ADAPTATION OF HOLE SIZES AND LOCATION TOLERANCES FOR ASSEMPLY COMPOSITES w.r.t DIFFERENT TOLERANCING SYSTEMS

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ABSTRACT

This paper gives methods and formulae for adapting the size of holes and their centre distance or positional tolerances for different assemply composites w.r.t different tolerancing systems.The use of these methods will ensure free assemply of mating parts with fastening device such as screws, bolts,rivets,pins and studs.

INTRODUCTION

There are two separate conditions under which fasteners are assembled,described here as the floating fastener condition and the fixed fastener condition.In some application it may be desirable to make further allowances,such as a small increase in hole diameter or reduction in the location tolerance ,to provide enough clearance under the least favourable conditions of size and position.Each of these condition will be treated separately.In the formulae in this work the following symbols are used:-

H = minimum diameter of hole
F = maximum diameter of fastener or stud
T = maximum dimension across the tolerance zone for location of holes

Subscripts are used to refer individual parts in an assembly, for example:-

H_1 = minimum diameter of holes in part 1

H_2 = minimum diameter of holes in part 2

FLOATING FASTENER CONDITION

The floating fastener type of assembly uses a fastening device, such as a bolt with a nut, which is free to float(not located in a fixed position) due to clearance holes in both of the assembled parts. Fig. 1. shows such an assembly, using one fastening device, where parts 1 and 2 are intended to be held in contact with one another along two of their sides.

Floating Fastener Condition-Coordinate Tolerances

Fig. 2. and Fig. 3. show the two separate parts with coordinate tolerancing, resulting in square tolerance zones for location of holes, within which the axis of the holes must lie. The least favourable assembly condition occurs when the clearance holes in the two parts are at their minimum sizes, and their axes are farthest apart. This occurs when they are at diagonally opposite corners of tolerance zones, as shown in Fig. 4. This condition is shown in an enlarged view in Fig. 5. From this example we can see that the minimum size of the holes is equal to the maximum fastener size, plus the maximum dimension across the tolerance zone for the location of holes. Expressed algebraically this is:-

