IGF- Gruppo Italiano Frattura

Giornata di Studio sulla

Fatica ad atissimo numero di cicli

Torino, 5 novembre 2008

POLITECNICO DI MILANO

RESISTENZA A FATICA AD ALTO NUMERO DI CICLI DI MATERIALI COMPOSITI PULTRUSI

(HIGH-CYCLE FATIGUE STRENGTH OF COMPOSITE PULTRUDED MATERIALS)

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Introduction

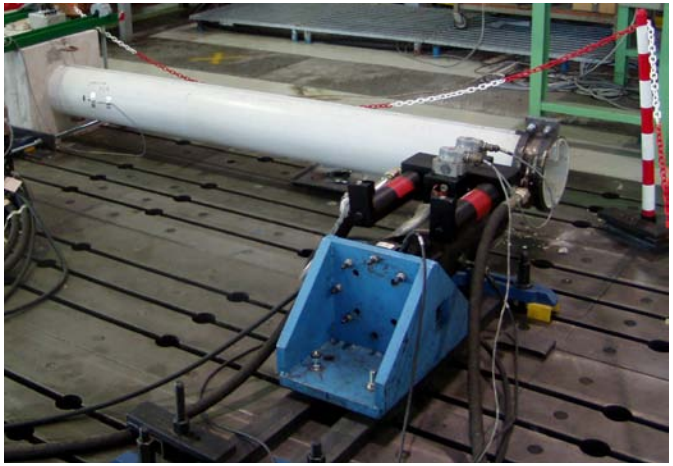
- ✓ Pultrusion is one of the most attractive technological process for obtaining polymer matrix composite parts to be manufactured with large production rates and volumes.

- ✓ Due to this characteristic and to some peculiar aspect of their physical and mechanical behaviour, pultruded composite are getting more and more used in structural applications in civil infrastructure.

- ✓ Pultruded materials are becoming a serious alternative to metal alloys for the construction of shaped beams, pedestrian bridge decks, post for railway noise barriers, floors of bus and other structural parts.

- ✓ However, their application in structural engineering is still somewhat limited by the incomplete knowledge about the fatigue strength.

Some structural applications of pultruded materials



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Aim

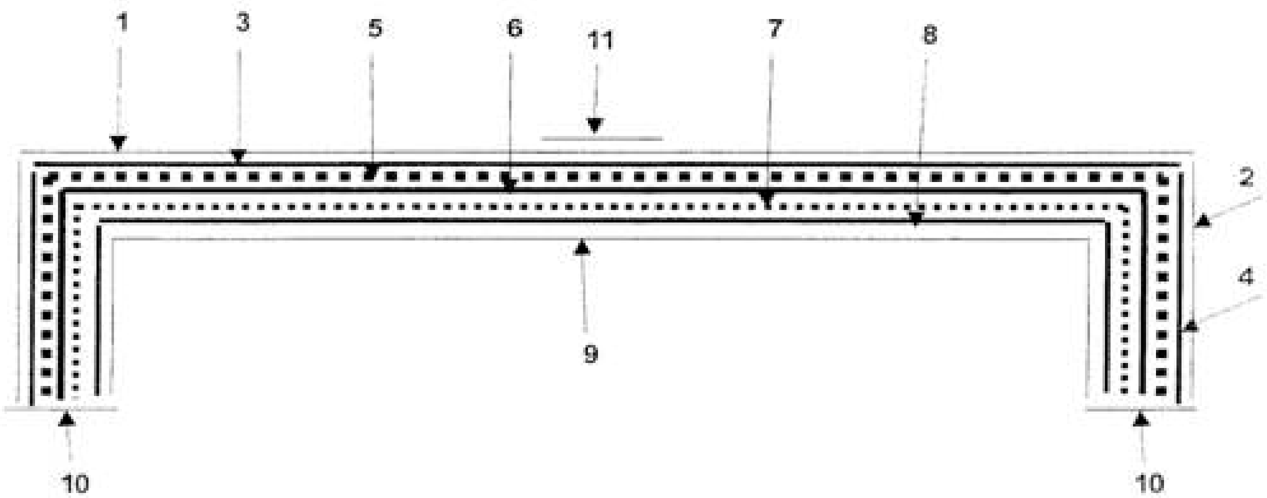
- To investigate the fatigue strength of a composite pultruded materials in the high-cycle fatigue range.
- To assess the existence of a fatigue limit for this material
- To investigate the fatigue failure mechanisms by means of SEM and optical microscope observations.

