



HAL
open science

STUDY FOR MANUFACTURING A CORNER FITTING OBTAINED BY RESIN FILM INFUSION PROCESS

Jorge Lopez Torres, Philippe Marguerès, Francis Collombet

► **To cite this version:**

Jorge Lopez Torres, Philippe Marguerès, Francis Collombet. STUDY FOR MANUFACTURING A CORNER FITTING OBTAINED BY RESIN FILM INFUSION PROCESS. 12th European Conference On Composite Materials, Aug 2006, Biarritz, France. hal-04496826

HAL Id: hal-04496826

<https://hal.science/hal-04496826>

Submitted on 8 Mar 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

STUDY FOR MANUFACTURING A CORNER FITTING OBTAINED BY RESIN FILM INFUSION PROCESS

Jorge Lopez Torres, Philippe Marguerès, Francis Collombet

LGMT – PRO²COM-IUT Paul Sabatier – Département GMP
133c avenue de Rangueil, BP 67701, F 31077 Toulouse CEDEX 4.

ABSTRACT

The work presented here proposes the manufacture of a structural part called corner fitting obtained by Resin Film Infusion and focuses on the influence of stacking sequence, thickness variation and cure cycles. This study takes part in a global study aiming at following up composite structures -carried out by fast and economic methods- from manufacture up to the ruin.

1. INTRODUCTION

The most important parameters for composite fabrication are often the cost, the performance, and the ratio performance/cost. Composites made from prepregs are generally cured in autoclave to achieve high fibre volume content, a low volume fraction of voids and a high strength-to-weight ratio. For the manufacture of large structures that cannot be autoclave cured other processes can be used: Resin Film Infusion (RFI) [1], pultrusion [2], Resin Transfer Moulding (RTM) [3], compression moulding, filament winding [4], structural reaction injection moulding [5], Vacuum Assisted Resin Transfer Moulding (VARTM) [6]...

RFI is one of the liquid moulding techniques [7, 8, 9] which allows to reduce the manufacturing costs as only one sided tool is needed [1, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17]. Here the resin infuses through the preform thickness to the opposite face under the action of heat, vacuum and/or pressure. The material -commercially known as HexFIT®- is a partially preimpregnated fabric supplied as a stack of resin films that are interleaved between layers of dry fibre reinforcements. It is made of E-glass fibres and epoxy resin (M9.6 FL). Its high fibre-plus-resin areal weight (approx. 2150 g/m²) and high thickness (approx. 1 mm) makes it suitable for large and thick laminates to be moulded quickly and economically with low void content, providing a more rapid lay-up with less handling than conventional composite materials. Here lies the challenge of the study: we have to manufacture with this material a complex structure made of three perpendicular planes joined in a curved corner.

The manufacture of specimens called demonstrators (200 mm-side corner fitting to be representative of the real part) is studied here taking into account the variation of the stacking sequence and the total thickness. The main objective of the present study is to correlate the processing conditions to the variation of mechanical characteristics obtained during a prospective phase of characterization [18].

2. RAW MATERIAL

HexFIT® [19] is a film of prepreg resin combined with dry reinforcements of glass or carbon fibre. HexFIT® is processed by applying heat and vacuum, which activates the resin, enabling it to flow and infuse the reinforcement. HexFIT® provides a quick and cost-effective way of producing large, thick laminates, ensuring full infusion of the reinforcement. Wind turbine blades, nautical and automobile structures are typical

applications. The reinforcement of the used HexFIT® is made of two E-glass 2x2 twill woven fabrics.

A first characterization of this material was undertaken to evaluate mechanical and physico-chemical properties on normalized specimens. Results are given in **Table 1**, **Table 2** and **Table 3**. Tg values obtained were within the range 85 – 100°C (110-135°C according to supplier).