$$H = F + T \qquad \text{or} \qquad T = H - F$$

For rectangular coordinate tolerances, which are equal in both

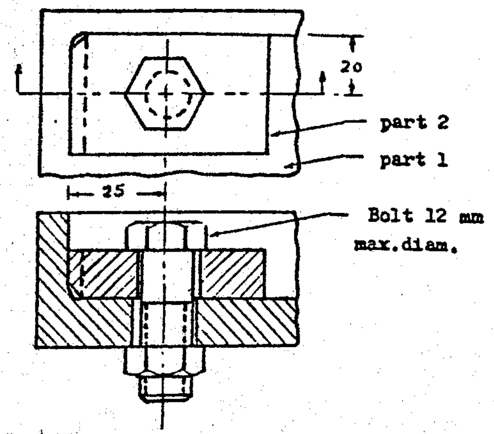


Fig. 1. Bolted assembly with floating fastener

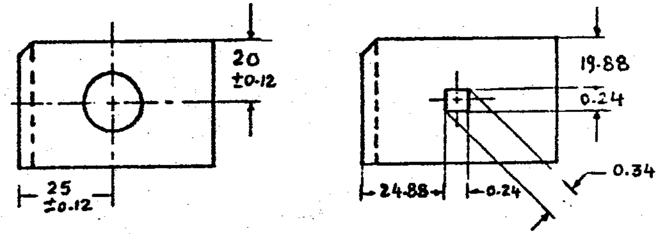


Fig. 3. Tolerance zone for part 2

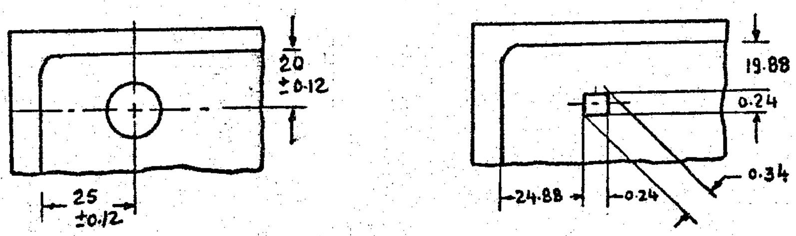


Fig. 2. Tolerance zone for part 1

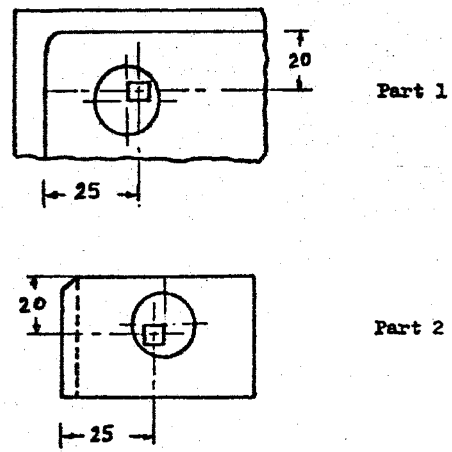


Fig. 4. Holes in extreme position

directions, the tolerance zone is square as shown, and its maximum dimension is 1.4 times the coordinate tolerances. If we let these tolerances be represented by the letter C the formulae for hole size could be expressed as:-

$$H = F + 1.4\ C \qquad \text{or} \qquad C = \frac{H-F}{1.4}$$

If unequal coordinate tolerances or polar coordinate tolerances are used, their formulae should be used to determine the maximum dimension across the tolerance zone. As an example, for the parts shown in figs. 2 and 3 the minimum hole diameter is:-

$$\begin{aligned} H &= F + 1.4\ C \\ &= 12+(1.4 \times 0.24) \\ &= 12.34 \text{ mm} \end{aligned}$$

Floating Fastener Condition-Positional Tolerancing RFS

The use of positional tolerancing instead of coordinate tolerancing results in a round tolerance zone. The maximum dimensions across the tolerance zone is therefore the value specified on the drawing. If desired, the specified positional tolerance could be 40 % larger than the corresponding coordinate tolerances, without increasing the hole sizes or affecting assembly conditions. However, if the manufacturing process is such that the coordinate tolerances could easily be held in two directions, it is most likely that the same tolerance could just as easily be held in all directions. This being the case, a positional tolerance identical to the coordinate tolerance could be specified, resulting in smaller hole sizes and a better fit with less play in assembly. For positional tolerancing the same general formulae apply as for coordinate tolerancing, except that T represents the positional tolerance

$$H = F + T \qquad \text{or} \qquad T = H - F$$

Fig. 6. shows two parts, similar to those of Fig. 2, except with positional tolerances on an RFS (regardless feature size) basis. The positional tolerance has been raised to 0.34 mm to provide the same extreme assembly condition as in the example with coordinate tolerances. Fig. 7. shows these parts with holes in an extreme position. In this example the minimum hole diameter for both parts is:-

$$
\begin{aligned}
H &= F + T \\
&= 12 + 0.34 \\
&= 12.34 \text{ mm}
\end{aligned}
$$

