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Dry drilling of Fiber Metal Laminates CF/AA2024. A preliminary study

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Abstract. Carbon Fiber (CF)/Metallic Alloy (MA) laminar structures, also known as Fiber Metal Laminates (FML) allow diminishing the airship weight. Because of that the use of these materials is growing continuously in the aerospace industry. These composites materials need to be drilled because of the assembly requirements in the different airship elements. The most common problems that can appeared when those structures are machined are related with the interaction of the tool with dissimilar materials, which need different cutting parameters for the optimized machining process.

This work reports on the results about a study of the dry drilling processes of hybrid composites Carbon Fiber/aluminum alloy, and especially CF/AA2024.

Keywords: AA2024, CF/AA2024 Hybrid Composites, Dry drilling, FML

Introduction

When the weight of an airship is reduced, its capacity is increased, often without increasing, even diminishing, the energetic consumption. This weight reduction involves the application of new development lighter materials. Notwithstanding, the physicochemical properties of these materials must guarantee the maintenance of the security conditions.

By these reasons, new light materials are continuously been developed for being applied in the aeronautical industry.

In this context, Carbon Fiber (CF)/Metallic Alloy (MA) laminar structures, also known as Fiber Metal Laminates (FML) have been successfully tested as aerospace materials [1]. In effect, in the last years the use of FML in the airship building has highly. Nowadays, there are many elements of the airship which are complete or partially formed by this kind of materials. Fig. 1 shows their applications in different elements of some AIRBUS products.

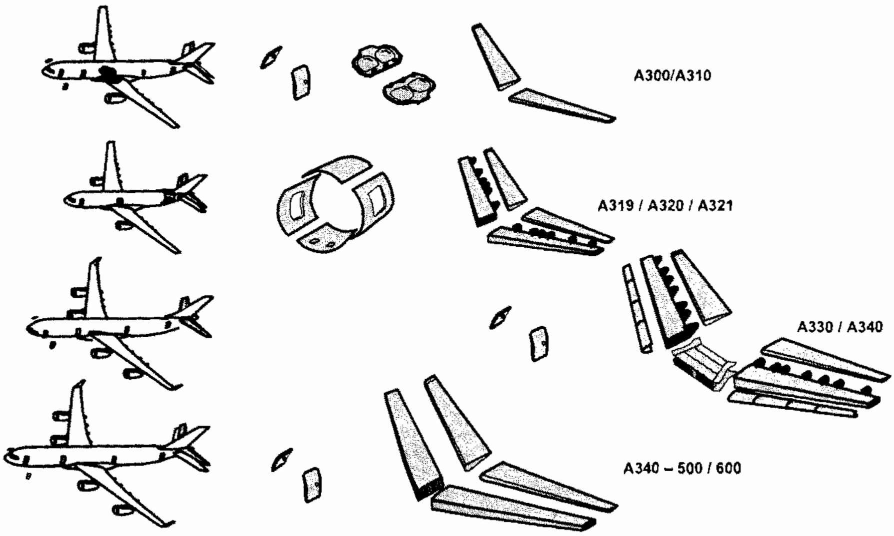

Fig. 1. Some examples of the FML's applications in the building of structural airship elements of AIRBUS.

Because of the assembly requirements in the different airship elements, the FC/MA laminar structures are usually subjected to different machining operations, mainly drilling. On the other hand, the environmental legislations has driven the machining procedures toward the application of cleaner technologies. So, the employment toxic cutting fluids (lubricants and/or coolants) must be minimised. In this way, dry machining has been promoted as an environmentally friendly alternative to classical machining processes which use those cutting fluids [2,3].

The most of troubles that can be produced in the dry drilling of FML's are commonly caused by the action of the tool over two or more materials with different mechanical properties. So, One Shoot Drylling (OSD) operations are rendered difficult by the dissimilarity between the optimized cutting parameters for each one of the materials that form the FML structure. This carries on the necessity of taking cutting parameters distinct of those selected for obtaining the required surface finishing in each material. This problem can be seen also complicated by the own characteristics of the process: tool geometry and material, automation level, etc.

