

Technical article

Transfer of dimensions: a simple example

Suppose that the task at hand is to manufacture a lot of ten thousand parts as pictured below in figure 1. In that figure, only the dimensions of interest for this exposition are indicated. Those dimensions have been carefully determined by a designer, based on his best knowledge, applying state of the art technology. Those dimensions happen to be all 10 mm, with a tolerance of ± 0.1 mm. This means that the part is expected to function properly if those dimensions are kept between 9.9 and 10.1 mm.

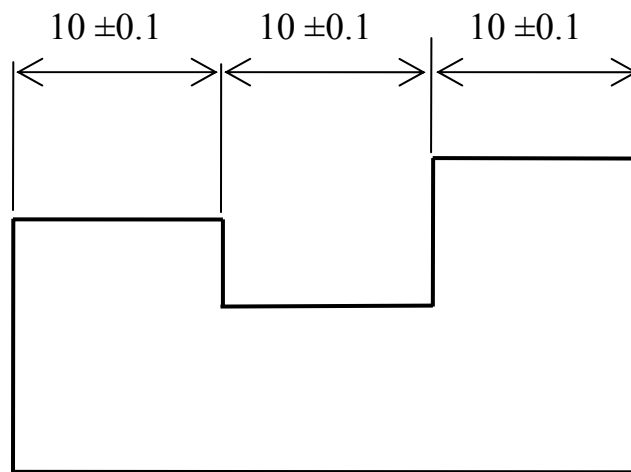


Fig. 1. A design showing the functional dimensions of a part.

Suppose that, for the purpose of manufacturing those parts, the manufacturing people in the factory request that the print, as used in the process, be modified so that all the dimensions are taken from the left end of the part, as shown in figure 2.

It is clear that the nominal dimensions can be 10, 20 and 30 mm. The question that is unclear is how the values of tolerances are affected by the change in dimensioning. The new tolerances are represented by the variables x , y and z , as indicated in figure 2. It is the purpose of this article to show how the new values for the tolerances can be calculated.

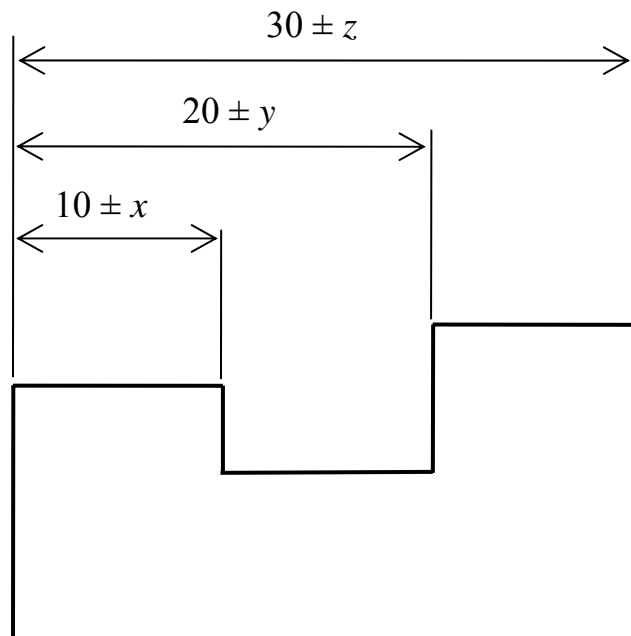


Fig. 2. The design is changed, to show all the dimensions measured from the left end of the part.

The two dimensions that have been replaced still must be met, as they were in the original design. The tolerances in the modified drawing will have to be such that conditions *A* y *B*, as shown in figure 3, have to be the result of the calculations for the new tolerances.

Let's suppose that –in a first approach– we decide that the tolerance for 10 mm (variable *x*) will be half of that for 20 mm (variable *y*), and then it would be fair to give the dimension of 30 mm a tolerance *z* that is three times the value of *x*. Somehow it makes sense to assign tolerance values that are directly proportional to the magnitude of the nominal dimensions. A better approach would be to assign tolerances following the practices of the ISO system of limits and fits, but let's assume that we are satisfied now by making the tolerances proportional to the nominal dimensions, in a first approach to the problem. It will be shown that this leads to a problem. Thus, we would have the following equations:

$$y = 2x \quad [1]$$

$$z = 3x \quad [2]$$

The values of conditions *A* and *B* are those originally specified in the original design.

$$\begin{aligned} \text{Condition A (maximum value)} &= 10.1 = A_{\text{MAX}} \\ \text{Condition A (minimum value)} &= 9.9 = A_{\text{min}} \end{aligned}$$

and the same values apply in this case for condition *B*, by design. $B_{\text{MAX}} = 11.1$, $B_{\text{min}} = 9.9$ mm.