Material

•Glass-fiber reinforced composite obtained by pultrusion.

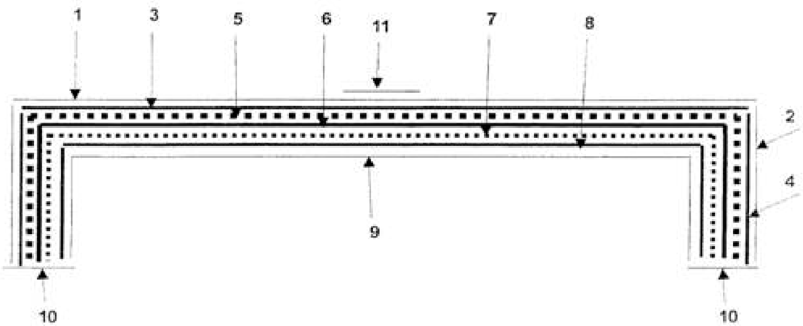
•Matrix made of equally distributed polyester not saturated resins commercially called Leguval W 24 GA and Synolite 0175-N-1. The global density of the matrix is about 1,3 g / cm^3.

•The glass fibers have a ultimate tensile strength of 1800 MPa, an elastic modulus of 76 GPa and a volumic mass of 2.53 g/cm^3.



Section from which the specimens were cut

Material

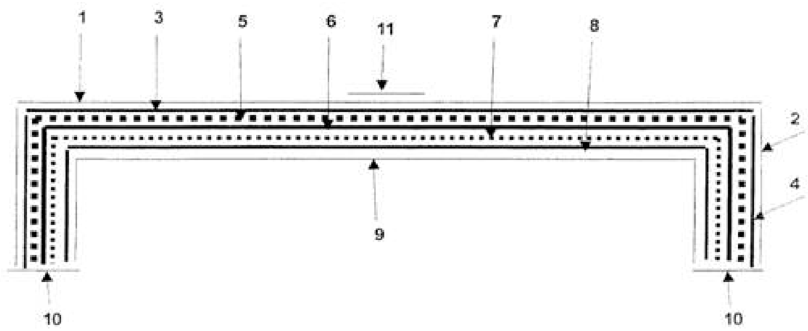


Lay-up of the section from which the specimens were cut

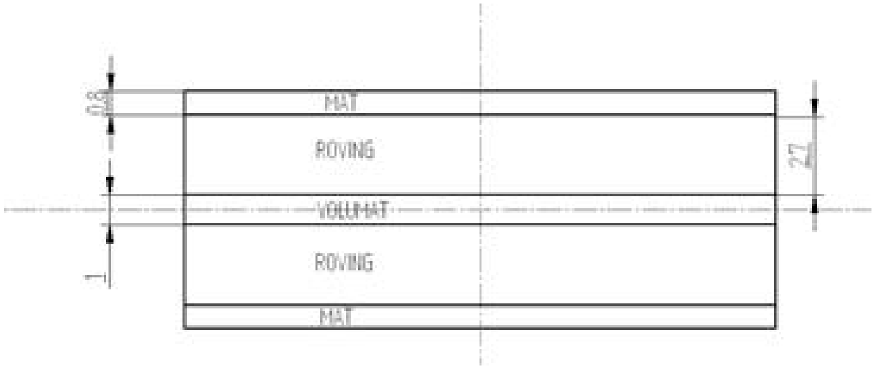
Position	Width (cm)	Material	Mass per unit length (g/m)	Roving mass per unit length (g/m)	Weight %
1	17	SONTARA	5.95		
2	6	SONTARA	4.2		
3	16	MAT	48		
4	5	MAT	30		
5		ROVING		960	
6	21	VOLUMAT	126		
7		ROVING		547.2	
8	21	MAT	63		
9	23	SONTARA	8.05		
10	5	SONTARA	3.5		
11	4	REEMAY	0.8		
		Total woven	289		16
		Total roving		1507	84
			Total resin	1796	57
			Total glass	1354	43
			Total weight	3150	100

Chemical composition of the layers of the pultruded material (the position refers to the figure).

