# Sandwich panels in shipbuilding

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ABSTRACT

*In this paper a short historical outline of laser technique development and its application to welding sandwich panels, is presented. Laser-welded sandwich panels of different geometry, today introduced in industrial scale, were described. Prefabrication process of folded ship constructions, in particular, of panel-to-panel connections and hybrid (sandwich panel – conventional construction) structures, was discussed. Attention was paid to various aspects of prefabrication, assembly and use of panel constructions.*

**Keywords** : laser welding, laser - welded steel panels, I-core panels, connection of panels, double skin structure, ship structures

## INTRODUCTION

Industrial use of the laser radiation started in the 1960s. The ideas of Einstein, theoretically explained in the years 1914-1919, were developed in 1950 in the USA by A.L. Schawdow and C. H. Townes who provided fundamentals of the process. Continuation of the work, carried out also by Basow and Prochorow during the years 1953-1954, showed that forced emission of energy by microwaves is possible in the laboratory-scale. As a result the first MASER (Microwave Amplification by Simulated Emission of Radiation) was built by Townes and his collaborators, Gordon and Zeiger, in 1954.

Some years later, in 1960, an optical maser was built in the laboratory of the Hughes Aircraft Company, California. Under the name LASER (Light Amplification by Stimulated Emission of Radiation) it has brought revolutionary changes into many fields of technique, medicine, optics, astronomy etc.

The main advantage of the laser beam comes from its enormous density of energy as compared with conventional sources of energy. The laser beam energy density ranges from$10^8$ to$10^9$ W/cm$^2$ whereas conventional welding procedures, such as the hand electrode welding, offers only $10^4$ W/cm$^2$, and TIG (tungsten innert gas) process - $10^5$ W/cm$^2$. This is still higher even that of other new welding processes with high-energy output – such as the plasma welding process - $10^6$ W/cm$^2$ or the electron beam welding -$10^7$ W/cm$^2$. Such high energy density leads to an essential increase of speed of welding process, a perceptible reduction of the deformation energy, and consequently, to minimization of the unwanted post-welding deformations. It was the base to start – in 1990 – – intensive work aimed at the introduction of laser welding technique into the shipbuilding industry.

## LASER-WELDED PANELS – – AN INNOVATIVE STRUCTURAL SOLUTION

The development of laser technique brought to building $CO_2$ lasers of about 20 kW power and ruby ones of 6 kW power, opened the way to the application of laser welding in shipbuilding. The introduction of such technique required, however, the creation of laser-weldable ship structures – as the first step. Because of the higher demands concerning joint preparation it was not possible to simply take over the ship hull "classical" construction consisting of plating and crossing stiffeners. Fig.1 presents a comparison of the classical (conventional) ship structure – for which the advantages of the laser welding could not be exploited in the initial development stage – with the sandwich panel structure prepared to the laser hybrid welding process (laser welding combined with MAG – metal active gas welding).

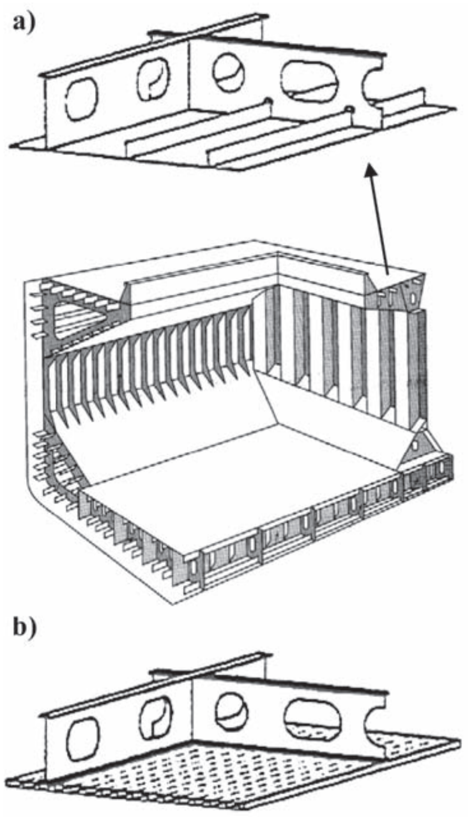


***Fig. 1.*** *Ship structure:* ***a)*** *classical (conventional),* ***b)*** *sandwich [1] .*

Since industrial lasers are currently built as stationary installations (Fig.2), the research is focused on production of the stiffened flat (or weakly bent) plate sections (Fig.1a and 1b). A conventionally stiffened flat section has an orthogonal stiffening system consisted of the rolled bulb or angle profiles in one direction, and welded T-beams in the second one. Large length of the fillet welds to be welded, combined with the introduction of considerable amount of heat constitute the factors reducing productivity and production quality. A hybrid structure (created from a laser-welded panel and one-directional T- beam) can be used instead, so the numerous stiffeners of the first direction can be omitted hence to reduce all the above-mentioned problems (Fig 1b).

