

Blind Bolts Developments

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ABSTRACT

There is an ever growing demand for blind fastener in the aerospace industry. This demand is driven not only by the advantages of single sided installation, but also by the potential to fully automate their installation process.

Blind fasteners can easily be integrated with innovative end-effectors that combine drilling, installation and inspection systems, enabling the reduction of process cycle times and their associated cost savings.

Clearly the advantages of single sided installation are a key benefit, but it cannot be forgotten that currently the mechanical performance of these systems is reduced compared with conventional threaded or swaged parallel shank fasteners. There are other important drawbacks existing around them which could penalise significantly the optimised design and performance of the structures.

Specific key characteristics that take into account some of these drawbacks have been established by Airbus which will be referenced in this paper.

Recently some improvements in new system concepts based on the typical pull and threaded type versions have been achieved by the main aerospace fastener suppliers, based on better mechanical performance, improved cosmetic appearance of the fastener head, etc.

This paper will give a global view of the characteristics that are considered more important for evaluation of the next generation of blind systems to allow their optimised implementation on new applications as well as a chance to view some new systems developed by the Suppliers.

1. INTRODUCTION

A significant increase in demand for blind bolt fasteners is expected in the aerospace industry, not only due to their ability to be installed from only one side of the structure, or their clear advantage where it is necessary to join components with no access from the opposite side (no possibility of installing two-part fasteners), but for the ease at which they can be implemented on robotic systems (anthropomorphic robots as well as parallel kinematics mechanisms) enabling their installation processes to be completely automated.

These advantages together with the general capability that automatic systems provide in performing all the various steps that comprise a typical assembly process (correct positioning of the end-effectors, drilling/countersinking, fastener grip length measurement, sealant application for wet installations, fastener selection and loading, fastener installation, dedicated inspection systems, etc.) present a multitude of opportunities from the use of these systems, leading to a key benefit based on process time/cost reduction. In summary, these fasteners provide the possibility of a full implementation of what it is called "One Side Assembly" plus "One Way Assembly" ("OSA" + "OWA") processes.

However these fastening systems currently present specific drawbacks compared with conventional two-part fastening systems which must be taken into account during the design of the structures as they could penalise significantly optimised designs as well as structure performance.

Specific "Key Characteristics" (KC) were established by Airbus to simplify the evaluation and analysis of any blind system (applications on specific structures or components, etc.). These "key characteristics" are presented in this technical paper with the aim that they are considered for new developments.

In Addition, based on these KCs, Airbus presented to the fastener suppliers a series of target requirements and improvement proposals to enable them to develop new systems to enable to extend the use of blind fasteners on new applications and installation processes along with the subsequent associated benefits for all aerospace component manufacturers. From these new requirements new blind systems are currently being developed by several fastener suppliers. Some proposals, corresponding to the suppliers “Alcoa Fastening Systems” (AFS) and “Monogram Aerospace Fasteners” (MAF) shall be presented as examples in this paper for illustrations purposes only.

2. BLIND FASTENERS

The use of blind fasteners offers clear benefits regarding the installation processes, however there are specific drawbacks which must be considered during the design of the structure, and the feasibility of specific applications for which the fasteners are aimed to be used should be considered beforehand.

These drawbacks are not only confined to the reduced mechanical properties of these systems compared with conventional threaded or swaged parallel shank fasteners, but with others related to the cosmetic aspect of their countersunk heads, blind side geometry, inspectionability, etc., affecting directly the performance of the structure (mechanical, aerodynamic, and visual requirements). The development of new blind fasteners in an attempt to overcome these drawbacks will allow an extension of their use to potential new applications as well as by replacing conventional non-blind fasteners on current ones.

Based on these drawbacks, Airbus has established specific “Key Characteristics” to be considered when evaluating and analysing blind systems. They refer mainly to the “correct understanding of the forming process sequence”; blind side ring (geometry and dimensions); “possibilities for Inspection”; “Positive locking”; “Mechanical performance and failure modes”; “Visual quality”. The KCs are described in the following paragraphs.

Note: Data indicated in this document is given as reference (rough figures) and it must not be used for any purpose other than to understand what is indicated in this technical paper. Except where otherwise indicated (new developments from the Suppliers) the data corresponds to two typical blind fasteners used in the aeronautic industry taken as reference to compare with new systems. One of these blind fasteners corresponds to a “Threaded-type” made from Ti (external body), cres (corebolt or spindle), and stainless steel (blind sleeve), with the trademark “Composi-Lok®” or “Accu-Lok®” in function of their manufacturers (MAF & AFS); the other system corresponds to a “Pull-type” fastener, all its

components are made of cres material, and has the trade mark “Unimatic®” (AFS). Both systems were developed in the past to be installed on composite and/or metallic materials.

2.1. “Key Characteristics (KCs)”

2.1.1. Forming Process sequence

A good knowledge of the installation process of a blind fastener and the kinematics of its parts is very helpful to understand what the behaviour of the system will be in its intended application as well as of possible issues that can occur during the life of the component.

