Gap Analysis in Flanged Unions

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The industrial use of simulation tools allows us to obtain a good approach in the knowledge of the phenomena that take place in the process that is modeled. Several factors of the flange design have a direct influence on the value of the gap. The value of the gap determines the capacity of the union to contain fluids under pressure, as well as the type of sealant to be indicated. Therefore, this paper presents the analyses, made using the finite element method, of the influence of different geometric parameters in the gap value and the behavior of the gap when each parameter is modified while all other parameters are maintained constant. We expect that this paper will serve to the designer as a guide to adjust the different parameters to reach the working necessities of flanged joints.

1 Introduction

One of the most important problems that faces the mechanical transmissions industry is the necessity of a perfect impermeability to internal and external media. Because of the use of new synthetic oils, the new mechanical transmissions have become a truly black box whose life exceeds the life of the vehicle (machine) in which it is integrated. The idea of a zero-maintenance and zero-service transmission during the life of the machine that contains it, generates new demands in which appears the necessity of a perfect sealing. Several specific solutions are applied to guarantee a perfect sealing, some are more sophisticated (and expensive) and some are simpler and cheaper. For the mass production industry, such as the automotive industry, the simplest and feasible solution is given through the application of a liquid sealant in the direct sealing zone. The liquid sealant after a relatively short period of time (10 minutes to 24 hours) becomes a resistant and impermeable solid. For each type of union that needs to be sealed exist a specific amount of conditions related to the preparation of the surfaces, that must be satisfied in order to reach the intention of a perfect sealing. The flange form union is widely used in mechanical transmissions. These unions have several fastener points (tighten points) that should be correctly distributed to obtain an admissible gap value between the sealed surfaces. The liquid sealant manufactures demand, as a requisite for the correct application of their products, a maximum gap value between the contact surfaces so that the sealant capacity will not be surpassed, and guarantee a durable and high resistance gasket. The gap value between two contacting surfaces depends of several factors such as the geometric properties of the flanges (shape, roughness, waviness, flatness, etc.), elastoplastic properties of the materials involved, distribution and shape of the fasteners, and others. Considering the complexity of the work the best tool to solve the problem theoretically is the computer simulation. This paper is intended to present a possible solution in the design of flanged unions and sealing problem of mechanical transmissions through a specific simulation program and present the numerical results obtained.

2 Identification of the most important parameters.

In order to identify the gap value in a flanged union the parameters involved can be classified into:

- Geometric design.
- Waviness and flatness.
- Roughness and surface finish.
- Tightening sequence of the fixing points.

Since geometric parameters are determinant to reach a satisfactory design in which the gap value is under the acceptable sealant value, this paper only analyzes these parameters. A further analysis on other parameters must be done.

All the analyses consider an ideal surface in which waviness, roughness, etc. does not affect the gap behavior. The materials considered are aluminum (Young Modulus of 72 GPa) for the flanges and steel for the fasteners (Young Modulus of 207 GPa).

3 Parameter analysis

Every analysis was made changing the value of each geometric parameter while all other parameters were maintained fixed.

3.1 Distance between tightening points

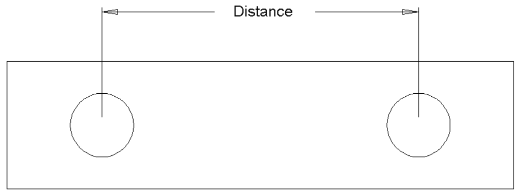
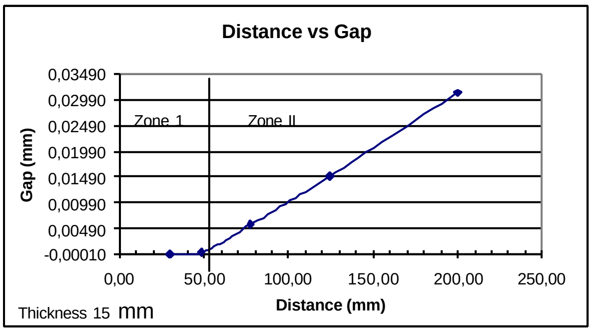


Fig. 1 Distance representation



Graph. 1 Distance vs Gap

When the distance between tightening points is changed (fig. 1), a lineal behavior of the gap is observed (graphic 1). The more the tightening points are separated the greater the gap in the joint becomes.

