

Axial and Orbital Drilling of Thick Stacks for New Aircraft Assembly Process

Abdelatif Atarsia
Mapal Dr Kress KG

ABSTRACT

This technical paper deals with design and manufacture of axial and orbital cutters for drilling large diameters holes in Carbon Fiber Reinforced Plastics (CFRP) / Titanium (TA6V) thick stack by means of an Automated Drilling Unit fixed on a drilling template. Creating tools that drill such stacked holes in a single operation is particularly difficult. The common strategies for tool designs designated to cutting composites stacked with metals as titanium include uncoated carbide, tools with a diamond coating applied by chemical vapor deposition (CVD). It is also question of what kind of drilling process should we use to achieve larger holes in minimum time. Therefore, axial drilling process with pilot, drill and ream steps find a competitor drilling process named orbital drilling which can achieve both operations in one step allowing then, burrless, free delamination, small and easy removable chips all with one tool being able to achieve different hole sizes. The present study compares the quality of drilled holes in term of both materials hole diameters, exit burr and cycle time which become a decision gate for the process choice.

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INTRODUCTION

To increase aircraft efficiency and reduce lifecycle costs, aerospace industry is using more composites and titanium stacks, which exhibit high strength-to-density ratios and excellent mechanical properties in the extreme loading conditions. The hybrid structure of carbon fiber reinforced plastics composite (CFRP) and titanium (Ti) stack has been widely used due to its unique ability to withstand high stress in service. Due to the dissimilar machining characteristics of CFRP and Ti, the CFRP-Ti stack is very challenging to drill while manufacturing and assembling the aircraft structure. In addition to the challenge of drilling these dissimilar materials together, many following challenges arise in current aircraft assembly. They are drivers for increased performance and quality requirements from the drilling process. These drivers are the need to drill larger diameters and thicker stacks, the increased trend toward one-shot drilling, dry or near-dry machining and one-up assembly to reduce assembly time. Although there is increased use of both large- and small-scale automation, pneumatic drill motors are still primarily used in final assembly operations, and increased use of lean principles. These items all reduce tool life to the degree that a new cutting tool material is needed to reduce the cost per hole

and improve productivity. Another driver for longer tool life is decreased flow time in final assembly (1).

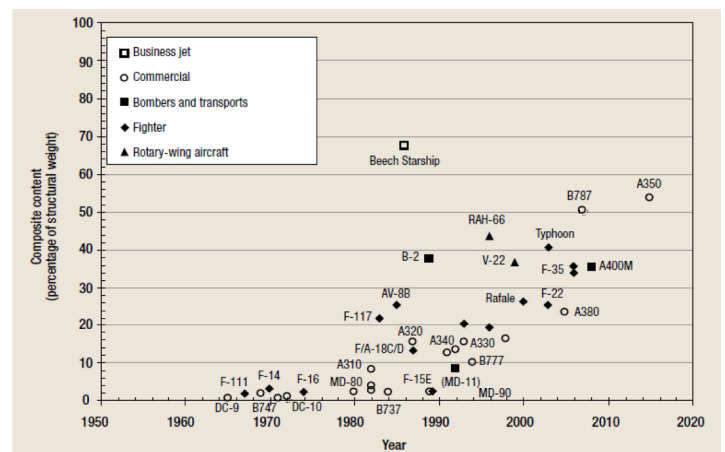


Figure 1. CFRP content in aircraft industry over time (1)

Figure 1 and 2 are nice pictures on how composites and titanium are used in new generation aircrafts compared to most aircrafts actually in service since many years. Using carbon fiber reinforced composites (CFRP) results in

hundreds of fasteners disappearance. However, a large number of holes left deals with stack drilling of CFRP with metallic materials such as titanium. Therefore, large diameter drilling in thick CFRP/Ti stacks becomes the biggest challenge in the new aircraft assembly process.

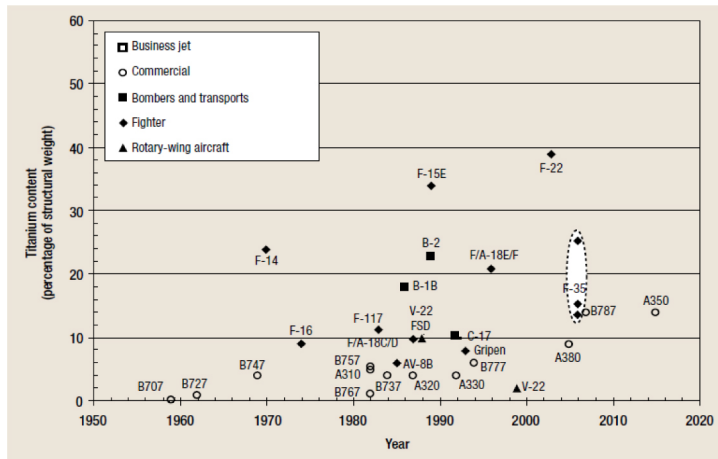


Figure 2. Titanium content in aircraft industry over time (1)

