

Methodology for Classification of Shim Materials

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ABSTRACT

As a result of the increasing use of fibre reinforced plastic (FRP) components in a modern commercial aircraft, manufacturers are facing new challenges - especially with regards to the realisation of significant build rates. One challenge is the larger variation of the thickness of FRP components compared with metal parts that can normally be manufactured within a very narrow thickness tolerance bandwidth. The larger thickness variation of composite structures has an impact on the shape of the component and especially on the surfaces intended to be joined together with other components. As a result, gaps between the components to be assembled could be encountered. However, from a structural point of view, gaps can only be accepted to a certain extent in order to maintain the structural integrity of the joint. Today's state of the art technologies to close gaps between FRP structures comprise shimming methods using liquid and solid shims. Another option is the use of peelable shims that offer significant economic benefits compared with liquid and solid shims. However, the influence of different peelable shim materials on the bolted joint performance is still a subject of investigation - especially with regards to chemical resistance.

Therefore a larger investigation campaign has been initiated in order to establish a comprehensive description methodology for shims that would enable an optimised application-related selection of shim types and materials in terms of mechanical, chemical manufacturing performance and costs.

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INTRODUCTION

Liquid shims are typically structural adhesives with a high compressive strength and good chemical resistance. Liquid shims require a certain curing time to achieve the final strength. In order to ensure the material performance, the application process is complex and consists of multiple steps that require close control of several parameters such as temperature, humidity and surface quality.

Solid shims are solid monolithic elements made from metal or composite material. Very often, these parts have to be available in different thicknesses and shapes, depending from the measured gap dimensions (topography). This is preventing any effective standardisation as well as sourcing in high and cost efficient quantities. Solid shims require to be held on stock in significant numbers in all variations and block space and capital, therefore.

Peelable shims, or peel shims, consist of several individual layers of material that are attached by means of a non-structural adhesive. The thickness of the shim can be adapted by peeling down layer by layer until the desired thickness is obtained. Peel shims are recognised for offering benefits such as significant lead time reduction in the assembly process (zero curing time) and an optimisation of the stock concept as well as lower costs compared with tailored solid shim alternatives. However, there are some technical aspects for peel shims such as temperature range, chemical resistance and limited interlaminar shear strength which may prevent their use in specific areas.

In order to guide the designer to the most appropriate shim based on the given parameters a methodology has been developed that enables a classification of shims according to their key characteristics (see [Figure 1](#)).



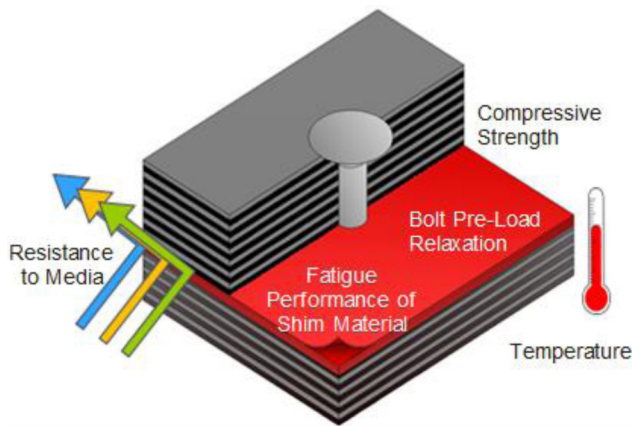


Figure 1. Key characteristics required for classification of shims

A test campaign was undertaken by Airbus in order to identify and cover all required parameters that would enable a comprehensive description and comparison among different shim types, materials and their application.

This paper contains a proposal for a methodology for the classification of a certain application requiring shimming that enables the selection of the most appropriate shim material for civil aerospace applications. It also contains a proposal of a generic approach on how to test new shim materials (especially peelable shims) in order to obtain their key characteristics.

CLASSIFICATION OF APPLICATION TO BE SHIMMED

Today's market is offering a huge quantity of various shim materials so that design or production can choose between different types of liquid, solid or peelable shims. The classification of the application and a subsequent analysis of advantages and drawbacks shall enable a shim selection that is optimized with regards to performance and costs. This methodology shall prevent situations too costly materials were selected when a lower cost solution would have been available. Costs are further understood as direct costs associated with the procurement of the material but also related to manufacturing operations and downtime (e.g. due to curing time) of the component.