This work reports on the results about a preliminary study of the dry drilling of CF/AA2024 FML's based on the surface finishing of the holes measured through roughness average, Ra.

Experimental Procedure

Carbon Fiber and AA2024 Aluminium-Copper alloy sheets with thickness between 4 and 8 mm were used as workpieces in this study. Nominal composition (mass percentage) has been included in Table I.

Table I. Alloy AA2024 composition (% mass)

Cu	Mg	Mn	Si	Fe	Zn	Ti	Cr	Al
4.00	1.50	0.60	0.50	0.50	0.25	0.15	0.10	Rest

From these sheets of both materials CF/AA2024 FML pairs were prepared with a mechanical jointing by using a vertical seizure pincers. This kind of joint is conditioned by the assembly requirements in some airship structural elements.
Dry drilling tests were conduced in a EMCO CNC Machining Center, VMC-300 model, equipped with a Siemens 810-M Numerical Control. Cutting speeds in the range 25-50 m/min and feeds between 0.05 and 0.2 mm/rev were employed as cutting parameters, Fig. 2(a).

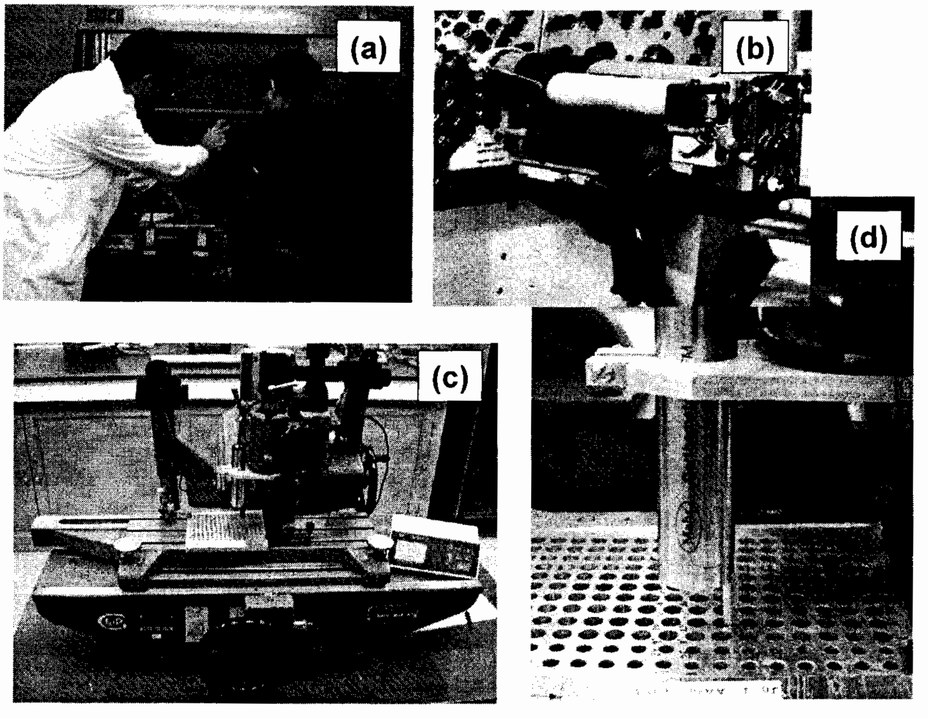

Fig. 2. (a) EMCO VMC-300 CNC Machining Center. (b) Pattern dry drilling, as it is carried out in the Shop Floor. (c) and (d) Holes inside roughness measurements.

TiN and CrN covered and not covered WC-10Co drills were used as cutting tools. Surface precision was evaluated making use of a Perthen profilometer, Perthometer M1 model, Fig. 2(c,d). Additionally, data were acquired, treated and processed through the Perthometer Concept software. This software also allows carrying out a flexible measurement data management.
Tests were monitored by using a Nikon digital camera, model Coolpix 4500. On the other hand, morphological and compositional changes in the tool surfaces were analyzed through the application of techniques of Scanning Electron Microscopy (SEM) combined with Energy Dispersive Spectroscopy (EDS). SEM and EDS analysis were carried out in a Quanta 200 Scanning Electron Microscope equipped with a EDAX EDS Microanalysis System.