	Young's Modulus (MPa)	Strength (MPa)	Ultimate Strain (%)	Thickness (mm)	Width (mm)
Weft direction	21869 ± 1288	424 ± 19	2.4 ± 0.1	3.9 ± 0.2	50.1 ± 0.2
Warp direction	18856 ± 978	355 ± 17	2.2 ± 0.2	4.7 ± 0.1	50.3 ± 0.3

Table 1. Tensile properties of normalized specimens

	Bending strength (MPa)	Bending Young's Modulus (MPa)	Thickness (mm)	Interlaminar shear strength (MPa)	Thickness (mm)
Weft direction	474 ± 4	17705 ± 84	5.1 ± 0.01	43 ± 1	5.1 ± 0.1
Warp direction	458 ± 9	16725 ± 46	4.89 ± 0.1	44 ± 1	4.8 ± 0.1

Table 2. Bending and interlaminar properties of normalized specimens

Total Heat of Cure (mJ/mg)	Onset Cure Temp (°C)	Cure Completion Temp. (°C)
176.38 ± 8.24	120.24 ± 0.11	145.86 ± 0.18

Resin density given equal to 1200 kg.m⁻³ and fibre volume content is assumed to be

Table 3. Physico-chemical properties of normalized specimens

3. MANUFACTURE OF CORNER FITTINGS

3.1. Tool geometries

The corner fitting specimens were laid up and cured on a solid steel tool. It is a 350 mm side cube machined to an angle of 90° and a corner radius of 15 mm (**Figure 1**).

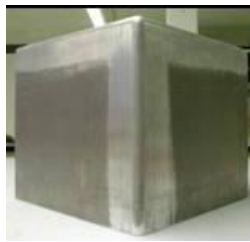


Figure 1. Tool used for the manufacture of the corner fitting

3.2. Lay-up and processing

Three different procedures were followed to achieve the best way to lay-up the corner fittings. Identical consumable supplies were used (Figure 2-a). Specimens were processed by the same curing cycle (called "short cycle" and proposed by the supplier): 60 min at 120°C (with a 3°C/min heat up rate) before cooling (with a 1°C/min cool rate) and constant 300 mbar absolute vacuum. Thermocouples (Figure 2-b) were placed on the parts, near to the tool surface, inside the specimen and near to the bag surface (indicating temperature in the oven). The corner fitting was then covered with different consumables products and placed inside a vacuum bag.

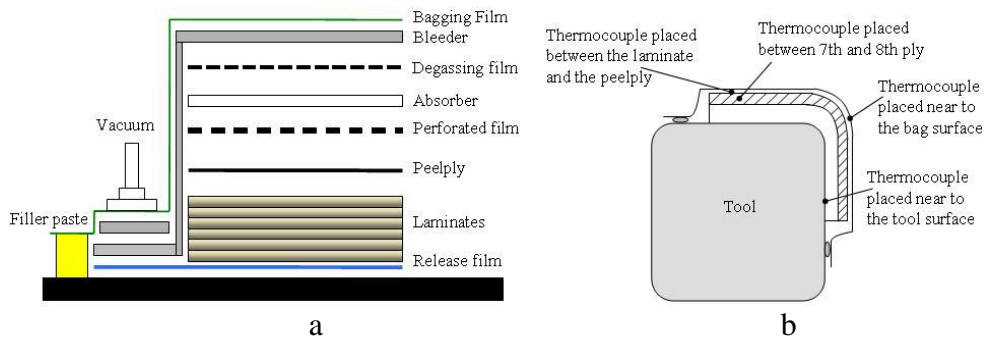


Figure 2. a- Consumables supplies used for oven curing; b- Thermocouples

The first one proposed to stretch uniformly each ply on the corner. Due to high resin content of the tacky face and the high fibre-plus-resin areal weight this kind of manufacture led to a non uniform lay-up causing out of plane deformations after curing. The second procedure proposed to use a closed matched-metal mould. The figure (Figure 4) clearly shows that the resin flow and the compaction on inner edges are not homogenous.

