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Numerical process based on measuring data for gap prediction of an assembly

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Abstract

The assembly stages enhancement is an important economic challenge for aeronautics industries. After the pre-assembly, gaps exist between components because of compliance and geometrical defects of components. Assembly requirements impose to fill these gaps, without installing internal stresses. A shimming step is currently necessary. It needs gaps measurement, which was identified as a problematic and expensive non-added value stage. Thus the trend is at gap prediction in order to remove gap measurement operations. This paper develops a numerical process allowing predicting gap before assembly step from component measurements. The main issue relates to the integration of measuring data into simulation process. Gap prediction stage is firstly located into the assembly process, in order to define constraints about gap representation. Then gap prediction process principle is detailed, highlighting measuring data integration. This method was subjected to an experimental validation. The entire process was carried out, from component measurement to gap prediction. Several comparisons were achieved to characterize the predicted gap.

Keywords: Assembly; gap prediction; optical measurement; geometric characteristics

1. Introduction

In the aeronautical industry, the tendency is at low fuel consumption, with works on weight reduction. The choice of industrials especially focused on composite materials and hybrid structures, which are more lightweight for equivalent mechanical characteristics. However the use of composite requires the limitation of internal stresses into the assembly in order to ensure the integrity of this one. Thus it is necessary to control the geometrical quality of components and assembly to avoid internal stresses installation during assembly steps. Even so geometric quality control doesn't prevent the resort to expensive non-added value operations. Some research institutes and companies gathered together within the European LOCOMACHS project [1], in order to find alternatives.

For example, considering aeronautic structure components, they are often large, thin and compliant. Moreover components positioning's on assembly tools are over-constrained. Thus all these things do so that gaps exist between the components, at the pre-assembly stage, as it is illustrated on figure 1.

The current solution in aeronautic industry is to proceed to shimming operations during the assembly process, in order to fill these gaps and to avoid too high stresses. Shimming step requires first gaps evaluation, visible on figure 2 (a). Gaps are currently evaluated by direct measurement. Unfortunately this gaps measurement step is counterproductive: it requires a lot of direct gap measurements at the interfaces – using standard shims set or a capacitance measuring device –, it is not systematic, sometimes iterative, and it is time consuming and

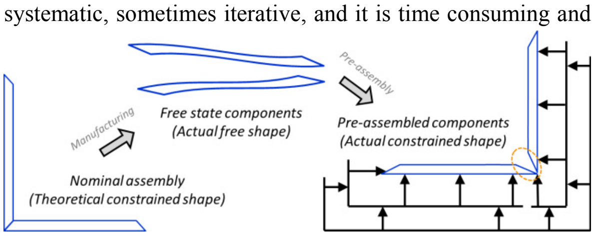

Fig. 1: Gaps origin during pre-assembly process.

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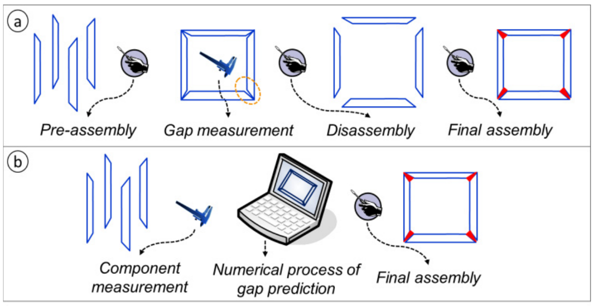

Fig. 2: Current (a) and planned (b) processes.

costly. This gaps measurement step is so considered as an expensive non-added value operation.

Some works are therefore related to the shimming process modification. A followed way, regarding the work presented in this paper, is to replace gap measurement operation by gap prediction between components. The main purpose is to remove gap measurement stage, which is time consuming. The planned process is visible on figure 2 (b).

In order that this gap prediction be significant, it requires the improvement of assembly behavior simulations, especially integrating physical measuring data. This allows representing the components actual geometry, at least characteristics that are considered as relevant towards simulation objectives.

