Tool Vibrations for the advancement of the Vacuum Infusion process

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Introduction

Vacuum infusion has been established as a high quality process but not high enough for aerospace primary structures. In order to improve fibre volume fraction and void content of conventional Vacuum Infusion several techniques have been proposed but only few include dynamic means during the process such as the audio frequency vibrations applied to the injection pressure and the mechanical vibrations applied to the mould. In the latter case, a RTM mould is vibrated during and/ or after the filling process by applying external mechanical vibrations to the mould in order to eliminate dry spots and improve quality (1,2). With respect to vacuum infusion, research has been focused on improving the fibre compaction by external means such as a (pulsed) press (3) but besides the difficulty of reproducing this technique at industrial scale, the permeability of the preform is further decreased leading to higher injection times. On the other hand, some studies have shown that the application of vibrations at the curing of prepregs can improve part quality (4,5).

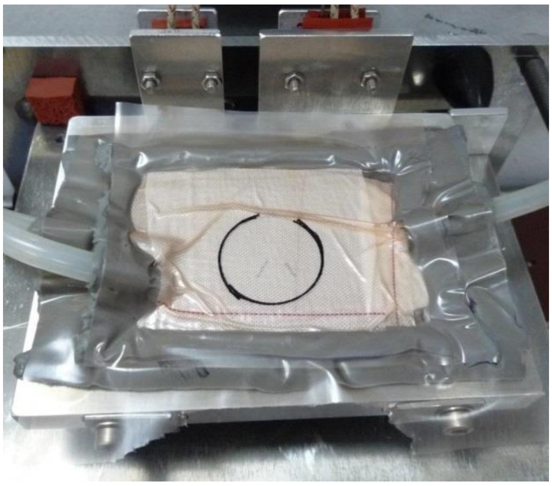

Figure 1: *Small heated vibrated mould with double vacuum bag set-up.*

In the present work a new mechanical system has been developed for the application of mechanical vibrations in a vacuum infusion tool used for the manufacturing of advanced cfrp parts. To maximise the advantages of this system i.e. void content reduction and higher compaction, vibrations are applied between the end of the filling stage and the beginning of

the curing stage enhancing the escape of entrapped voids as well as fibre nesting. The latter can be achieved combining also the vacuum pressure and the resin's lubrication effect.
To explore this concept two vibration mechanisms have been developed able to shake a flat tool at various frequencies and magnitudes. At the same time the set-up should maintain all the necessary conditions for manufacturing advanced composites such as homogeneous temperature distribution up to 190°C and a good vacuum level. At first in a feasibility study a conventional small-scale vibration mechanism was constructed to shake a very small tool as depicted in fig.1. For the trials the Hexcel RTM-6 resin was used with aerospace grade 2x2 twill-weave carbon fibre. The resin was injected at 120°C and cured at 180°C for 2 hours.

Table 1: *Comparison of vacuum infusion part quality with and without tool vibrations.*

	@Vacuum port		@injection port	
Experimental Set-up	V_f %	VC %	V_f %	VC %
w/o vibrations	53,1	0,564	52,2	0,571
Large amplitude/Low frequency vibrations	59,8	1,021	57,1	1,292
Small amplitude/High frequency vibrations	58,3	0,834	57,2	0,872

Analyses of coupons from these trials showed an increase of fibre volume content from 53% on a conventional VI to 57-59% in the vibration case (Table 1). Overall the set-up of lower magnitudes at higher frequencies up to 100 Hz showed the best performance resulting to an average increase of fibre volume fraction by 10%. Encouraged by the good results an upscale industrial system was developed and constructed using an advanced concept for the manufacturing of 1 m by 1.5 m cfrp skins as can be seen in the fig.2. At the conference extended results will be presented from the trials that will be performed at Anadolu University where the system has been installed.

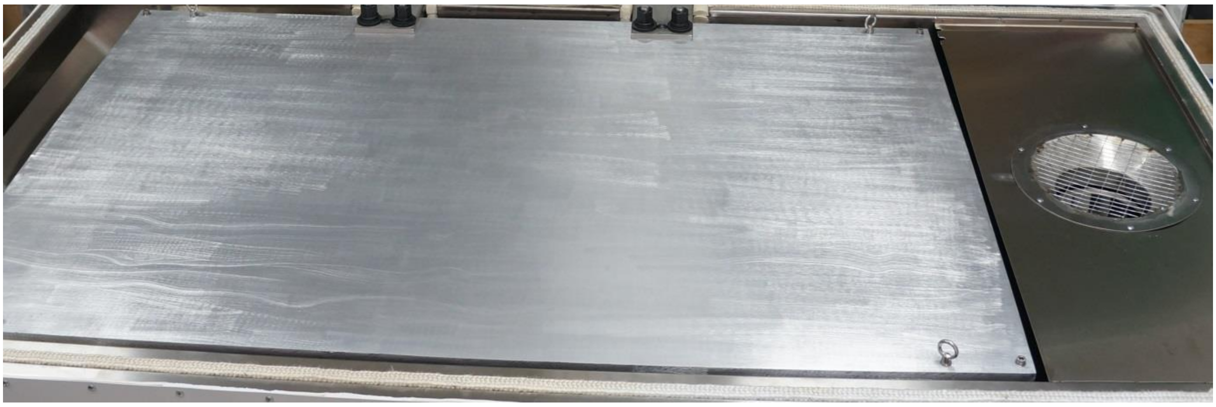

Figure 2: *Overview of the model identification procedure.*

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