EXPERIMENTAL STUDY ON THE INFLUENCE OF CYCLIC COMPACTION ON THE FIBRE-BED STATIC AND DYNAMIC COMPACTION RESPONSES

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Introduction

A wide variety of fibre reinforced polymer manufacturing processes involves compaction of the fibre bed. Processes like Compression Resin Transfer Moulding (CRTM) use a through thickness impregnation technique to reduce flow path-lengths to few millimetres and speed up the impregnation process. The injection of the resin at the high pressures needed to ensure a full saturation of the preform induces deformation of the fibre bed. Hence, the knowledge of compaction behaviour of the fabric preform is of significant importance while designing moulds and optimizing manufacturing processes. For a detailed study, it is necessary to consider the non-linearity of the response as well as the viscoelastic nature of the fibrous preforms [1], and effects deriving from the compaction history.

This experimental work deals with the influence of cyclic compaction on the fibre-bed static and dynamic compaction responses. The hypothesis behind this study is that a master compaction curve obtained after cyclic loading exists for every textile, assuming a certain preform configuration. Moreover, the loading in question has significant effects on the quasi-static and dynamic (time dependent) responses of the textile.

Experimental procedure

In this study, we perform compaction tests on three different glass fibre reinforcements: a twill 2/2 woven (290 g/m^2), a (±45°) biaxial NCF (444 g/m^2) and a chopped strand mat of 15 tex (300 g/m^2). The samples of the dry textiles are tested using a procedure combining two different loading profiles: stepwise and cyclic compaction. The stepwise loading permits to assess the static and dynamic compaction responses of the textile [2]. It consists of loading the sample with a constant velocity of 1 mm/min up to a defined fibre volume fraction. The position is held constant to allow for relaxation, and the holding pressure is measured. The sample is then compacted further repeating the same process. Fibre volume fraction values range from 40% to 60% for the woven and NCF and from 24% to 40 % for the random mat. On the other hand, the cyclic loading, defined as a preconditioning, allows development of the master compaction curve. It consists of a series of compaction cycles up to a predefined pressure level of 4 bar, 3 bar and 11 bar for woven, NCF and mat fabric respectively [3]. The loadings are applied consecutively at a constant compaction rate of 24 mm/min. Five samples of each material, consisting of 40 square plies with a side length of 150 mm, were subjected to a stepwise loading before and after 100 compaction cycles.

Results and conclusions

Figure 1a shows typical cyclic compaction curves for the mat fabric, while the stepwise compaction results of the five samples are averaged. The responses in the last step are presented in figure 1b, before and after preconditioning for each textile.

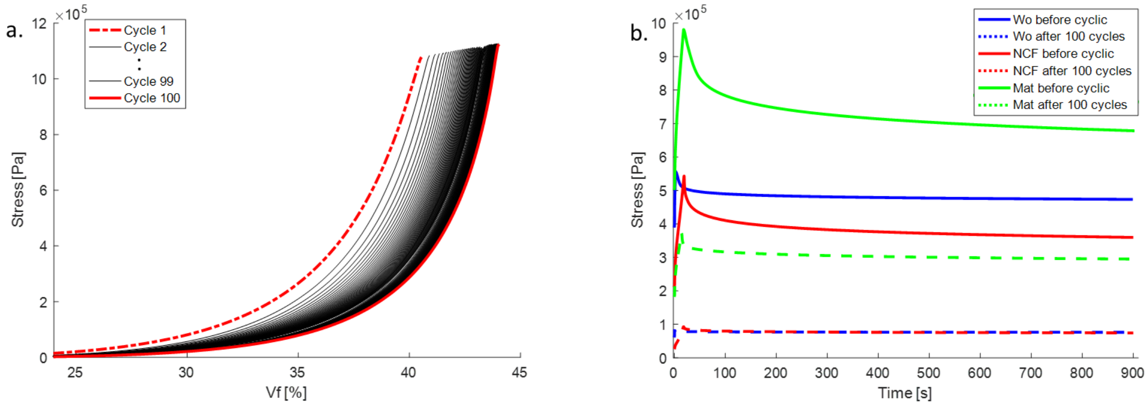

Figure 1: *Cyclic compaction curves (Mat textile) (*a*). Final compaction step before and after preconditioning (b).*

Figure 1a shows that, at a certain pressure, the fibre volume fraction increases continuously over the cycles, a similar behaviour is noted as well for the woven and the non-crimped fabrics. However, the increment in fibre volume fraction decreases over the cycles; the difference between cycles $i+1$ and cycles i decreases with the number of cycles and tends to zero. The observed plastic behaviour is a consequence of the evolving nesting, the yarns flattening and the rearrangement of the fibres and the bundles into a denser configuration. The increased ordering brought forward with each cycle is more efficient; it unifies the different specimens' compaction histories and leads to a master curve, thus supporting the convergence hypothesis.

The achieved configuration causes the decrease in both quasi-static and time dependent compaction responses, which is pointed out in figure1b. It is also noted that the preconditioning reduces the difference between these two responses, which suggests the diminution of viscoelasticity. In addition, cyclic compaction reduces the sample variation and leads to more reproducible results. Table 1 highlights the pressure drop after the preconditioning, and summarizes the holding pressure differences between the five samples at the end of the last step, before and after cyclic loading.

Table 1: *Effect of the preconditioning on the static, dynamic response and the reproducibility.*

	Pressure drop after 100 cycles		*Sample variation*	
	quasi-static	*Dynamic*	*Before cyclic*	*After 100 cycles*
Woven	83%	85%	25%	13%
NCF	79%	83%	15%	11%
Mat	56%	61%	23%	17%

This work highlights the effects of preconditioning on the quasi-static and time dependent compaction responses, where cyclic loading considerably reduces the compaction response. In addition, it unifies the material behaviour and normalizes its compaction history. The results of such a procedure could be exploited in the study of the fibre-bed behaviour and the validation of numerical models. It is also significant for processes limited by the injection pressure as higher fibre volume fractions can be achieved translating in potentially better mechanical properties.

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