Degradation measurement of fibrous reinforcement inside composite material

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Context of the study

During the weaving process, damaged on yarns are observed and can lead to severe mechanical loss of properties on the final composite material. A study achieved by Rudov Clark et al has confirmed these observations by studying the impact of the production of a 3D warp orthogonal interlock fabric composed of E-glass fiber. See also [2] [3] [4] for 3D structures definitions. They found that the tensile strength of the yarn after Jacquard weaving process is reduced by 30 to 50% and 5 to 7% for the Young's modulus. This loss of strength can be mainly explained by the use of fiber glass yarns, which are more sensitive to internal friction fibers during weaving, by the different hand manipulations and certainly by a non optimized weaving process. Moreover a study made by Boussu and all show the degradation of yarn inside a weaving structure made with Twaron ® aramid fibre. It has been shown that the loss is more important in the warp than in the weft direction and can be spread from 30 to 40% for ends (respectively 25 to 33% for picks). The number of crossover points, due to the different weave diagrams, and the end and pick densities of the fabrics tend to influence the breaking strength loss of a yarn into a fabric. [5]

Considering these high observed values of loss on the mechanical properties of these 3D fabrics, it could be very interesting to focus on the weaving process to determine which parameters really influence the yarns damages. Thus, a complete and detailed analysis of the different weaving steps has been achieved to measure the loss of properties of aramid yarns type Kevlar 29 ® 3300dtex useful for the ballistic properties of our final composite material.

Tensile tests are performed with a MTS machine available in Gemtex laboratory with the NF EN ISO 2062 standard. The yarn length of 250mm is placed between two claws, and then stretched at a speed of 250mm/min with a load of 1kN.

Experimental study

The first step of our study consists in verifying the mechanical yarn properties of the yarns inside the bobbin. For the second step, 25 twists per meter on the yarn have been done in order to reduce the thread by thread friction during the weaving process. Then, during the third step, the yarn is safely conducted into a warping and beaming process.

Experimental results

Concerning the DuPont data indicated in table 1, we note a huge difference compare with our tests results. We lost 20% and 46% of respectively the breaking tenacity and young modulus. Concerning the breaking elongation, we have an increase of the data about 29%. We decide also to keep our results for the next tests and conclusion.

Difference between DuPont data and verification tests (%)	
Breaking tenacity cN/Tex	-20,07
Breaking elongation %	28,93
Young modulus GPa	-46,43

Table 1: Difference between DuPont data and our tests results

The influence of 25 twists / meter is also noted with an increase of the breaking tenacity and young modulus respectively of 7% and 12.5%. As we can see in table 2, adding twist decrease the breaking elongation.

	Breaking tenacity cN/Tex	***Breaking elongation %***	***Young Modulus GPa***
Influence of twist on mechanical properties of the yarn (%)	**6,90**	**-10,04**	**12,62**

Table 2: Influence (%) of 25 twists / meter on the mechanical properties of the yarn

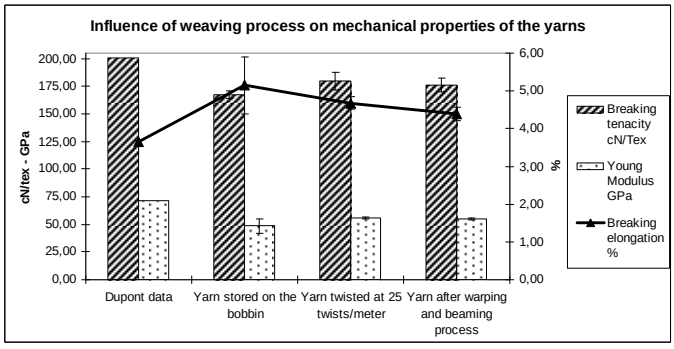
The third step which concerns the influence of warping and beaming process, shows a slight

influence on the mechanical properties of yarn with a maximum degradation of 7% for elongation at break, and around 2% for the breaking tenacity and Young Modulus.

	Breaking tenacity cN/Tex	*Breaking elongation %*	*Young Modulus GPa*
Degradation of the fibre after the warping and the beaming process compare with the yarn twisted (%)	-2,01	-6,61	-1,31

Table 3: Degradation of the yarn due to the warping and beaming process

The next graph shows all the results of the influence of weaving process on the mechanical properties of the yarn.



Graph 1: influence of weaving process on mechanical properties of the yarns

Conclusion:

This study helps us to understand the influence of the weaving process on the yarn.

The first remark concerns the marketing data which should be verified each time we receive the yarn. Indeed the commercial data may be an average of all the yarns made but are not representative of the yarn delivered.

For the second step, we note that adding a twist on the yarn provides much more resistance. In fact we have an increase of about 7% and 12.5% of the tensile strength and Young Modulus, but a loss of elasticity of 10%. This can be explained by the fact that the mono-filaments are consolidated together during the twisting providing additional rigidity therefore a decrease of elasticity but an increase of breaking properties.

Concerning the warping and beaming process, these two steps cause damages on the yarn properties with a decrease of 5% for the breaking tenacity, 6,6% for breaking elongation and 1,31% for young modulus.

This degradation can be due to the fact that the yarn is wrapped with a high speed on the beams that create an angle of curvature which may affect the mechanical properties of the yarn. However the degradation is slightly and doesn't exceed the degradation reported by Rudov Clark and al for the E glass fibre which are much more brittle compare with aramid fibre. These results show that, we have to apply a twist on the yarn in order to restrict the degradation on the fibre and compensate the influence of the warping and beaming process.

A next study will be made to determine the influence of yarns placement inside three 3D warp interlock fabrics in order to compare the results with the conclusion made by Boussu and all.

Acknowledgments

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