*Fig. 2. Laser welding machine for panels of up to 12 m in length [2] .*

The mentioned laser-welded panel consists of two shell plates between which is mounted one-directional stiffener system. The stiffeners are connected with the plates by laser welding executed from outside of the plates. Principle of the process is shown in Fig.3. The laser beam penetrates the shell plate through and the end of the adjacent stiffener and joins this way both the elements.

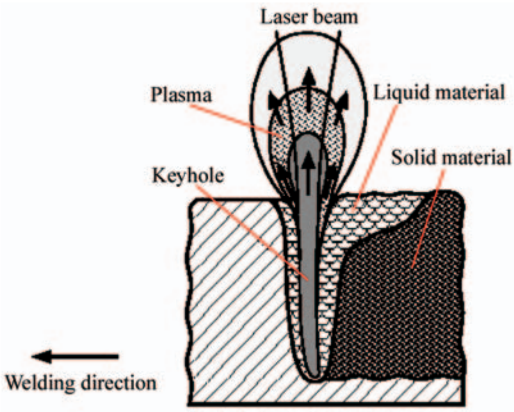


*Fig. 3. Depth effect of the laser beam [3] .*

Panels welded in such manner show smaller welding deformations and have a better flatness in comparison with conventional structures. The laser-welded panel is shown in Fig.4.

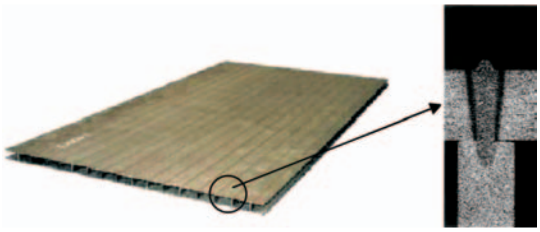

*Fig. 4. Laser-welded panel fitted with flat steel stiffeners (webs) – (I-core) [4] .*

The industrially produced I-core panels can be made in a variety of geometrical dimensions as follows : shell plating thickness from 1.5 to 10 mm, panel width from 500 to 3 000 mm, panel length from 1 000 to 10 000 mm, panel depth from of 40 to 100 mm, stiffener spacing from 80 to 120 mm, minimum stiffener thickness of 3 mm. The joining method in question offers possible application of different geometries of internal stiffeners, for example : X-core, V-core, L-core, O-core, Z-core and other (see Fig.5).

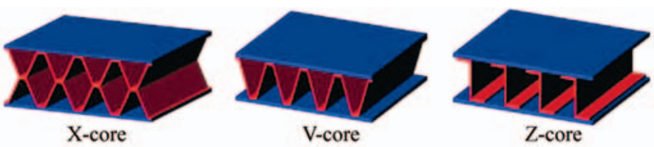


*Fig. 5. Different forms of core of sandwich panels [5] .*

From the shipbuilding point of view, I-core panels seem to be the most suitable because they have an optimal relation of its mass to stiffness both in the longitudinal and transverse direction, and are relatively easy for manufacturing.

Beside of these completely flat, also panels with one-directional curvature can be manufactured. Such panels can be used for example for roofing huge halls or covering concrete walls. An example of the panel with one-directional curvature is presented in Fig.6.