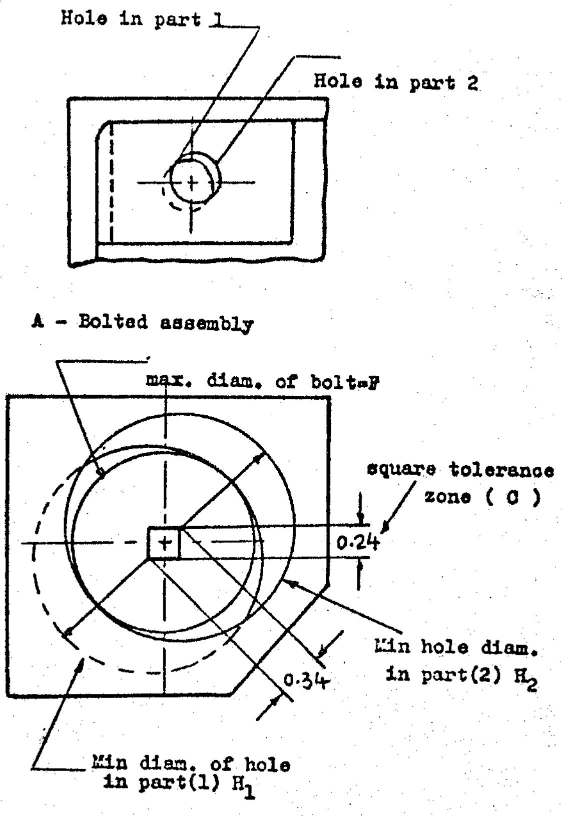
Floating Fastener Condition - Positional Tolerancing MMC

If MMC (maximum metal condition) is specified with the positional tolerances, as shown in Fig. 8, the calculations for the minimum hole size are exactly the same as for the RFS condition. The difference in the requirement is that, on a RFS basis, as the size of the hole approaches its maximum diameter, more clearance is provided all around the fastener without the position of the hole changing. When MMC is specified, this increase in clearance may be utilized to permit a greater variation in the position of holes. This is illustrated in Fig. 9.

Calculating Clearance

The formulae given have been based on determining the minimum hole diameter, or the maximum permissible tolerance for location, which would just permit the parts to assemble without any clearance under extreme conditions.

Clearance is usually expressed in terms of the difference between diameters, i.e, the difference between the diameter of a hole and the diameter of the mating part which assemble into it. The same formulae can be used to determine the minimum clearance for any given drawing specifications. For example, in Fig. 6. we saw how, with a positional tolerance of 0.34 mm, the minimum hole



B - Enlarged view

Fig. 5. Superimposed tolerance zone

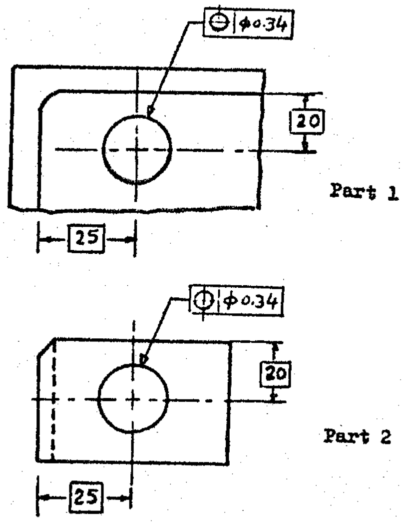


Fig. 6. Holes located by positional tolerance RFS

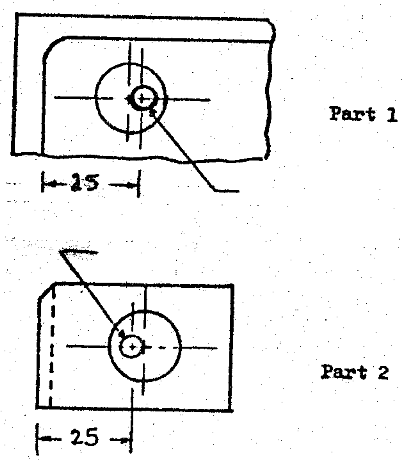


Fig. 7. Parts with holes in an extreme position

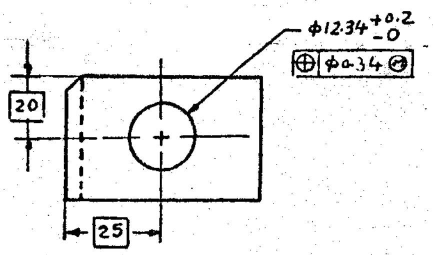


Fig. 8. Positional tolerance on MMC basis

diameter had to be 12.34 mm. If a positional tolerance of 0.2 was substituted the minimum hole required would be $H = F + T = 12.2$ mm. Therefore a minimum 12.34 mm hole would provide 0.14 mm minimum clearance on diameter, or an extra 0.07 mm all around. The maximum diametral clearance is $H-F$, where H = maximum diameter of hole, F = minimum diameter of fastener.