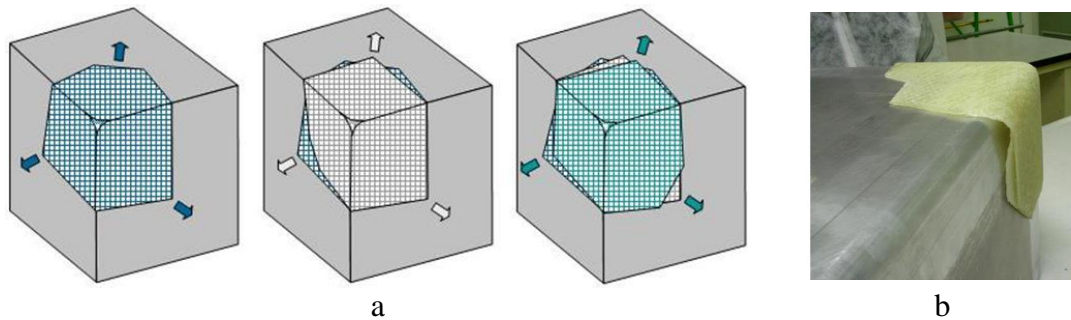


Figure 3. a- Lay-up procedure using the stretch of the layers b- Resulting out of plane deformations.

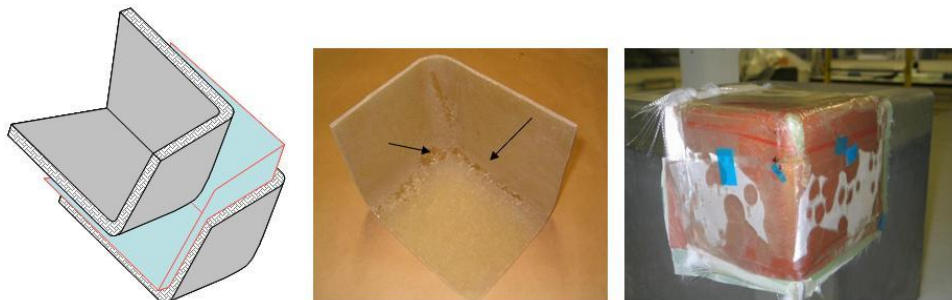


Figure 4. Lay-up procedure using a closed matched-metal mould

A third manufacture of the corner fitting has been proposed to avoid manual deformation of the layers. Three different cutting templates were design taking into account the work piece contours and the parting lines (Figure 5 and Figure 6).

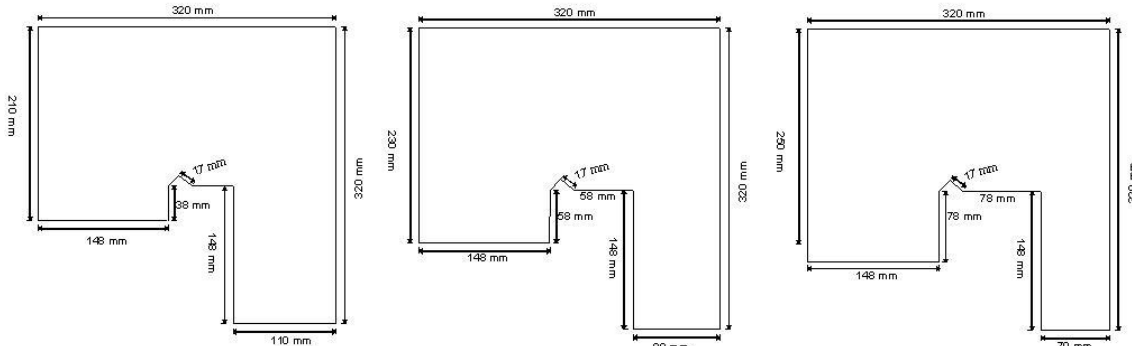


Figure 5. Dimensions of the standard patterns used for the cutting of layers of HexFIT® [2x2 twill]₂.

