

USE OF COMPOSITES IN THE VISBY CLASS STEALTH CORVETTE

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ABSTRACT

The full composite Visby Class Stealth Corvette was delivered from Kockums AB to the Swedish Defence Materiel Administration (FMV) in early June 2002. Many years of intense research and development work carried out by engineers and officers lay behind the creation of the worlds biggest and most stealth adopted CFRP-ship this far. Initially it was proposed building the ship in GRP-sandwich but it was soon realised that GRP-sandwich would not meet the requirements of low weight, low signatures and electro magnetic shielding.

This paper deals with the use of carbon composites in the Visby Class Corvette and some of the experiences gained and difficulties that have been faced in the design and construction phase of the project.

THE VISBY CLASS CORVETTE

FMV and Karlskrona Shipyard signed the contract for design and construction of the Visby Class Corvette in October 1995. The 72m long ship, with a crew of 43 people, is a 600 tonnes multi purpose vessel developed by FMV capable of various tasks such as surface attack operations, mine hunting, mine laying, anti-submarine warfare and patrol duty at speeds exceeding 35 knots.

Furthermore, the ship's hull fulfils the following performance requirements:

- Low weight
- High Stiffness and strength
- High impact resistance and damage tolerance
- High shock resistance from underwater detonations
- Low radar signature
- Low magnetic signature
- Low acoustic signature
- Low IR signature
- EMI-shielding
- Last but not least: Low acquisition and maintenance cost

Meeting both operational and performance requirements, it was indeed a challenging engineering experience.

Stealth requirements also imply that no small discontinuities in the hull shape are allowed since they are catastrophic for the radar cross-section of the ship. The principle for the Visby Class Corvette is to create reflective surfaces in order to direct incoming radar signals to four main directions and elevation angles, hence the somewhat “edgy” shape of the ship.

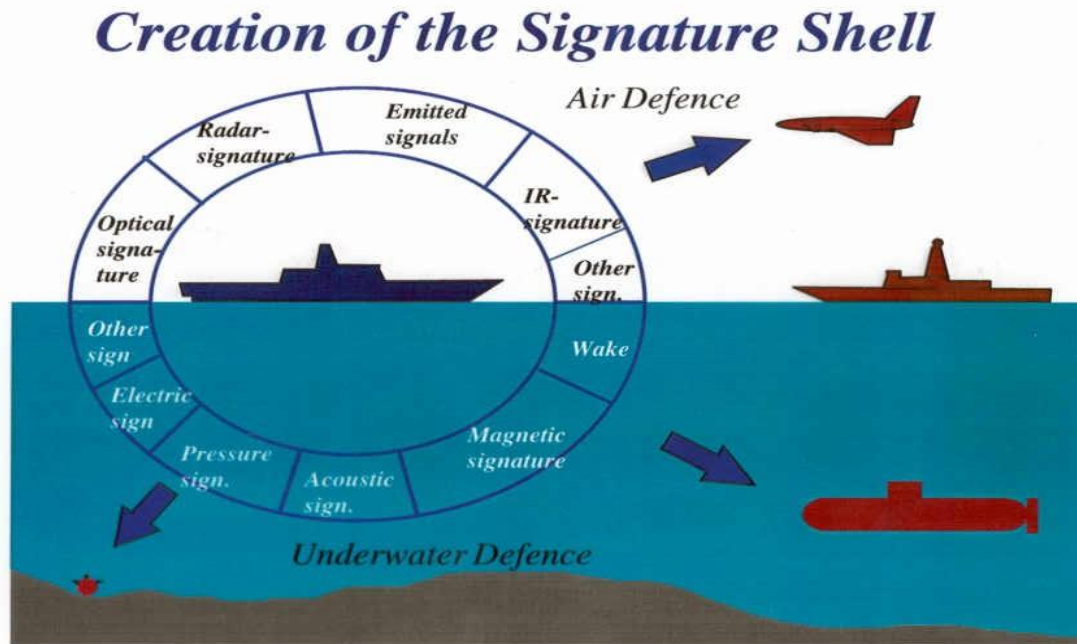


Figure 1 – Creation of signature shell

MATERIAL CONCEPT

Traditional material combinations, such as glass fibre reinforced polyester in a sandwich design, used for the mine counter measure vessels would not stand up to the requirements for the Visby Class Corvette. However, a good solution to obtain the lowest possible structural weight of the hull was to use a carbon fibre composite, which has a high strength and stiffness to weight ratio. Carbon fibre laminates are also electrically conductive which provides solutions comparable to metallic materials when it comes to meeting radar reflection and EMI-shielding requirements.

Questions that arose early in the project were how the use of a carbon sandwich construction would affect factors such as producability, toughness and maintenance costs.

Material research and development

Previously, the use of other matrix systems than epoxy together with carbon fibres was not common, and the use of epoxy in a hand lay-up process was not an alternative in this case either due to restrictions in the Swedish health legislations. Other matrix systems were therefore considered, but not many carbon fibre manufacturers deliver fibres with sizing for epoxy. Finally, a Toray T700 fibre with a new vinyl ester sizing was chosen and in combination with a rubber-modified vinyl ester, it provided the laminate mechanical properties needed (i.e. tensile strength, compressive strength and delamination strength).