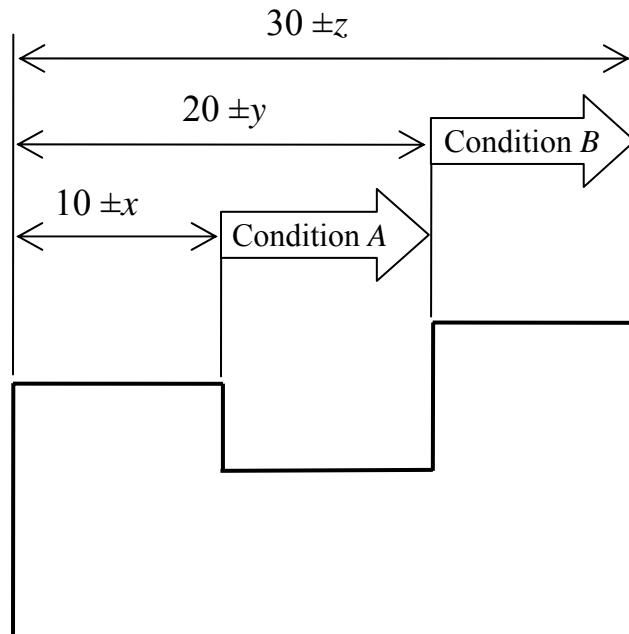


Fig. 3. The dimensions that have been replaced in the original design still have to be met, and are now conditions *A* and *B*, indicated with block arrows in this figure.

It must be kept clear that conditions *A* and *B* will no longer appear in the design that must be produced in the shop floor; the manufacturing process can be done according to the instructions on the shop floor, but the inspection must comply with what is specified in figure 1.

From figure 3, we can see that satisfying condition *A* implies the following expressions:

$$(20 + y) - (10 - x) \leq A_{\text{MAX}} = 10.1 \quad [3]$$

$$(20 - y) - (10 + x) \geq A_{\text{min}} = 9.9 \quad [4]$$

In order to specify condition *B*, we write the next two equations:

$$(30 + z) - (20 - y) \leq B_{\text{MAX}} = 10.1 \quad [5]$$

$$(30 - z) - (20 + y) \geq B_{\text{min}} = 9.9 \quad [6]$$

In order to find our resulting system of constraints, by summarizing the previous six expressions and doing a little algebra, from equations 1 and 2:

$$2x - y = 0 \quad [7]$$

$$3x - z = 0 \quad [8]$$

And from inequations 3 to 6, only two independent expressions are obtained:

$$x + y \leq 0.1 \quad [9]$$

$$y + z \leq 0.1 \quad [10]$$

Two expressions are obtained because the tolerances are symmetric, indicated by use of the \pm sign in the specifications of tolerance.

The resulting expressions can be presented as a system of four expressions with three unknowns, as follows:

$$2x - y = 0 \quad [7]$$

$$3x - z = 0 \quad [8]$$

$$x + y \leq 0.1 \quad [9]$$

$$y + z \leq 0.1 \quad [10]$$

This system seems to be overconstrained. There are more mathematical constraints than variables. Sound judgment has to be applied to solve it. There are standard mathematical procedures that were developed to deal with this kind of problems, but fortunately this one is easy enough to be solved without resource to advanced knowledge.

Now it is only necessary to realize that constraints [9] and [10] are more important, for the purpose of complying with the design specifications shown in figure 1, than equations [7] and [8], since these latter equations were only suggested by intuition or common sense.

An easy way to work around the problem is to replace equations [7] and [8] by the following requirements:

$$x \leq y \quad [11]$$

$$y \leq z \quad [12]$$

In the following section it will be shown that a valid solution could be given by $x = 0.4$, $y = 0.4$ and $z = 0.6$ mm.

Results

Figure 4 shows a result that is consistent with the previous calculations. It can be easily verified that conditions *A* and *B* are met.

