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Again in this issue, I would like to introduce my early days’ research activities related to advanced composites conducted from the late 1970’s to mid1980’s. When I joined to National Aerospace Laboratory of Japan (NAL, which is similar to NASA) in 1978, my assignment was to support the development of a complete CFRP horizontal tail of the NAL research STOL aircraft named “ASUKA.” This project was the first attempt to design and build carbon fiber/epoxy aerostructures conducted within Japan. It was one of the earliest ambitious plans in the world at that time. One structural feature was the sinusoidal corrugated web vertical wall for the main spars like the AV-8B aircraft made in the USA. For achieving sufficient drapability to the spar mold, 8 Harness Satin prepreg of carbon fiber/epoxy was employed as the web material throughout in this project. One day in late 1979, an engineer from MHI (Mitsubishi Heavy Industries, Co. Ltd, the main contractor of this project) came to me and asked the reason why consolidated 1-ply 8 Harness Satin plate deformed so seriously, almost changing into a cylinder. They fabricated single ply 8 Harness Satin plate material to evaluate mechanical properties. At that time, the knowledge about composites made of textile reinforcements was very limited, particularly for satin-weave type fabrics. I then created models of 8 Harness, 5 Harness and 4 Harness Satin fabrics with blue and white wool threads which my wife brought from her home. Actually, we were newly married! Using the satin fabric models, I very easily found the true reason of deformation, loss of the symmetry with respect to the mid-surface of single-ply satin woven plates. As the next step, I conducted a full literature survey of various composites journals and learned that I could open up an entire new field on the mechanics of fabric composites. Then, I wrote my first paper about this topic entitled “Anti-Symmetric Elastic Properties of Composite Plates of Satin Weave Cloth” for submission to “Fibre Science and Technology”. The paper was accepted and published. At the same time, I was offered a chance to do research at University of Delaware, USA, with Professor Tsu-Wei Chou. When I visited his office in October 1980, he allowed me to continue the textile composite mechanics work I had previously started. Since then, we published several papers of the early portions of textile composites mechanics with high citation indices.

When I went back to Japan after two years stay at the University of Delaware, the project reached to its final stage of the strength test of the 1/2 scale model of a full CFRP horizontal tail. I joined the test team and discovered another important phenomena concerning the compression strength of composite structures. A description of its detail is skipped here. However, my lessons-learned that new topics can be frequently discovered in the linkage between academia and practical challenges could be broadened to many people within composites research fields. Although the fully developed CFRP model would not be realized as the real flying empennage, the technology accumulated in NAL and MHI was handed over to Japan’s original fighter aircraft’s (so-called F2) main wings. Finally, it consisted of the technology basis of for the Boeing 787 main wing production.
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CEO and Executive Director, Gregg Balko • gregg@sampe.org
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SAMPE Journal Editorial Office
1161 Park View Drive, Suite 200, Covina, CA 91724-3759 USA
Phone: +1 626.331.0616 • Fax: +1 626.332.8929

Publication Staff
Technical Editor, Dr. Scott Beckwith • swbeckwith@aol.com
Production Manager, Jennifer Stephens • jennifer@sampe.org
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A Note From the Technical Director

“Improved Composites Design & Certification Approach”

Aerospace and automotive engineers and technologists approach design, manufacturing and certification much differently than automotive engineers and technologists in how they view advanced composites to develop structural products. We know the cost of developing new materials, new design approaches and modifying manufacturing processes to achieve technological developments is both tortuous and extremely expensive. I have heard comments from the major commercial aircraft manufacturers that designing and building a next generation aircraft needs significant changes in the design and certification process if to be economically viable. The cost of traditional design methods and material property/“material allowables” testing via the old “pyramid coupon-to-full-scale structure” testing is cost-prohibitive. That is particularly true for both thermoset and thermoplastic composites. We see extensive developments in textiles, fabrics, “spread tow”, “thin ply” and other new materials. Virtual testing methodologies are a cost-effective option for verifying design material allowables and inputs to design iterations. This illustrates one difference in the automotive and aerospace communities. Automotive engineers embrace virtual testing. Unfortunately, virtual testing still appears a long way off in the aerospace market. Automotive engineers are pushed to create new designs annually for a larger number of models.

Automation design methodology tends to look more at simulation methodologies. As a result design changes, modifications, and materials incorporation are made a lot faster than one sees in the aerospace world. The SAMPE Technical Excellence Committee has specifically been tasked by the North America Board of Directors to focus on the differences between aerospace and automotive in these areas. I expect to see more focus in various conference and workshop events that address virtual testing and computational modeling and mechanics – two areas that appear primed to see increased application in the future.