For a specific thickness of the flange, two zones could be identified in the behavior of the gap. In the first region (zone 1) the value of the gap is zero and this value could not be changed by approaching the fasteners. The gap will increase lineally when the fasteners are moved away.

3.2 Thickness of the joint

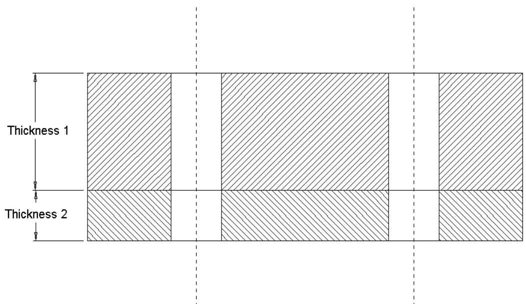
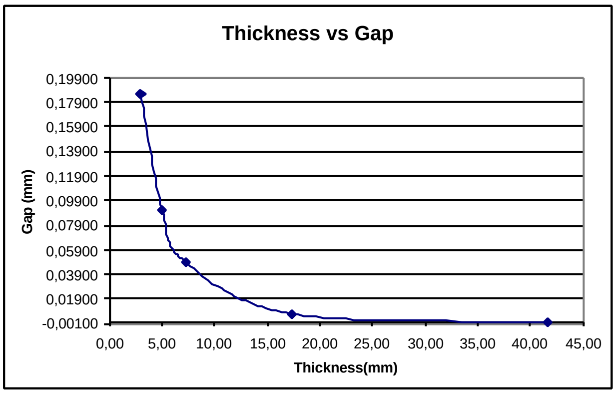


Fig. 2 Thickness representation



Graph. 2 Thickness vs Gap

The thickness value in flanged unions has an important influence in the gap behavior, because a greater thickness implies a more rigid flange that minimizes the joint deformation. The behavior is exponential (graphic 2), and when a "critical" value is reached (in this case 20 mm) the gap value can be considered despicable.

3.3 Radius of Curvature

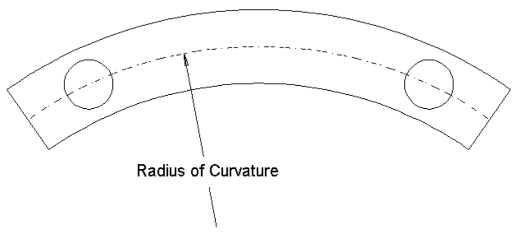
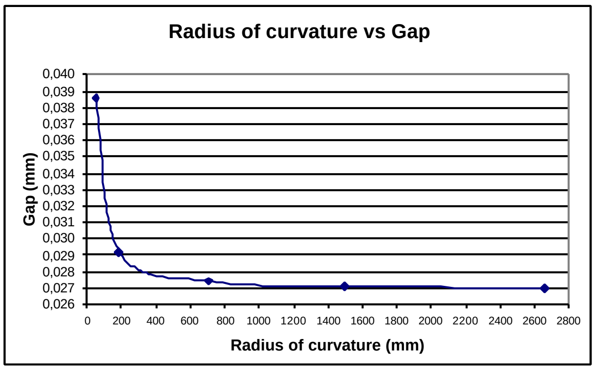


Fig. 3 Radius of curvature representation



Graph. 3 Radius of curvature vs Gap

When the radius of curvature is increased the gap value decreases with an exponential behavior (figure 3). This behavior is due to the displacement of the line of action of the force out of the joint (straight line between fasteners), therefore the force transmission would not be uniformly applied through the joint. This effect also causes a non-uniform gap distribution in the flange, this means that different gap values will be present in the axis of symmetry, with the maximum value in the exterior line of the flange.