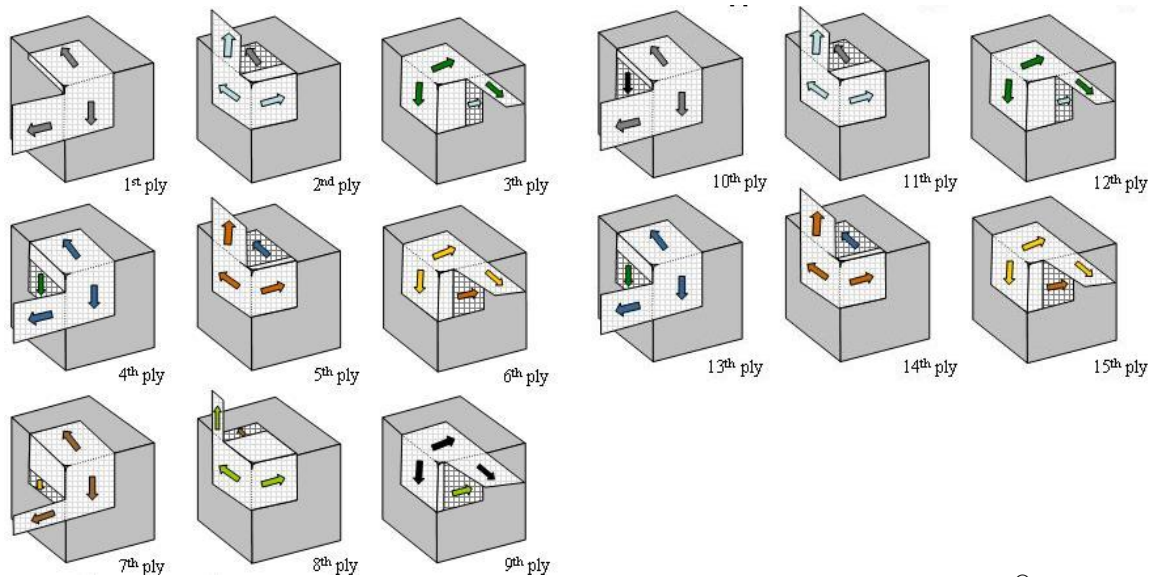


Figure 6. Stacking sequence of corner fitting fabricated with 15 plies of HexFIT®

4. RESULTS & DISCUSSION

Three 200 mm-side corner fittings containing respectively 3, 9 and 15 plies (called resp. A1, B1 and C1) were laid-up and cured using the "short cycle"(Figure 7-a). The thicker one shows a common industrial thickness fitting found in attachment fittings. Measures of volume ratios of the fibres and the voids were undertaken on the three sides of each specimen (using calcinations method). Results are given in Table 4 and show that the volume ratios of the voids increase with the number of plies and are greater than 2.7 %. In order to achieve smaller volume ratios of voids another cure cycle, called "long cycle" (Figure 8) was proposed to aid the resin flow.

Specimens with the same number of plies (A2, B2 and C2) were heated up to 80°C (with a 1°C/min heat up rate), held at 80°C during one hour, heated up again to 120°C (with a 1°C/min heat up rate), held at 120°C during one hour and then cooled (with a 1°C/min cool rate) and constant 300 mbar absolute vacuum. Obtained results are given

in Table 4 and show that the volume ratios of the fibres are equal for the same number of plies but that volume ratios of the voids are equal or smaller than 2% and increasing with number of plies. A comparison between specimens C1 and C2 is given in Figure 7-b.



Figure 7. a) Corner fittings A1, B1 and C1 laid-up with respectively 3, 9 and 15 plies using "short cycle" b) Corner fittings made of 15 plies cured resp. with the long (C2) and the short cycle (C1).