DRILLING CFRP/TITANIUM STACKS

Since automated Aerospace assembly sites are looking for one shot drilling CFRP/Ti stacks without any disassembly before riveting the structures, the drilling process development become much aggressive in term of cutter performance giving the highest number of holes according to final product specifications (PS). Therefore, final hole for all substrates (CFRP and Ti) has to be achieved according to diameter, entry & exit burr, delamination, surface roughness, countersink concentricity, in one shot which means one tool in minimum time.

Developing a cutter passes through identification and deep analysis of all physical aspects during the drilling of stack components separately then joined together. A first study conducted on barrier limit between drilling CFRP and metals as illustrated in figure 3 reveals that metal drilling as known since many decades is based on pure continuous mechanics, which is not the case when drilling CFRP. A cutter drilling very tough carbon fibre reinforced fully cured epoxy resin is working in most of the drilling process under fracture mechanics law. The fibres have to be aggressively broken but care must be taken to get a smooth final surface finish, which means, a well-established control of machining parameters as spindle speed and feed. At this point, cutter's geometry is developed taking the fibre type and properties as primary input. As an example, a multidirectional CFRP layout configuration does not have to be treated as a same case like a unidirectional fibre layout composites. Difference can be explained by the fact that, unidirectional layout has no support of fibre between each other like a woven or stitched and this aspect results in non-cut fibers and delamination.

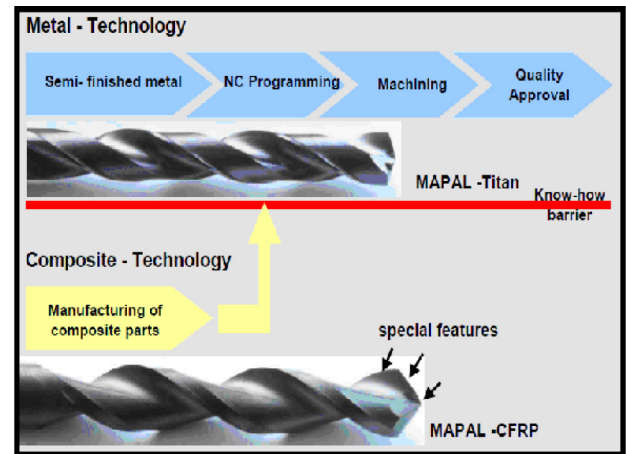


Figure 3. process know-how in machining metal vs. carbon fibre reinforced composites

On a second hand, stacking CFRP with metal to get a one shot drilling deals with material substrate behavior and response to drilling effort. CFRP material is well known as a very stiff with special thermal expansion behavior. Most of the studies revealed that drilling a CFRP substrate always bring the hole near the cutter diameter when the process is done properly. This is a result of a hole contraction against the cutter during the machining process. However, the same studies revealed also that metal drilling when conducted on titanium or aluminum leads to hole diameter larger than what is expected to be from the cutter diameter. Again, the phenomenon is purely physical when we look to thermal expansion and densities of these materials as figure 4 shows.

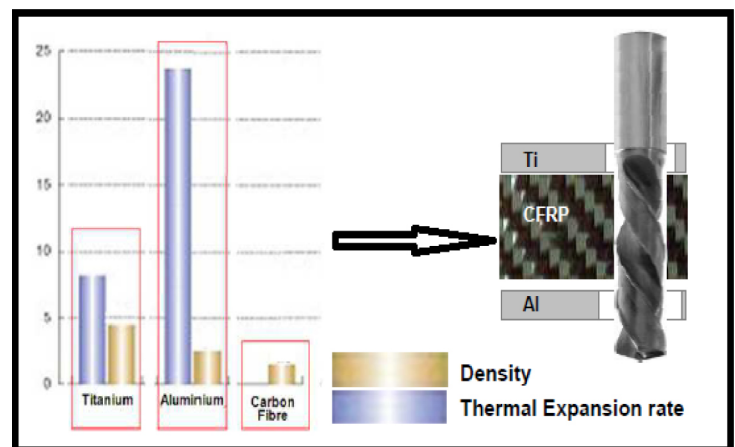


Figure 4. Effect of stacked material properties on final drilled hole diameter

For static and fatigue issues of the aircrafts structures, specifications for stack drilling require more and more tight tolerances for hole diameters and assembly purpose. H8 or H9 tolerances are well known to be hard to achieve in composite materials drilling and therefore, achieving H8 or H9 tolerance in a stack drilling was the mostly studied aspect