3.4 Width

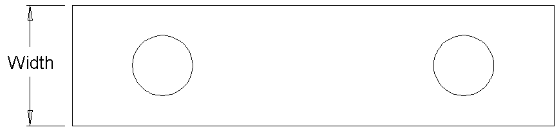
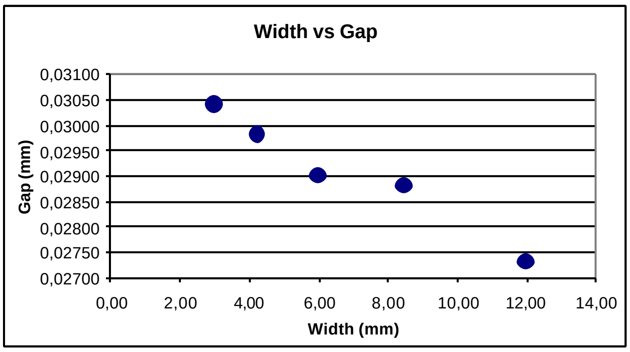


Fig. 4 Width representation



Graph. 4 Width vs Gap

The width does not represent an important parameter on the gap behavior, because the range of variation is non significant (less than 4%). Nevertheless the width is a very important factor in the sealant selection, because of the relation of the surface with the adhesive capacity.

3.5 Height of fastener application

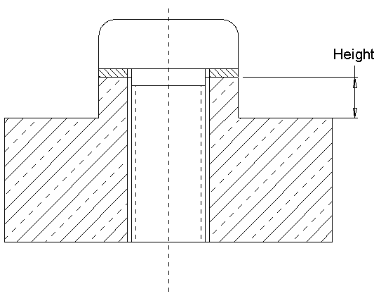
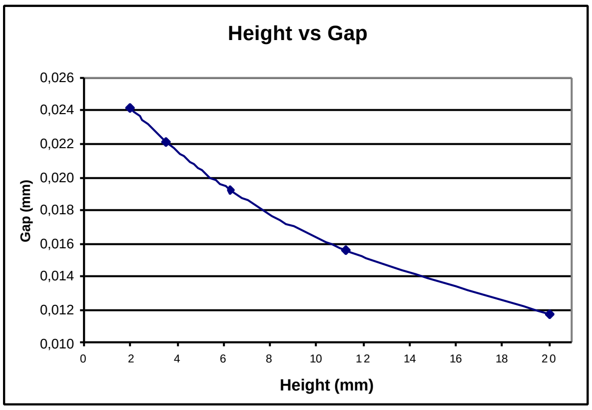


Fig. 5 Height representation



Graph. 5 Height vs Gap

If the height at which the fasteners are placed is increased, such as a local thickness increment (figure 5), a diminution of the gap value is observed, because of the cone effect in the force distribution which helps generates a more uniform force distribution in the flange.

3.6 Eccentricity

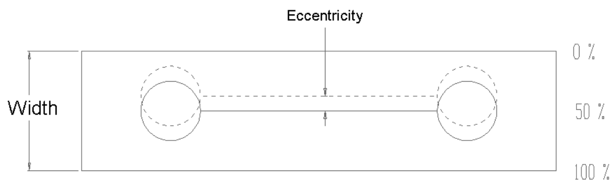
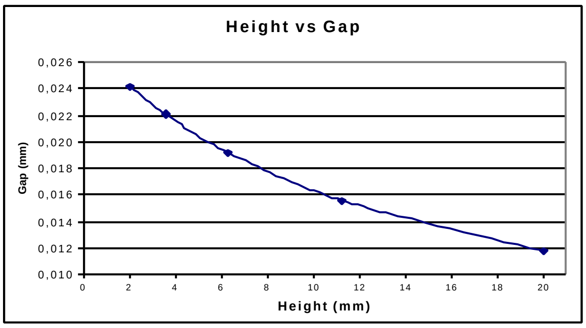


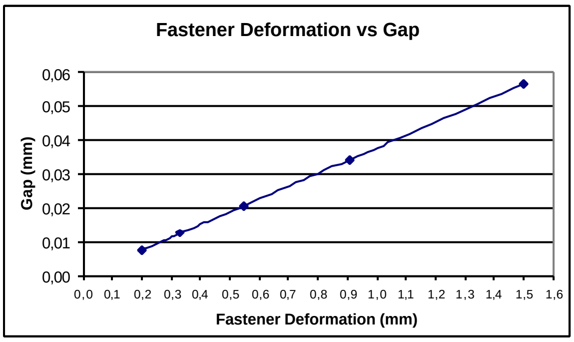
Fig. 6 Width representation



Graph. 6 Eccentricity vs Gap

When a certain eccentricity exists between fasteners, with respect to the middle line of the flange (figure 6), a gap diminution will be generated. Because this eccentricity approaches to the flange (symmetry line of the curved union) to the force transmission line. The influence is not significant (less than 6%).