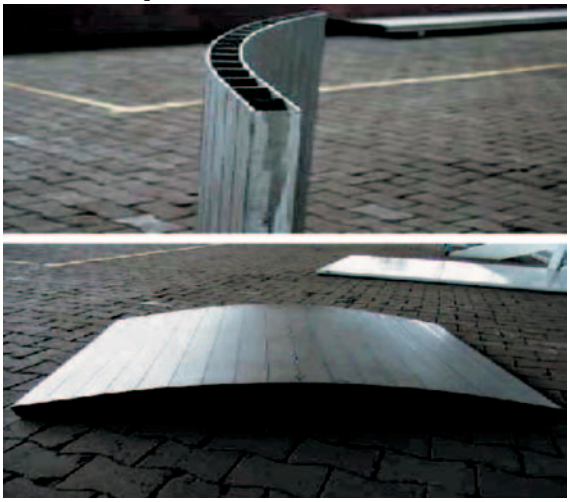

*Fig.6. Laser-welded panel with one-directional curvature [6] .*

For the improvement of the stiffness or for raising other properties such as sound insulation, the panel's interior can be filled with an additional material such as expanded polyurethane, balsa wood or lightweight concrete. Such core material can also improve corrosion resistance or reduce thermal conductivity. The application of the core material also improves buckling strength of the shell plates.

The shell plate buckling between supporting stiffeners is one of the most important problems in the dimensioning of steel sandwich structures. The small thickness of shell plating leads to a relatively small value of critical buckling stresses. The critical load can be increased by the supporting effect of the filling. As an example, the panel with lightweight concrete filling is presented in Fig.7.

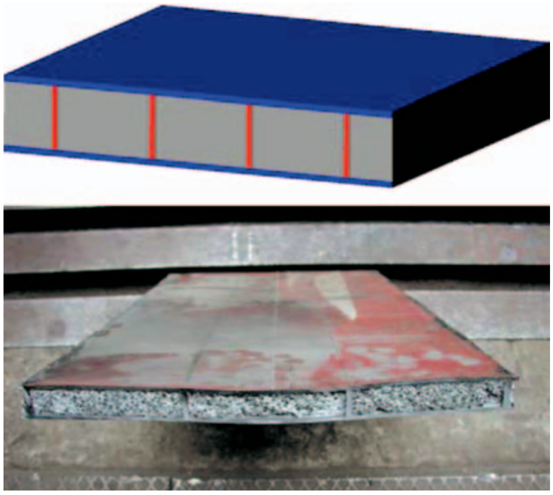

*Fig. 7. Laser-welded panel with filling [7] .*

The panel's internal space between two shell plates can be also used as a channel for cables or tubes widely applied in ship construction. The cables or pipes (for drink water or sewage system, heating equipment, etc.) placed inside can be fixed directly by the panel filling, so that fixing elements are not necessary.

## MODULAR SECTIONS BUILT OF LASER-WELDED PANELS

To form bigger sections of ship structure, connection of some panels is necessary. The panel - panel connection in the plane parallel to the stiffeners (see Fig.8) is less critical in comparison to that in the plane perpendicular to them because in the other case load is transferred only by the relatively thin shell plates.

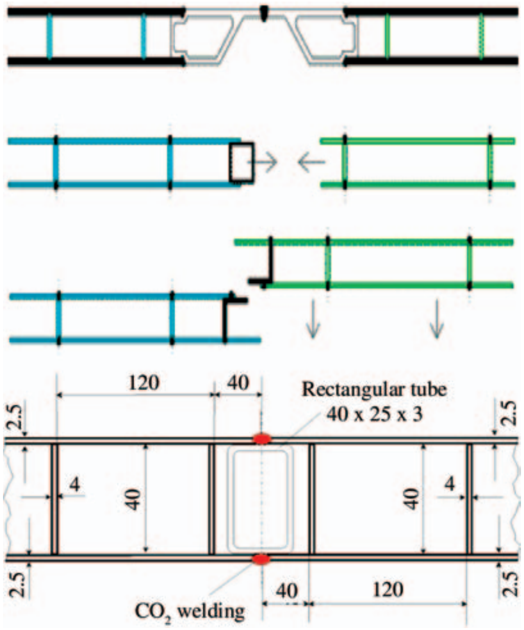


***Fig. 8.*** *Ways of making panel -panel connection in the plane parallel to the stiffeners [8] .*

Such prefabricated sections are then used as – for instance – deck construction or transverse and longitudinal walls (bulkheads) of ship hull. Fig. 9 (up part) shows a deck construction with T - girders put - on, and prior – installed tubes. The down part of Fig.9 shows a ship interior with walls erected from sandwich panels. The modular character of the sandwich panels makes arrangement process easy and significant labour saving possible because the almost deformation-free sandwich elements constitute basically post-treatment-free modules.