The mechanism by which the blind side is formed on the opposite side has an influence on its final geometry/ dimensions, and the possibility of cracking during the deformation process, and the radial expansion of the shank, etc. The use of the above considerations, can establish possible failure modes, and highlight limitations regarding its compatibility with metals or composite components, etc.

Figure-1 shows typical sections corresponding to those systems indicated in the previous section taken as reference, currently being installed. For “Threaded-type” fasteners, the installation is performed by threading the inner corebolt (spindle) on the shank of the bolt (also known as the nut). During the rotation, the blind side is formed (Figure-2) until a specific tightening torque is reached, then the corebolt breaks-off leaving the fastener installed. Locking of the system is achieved by means of three indentations around the periphery of the shank (nut) which induce a local plastic deformation of the inner thread preventing the screw from loosening.

The installation process for “Pull-type” fasteners differs from that of the “Threaded-type” in the way in which the inner spindle moves along the axis of the fastener forming the blind side until a specific position is reached. A collar is inserted in a recess around the head for locking purposes, and then the spindle breaks-off leaving the fastener fully installed.

The likely defects that can appear depending on the specific installation process are shown in Figure-3.

“Threaded” blind fasteners may induce plastic deformation on the plate where the blind side comes to bear, in the vicinity of the blind sleeve contacting the plate (in the case of the photograph the plate is made from Al). A large footprint (blind diameter) that a fastener presents after its installation is a good indicator of good performance in e.g. composite structures, avoiding ply delaminations and the possibility of “pull-through” failure mode. The shape of the blind part shows that it can suffer a significant deformation under tension loads, until the preload value is reached, which

signifies that beyond this value the fastener can be “lost” (no preload in the system) affecting the fatigue life of the joint.

On other hand, taking a look to the blind side of the “Pull-type” fasteners, around the hole exit, it is possible to foresee a high level of stress concentration around this area, that as a function of the fastener and component materials can be a possible indicator of its incompatibility with composite structures (ply delaminations could appear around this area). Moreover, these fasteners present a smaller blind diameter than the threaded-types that could lead to “Pull-through” failure modes in specific cases.

In summary, a correct evaluation of the “Forming Process Sequence” is a very good indicator of the mechanical behaviour that the system under evaluation can exhibit when used on metallic, composite or hybrid structures, as well as of possible failure modes as a function of the type and level of load, etc.

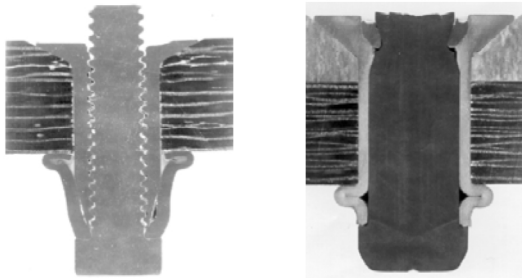


Figure 1. Typical installation of a “Threaded-type” and a “Pull-type” Blind Fastener

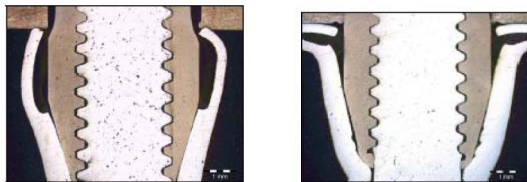


Figure 2. “Threaded-type” Blind Fastener - Blind side forming process

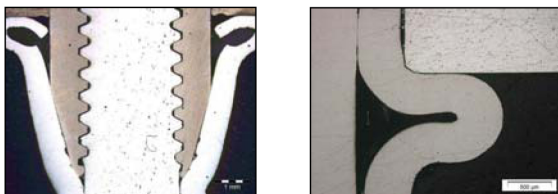


Figure 3. “Threaded and Pull-types” Blind Fasteners - Possible defects during the installation

2.1.2. Blind Side evaluation

Two characteristics shall be considered in the evaluation of the opposite side of the fastener and how it can affect the performance of the structure.

The first one shall be to assess the probability of the development of cracks in the blind area due to the large deformation that it undergoes during the installation process as well as of their size (Figure-4). In function of the applied loads, the cracks may propagate due to vibrations and loads applied leading to the possibility of producing a typical fatigue failure.

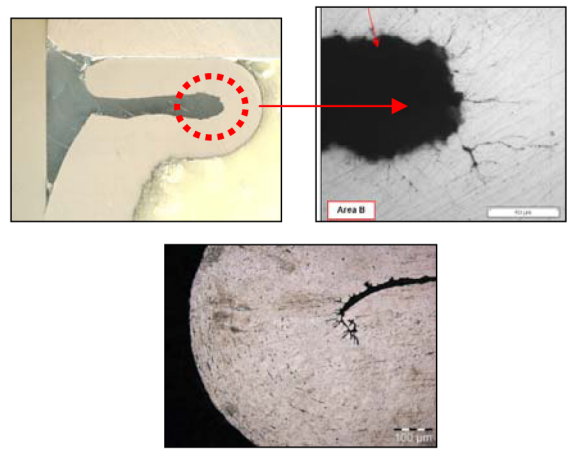


Figure 4. Cracks inside the blind side caused during the installation process

Another important parameter that should be checked is the “footprint diameter” / “shank diameter ratio”. This parameter determines the possible application of the fastener on composite, metallic or hybrid structures as well as possible failure modes. The bigger it is, the better the behaviour of the fastener will be on composite applications due to the larger bearing area under the blind part giving better stress distribution - and additionally, the higher the resistance to “Pull-through” will be.