3.7 Fastener Deformation (Torque applied)



Graph. 7 Fastener Deformation vs Gap

If fastener deformation is increased, due to an over torquing or because the maximum admissible torque of the fastener is indicated, the gap between the flanges will increase lineally (graphic 7). Therefore, for thin plates (less than 8 to 10 mm) it is convenient to apply a torque under the maximum admissible torque value to avoid an excessive flange deformation.

3.8 Bore Diameter

These analyses were made under 3 different considerations:

- Maintaining a constant distance between fastener points –bores– (figure 7).
- Maintaining a constant distance between bores and maintaining a constant angular relation between the bore center and the flange width (figure 8).
- Maintaining a constant flange length and a constant angular relation between the bore center and the flange width (figure 9).

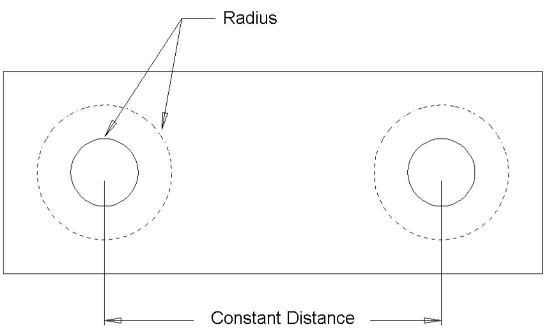


Fig. 7 Bore Radius representation

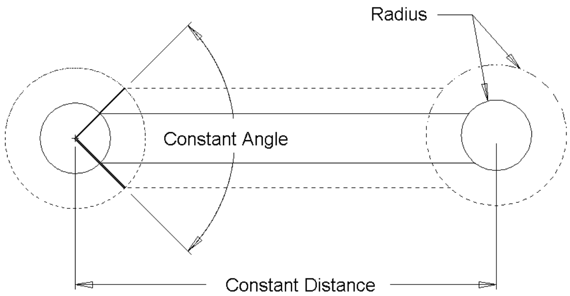


Fig. 8 Bore Radius representation with constant distance.

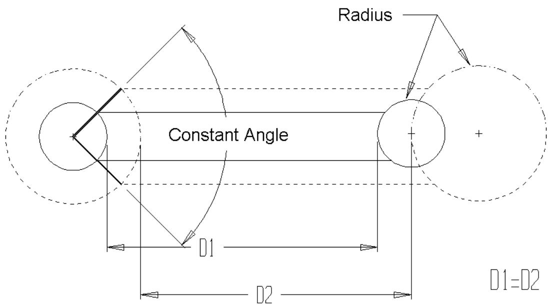
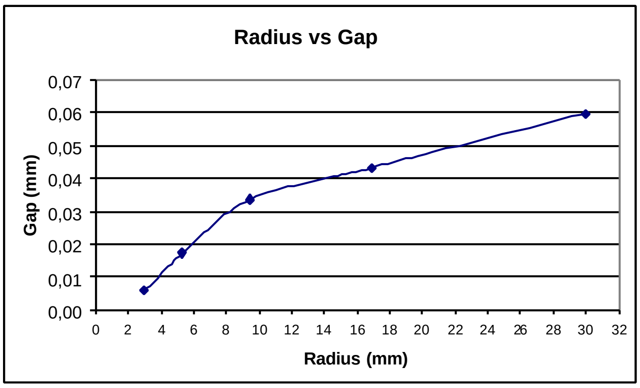
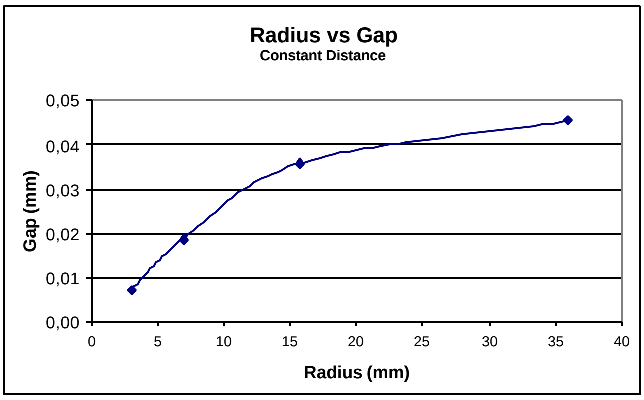