Unequal Tolerances and Hole Sizes

It is some times desirable to have different tolerances for location, or different hole sizes, in each of the assembled parts. One reason for this may be because one part already exists, and the other must be designed to mate with it. In such cases the hole sizes and the positional tolerances must be separated, and the previous formulae, $H = F + T$, becomes

$$H_1 + H_2 = 2F + T_1 + T_2$$

or

$$T_1 + T_2 = H_1 + H_2 - 2F$$

Therefore if two parts having the following tolerances have to be assembled with a minimum 12 mm diameter bolt, we have

	Part 1	Part 2
H = minimum hole diameter =	12.38	12.2
T = positional tolerance =	0.14	T_2

$$\begin{aligned} T_2 &= H_1 + H_2 - 2F - T_1 \\ &= 12.38 + 12.20 - 24.00 - 0.14 \\ &= 0.44 \end{aligned}$$

This is shown, with tolerances exaggrated for clarity in Fig. 10. Note that with unequal tolerances the fastener moves off centre in its extreme condition. The deviation of the fastener center from true position is $H - F - T$ when based on the larger hole, or $T - (H-F)$ when based on the smaller hole. Both formulae should give the same result.

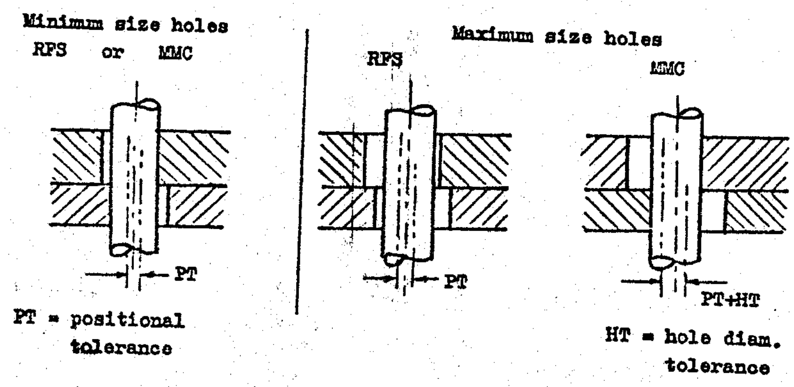


Fig. 9. Extreme position of holes on RFS and MMC basis

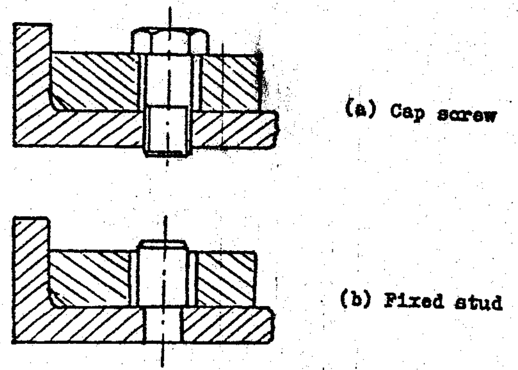


Fig. 11. Fixed fastener assemblies

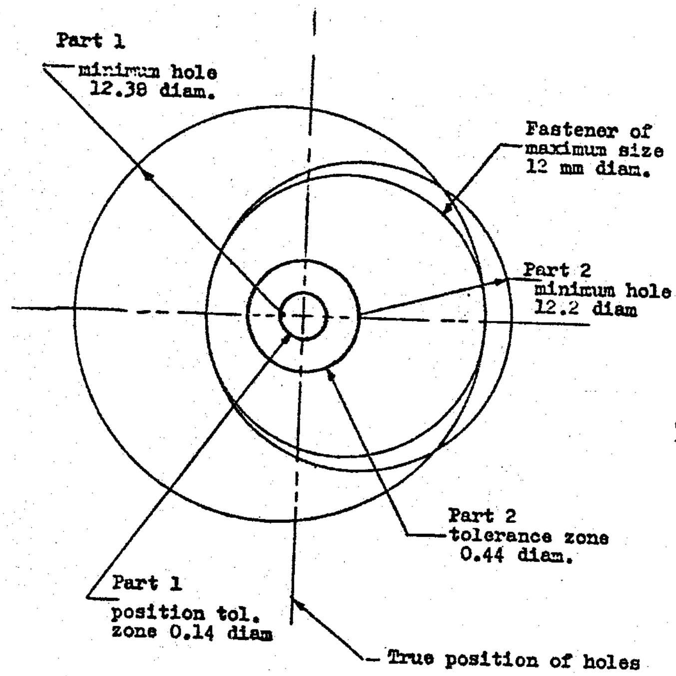


Fig. 10. Tolerance zones when tolerances are unequal