An optimised value for this ratio depends on the type of materials to be joined, thicknesses, applied loads, etc., but Airbus has established “1.5” as a reference, for composite applications.

2.1.3. Inspect ability

Blind fasteners are not easy to inspect and wherever possible, inspections on them do not guarantee a high level of confidence that the installation has been performed correctly.

Several inspection possibilities exist depending on of the fastener type (e.g. checking of the protrusion/intrusion of the fastener core bolt break-off limits; measurement of possible under head gaps; seating and dimensional finish of the

formed head on the structure, etc.) but as it is not possible to check every fastener because generally these fasteners are installed in areas with little or no access to the blind side of the structure, none of the possible inspection methods currently guarantees a 100% level of confidence in the integrity of the installation.

Moreover, fasteners without the need to shave the spindle after their installation are being requested ever more and more to reduce process time and cost. This option removes the ability to inspect the protrusion/intrusion of the spindle making quality control more difficult.

The application of any existing inspection method as well as the development of any new one (monitoring of load-displacement or load-rotation angle during the process installation; unseating torque after installation; spindle protrusion before shaving, etc.) is of fundamental importance for blind fasteners. An example of a typical installation defect that is difficult to detect is related to the anomaly that it is entirely possible for specific “Pull-type” fasteners to be installed in “fresh air” showing a perfect final geometry at the end of the process (Figure-5, left). By considering that this fastener breaks flush regarding its head-component surface, and whether there is no access to the blind side, the installation would look perfect but the fastener would remain totally lost (no joint). When “threaded-type” fasteners are installed in “fresh air” to evaluate whether it is possible, it is clearly visible that it is incorrect (see Figure-5, right).

The setting of a fastener during installation shall ensure that clamping is achieved to guarantee the requested level of preload. This is a key parameter for blind systems.

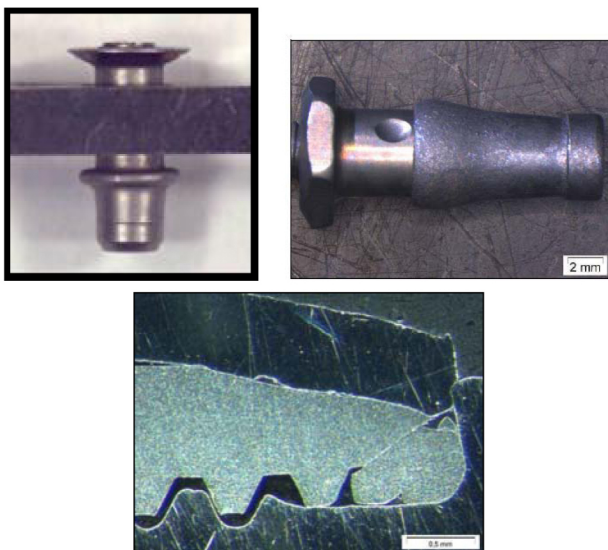


Figure 5. Possibilities of installation in “fresh air” (left: “Pull-type”; right: “Threaded-type”)

2.1.4. Positive locking

Blind fasteners must possess a means of positive locking using a mechanical or friction mechanism. The type of locking is very important as it can limit possible applications of the fastener (e.g.: friction locking fasteners must not be used in areas where their parts could be loosened by interactions with other components in the vicinity, etc.).

Figure-6 shows a typical locking feature consisting of three indentations located approximately 120° apart on the periphery of the nut of a “threaded-type” fastener. These indentations induce a local plastic deformation of the inner thread preventing the screw (“core bolt” or “spindle”) from loosening.

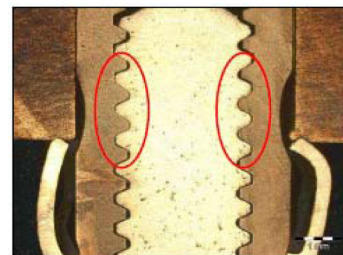


Figure 6. Typical “threaded-type” fastener locking feature

2.1.5. Mechanical performance and associated Failure Modes

A detailed understanding of the fastener mechanical performance is key to ensure they are used in the correct applications. In general the preload, tension, pull-through, and shear strength as well as the fatigue behaviour of the system, determined using generic representative joints and materials must be known prior to being able to perform any evaluation.

It must also be highlighted the importance of the evaluation of the mechanical characteristics together with the associated failure modes of the system.

The following are some examples of evaluations performed.

“Preload”

This characteristic is highly dependent on several factors such as friction between the various fastener components, sleeve forming process and loads, configuration and geometry, tightening speed, etc., and has a direct effect on the fatigue life of the component and joint assembly.

The preload is very dependant in function on the type of fastener and in general, for these specific systems is very low compared with “two-part” fasteners, with the requirement being around 10% to 20% of the ultimate tensile strength of