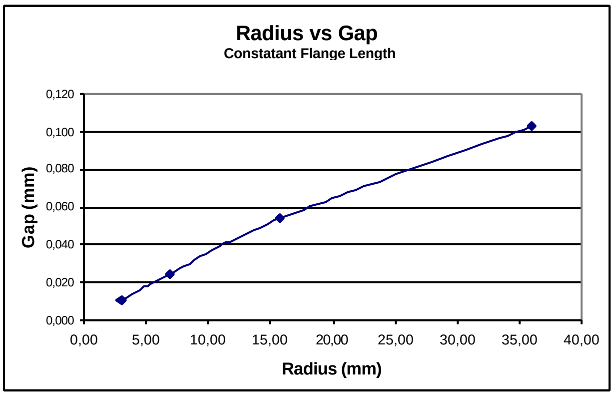
Fig. 9 Bore Radius representation with constant length.



Graph. 8 Radius vs Gap



Graph. 9 Radius (constant distance) vs Gap



Graph. 10 Radius (constant length) vs Gap

In the first case, a gap increment is observed when the bore diameter is increased (graphic 8), even though the flange length diminishes.

In the second case (graphic 9), a gap increment is also observed. The behavior is, as in the first case, exponential and tends to an asymptotic value.

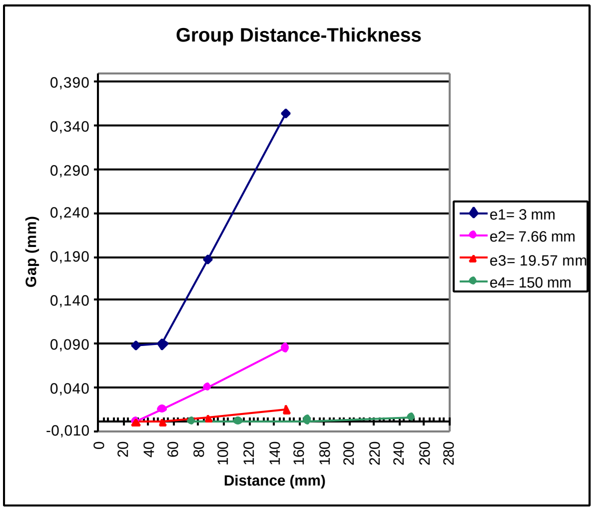
In the third case (graphic 10), the gap tends to a linear behavior when the bore diameter is increased.

4 Group of curves

From the previous results, it was decided to make a group of graphics containing two parameters so that a better comprehension of the gap behavior can be reached. The groups are:

- Distance and thickness.
- Eccentricity and radius of curvature.
- Distance and radius of curvature.
- Straight flange and curved flange comparison.

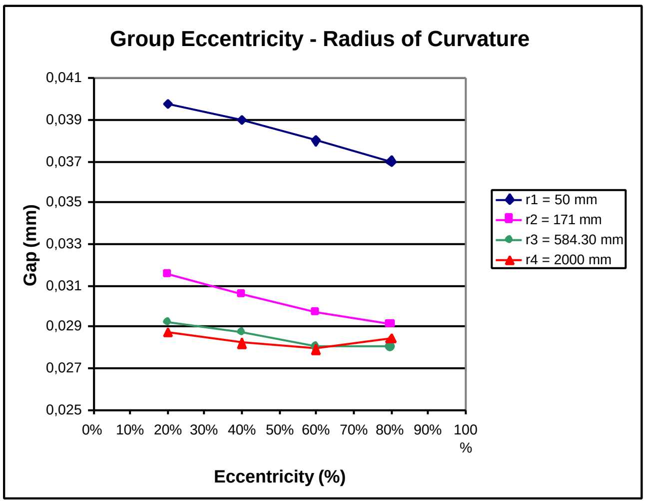
4.1 Group Distance – Thickness.