Where there are three or more parts to be assembled together the general formulae above must be satisfied for any combination of two parts.This cannot necessarily be acomplished by calculating values for two of the parts and making the tolerance for a third part identical to one or other of them.
Using the values shown in Fig. 10. if we tried to use a third part with a hole the same size as the one in part 2,the resultant positional tolerances for that part would be:-

$$T_2 + T_3 = H_2 + H_3 - 2\ F$$
$$T_3 = 12.20 + 12.20 - 24.00 - 0.44$$
$$= -\ 0.04\ \text{mm}$$

In other words,the positional tolerance for hole 3 would have to be less than zero,or would result in 0.04 mm interference with a zero positional tolerance.Either the hole sizes would have to be increased,or the positional tolerance for hole 2 decreased.A suggested solution might be to reduce the positional tolerance for hole 2,making the tolerances for 2 and 3 equal. Thus if T_2 and T_3 are equal,each tolerance is:-

$$\frac{H_2 + H_3 - 2\ F}{2} = \frac{12.20 + 12.20 - 24}{2} = 0.2$$

Part 1 would then always show a clearance around the fastener.

All of the formulae in this work are equally applicable to coordinate tolerancing,as long as it is rememberd that tolerance T then represents the diagonal of the tolerance zone.

FIXED FASTENER CONDITION

Fixed fastener condition refers to the type of assembly where fastners are fixed in position in one of the parts,such as parts assembled with screws,studs.......etc. Fig. 11. shows two typical assemblies of this type.