Other comprehensive research and development programs were carried out together with material suppliers, research institutes, universities etc. in order to fully understand the

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behaviour and limitations of the CFRP-sandwich material concept. Special efforts have been made studying e.g. sandwich panel wrinkling strength, impact and point load resistance, fracture toughness, post curing and treatment and fabric manufacturing technique.

The limitations in the material concept did not seem to be related to the fact that a rubber-modified vinyl ester is used, but rather to imperfections in the knitted non-crimp fabrics. Fibre wrinkles are catastrophic to the mechanical strength, should they appear at a critical position. It is therefore of great importance that the stitching yarn is selected with care.

The chosen material concept can be summarised as follows:

Skins: HS-carbon >2.0% elongation, 12K knitted non-crimp fabric, rubber-modified vinylester

Core: PVC-foam, standard and ductile versions



Figure 2 – Visby at launch

Production technique

In order to achieve the benefits of the carbon fibre, the traditional labour intense wet hand lay-up technique was by no means optimal. Instead the resin infusion technique, utilizing vacuum, was further developed and introduced. Panels with an area of up to 60 m² with laminates on both sides can be vacuum infused in one shot.

Benefits from using the less labour intense (i.e. cost saving) vacuum infusion technique include high fibre content, low styrene emissions, low void content and perfectly smooth surfaces required in order to obtain correct radar cross section properties.

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The hull is built in three sections, which after some pre-outfitting are joined together, much in the same manner as conventional steel vessels.



Figure 3 – Infusion of panels

LOAD AND STRENGTH CALCULATIONS

Ships for the Swedish Navy shall, where applicable, be designed and calculated to meet the strength requirements as defined in "Det Norske Veritas (DNV), High Speed and Light Craft" rules. In addition to calculate the loads according to the DNV-rules, a comprehensive study was carried out by a team consisting of Saltech Consultants, KTH (Royal Institute of Technology) Ships Technology, Kockums Karlskrona Shipyard and FMV. Several methods including, direct calculations, strip calculations and non-linear computer simulations were used in the predictions. In addition, the calculation results were compared with model tests.

Multiaxial fabrics allow a more optimized fibre orientation, which again require more defined design loads and more advanced calculation tools. The deeply analysed load spectra in addition to comprehensive material testing, allowed and drove the Karlskrona Shipyard to focus the strength calculations on FE-analysis.

The FE-model of the corvette was split into seven sections built of shell elements. The boundaries of each of these sections have their boundary-cuts compatible to the neighbour sections and each section has a variable mesh. This compatibility and flexibility of the mesh makes it possible to build different FE-models of the complete corvette, or sections of it [6].

The different load cases applied to the model were such as:

- Global bending moment. Hollow- and crest landing respectively
- Global torsion
- Slamming pressure and sea pressure applied on bottom- and side-plating

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- Liquid pressure applied on watertight bulkheads, and tanks
- Local loads from i.e. heavy equipment.

STRENGTH VERIFICATION PROGRAM

The ship has also been fitted with a measuring system with a number of strain gauges, core shear gauges, pressure gauges and accelerometers. These gauges give online information to the commanding officer about the forces the ship is exposed to, and is an aid in judging whether speed needs to be reduced or course changed in order not to overload the hull structure.

Results from the first sea trial indicate that the predicted strains are close to the measured ones with some conservatism. The slamming pressures measured in the bottom panels of the ship are also close to prediction but the duration of the peak pressure is shorter than expected, which also implies that the original assumptions were conservative.

NON-DESTRUCTIVE TEST METHODS

As the Visby Corvette is a highly optimised ship structure and the simple fact that carbon fibre laminates are black and not see-through makes it important but almost impossible to visually inspect manufactured panels. The method of laser shearography has been used in the aircraft industry for sometime and was found to be suitable also for inspection of sandwich panels for the Visby Corvette. It is a fast and relatively simple method where reference image is stored after which a vacuum pressure is applied to the structure creating stresses in the material. The new image (with vacuum applied) is compared with the reference image and possible sub-surface flaws will be indicated on a monitor.

On Visby, all of the panel joints and sections joints have been tested using this method, providing insurance that no built in defects go by unnoticed. Further research projects have been and are being carried out as we speak on development of this method.

CONCLUSIONS AND FUTURE PROJECTS

In a carbon fibre sandwich construction like the Visby Corvette a number of functions can be integrated, such as low weight, smooth surfaces for low signature, EMI-shielding and high shock resistance and judging from the first sea trials this has been a most successful solution. It is estimated that a weight saving of up to 50% can be achieved without a significant increase in cost compared to a steel construction. With low weight the performance of the ship is increased as we can extend the range and speed for either constant propulsive power or increased payload.

FMV have now begun studies on the next surface combatant for the Swedish Navy. It is likely that the ship will be in the range of 90-120 m due to the operational requirements, such as international partnership operations. Future signature requirements together with a cost effective hull structure will definitely be the drivers in the choice of hull material and manufacturing process. Ongoing studies are also looking at how to an even greater extent integrate a number of functions and properties such as ballistic protection, fire resisting

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properties, signatures and structural health monitoring. The possibilities of building the vessel in an FRP-composite/sandwich design will be deeply investigated, and there are still some limitations that need to be challenged.

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