Fire-retardant Composite Panel for Shipbuilding

Fiber-reinforced composite materials are rarely used in cruise or merchant ships for fire safety reasons. Saertex has now developed a fire-retardant standard panel and worked additionaly with the Meyer Group to incorporate the composite into a sandwich construction for the sun deck and exterior walls of a river cruise ship, achieving a 45 % weight saving.

Persuasive effort

The use of fiber-reinforced plastics (FRP) has been standard in boat building for many years. However, to date, these materials have scarcely been used in large ships such as cruise and merchant vessels, despite the numerous benefits using such composite materials would offer in terms of energy savings, fire safety, design freedom and maintenance. In a research and development project, Saertex, together with the Meyer Group, successfully replaced steel and aluminum in ship construction with composite materials. The entire sun deck and the exterior walls directly below it for the shipyard's newly developed, 110-m river cruise ship were implemented using a sandwich construction that saves 45 % of weight in this case. The biggest development challenges were, firstly, with the mechanical properties of the upper and lower decks and the stringent fire safety requirements for ships. Secondly, a number of people and the authorities had to be persuaded that composite materials would represent a comparable, if not superior, solution to steel. Various fire tests were performed and a mock-up measuring 11.4 × 10.2 m was built to convince the different groups of people, namely traditional steel shipbuilders, shipowners and national and European authorities, of the suitability of the material. Furthermore, various presentations and demonstrations had to be put on for the relevant authorities like the ship classification society DNV GL, the Central Commission for Navigation on the Rhine (CCNR) in Strasbourg and the Federal Ministry of Transport to obtain approval by the CCNR, the supreme authorizing body for inland water vessels in Europe.

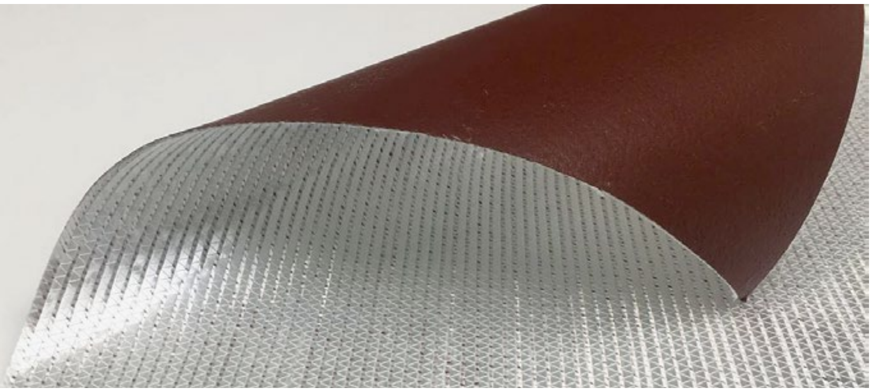

FIGURE 1 Leo-coated fabric is a modified multiaxial glass-layered material using additives to create insulating layers (© Saertex)

Maritime Standard Panel

The materials were designed through close cooperation between the Meyer Group and Saertex. A selection of materials is used from the Saertex product line "Leo," developed to meet exceptionally high fire safety requirements. They comprise multiaxial layers of glass with the Saerfoam product as core material, a vinyl ester resin and an additional protective layer. The new design reduces the draft of the river cruise ship by 5 cm, enabling the shipping company not just to prolong the cruise season, but also open up additional navigable waters for its fleet. It also lowers fuel consumption and thus the vessel's emissions. This project represents a milestone for the future use of composites in support structures for large ships, since both the technical feasibility of the creation of large structures and the certifiability of this completely new materials technology for shipbuilding could be demonstrated.