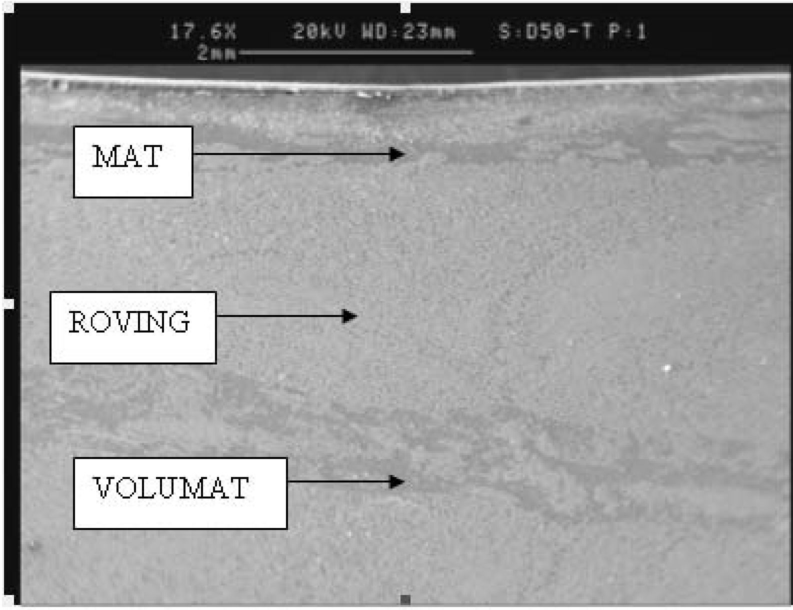
Material



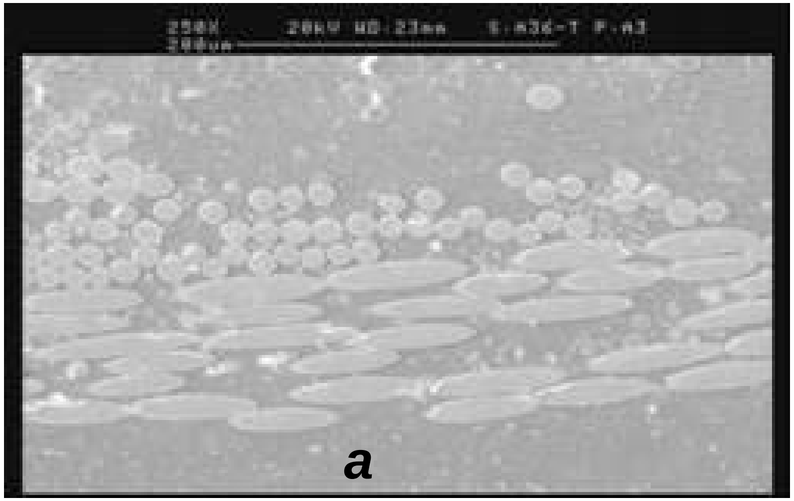
Lay-up of the section from which the specimens were cut