Graph. 11 Group Distance - Thickness

When the distance between fasteners is decreased and the thickness is increased, a considerable diminution of the gap value is possible. Therefore, the compensation of a wide distance is feasible by increasing the flange thickness (graphic 11). This effect is due to the increment in the joint rigidity.

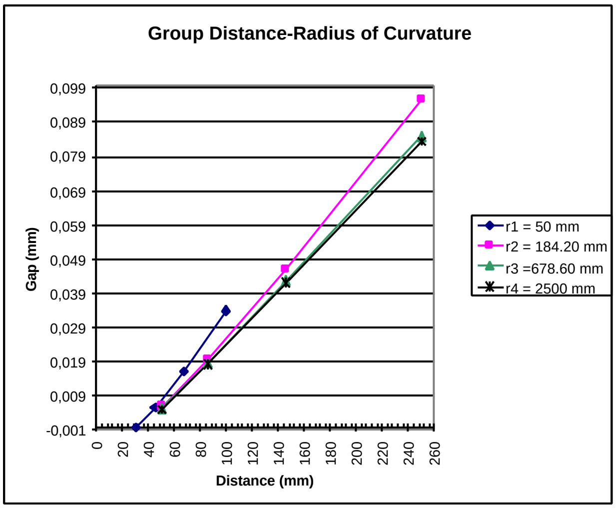
4.2 Group Eccentricity – Radius of curvature.



Graph. 12 Group Eccentricity – Radius of Curvature

In this group of curves it is observed that the lower the radius of curvature the higher the effect of the eccentricity in the gap value (graphic 12); because line of action of the force between the fasteners is approximated to the flange. If the radius of curvature is high (approaching to a straight flange) the eccentricity will increase the gap value. The influence of eccentricity is only in a small percentage (in the analyzed case only 10%).

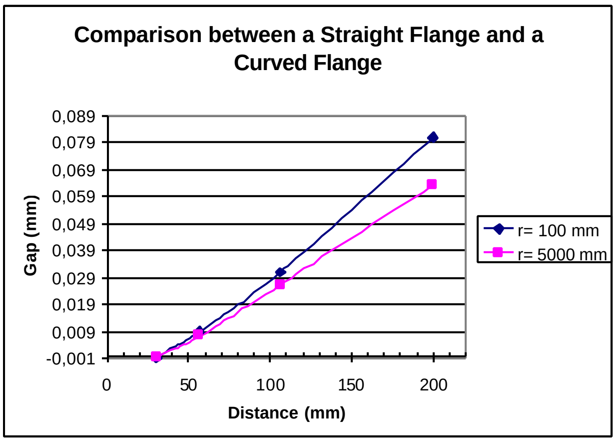
4.3 Group Distance – Radius of Curvature.



Graph. 13 Group Distance – Radius of Curvature

The influence that the radius of curvature has in the gap value as the distance between fasteners is changed is observed in graphic 13. Even though the distance is kept constant, the lower the radius, the greater the influence. This is corroborated in graphic 14. In this group, the influence of the distance is more important because it causes an appreciable change in the gap value.

4.3.1 Comparison between a Curved Flange and a Straight Flange.



Graph. 14 Comparison between a Curved and Straight Flanges.

If we compare the results of a straight flanged union with those of a curved union at the same distance between fasteners, we will notice that the influence is greater at longer distances, due to the flange separated from the ideal transmission force line.

5 Conclusions

The results obtained through the finite element simulation show a good concordance between the theoretical results and the practical observations. The use of the FEM (finite element method) guarantees a possible extension of the results through a more wide application fields. It also allows to avoid serious errors in the selection of parameters, which could cause high expenses and lost of time in the construction of flanged joints. Through the correct selection of design parameters it is possible to guarantee a reliable and long life sealing.

The results obtained in the numerical research show that the more significant factors in flanged unions are: the distance between fasteners, the thickness of the plates, the deformation (applied torque) of the fasteners. Other less important factors are: the radius of curvature, the eccentricity, the width (but it is an important parameter in the sealant indication).

Unfavorable gap situations could be compensated through the modification of parameter that increase the rigidity of the union, as it is shown in graphic 11, where a thickness high enough could give zero-gap even with highly separated fasteners.

The knowledge of the influence of the different parameters in flanged unions gives the designer the possibility to establish certain criteria for safe design.

6 References

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