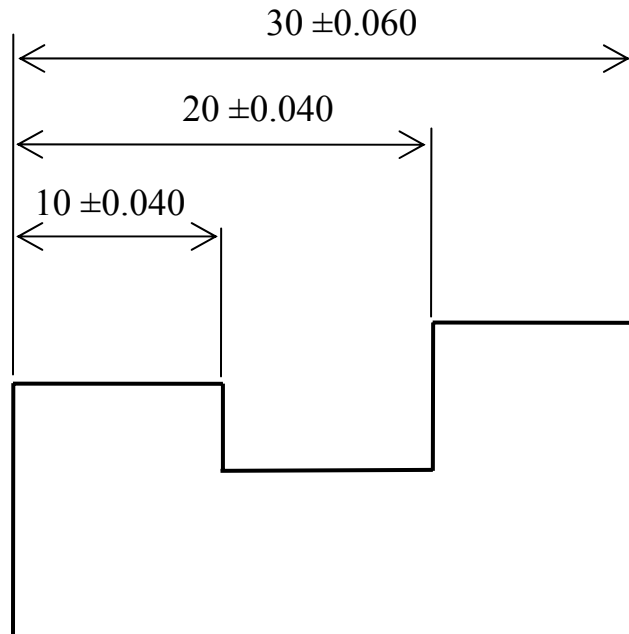


Fig. 4. Shown here are the results of the calculations for transfer of dimensions with tolerances.

Figure 4 complies with the design specifications that were shown in figure 1. However, figure 1 is not equivalent to figure 4. The relationship of equivalence or compliance works only in one direction.

It must also be noticed that sizable portions of the tolerances originally specified in figure 1 are no longer available for the process, after dimensions have been transferred. This is an unavoidable result of transferring dimensions with tolerances. The smallest dimension, which originally was 10 ± 0.1 mm, has now been transferred to become 10 ± 0.04 mm, thus giving up 60% of the tolerance.

Conclusion

Transferring dimensions with tolerances is sometimes unavoidable, when the manufacturing process requires the transfer to be done, in order to make some process possible. Sometimes the transfer is only convenient for purposes of inspection. The least expensive manufacturing process is often that in which the transfer of design specifications can be avoided altogether. Practical examples will be presented in successive articles.

The motivation to write this article came from multiple occasions in which the author, when inquiring practicing engineers in industry, professors in academia or engineering students, has presented the problem of transferring the design specifications shown in figure 1 to the form of figure 2. Unfortunately quite often the quick answer has been as shown in figure 5, which is incorrect, as the reader can now see.

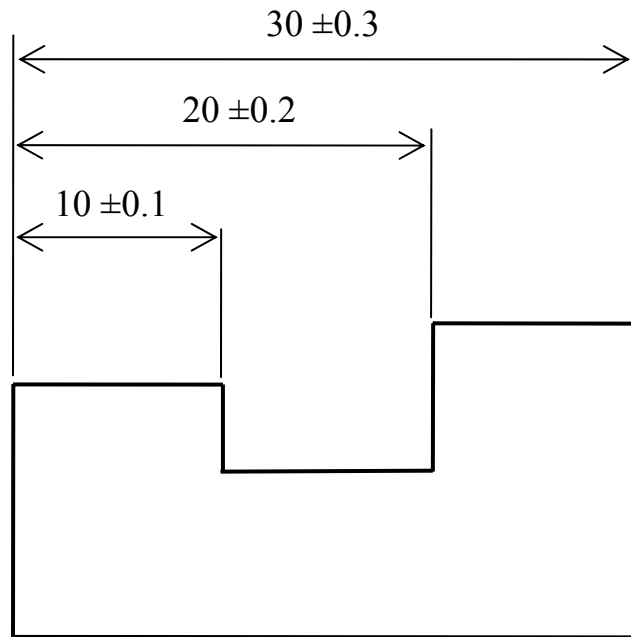


Fig. 5. An incorrect solution to the problem.

The author of this article has often encountered quality problems in manufacturing industries, problems that can be traced back to inappropriate knowledge of the little known – albeit simple – subject of transfer of dimensions.

Referentes:

1. Jiménez, Pierre. *Acotación Funcional*. Ed. Limusa, México, 1985.