This development is important, not just for inland waterway vessels but also large, ocean-going ships, since e.g. fire safety

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TABLE 1 Sample test results for smoke formation in accordance with IMO FTP Code, Part 2, Smoke and toxicity measurements for a sandwich structure with core material with a minimum dry layer of 500 µm (© Saertex)

Results	$D_{s,max}$	Time to $D_{s,max}$ [s]	Trial end [s]
25 kW flaming	37.84	1198	1200
25 kW non-flaming	121.39	1193	1200
50 kW flaming	229.85	1200	1200

requirements are based on the same regulations of the International Maritime Organization (IMO). This project has again shown that the numerous possibilities of using composite materials offer benefits as well as being associated with challenges. There are many possible ways of meeting the requirements set out in the project. Consequently, various decisions regarding the structural components had to be made at short notice, to meet not just the fire protection requirements but also those relating to:

- lightweight design
- mechanical performance
- noise characteristics
- thermal insulation
- workability
- transport logistics.

The numerous influencing factors hamper the selection and design of materials in maritime projects. Moreover, available data on composite materials and lightweight design is often very scarce. It is not possible to use standardized raw materials or semi-finished products.

> The new design reduces the draft of the river cruise ship by 5 cm.

With this in mind, Saertex developed a new, so-called standard panel for use in the maritime field, which was then subject to comprehensive tests. Users can benefit from the results obtained by using them to underpin their own use cases. The results included values concerning

- fire behavior: smoke density, toxicity, thermal release and structural integrity
- sound transmission
- mechanical characteristics

and can be used as input for finite element (FE) calculations.

The maritime standard panel is the basis for selecting and optimizing materials with regard to the project requirements. The experience gathered from the current project influences not only the choice of materials, but also their production and application.

One important development when producing the maritime standard panel was substituting the previous protective coat with a textile-based protective layer. The previously used protective coat is a vinyl-based gel or top coat with good fire protection properties. It carbonizes in a fire, acting as a first barrier layer, isolating the laminate structure and protecting it against fire. However, this protective coat has disadvantages for the production of fire-retardant components, since a second production step is required to apply the gel or top coat to the finished part.

Saertex successfully avoided the use of this protective coat, considerably streamlining the production of the flat, fire-retardant panels. For this purpose, the fire protection-relevant materials providing the isolating layer are attached directly to the glass layer, as shown in Figure 1. The covering layer – modified to provide fire protection – is laid up into the mold like a standard layer and processed using vacuum infusion technology. Mechanizing the application of the intumescent coating to the layer allows a standardized and reproducible layer thickness of the material to be achieved. This is a further advantage over the sprayed application of the conventional protective coating.

The fire protective properties of this coating are also good, due to the low proportion of organic bonding agents compared with a vinyl-based protective layer variant on the fiber layer modified in this way. The effective fire-protective coating makes it possible to build up the laminate structure using standard resin systems.

As already outlined, the developed maritime standard panel was subject to various fire tests in accordance with the IMO FTP Code to confirm the fire characteristics, Figure 2. The fire tests were performed with a dry layer thickness of around 500 µm, the minimum achievable coating thickness. This variant offers maximum lightweight design potential and is also the most appealing from an economic perspective, owing to the low amount of material required. As a general principle, the dry layer thickness can be varied, as the maritime standard panel has an adaptable modular structure. Table 1 shows the example fire test results. The reference value for use as a floor covering is $D_{S,max} < 500$, < 400 for the top ceiling covering and < 200 for partition walls and linings, where $D_{S,max}$ corresponds to the maximum specific optical thickness.

The requirements for all application areas are already fully met with a test intensity of 25 kW for a dry layer thickness of around 500 µm; only smoke formation is just outside the requirements for partition walls in a test with 50 kW. Components for the top ceiling

TABLE 2 Values of toxicity measurements (© Saertex)

Gas	No.	50 kW	25 kW flaming	25 kW non-flaming	Set
CO	2	762.70	254.27	111.93	1450 ppm
	3	869.70	248.81	206.94	
Average	–	**816.20**	**251.54**	**159.43**	
HF	2	0.00	0.29	0.00	600 ppm
	3	0.00	0.82	0.00	
Average	–	**0.00**	**0.55**	**0.00**	
HCl	2	0.00	0.00	0.00	600 ppm
	3	0.00	0.00	0.00	
Average	–	**0.00**	**0.00**	**0.00**	
HCN	2	47.64	19.96	8.16	140 ppm
	3	58.77	16.95	24.70	
Average	–	**53.21**	**18.46**	**16.43**	
NO-NO_2	2	0.00	0.00	0.00	350 ppm
	3	0.00	0.00	0.00	
Average	–	**0.00**	**0.00**	**0.00**	
SO_2	2	0.00	0.00	0.00	120 ppm
	3	0.00	0.00	0.00	
Average	–	**0.00**	**0.00**	**0.00**	
HBR	2	1.83	1.51	0.74	600 ppm
	3	1.33	0.49	0.68	
Average	–	**1.58**	**1.00**	**0.71**	