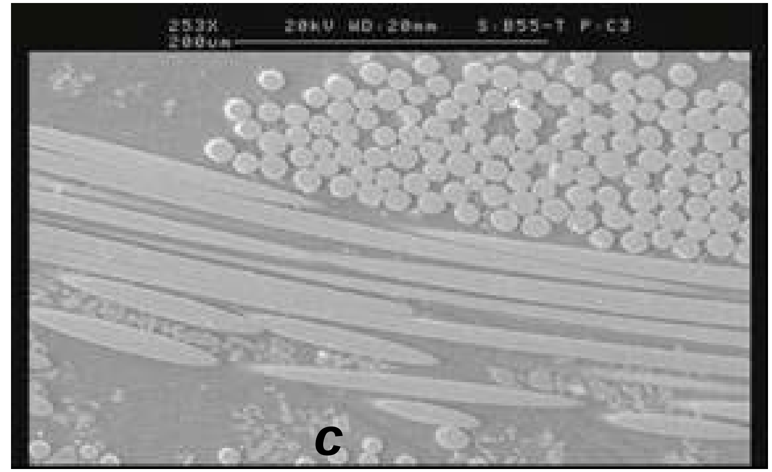


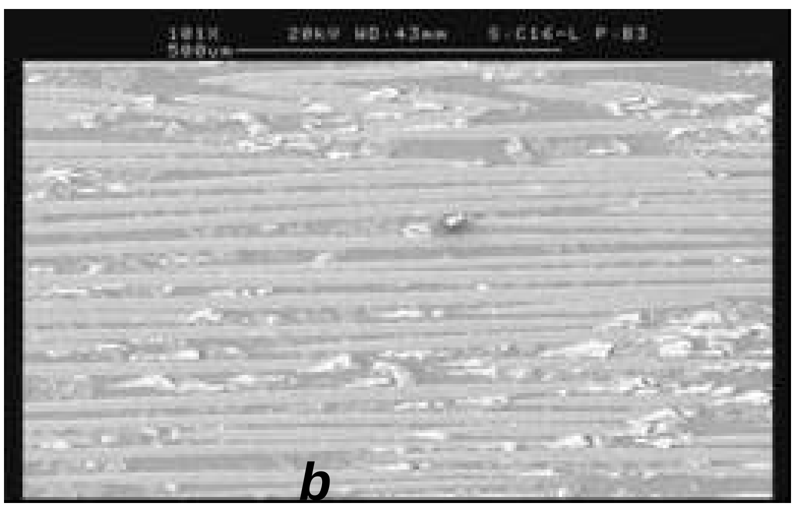
Layer definition in a generic section of the samples.



SEM micrograph showing Mat, Roving and Volumat layers.