Resultados y Discusión

Pictures included in Fig. 3 show some of the main troubles found in the dry drilling processes of Carbon Fiber and AA2024 alloy. Thus, Delamination and volcanic effect are the most frequent troubles in the CF drilling, Fig. 3 (a,b).

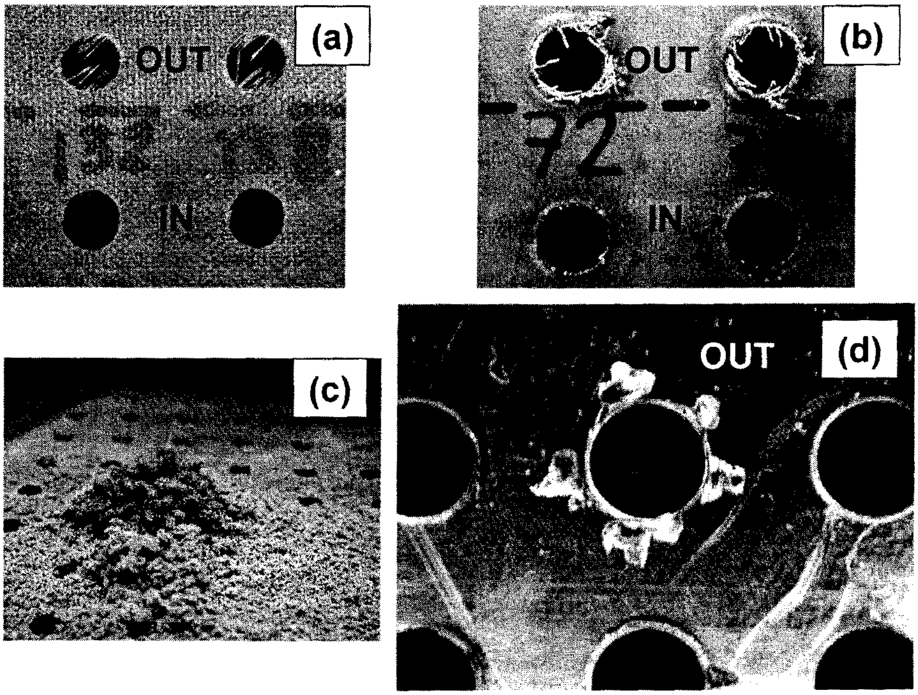

Fig. 3. (a) CF drilling process troubles: delamination and volcanic effects. (b) Copper mesh covered CF. (c) CF dust. (d) Exfoliation waste effects in the hole drill-out when drilling AA2024 sheets.

Additionally, carbon fiber is not broken giving rise to chips but dust, Fig. 3(c). This dust cannot be easily removable, specially in wet environments. In this case the tool breakdown can be accelerated, Fig. 4.

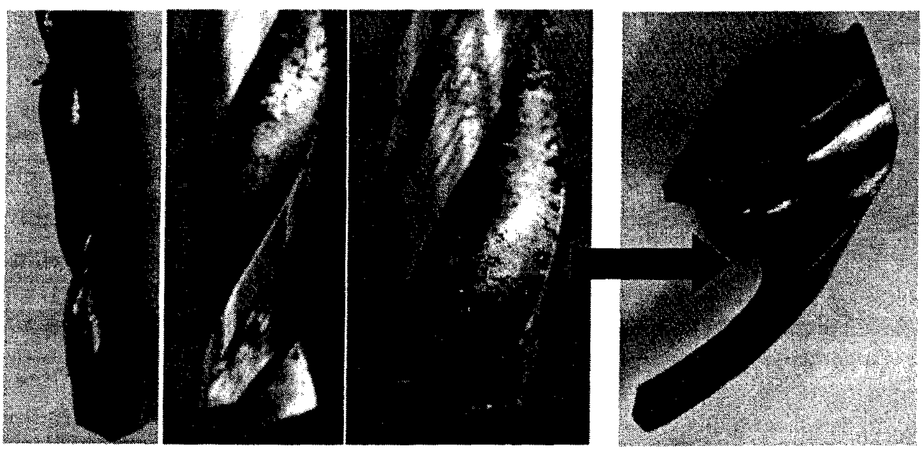

Fig. 4. Adhesion of carbon fiber dust to TiN covered WC-Co drills. Tool wear and tool break-down after drill dulling.