and floor coverings are already qualified with this thin layer thickness. A slight increase in the dry layer thickness is likely to also significantly reduce the values for 50 kW, especially as the peak for all tests was only measurable at the end of the test.

The toxicity values of the composite material panel that were established, Table 2, were significantly below the permissible threshold values for all measurement values. Different dry layer thicknesses of the coated textile were measured to determine the influence of the dry layer thickness of the coated textile, Figure 3 and Table 3.

The tests in the small furnace are conducted following IMO FTP Code, Part 3: Fire test procedure for vertical and horizontal divisions. The temperature load in the furnace is in accordance with the standard time-temperature curve and comparable with the IMO test. Only the size of the test specimen differs. Depending on the requirements profile (A/B/F classification), the maximum temperature rise at the rear of the element is 140 or 180 °C.

After 30 min of testing, the maritime standard panel still has a temperature reserve on the side facing away from the fire. The mean temperature rise with a dry layer thickness of around 1100 µm on the coated textile is around 85 °C. This delta is reached with a dry layer thickness of 500 µm after around 20 min, Figure 3. The test for the divisions back up the results of the previous fire tests.

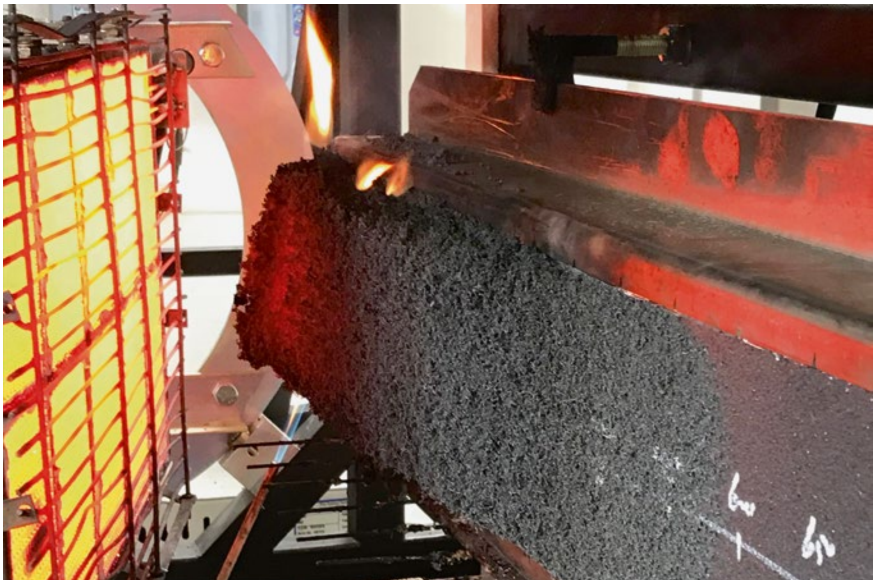


FIGURE 2 Test specimen in the fire safety test in accordance with IMO, Part 5, for measuring flame propagation (© Saertex)

TABLE 3 Occurring heat flow density (Critical Flux at Extinguishment, CFE) at the surface of a test specimen depending on the layer thickness (© Saertex)

TSD [µm]	CFE [kW/m²]
500	18.25
650	24.05
800-900	27.51
1000-1100	28.90

The fire protection properties of the component can be significantly influenced by deliberately adjusting the dry layer thickness.