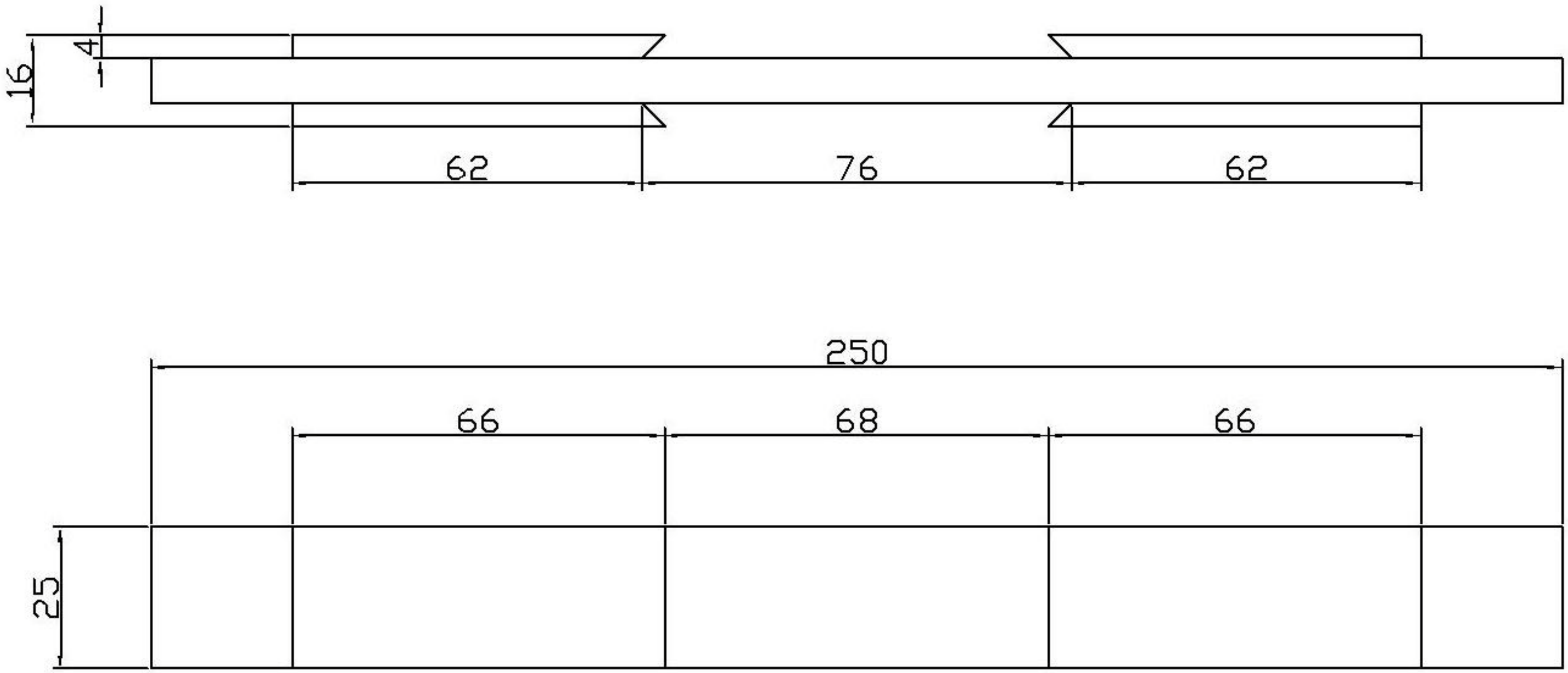






SEM micrographs of Mat (a), Roving (b) and Volumat (c) layers.

Static tests



Shape and dimension of the samples used in the static tests (ASTM D 3039/D 3039 M-00; EN ISO 527-5: 1997).

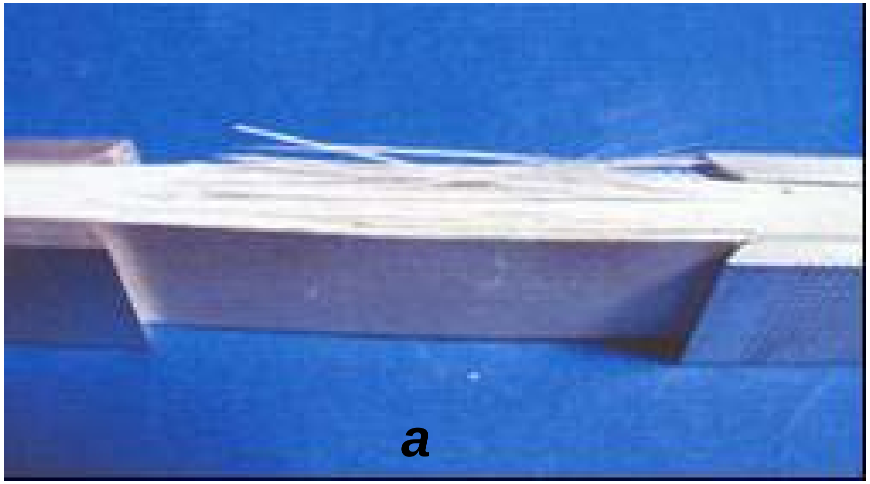
Static tests results

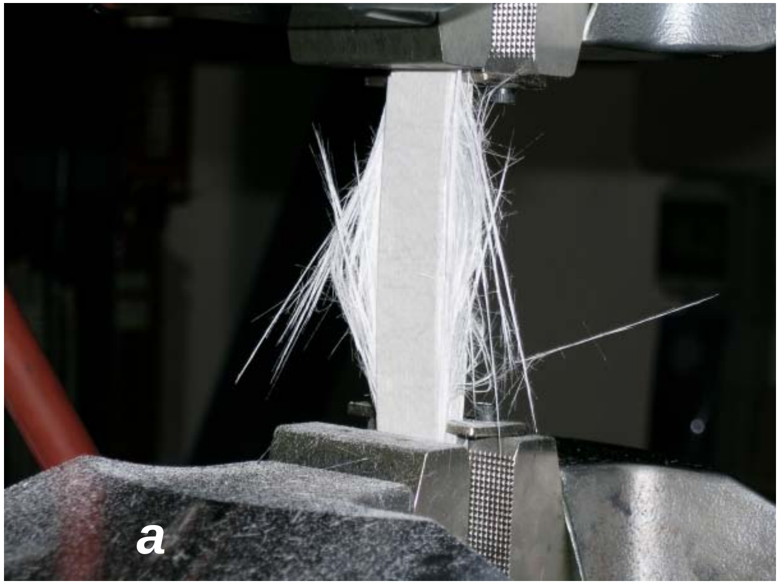
	Specimen	E (MPa)	UTS (MPa)	Elongation %	Failure type	Failure zone
Tensile tests	1	30605	367	1,20	DGM	Middle
	2	30794	377	1,23	DGM	Middle
	3	31005	377	1,21	DGM	Middle
	4	30003	361	1,20	DGM	Middle
	5	28791	381	1,32	XGM	Middle
	Mean value	30240	373	1,23		