"Short cycle"			"Long cycle"		
SPECIMEN	$V_f\%$	$V_v\%$	SPECIMEN	$V_f\%$	$V_v\%$
A1	39.3 ± 0.6	2.7 ± 0.7	A2	39.9 ± 0.3	1.1 ± 0.4
B1	36.5 ± 0.8	3.0 ± 0.3	B2	36.5 ± 0.6	1.3 ± 0.3
C1	37.5 ± 1.6	4.5 ± 1.3	C2	34.7 ± 0.3	2.0 ± 0.3

Table 4. Volume ratios of fibres ($V_f\%$) and voids ($V_v\%$)

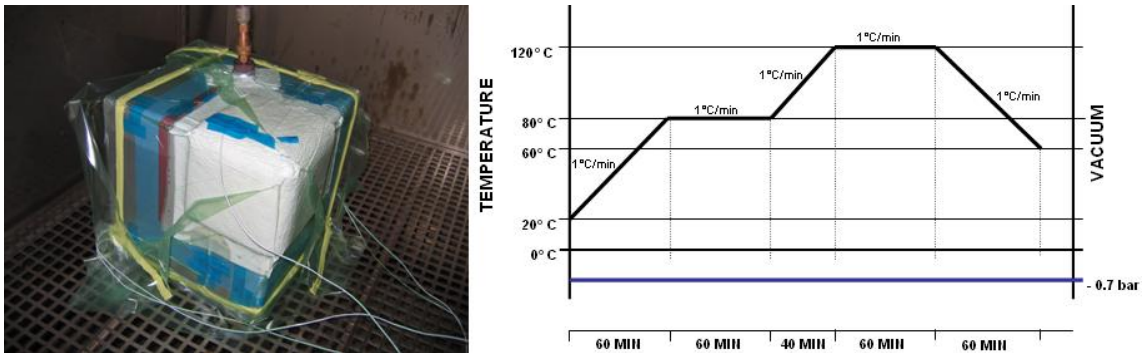


Figure 8. Process and cure cycle for the "long cycle"

For specimens C1 and C2 the temperature was monitored during the two cure cycles using four thermocouples placed as described above (Figure 2-b). For the "short cycle", results show that the temperatures in the specimen do not follow the imposed cure cycle (Figure 9) and that the exothermic peaks are delayed in time. This is not the case for the "long cycle".

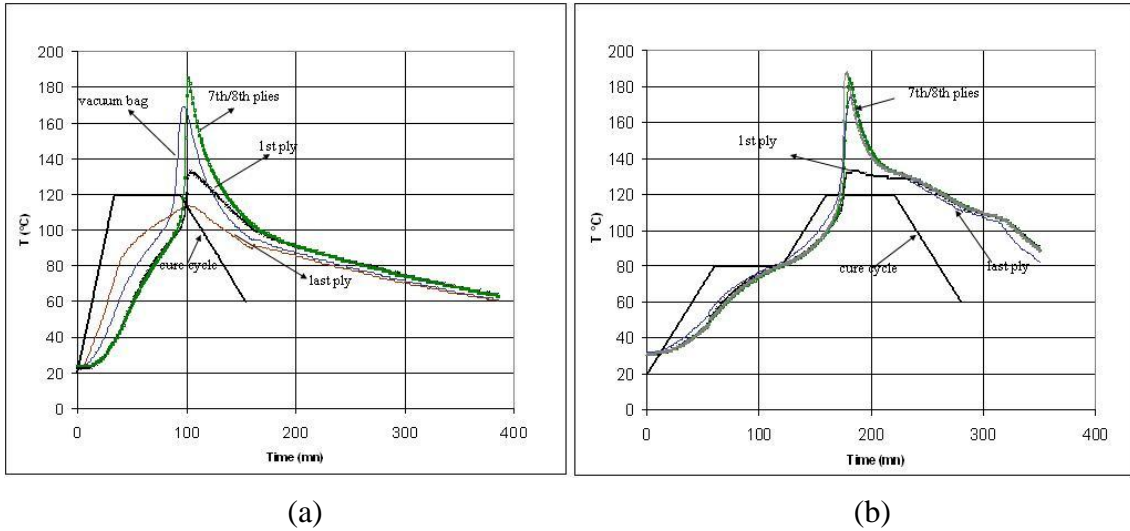


Figure 9. Variation of the temperature in the laminates for (a) "short cycle" (b) "long cycle"

Measures of the thickness and the weight were made to compare the two specimens. Despite no significant differences a non uniform final thickness is observed. Thickness varies approximatively from 1 to 3 mm from the corner to the edges. A first study was carried out with a 900 x 900 x 5 mm plate and highlighted this phenomenon. Two cartographies were done using ultrasonic echography (Figure 10), and infra-red method (Figure 11). The thickness variation is mostly controlled by the location of the connector to the vacuum pump and the vacuum tape, the flexibility of the vacuum bag and the evolution of the resin viscosity depending on the cure cycle.

