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TECHNOGICALLY IMPROVED STRENGTH OF CRITICAL STRUCTURAL ELEMENTS OF HIGH-SPEED SHIPS

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ABSTRACT
Design and production of a new type of high-speed ship, named Gliding Wing, is a demanding task, due to its desired capabilities, complex structure, and hard operational conditions. It is necessary to apply new materials and include appropriate production technologies in a shipbuilding process. This paper suggests some of the materials to be used for production of thinner components resulting in an overall lighter structure. Accordingly, appropriate surface treatment technology, shot-peening, is proposed to achieve a higher strength of critical structural elements. It is also shown that same technological process can improve fatigue strength of treated elements which is of great importance due to significant fatigue problem of considered structures.
Keywords: high-speed ship, surface strengthening, shot-peening, fatigue strength

1. INTRODUCTION
The limits of today's transport vehicles impose the need for development of a new means of transportation which have to be faster, safer and more comfortable then present vehicles. Possibilities of some non-standard types of vessels have been recognized and investigated by the authors and results were presented in modified Von Karman – Gabrieli diagram [1]. It was concluded that high-speed ships of the next generation (Farop, Bracera – fig.1, Gliding Wing fig. 2) fill the gap between relatively slow sea-going vessels and aircrafts [1, 2]. These ships offer more carrying capacities than aircrafts, both for cargo and passengers, and at the same time they achieve significantly greater speed than standard ships.

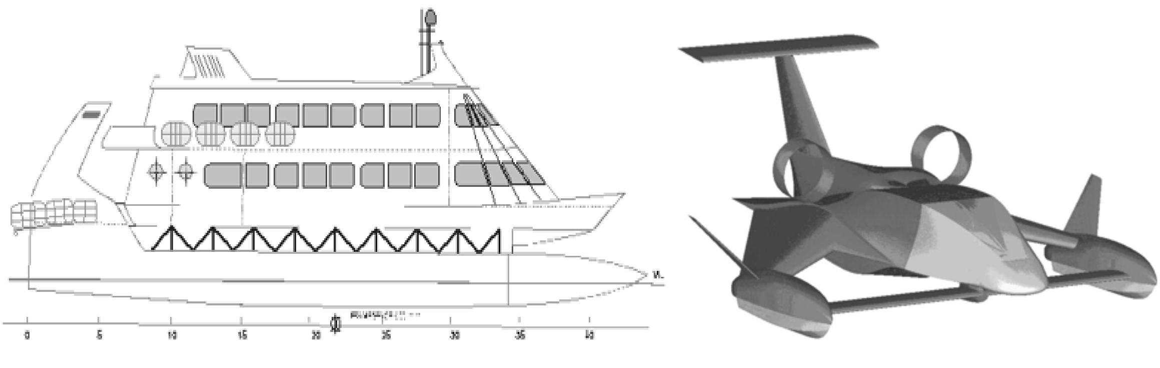

Figure 1. New types of high-speed ships: Farop (left), speed 60 kn, Bracera (right), speed 120kn

Gliding Wing has particularly good capabilities and represents potentially a very good alternative for the future sea-going transportation. In its first design version, named 'Spalato'; it reaches speeds up to

80 knots on the sea level [3]. Moreover, recent structural and propulsion improvements make it able to reach speed of nearly 120 knots [4]. To achieve that vessel emerges from water and flies on low heights, 20 – 30 m above the sea level. While flying, Gliding Wing utilizes a well known WIG (Wing-In-Ground) effect. WIG effect makes Gliding Wing more efficient – it can cruise at desired speed with lower fuel consumption.

This non-standard type of vessels requires a special attention both in design and production phase of development. It has to be adequately aerodynamically shaped, with light and strong structure. All standard issues regarding strength of ships are additionally expanded with structural strength problems typical for aircrafts; especially a fatigue strength problem is emphasized [5, 6]. Therefore, it is necessary to introduce a new shipbuilding materials and appropriate production technologies to improve structural strength and even to achieve appropriate structural form.

2. THE CHOICE OF MATERIALS FOR CRITICAL STRUCTURAL PARTS

Demanded characteristics on materials were: corrosion resistance, good welding characteristics, low density (1,8 - 2,4 kg/dm3), good strength and stress characteristics (200-350 MPa). After comparing a large number of different types of aluminum and steel alloys, and based on a long experience in ship and aircraft production [7], it was concluded that following materials, unusual in classic shipbuilding, meet desired requirements and are recommended for building of the critical elements of Gliding Wing structure (Fig 3):

- Al-alloys: 5454 (AlMg2,5Mn), 5080 (AlMg4,5Mn), 6063(AlMgSiO,5), 6353 (AlMgSi1),
- Al-Li alloys: (8090).