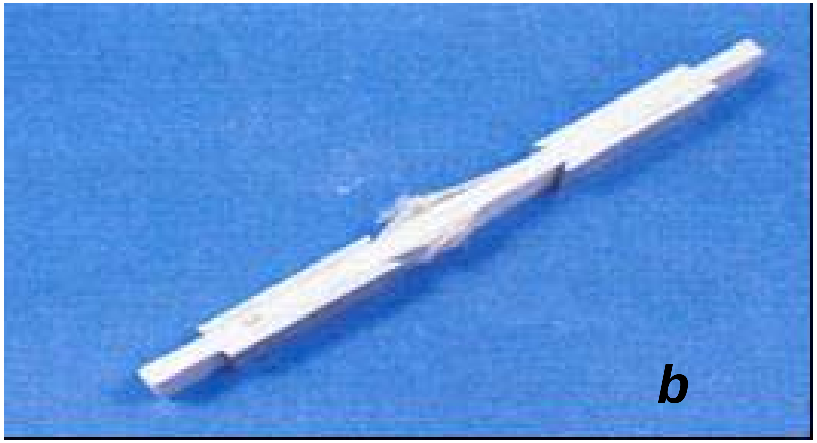
	Specimen	E (MPa)	UCS (MPa)	Elongation %	Failure type	Failure zone
Compres-sion tests	1	31311	454	1,45	DGM	Middle
	2	27296	383	1,40	DGM	Middle
	3	26607	382	1,43	DGM	Middle
	4	26973	375	1,39	DGM	Middle
	5	31313	402	1,28	DGM	Middle
	Mean value	28700	399	1,39		

Summary of the results of the static tests (DGM= edge Delamination Gage Middle, XGM=eXplosive Gage Middle)

Static tests results





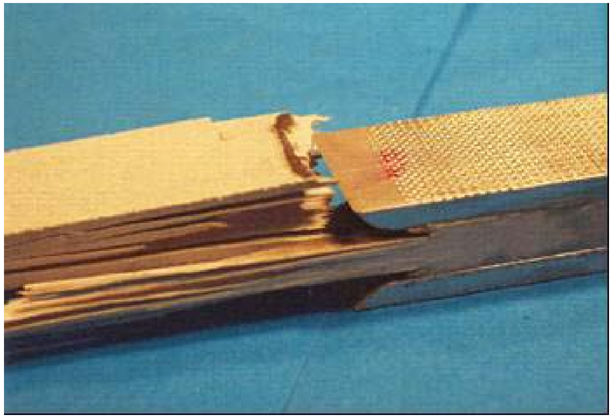


Typical aspect of a DGM failure: (a) tensile failure, (b) compression failure.