SAMPE offered a “computational modeling and science” tutorial recently at the Dallas CAMX 2015 program in October. Interest in this field of modeling and analysis has been growing steadily. It has been providing the necessary continuity in understanding, and modeling, material behavior that we see at so many levels but have failed to provide the complete set of tools necessary to improve design and analysis computational speeds for reducing the cost of the design process itself. Engineers need simulation and computational software tools that can improve and speed up the design process involving complex advanced composite material systems out on the near term horizon. Given a number of perceived tools in these areas of testing and analysis methodology, the structural certification process of new aerospace systems could become “less cost-prohibitive” and “more proactive.”
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Evolution in Composite Injection Moulding Processes for Wing Control Surfaces

D. Gueuning and F. Mathieu
Sonaca S.A., Gosselies, Belgium

Abstract
Since 2010, Sonaca is engaged in R&D projects, with the support of Radius Engineering and Coexpair, aiming to design, develop, manufacture and test monolithic CFRP flap structures made from the conventional 8552 resin prepreg system and the newest SQRTM process (‘Same Qualified Resin Transfer Moulding’) in order to assess several additional benefits of this process over the conventional RTM process, amongst which the use of already qualified tough prepreg materials and the ease combination with automatic deposition and preforming techniques of UD-tapes. Following advantages were also considered during the initial trade-off analysis for the technology selection of such wing control surface structure having very stringent requirements in terms of structural performance, weight optimisation, aerodynamic quality and cost:

- Strong control on thicknesses,
- Strong control on the geometry (radii, plies conformity),
- High surface and internal laminate qualities,
- Robust process generating less scraps and non-conformities,
- High level of part integration possible.

Introduction
Sonaca is producing today, in serial production, hybrid slat structures on the A350 program. The concept resulted from an important R&D project (‘Newslat’) running from 2003 till 2010 and consisting finally in the assembly of a metallic nose skin with a composite rear structure produced from a closed mould RTM process based upon the RTM6 epoxy resin and carbon fabric/carbon non-crimp fabric reinforcements, allowing very high product dimensional characteristics together with very good internal and surface quality. This concept demonstrates now in serial production to be very efficient in terms of part quality and robustness but the use of the dry fabrics and dry non-crimp fabrics do not allow automation of the lay-up deposition.

In 2010, Sonaca decided to launch an extensive research and development programme (‘Ecotac’) to develop the newest SQRTM (Same Qualified Resin Transfer Molding) process for application on wing control surface components and, followed in 2013, by another programme with the final aim to bring the technology up to TRL9 for use on flaps of an actual regional aircraft project (Figure 1). Today, Sonaca can be considered as the first European company having introduced this advanced technology in production.

Figure 1. SQRTM TRL Road Map at Sonaca.
SQRTM process involves prepreg material cured in a closed mold. The pressure inside the mold is applied by a small quantity of prepreg resin (to be available in bulk form) that is injected to fill the tool cavity around the edges of the part and maintained until the gel of the prepreg material. The process combines advantages from prepreg materials (use of high tough resins and ease combination with automatic deposition and preforming techniques of UD-tapes) and RTM process (dimensional and surface qualities). Following advantages were also considered during the initial trade-off analysis for the technology selection of such wing control surface structure having very stringent requirements in terms of structural performance, weight optimisation, aerodynamic quality and cost:

- Strong control on thicknesses,
- Strong control on the geometry (radii, plies conformity),
- High surface quality,
- Robust process generating less scraps, less non conformities and repairs,
- High level of part integration possible,
- Faster NDT inspection (less scatter at the part surface due to the better surface roughness),
- Automation possible with the use of UD reinforcements (AFP or ATL) and it can be pushed further than autoclave (no vacuum bag, more repeatable process).

The main injection/curing steps are (Figure 2):
- Putting the resin inside the injector, degassing and heating it to the specified resin injection temperature,
- Applying vacuum to the mold having the prepreg lay-up placed inside,
- Heating-up the tool to the specified injection temperature,
- Opening the injection line and adjusting injection pressure or resin flow,
- Shutting-off vacuum port valves on tool when resin appears,
- Ramping tool temperature to the curing temperature,
- Shutting-off the resin injection,
- Holding the curing temperature/time.

**SQRTM Composite Flap R&D Project**

**SQRTM Flap Demonstrator Part and Tool Concepts**

The demonstrator (Figure 3) has been designed to be composed of only four main elements: a lower skin with an integrated front spar, an upper skin with an integrated rear spar, a D-nose and a trailing edge. Selected raw material was 8552 resin with AGP193 fabric and AS4 UD-tape carbon reinforcements as well as expanded copper foil 3 CU 7-125 on the outer surface of the skins, D-nose and trailing edge. Fabric material
was chosen for the skins while tape has been used for the co-cured stringers.

The tool was designed to be able to manufacture the four composite parts in one single mould/injection. A cross-section of the tool is showed Figure 4.

_Demonstrator Manufacturing Results_

After ply cutting-off and laying-up of the pre-formed plies, the mandrels were positioned on the tool and the mould was closed before its installation in the SQRTM press. The parts were injected with 8552 resin and cured with the cycle shown in Figure 5.

After cooling and de-moulding, a visual inspection of the cured parts revealed a really exceptional part quality as shown by Figures 6a through 6d.

Dimensional inspection was performed based upon ultrasonic measurements and micrographics. Over more than 150 thickness control points selected, no value was found out of the allowed +/-8% tolerance around the nominal thickness.

Furthermore, the micrographic cuts analysis has confirmed that the demonstrators presented a very good level of internal quality (skin, stringers, spar and joggle areas) as shown in Figures 7a through 7d:

– No delamination,
– Good compaction of the plies (even at difficult areas such as radius in spars, stringers, joggles, ...)
– Good filling of the stringers with the noodle fillers,
– Good filling of the joggles with the fillers,
– Thicknesses compliant with the requirements,
– Spar radii and stringers radii compliant with the requirements,
– No internal ply waviness.

The C-scan US NDT reports have confirmed the fully satisfactory internal quality of the produced parts for what concerns porosity and inclusion.