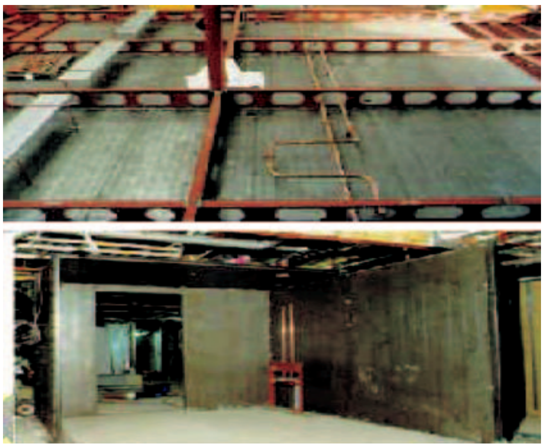

***Fig. 9.*** *Deck and wall sections made from laser-welded panels [9] .*

The smooth surface of the panels can be painted without additional preparation and does not need any additional covering.

## HYBRID STRUCTURES

The structure which contains both conventional and laser-welded components is called *hybrid* structure. The using of laser-welded sandwich panels often requires – (e.g. in bow or stern area of ship deck) that the panels have to be combined with the conventional structures. To this end additional joining elements are also necessary. A typical hybrid construction is presented in Fig.10.

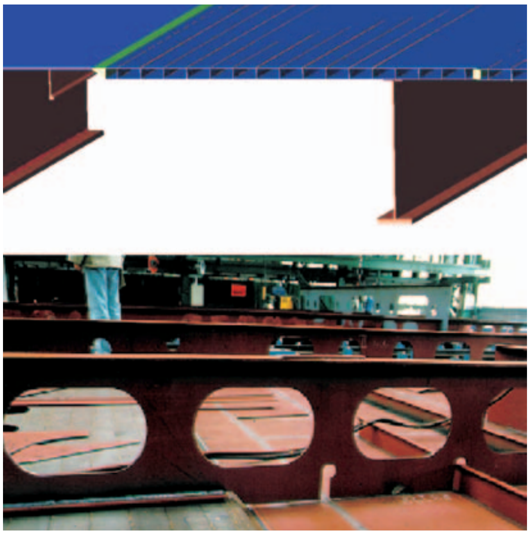

***Fig.10.*** *Example of a hybrid structure [10] .*

Due to the fact that at the moment any rules for application of such structure do not exist, each particular design has to be subjected to a separate evaluation. However on the basis of the results of certain research investigations it is possible to formulate some general principles related to sandwich structures – see Fig.11. Every concentrated load applied to sandwich structure should be introduced rather into a stiffener than non-supported plate area to avoid a local failure. Otherwise – a local strengthening in such points is necessary.

The rigid fixing of panel edges leads to a smaller value of global deflection than that in the case of their simple supporting. Connection of sandwich panel and conventional structure always creates a high - stress region.

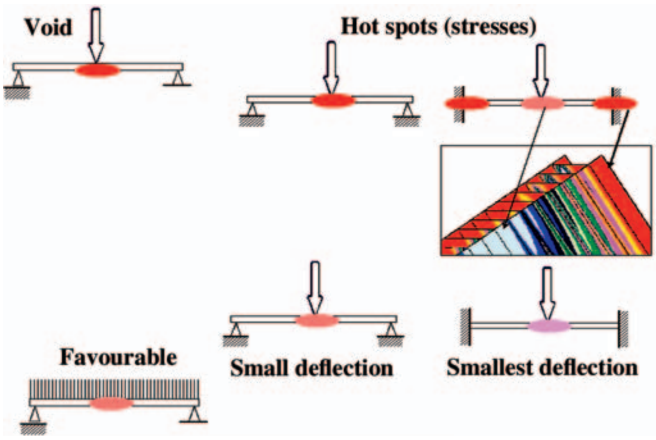


***Fig.11.*** *Strength problems regarding sandwich structures [11] .*

Problems of the joining two sandwich panels and a sandwich panel with a conventional structure have been presently subjected to intensive studies.

## SUMMARY

Laser-welded panels constitute innovative modular components which already have found application to ship structures. They are characterized by considerably greater stiffness at the same mass, as compared with conventional structures, and they are easier in assembling.

Effectiveness of the hull structure assembling process can be considerably improved by using sandwich elements when the still open organizational and strength problems are solved.

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11. Author's figure



*Versatile stand for strength tests of natural scale ship hull units,*
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