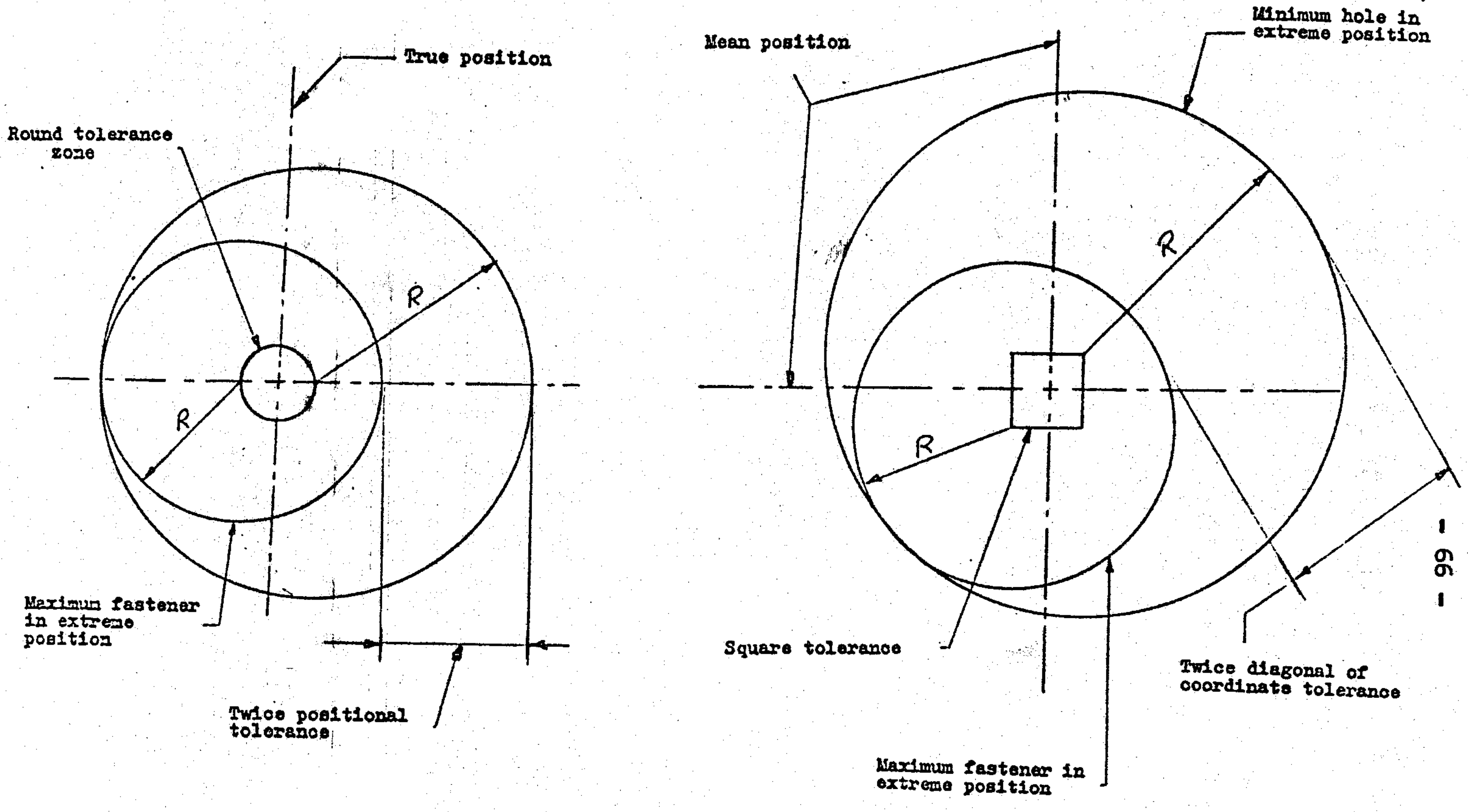


Fig. 12. Comparison of tolerance zones for positional and coordinate tolerance

In such assemblies the hole in one part is tapped to receive a screw or thread part, or reamed or bored to obtain a press fit for a stud. The assembly clearance is provided by the hole in the other part. The minimum size of this clearance hole is:-

$$H = F + T_1 + T_2$$

or, if the same positional tolerance is specified for both parts:-

$$H = F + 2\,T$$

These formulae apply either to positional tolerancing, where T is the specified value, or to coordinate tolerancing, where T is the length of the diagonal of the tolerance zone, Fig. 12. shows comparison of tolerance zones for positional and coordinate tolerance. It should be noted that these formulae do not compensate for lack of perpindicularity of fixed fasteners, when the holes for such fasteners are not made perpindicular to the surface of the holes. To provide for such conditions extra hole clearance may be required.

CONCLUSION

This analysis gives methods and formulae for calculating the size of holes and their centre distances, or positional tolerances. The use of these methods will ensure free assembly of mating parts with fastening device such as bolts, rivets, ...etc.
The formulae presented are designed to produce a metal-to-metal fit at the maximum material sizes. Therefore all parts manufactured using these formulas should assemble with no interference and no clearance when holes are at their minimum size and external feature or fastening devices are at their maximum sizes.

REFERENCES

1. Jensen, H. Cecil, Hill R. "Engineering Tolerance". First Edition Wiley, New York (1976).

2. Gladmann, C. A. " Discussion on Unresolved Problems of Tolerance Technology ", Annals of the Cirp Vol. 30/1/1981