Large-scale Tests

The IMO Part 10 test, also known as the room corner test in accordance with ISO 9705, was also performed to avoid appraising the performance of the material solely on a small scale. In this full-scale test, a complete test room made from the material being examined is set up and exposed to a burner output of 100 kW for 10 min, Figure 4. At the end of the initial 10 min, the burner intensity is increased to 300 kW for a further 10 min.

The failure criteria for this test include flashover. This significant increase in the peak heat release rate is equal to the full development of a fire. Classic, non-fire-retardant components made from composite materials already fail this test after 2 to 3 min, given that the intensity of the burner at 100 kW is high and the fact that the test takes place in a closed room in which all the fire gases collect. [1]

The maritime standard panel that was tested does not yet currently meet all the requirements of the IMO Part 10 test. No flashover may occur throughout the entire testing period of 20 min; in the test performed, flashover occurred at 12:15 min.

However, compared with non-fire-retardant components made from composite materials, the panel provides outstanding fire protection, as no additional heat release was detected during the initial 10 min when flames were applied at 100 kW, Figure 5. Smoke gas production was also in the undetectable range during the first 10 min, Figure 6.

It was only after the burner intensity had been raised to 300 kW that a significant quantity of additional heat was released via the formation of flammable gases from the laminate, finally resulting in a flashover. The panel can thus already be used in the military field without any further testing, as the requirements regarding flashover here are 10 min, Figure 7.

Risk-based Design

20 min test time must be achieved to qualify the material as fire-retardant in accordance with Part 10. The structure was initially tested with a dry layer thickness of 500 µm.

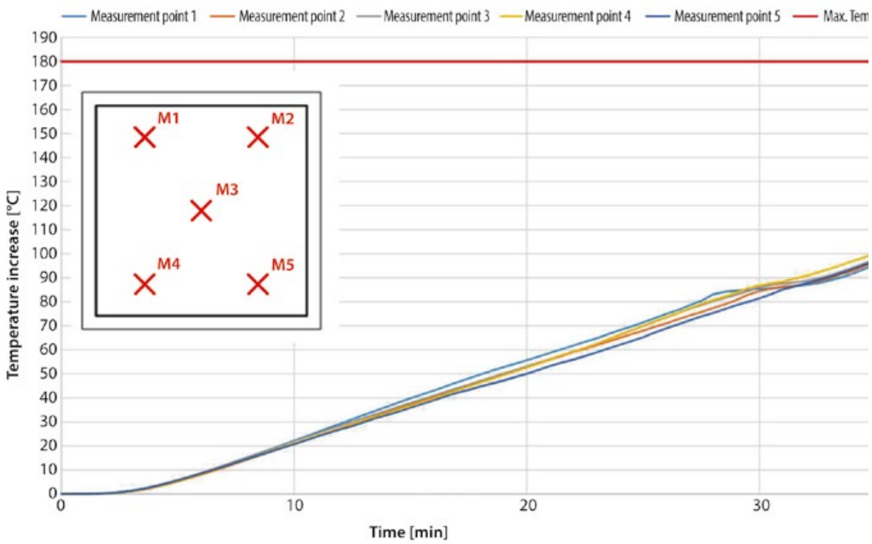


FIGURE 3 Temperature increase at the rear of the component in the test according to IMO, Part 3 (© Saertex)

No additional heat release developed during the initial 10 min when flames were applied at 100 kW.

