Identifying the drill position in composite and metal stacks using acoustic emission signal

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Drilling holes in stack made of carbon fiber reinforced plastic (CFRP) and aluminum or titanium is a major process in aircraft industry. Optimal drilling of holes in CFRP material requires a special type of drills and process parameters while drilling holes in aluminum or titanium require different types of drills and process parameters. For this reason, drilling holes in stack made of CFRP and metal under the same drill type under the same process parameters results in compromising of performance and efficiency [1]. In the CFRP problems, like pull out and delamination can occur and in the metal layer, larger burr size will develop at the holes exit. One way to improve the performance is to change the drilling parameters like feed rate and speed and adapting them to layer being drilled. For changing the process parameters, the position of the drill in the stack has to be determined. When drilling the holes with CNC machine and when the thickness of the stack layers thickness is known, changing the process parameters can pre-programmed. The problem arises when drilling holes in big parts or parts with changing profile thickness, where the holes are made with lightweight drilling machines or hand-held drilling machines.

Acoustic emission (AE) was used for detecting delamination and other malfunction during processing of CFRP [2,3]. During the investigation, it was shown that acquiring an AE signal and analyzing this signal in real time can result in determining the time and the position when the drill is close to exit the first layer and enter the second one or exit the stack. An example of the AE signal and the measured thrust force during drilling hole in a stack made of CFRP and aluminum layers, with a stepped drill is shown in Fig. 1a.

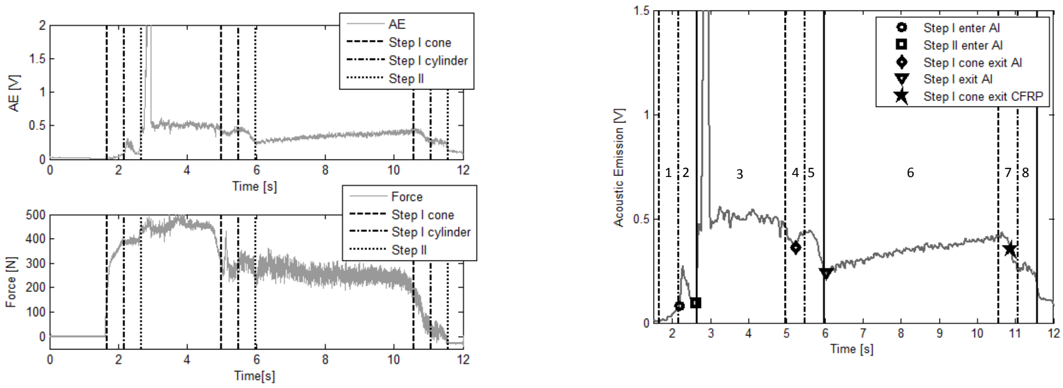

Fig. 1 a. The measured AE and thrust Force. b. The determined change of material time

The different vertical lines are indicating when the drill enters the layer, when the frontal part with the small diameter (5 mm) part of the drill is fully and when the full diameter (7.93 mm) of the drill enters the layer. As can be seen from Fig. 1a, there is a very good correlation between the AE and the thrust force measured signals when shape changes caused by the drill position take place.

A special gradient algorithm has been developed for finding the points in time where changes in the AE signal take place, indicating that the drill is entering or coming close to the end of a layer. On the AE graph depicted in Fig. 1b, the points where the changes were identified by the gradient algorithm are marked. The graph depict data recorded when the drilling started in the aluminum layer. The first two marks indicated the identification of the entering of the first step and the second step of the drill into the aluminum (zone 1,2). Two other points (zone 4,5) indicate when the drill entered the CFRP layer ant the point in zone 7 shows when the drill is close to exit the CFRP layer. These identified points can be used for changing the process parameters. For example when entering the CFRP layer to change the feed rate and when coming close to exit the CFRP layer to reduce the drilling speed, which in turn will reduce the thrust force and therby reduce the delamination damage.

This algorithm were implemented on results collected from 85 drilling experiments where the drilling started in aluminum side and on another set of 85 drilling experiments where the drilling started in the CFRP layer. The results showed the possibility to identify a head of time when the drill is coming close to the end of the CFRP layer in both cases - when the drilling started with the CFRP layer and in the case where the drilling started from the aluminum layer and ended with the CFRP one. Misidentification took place when the drill began to worn out, this was after 50 holes in case when the drilling started in the CFRP layer and there were 2 misidentification out of the first 40 drilling experiments when the drilling ended in the CFRP layer. One of the advantages of using the AE signal as a tool for identifying the position of the drill in the stack is that it is an indirect measurement method, compared to the thrust force measurement which has to be integrated into the drilling machine or into the workpiece holder.

In future work, other types of algorithm and training technics will be implemented to find the time when changes of the AE signal take place. Another task for future work will be to implement the developed algorithm in a drilling machine for changing the process parameters in real time.

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