conditions.

Part 2 conclusion

To ensure the condition of reliable BFC sealing, the targeted value of bolt-up force must consider both the sealing properties of the gasket, as well as the strength limits of the bolts, gasket and flange. This force is only released when the targeted bolt load has been sufficiently and evenly imparted to the flanges, and piping forces do not excessively resist it. Note: gaskets can only react to the forces imparted to them. Fortunately, specific guidance exists to help ensure successful levels of flange force can be reliably met. When they are, the resulting pattern of gasket stress meets the leak-tightness criteria required and/or intended of its design. When a gasket is correctly chosen, the cause of leakage can almost always be traced to a failure to inaccurately choose, or failure to control the flange forces.
Proper flange design, good piping alignment and good bolting practices go hand in hand to prevent both safety issues and reduce the costs associated with bolted flange connection leakage.

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