So the idea is to foresee the gap, before or during the assembly step, from measuring data stemming from alone components or partial assembly. This paper particularly focuses on the measuring data integration with a view to the gap prediction. Assembly simulation process and shim manufacturing process are not detailed in this paper.

In section 2, constraints about gap representation are exposed, and related works are analyzed. Then in section 3 gap prediction process principle is presented. Successive steps are then detailed, and uncertainty sources are stated. Next in section 4 assumptions allowing validating the numerical process are detailed. A use case is then presented and validation ways are analyzed. Finally works are summarized in the conclusion and some outlooks are proposed.

2. Constraints about gap representation

First it is necessary to define the notion of gap. Indeed the simulation phase involves predicting the gap geometry between components, and the manufacturing phase entails producing the shim corresponding to the predicted gap and realizing the assembly. Thus the gap geometry is the link between assembly simulation and shim manufacturing processes. This geometry representation way is constraint by the two processes.

We propose a general gap definition. The gap is: *the clear space between two parts of an assembly*. The main issue is then to characterize this physical clear space. Several modeling ways are possible, considering the gap geometry as: a mean distance between surfaces, a set of distances between surfaces, bounds min and max, a volume, an enveloping volume…

Some works dealing with gap concept and ways to represent it can be found in the literature. First of all Giordano [2] introduced the *clearance space* concept. A *Clearance space* corresponds to a domain in which the functional characteristic has to be contained in order to the functional condition be verified. This modeling is well-adapted to analyze key characteristics influence on a mechanism behavior, with for example a statistical approach. Only ideal surfaces are considered. Shape deviations are not taken into account.

Moreover Teissandier [3] introduced the *U.P.E.L.* concept. It characterizes bounds of displacement between two ideal surfaces. It can be extended to the characterization of relative position between two ideal surfaces of two different parts.

Then Bourdet [4] present an analyzing tool of the defects spreading within assemblies. In particular modeling is based on *joint deviation torsor* concept [5], representing deviations induced by a joint. Here also only substituted ideal surfaces are considered.

The *GeoSpelling* model [6], based on geometrical operations which are applied on geometrical features, permits to represent any geometry. Indeed it rests upon the *skin model* concept [7], allowing considering these geometrical features as ideal or non-ideal, and even as continuous or discrete. The choice is function of the viewpoint or the objective to achieve. This approach permits to imagine geometries with defects, for specification and verification.

Likewise *modal* representation used by Samper [8] is a way to represent geometry with defects. This is a discrete representation, based on natural modes of an ideal surface. This kind of representation allows simulating assembly behavior whose components have defects. The assembly validity is checked using *deviation space* method [2]. Stricher [9] use the same representation method, preferring technological modes typical of geometrical defects commonly met on the components. Technological modes are built by linear combination of natural modes, and allow reducing the number of variables necessary to describe the shape.

Andolfatto [10] propose a method, rested on the concept of *deviation field based*, to model component geometrical deviations and joint deviations. This representation way allows unifying representation tools above-mentioned, using the same base of deviation fields. The main advantage is the ease to represent local and global defects with the same representation way.

Thus few work in the literature address the gap concept with a discrete viewpoint. For example Franciosa [11] study a welding process of compliant assemblies. Geometrical defects on components induce gaps between them. A point-to-point distance, evaluated comparing nominal and actual geometries, is used to represent this gap. This gap modeling assumes that welding guns positions are precisely known.

Likewise Huang [12] study the gap-closing process in assemblies using a discrete viewpoint. Starting from a gap as input, he simulates the gap-closing process and analyzes deformations and lock-in stresses produced during this operation. In order to do this, he considers the gap as a set of point-to-point distances.

This representation way seems to be adapted to the issue addressed in this paper. Indeed the fact of using Finite Element simulation Method requires a data modeling