On the other hand, the aluminium-copper alloy shows exfoliation deforming in the drill-out holes, Fig. 3(d). This can be caused by the lost of the tool initial geometrical conditions when the machined material is accumulated in the different zones of the drill, Fig. 5.
Therefore, it is necessary to select the set of cutting parameters and cutting condition which allows minimizing the negative effect for both materials at the same time. So, this set of parameters and conditions must be selected looking for the improvement of the dry drilling of the CF/AA FML's.

Fig. 5. Material accumulated in WC-10Co tools after dry drilling AA2024 alloy.

In the case-study included in this work, feed is limited by the surface quality finishing and cutting speed is modulated by the dry drilling of the aluminium alloy. In fact, high cutting speeds cause the adhesion of material to the both clearance and rake faces of the tool, promoting the exfoliation deforming effect in the drill-out hole [4-6].
Fig. 6 shows the Ra evolution as a function of the number of holes for different v/f values for CF/AA FML's drilled using CrN covered WC-10Co cutting tools.

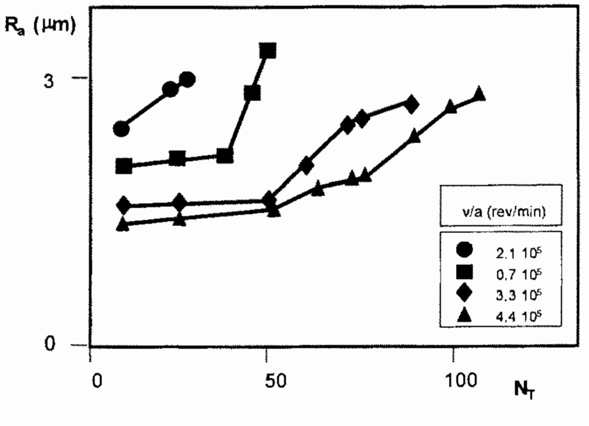

Fig. 6. Ra values obtained in drilled CF/AA sheets as a function of the number of drills for the indicated v/f values.

This kind of study (Ra-v/f) has been successfully carried out previously and it can establish the optimum relationship between both parameters, taking into account that there are two external conditions:

(a) Feed (f) value is upper limited by the externally imposed quality requirements. Lowest feed value can be only conditioned by economical considerations because of this parameter is associated with the operation time.

(b) Cutting speed range is upper limited by the own machining center characteristics and by the aluminium alloy machinability.

Coming back to Fig. 6, it can be observed as Ra diminishes as v/f, because of the increase of feed, except in the case of the highest cutting speed value as it has been obtained previously [6].

Conclusions

Nowadays, in the aerospace industry, there are very intense research efforts focused on the finding new lighter and more resistant materials. In the last decades, one of the most interesting alternatives to classical light alloys has been the so-called Fiber Metal Laminated (FML) structures, mainly formed by a light alloy supporting carbon fiber.

The airship assembly requirements force to make a lot of machining operations, principally drilling, over these materials.

This work reports on the results of a preliminary study about the dry drilling of Carbon Fiber CF/Aluminium Alloy (AA) sheets. This study has been achieved on the basis of the individual analysis of the dry drilling of each one of the materials.

Fibrillation-delamination is the most common trouble found in the CF drilling. In addition, CF dust abrades the tool surface and can carry on its wear.

Exfoliation-adhesion are the most common troubles found in the drilling of aluminium sheets. So, when CF/AA FML's are drilled, both effects are combined increasing the wear factor.

From the obtained results, in the cutting parameter range employed, the industrially applicable values are obtained when CrN covered tools are used at highest cutting speeds and lowest feeds.

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