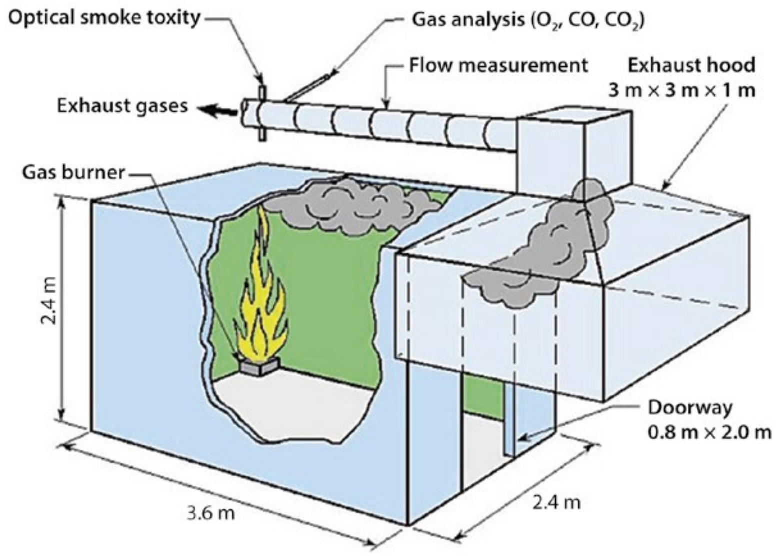
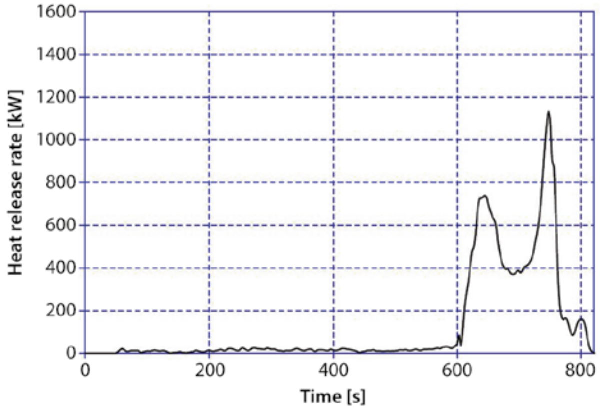


FIGURE 4 Schematic diagram of the room corner test (© RI.se)

FIGURE 5 Heat release in the room corner test (without burner) (© Saertex)



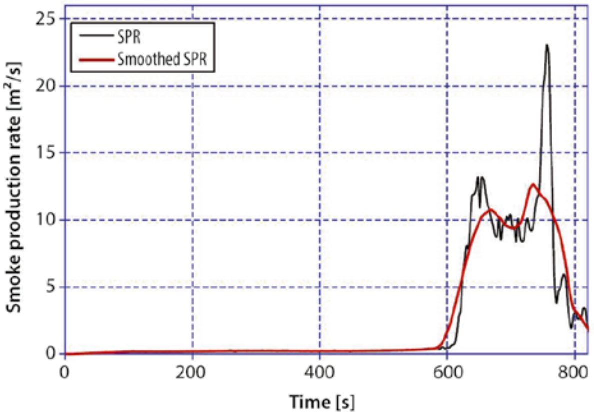


FIGURE 6 Smoke gas in the room corner test (without burner) (© Saertex)

FIGURE 7 Room corner test after approximately 10 min exposure to flame at 100 kW (© Saertex)

Compliance with the requirements is viable with a higher dry layer thickness, and further tests in accordance with IMO FTP Code, Part 10, are already being planned.

All tests were conducted to provide the end user with broader base data for its maritime project and shorten the general development times for such projects. The results obtained represent the current state of technology, which can be modified and optimized depending on the project in question. For the first time, data is now available that supplements the general characteristics profile of a sandwich panel made from composite materials, which includes the usual composite material parameters such as mechanical properties, weight, sound and thermal insulation capacity with the necessary fire protection characteristics. Costs, thickness and weight can be saved since using the new panel eliminates the need for any additional fire or thermal insulation.

The current requirements for materials in IMO-relevant ships cannot be met by composite materials due to the required non-combustibility test in accordance with IMO FTP Code, Part 1. The materials could therefore only be used in accordance with Solas Regulation 17. A risk-based design is necessary to deploy composite materials.

The recently published IMO FRP Guideline MSC.1/Circ.1574 allows the use of composite materials in maritime shipping. However, in this case composite materials must also undergo a risk assessment and fire safety must be considered. The fire test findings thus support the entire industry in the current discussion concerning the use of composite materials in maritime applications.

Reference

[1] McGregor, D.; Hoyning, B.: Fire Safety of Naval Vessels made of Composite Materials: Fire Safety Philosophies, NATO RTO specialists' meeting on Fire Safety and Survivability, Aalborg, Denmark, 2002

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