It is proposed to classify the concerned application based on the following characteristics:

1. operating temperature,
2. gap topography,
3. compressive strength,
4. shear loads (static and fatigue),
5. fire, smoke and toxicity (FST),
6. chemical resistance,
7. material compatibility,
8. weight,
9. cost,
10. installation time.

These ten characteristics can be bundled in four groups:

- I. Main design conditions:
 1. *operating temperature range*,
 2. *gap topography*
- II. Mechanical conditions:
 3. *compressive strength*,
 4. *shear loads*
- III. Environmental conditions:
 5. *fire, smoke and toxicity (FST)*,
 6. *chemical resistance*
- IV. Added value:
 7. *material compatibility*,
 8. *weight*,
 9. *costs*,
 10. *installation time*.

In a first step, the operating temperature and the gap topography shall be established. The main design condition class can be taken from the matrix in [Table 1](#).

Table 1. Main design conditions

OPERATING TEMPERATURE	-55°C to 250°C	A	D	G
	-55°C to 120°C	B	E	H
	-55°C to 85°C	C	F	I
		parallel	tapered	Inconsistent
GAP TOPOGRAPHY				

Airbus has conducted a test campaign to determine the performance of various shims related to applicable topographies and temperatures. As indicated in [Table 2](#), there is yet no technical solution for class G available.

Table 2. Main design conditions - shim mapping

OPERATING TEMPERATURE	-55°C to 250°C	A	D	G
	-55°C to 120°C	B	E	H
	-55°C to 85°C	C	F	I
		parallel	tapered	Irregular
GAP TOPOGRAPHY				

Solid Shim (green dashed box around G, H, I)
 Peel Shim (blue dashed box around A, B, C)
 Liquid Shim (red dashed box around D, E, F)

A further classification of the application is then done in a second and third step by using the following two matrices (Table 3 and Table 4) which are covering the mechanical and environmental conditions.

Table 3. Mechanical conditions

Shear loads possible	4	5	6
No/negligible shear loads	1	2	3
	< 85	< 150	< 400
COMPRESSIVE STRESS (in MPa)			

The compressive stress is a function of fastener preload, axial loading and joint thickness. As proposed in Table 3 the compressive stress level could be split in three groups. Liquid shims for example have lower compressive strength properties compared to metallic shims. Therefore, liquid shims could potentially be allocated to class [1;2;4;5], but they are typically too weak for class [3;6].

In terms of environmental conditions (see Table 4) it shall be assessed whether or not fire, smoke & toxicity is relevant (e.g. in pressurized cabin areas) and with which kind of media the shim could contact in service.

Table 4. Environmental conditions

FST not relevant	4	5	6
FST relevant	1	2	3
	Water, Anti-icing liquid	Water, Anti-icing liquid, Skydrol	Water, Anti-icing liquid, Skydrol, Fuel
CHEMICAL RESISTANCE			

Based on these three matrices designer can classify their requirements on shim materials based on the specific application. The classification is in the end containing the results derived by the assessment of these three matrices and is then consisting out of three digits, for instance: Class F54.

Two exemplarily assessments are provided below:

Example 1: Shim required for high load applications

Main design conditions:

- temperature up to 232C°
 - gap topography: parallel
- Class Axx

Mechanical conditions:

- Shear loads possible
 - Compressive strength: 350MPa
- Class A6x

Environmental conditions:

- No FST requirements
 - Contamination with water, anti-icing liquid, skydrol and fuel is possible
- Class A66

For this specific case a shim material that covers class A66 requirements would be a solution.

Example 2: Shim required to align non-structural components

Main design conditions:

- temperature up to 76°C
 - gap topography: parallel
- Class Cxx

Mechanical conditions:

- No shear loads expected
 - Compressive strength below 70 MPa
- Class C1x

Environmental conditions:

- FST requirements apply
 - Contamination with water and anti-icing liquid is possible
- Class C11

For this specific case shim materials that comply with class C11 can be used.

If there are several shims meeting the requirements the objective is to choose the one with the lowest risk of galvanic corrosion, the lowest weight, cost and installation time. This analysis can be done using Table 5 for instance, which is summarizing the advantages and drawbacks of different shimming materials. The assessment in Table 5 is based on an assumption to explain the general idea, but shall not be considered as universally applicable.

After consulting Table 5 with example 2 (align non-structural components) the recommendation would be to select a PET peel shim as this does not contribute to galvanic corrosion, it has a low density (low weight), the material price is very low and furthermore the installation time is considered as low.