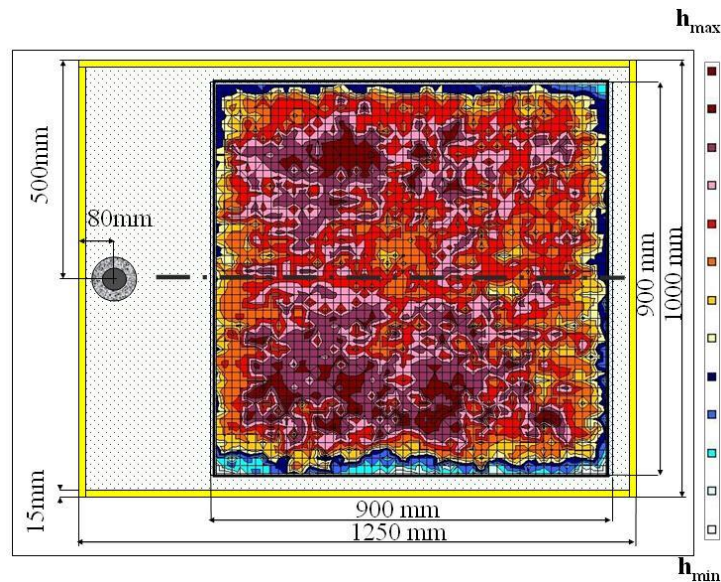


Figure 10. Thickness Ultrasonic Cartography versus the location of measurement

The infra red method was more difficult to implement due to the dimensions of the plate. However, the global information is close to that provided by ultrasonic measurements.

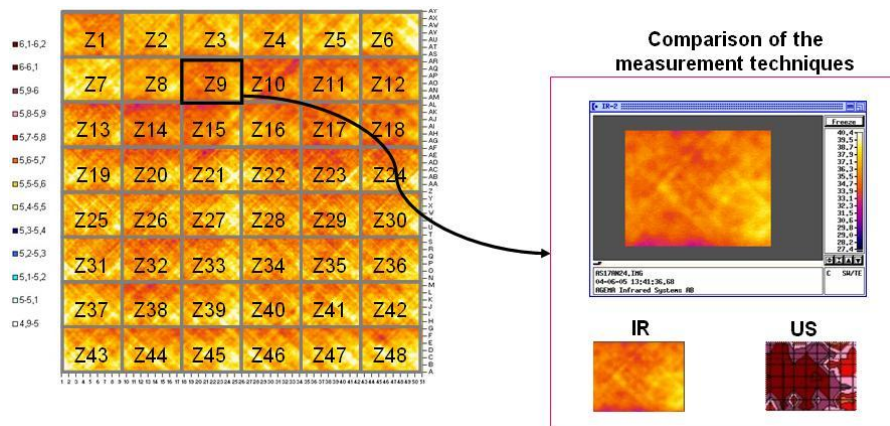


Figure 11: Infrared cartography and comparison with ultrasonic measurements

Ultrasonic approach could be proposed for the corner fittings but for thicker parts a strong ultrasonic attenuation complicates it.

5. CONCLUSIONS

This study highlights the capability to manufacture corner-fitting demonstrators using HexFIT® E-glass/2x2 twill/M9.6FL with high fibre-plus-resin areal weight. Lay-up using specific cutting templates seams to be the best way to avoid out of plane strains due to deformation of the reinforcements and the interaction with the tacky faces. To achieve a lower volume fraction of the porosity - using oven curing - it was proposed a cure cycle showing an intermediate isotherm to aid the resin flow.

