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Flexible tolerancing: A first step towards the use of nonlinear simulation of assembly

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Summary

In order to combine the lightweight and the stiffness of aeronautic structures in spite of their large size, they are built up by assembling many parts, one or two dimensions of which are much smaller than the others (beam, shells). As a consequence, assembling processes are difficult because of the flexibility of the parts. They can bend out under their own weight, which makes it necessary to use a lot of equipment, assembling jigs and clamping fixtures. Furthermore, many parts must be bent by clamping action before being assembled with fasteners. These assemblies have a high degree of static indeterminacy and are so complex that traditional methods of tolerancing can generate tolerances which are too tight for manufacturers [3] because the main assumption is that parts are infinitely rigid. The behavior of the structures is rarely simulated for tolerancing [5].

The point is to improve tolerancing tools with methods taking into account the flexibility of the parts [2] and the flexibility of the linkage devices, and to define the assemblability by mechanical criteria in addition to usual geometrical criteria. To that end, the parts of the structure are modelled in finite elements, linkage devices are modelled by connectors between nodes, and the assembling process is simulated. Geometrical defects are taken into account by varying the coordinates of the nodes in the meshing. Generally, flexible tolerancing methods simulate assembling processes by supposing linear assembly behavior and considering small displacements. It allows to assume that forces and displacements are proportional with geometrical defects. Thanks to the knowledge of influence coefficients [1] and assemblability criteria, boundaries of the tolerance regions can be calculated [6]. But in certain cases, linear behavior isn't realistic enough, especially when there are clearances in the linkages and contact uncertainties [4]. In these cases, it's necessary to consider the assembling process as a nonlinear problem. Indeed, computing contact behavior involves using a large displacement formulation. That's why the use of a finite element software is justified for the simulations. Thus a flexible tolerancing tool can be obtained by coupling this software to a statistical

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tool able to manage geometrical variations and simulation results.

The usual method has been applied on a basic example representative of the assembly of a fuselage skin. It consists in assembling a large curved panel on a rigid frame with nine fixtures. The panel is prone to two types of defects, twisting and canning. Each is defined by a limited value as an imput variables. The stress on the fixtures and geometrical deviations are observed as variables of interest and compared with the results of the other method which consists in coupling a statistical tool and a finite element software. The main difference between these approaches is the update of the stiffness matrix after implementing geometrical defects. In fact, using finite element software allows to compute the matrix easily for each draw of imput variables. This application is a first step towards nonlinear flexible tolerancing.

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