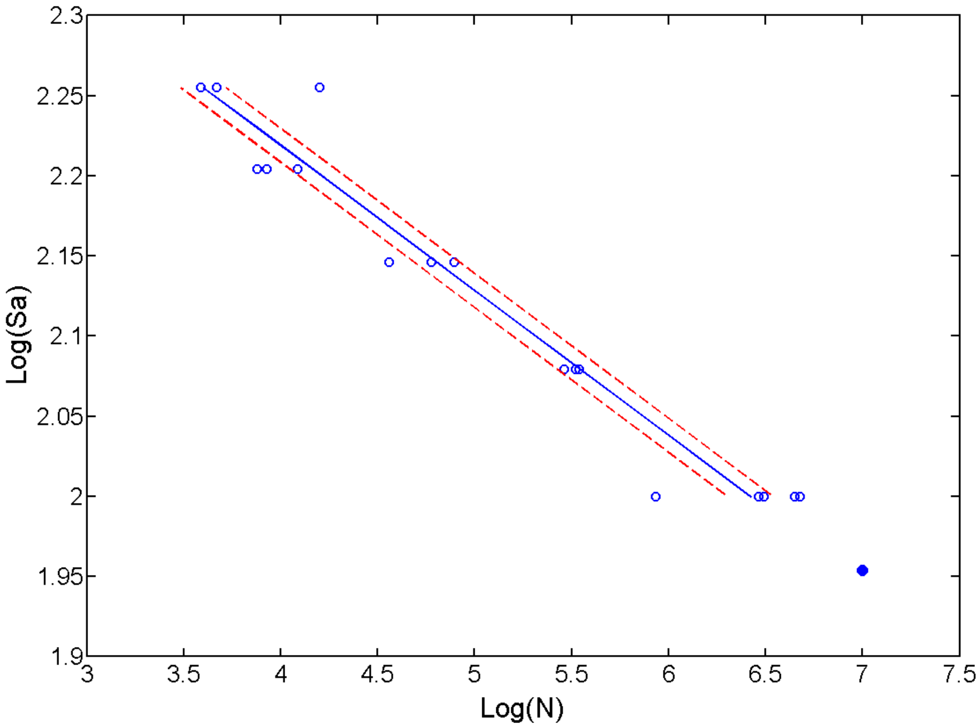
Fatigue tests

- Axial fatigue tests (R=-1) were executed, being the aim the determination of the S-N curve of the material and to verify the existence of a fatigue limit.
- The specimens had constant section and their geometry is the same o the static tests.
- The specimens were considered run-out if failure did not occur till 10.000.000 cycles.
- The results were elaborated by following the ASTM E 739-91 standard.

A specimen broken near the gripping zone.



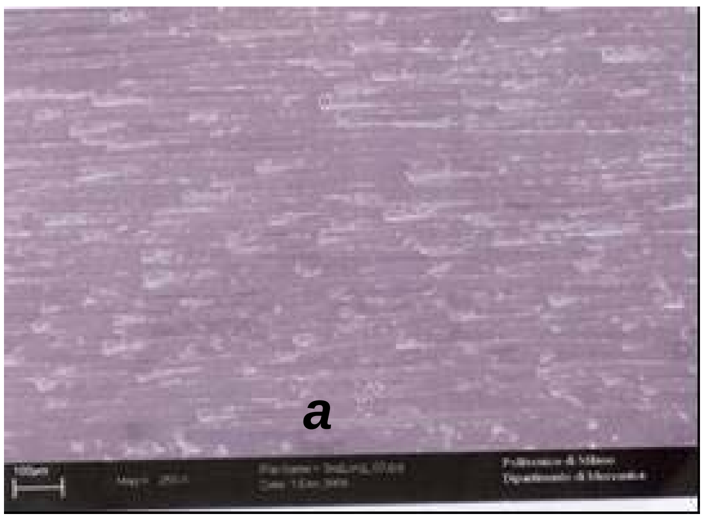
Fatigue test results

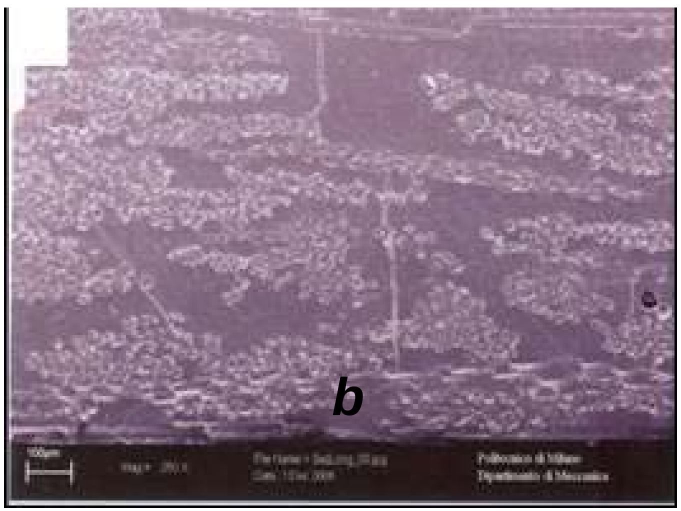


S-N curve of the pultruded material (Run-out=10E+07 cycles)

Defect count in the fatigued run-out specimens

	Mat	Roving	Volumat
Debonding	67	25	60
Fiber Cracks	30	15	8
Matrix cracks	5	0	0





SEM images of the fatigue specimens: (a) Mat, (b) Roving.

Conclusions

Static and fatigue tests were executed on pultruded composite specimens. On the basis of the results the following conclusions can be drawn:

• The static tests showed good uniformity and to assess that failure is mainly due to edge delamination gage middle (DGM).

•The fatigue tests showed the existence of a fatigue limit and a limited dispersion of the results.

•The main fatigue failure mechanism is the formation of cracks between matrix and fibers.

•The influence of the specimens geometry and of thr gripping device is observed.