In the perspective to evaluate the mechanical behaviour of this demonstrator the study will focus on the modelling of a simple mechanical test representative of industrial loading taking into account the volume fraction of the voids and the thickness variation. Thus further characterisation of the material with standard specimens has to be undertaken as with corner fittings demonstrators themselves.

ACKNOWLEDGEMENTS: We thank Hexcel Composites Dagneux (France), DDL-consultants (le Beausset, France) and the National Council of Science and Technology of Mexico (CONACYT).

REFERENCES

1. **James, R.**, "Investigation and development of the resin infusion between double flexible tooling (RIDFT) process for composite fabrication," The Florida State University, Fall Semester (2003), 5-25
2. **Berthelot, J. M.**, "Matériaux composites (comportement mécanique et analyse des structures)," 3th. Edition (1999), 3-71.
3. **Hammami A., Gauvin R. and Trochu F.**, "Modelling the edge effect in liquid composites moulding," Composites Part A 29A(1998) 603-609.
4. **Shen, C.**, "A filament-wound structure technology overview," Materials Chemistry and Physics 42 (1995) 96-100.
5. **Han, K., Jiang S., Zhang C. Wang, B.**, "Flow Modelling and simulation of SCRIMP for composites manufacturing," Composites Part A 31 (2000) 79-86.

6. **Jay R. S.**, "Vacuum Assisted Resin Transfer Moulding (VARTM), model development, verification, and process analysis," Virginia Polytechnic Institute and State University, Blacksburg, Virginia (2000), 2-28.
7. **Baker, A.**, Australian research into aircraft applications of high-performance fibre composites, Proceedings of APEC Forum on Science and Technology "Materials Science in the 21st Century", APEC Technomart IV, Suzhou, China September 2001.
8. **Kleineberg, M., Wenner, U. and Hanke, M.**, "Fuselage Manufacturing with Liquid Resin Infusion (LRI) technologies," DLR Institutes of Structural Mechanics, Lilienthalplatz, Braunschweig.,1-10.
9. **Kendall, K.N.**, High Speed Processing, in Report on the Workshop on Manufacturing Polymer Composites by Liquid Moulding, edited by R.S. Parnas, A.J. Salem, K.N. Kendall and M.V. Bruschke, National Institute of Standards & Technology, Washington, DC, NISTIR 5373, 1994
10. **Marsh, G.**, Reinforced plastics – Resin film infusion composites cost reducer. Composites Part A. (2002), p.44-49.
11. **Hinrichsen, J., and Bautista, C.**, The challenge of reducing both airframe weight and manufacturing cost , Space Europe, Volume 3, Issues 3-4, May-August 2001, Pages 119-121.
12. **Herrmann A. S., Kleineberg M.**, Low Cost Primary Composite Structures, EUROMAT 99, München, ISBN: 3-527-30124-0, 1999, pp. 343-351.
13. **Qui B., Raju J. and Kuruckenburger T.**, Manufacture of Advanced Composites Using the RFI Process, 6th SAMPE Symposium, Tokyo, Japan) October 1999.
14. **Lunn P.**, "Tooling materials ideal for resin infusion", Reinforced Plastics, September, 2004, 28-30.
15. **Kang M.K., Lee W.L.**, Analysis of vacuum bag Resin Transfer Moulding process", Composites Part A, vol. 33, 1605-1614.
16. **Schaefer H. A., Stickler P. B., McCarville D. A.**, Manufacturing evaluation of a low cost composite fitting for an aerospace application, 33rd ISTC - Seattle, WA - November 2001, 5-8.
17. **Antonucci V., Giordano M., Nicolais L., Calabrò A., Cusano A., Cutolo A. and Inserra S.**, Resin flow monitoring in resin film infusion process, Journal of Materials Processing Technology, Volumes 143-144, 20 December 2003, 687-692.
18. **Lopez T. J., Syed M. K.** "Characterization of composite material: HexFIT®". DEA report 2003, University Paul Sabatier III, Toulouse, France.
19. HexFIT® "Film infusion Technology for the rapid and cost-effective manufacture of composites" HEXCEL Composites product literature, March 2001.