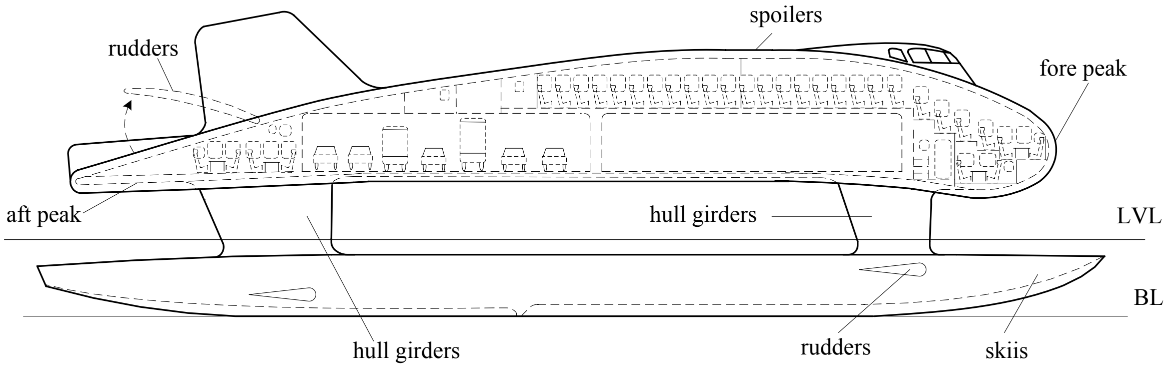

Figure 2. Critical parts of Gliding Wing structure

For elements that need to have higher strength different types of high-bearing steels may be suitable (low-alloy chromium-molybdenum steels, low-alloy chromium-molybdenum-nickel steels and chromium-molybdenum-nickel-vanadium steels, with strength 700-2000MPa).

Non-metallic materials were not considered but it should be pointed here that composites (carbon and aramid), polyamides, acryl-glass, etc. certainly meet some of requirements and shouldn't be disregarded in the future investigations.

3. TECHNOLOGY FOR IMPROVING STRENGTH CHARACTERISTICS

Each one of mentioned materials will have an important application in the production of vessel's construction parts, particularly those exposed to dynamical loading and influence of the sea water. The choices of a proper technological process and materials treatment can play a significant role in assuring highly desirable features of construction elements: better fatigue strength and resistance to corrosion.

Shot-peening is proposed here as appropriate technological process for improvement of the various material characteristics [8]. It can be used for increasing of materials fatigue life, decreasing of micro-corrosion and stress-corrosion, decontamination of elements surfaces after mechanical machining operations and providing enough roughness for good application of the first coat of paint and forming the plates (plastic deformation) of thin skins by peen-forming. On the basis of experience and research carried out so far, the fatigue life of materials could be increased by shot - peening process from 25% up to 70%, depending on various parameters [9].

The most important quality of shot-peening, in this case, is increasing the fatigue life by "surface strengthening" of material. Greatest tensile stresses are transferred from the surface of the structural element to its neutral axis, which means that they do not take place on the very surface but somewhere "under" surface; therefore they need more time to become the cause of the crack and break. Investigations also showed that shot-peening also prevents the development of established micro-cracks in surface layer [9].

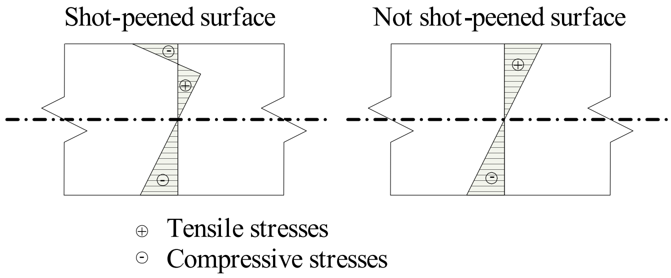

Figure 3. Distribution of stresses in the experimental sample-flat board [9]

3.1. Experimental results

At the current development phase of Gliding Wing the most interesting material is Al-Li 8090. Both, shot-peened and not shot-peened samples of Al-Li 8090 were subjected to dynamic loading and a number of cycles until cracking were determined. The experiment was conducted in accordance to the existing standards, exactly described technological process, instructions of the quality service and with control of all process parameters: Almen – intensity, percentage of surface covering, speed of abrasive jet, quantity of jet flow, etc. which best suited the selected material [10]. All the key features of the experiment are presented in following tables.

Table 1. Composition of selected material Al-Li 8090

Cu (%)	Mg (%)	Mn (%)	Fe (%)	Li (%)	Al (%)
1,32	1,9	0,002	0,05	2,37	94,35

Table 2. Sample Data

Sample thickness	Sample length	Sample width	Reduced Surface
4 mm	205 mm	95 mm	39,26 mm^2

Table 3. Test Data

Distance	Intensity	Shots 230	Saturating speed	Air pressure	Jet angle
200 mm	Almen N2	ϕ0,6 mm	1600 mm/min	0,6 bar	75^o

Table 4. Experimental Results

Not-shot peened (cycles)	Shot-peened (cycles)	Δ (%)
10500	13166	+25,38

4. CONCLUSION

Various structural elements of modern high-speed ships are known as very prone to fatigue cracks. These structural parts also need to be made of light and corrosion resistant materials with sufficient strength; materials such as here proposed Al-Li 8090. The intention of investigation was to improve strength characteristics, particularly fatigue strength, without increasing structure weight. Shot-peening as a procedure or treatment for surface strengthening is already known and accepted in industry. This process, generally speaking, causes the strengthening of surface and increases fatigue strength of the treated component. Shot-peening is safe, easily executable and controlled and has no bad consequences on metallographic and mechanical characteristics of material. This investigation has showed that materials appropriate for building high-speed ships are suitable for strength improvement by shot-peening. Experiment showed more than 25% increase in life cycles of shot-peened samples in comparison to not shot-peened samples. On the basis of above mentioned, we can conclude that the procedure of strength improvement by shot-peening technology should be involved in the production of high-speed ships of next generation.

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