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NEW SURFACE STABILIZATION METHOD FOR GRAIN CARGO TRANSPORT ON SEA

Summary

The artcile introduces a patented new type surface stabilazation method offered to use it mainly for sea-going multipurpose generel cargo vessels having one big size regtangular shape hold in case of grain transport. The proposal suggest to use pressed up air-cushions to secure the trimmed grain surface by filling up the void space above the grain surface. In the laboratory of the Aircraft and Ships Departmant at Budapest University of Technology and Economics the authors created a special experimental tool for checking the practical efficiency of their theory. The article describes and illustrates by figures and photos the findings of the experiments. The proposed grain surface stabilization process is still in laboratory phase, and still not approved by IMO. The industrial experiments of the proposed system will take place in the near future.

Key words: patented process for sea-going grain cargo transport, multi-purpose general cargo vessels, grain surface stabilization, ship stability, grain stability, air-cushions, IMO, International Code for the Safe Carriage of Grain in Bulk – International Grain Code 1991

NOVI POSTUPAK ZA STABILIZACIJU TERETA ŽITA NA MORU

Sažetak

Članak prikazuje novi patentirani postupak za stabiliziranje površine tereta predviđen prvenstveno za pomorske brodove za opće terete s pravokutnim skladišnim prostorom za žito. Postupak predviđa korištenje zračnih jastuka pod tlakom za popunjavanje praznih prostora u cilju osiguranje pomicanja tereta. Autori su proveli posebne laboratorijske pokuse za provjeru svojih postavki. Članak prikazuje ilustarcijama i fotografijama rezultate pokusa. Predloženi je postupak još u ispitivanju i nije potvrđen od strane IMO-a. Pokusi u naravi su predviđeni u bliskoj budućnosti.

Ključne riječi: patentirani postupak za pomorski prijevoz žitarica, višenamjenski trgovački brodovi, stabiliziranje površine žita, zračni jastuci, IMO, International Code for the Safe Carriage of Grain in Bulk – International Grain Code 1991

1. General

In case of carrying grain cargo by multipurpose general cargo ships having large size rectangular shape holds, one of the biggest problems is to ensure the proper stability of the vessel as per the IMO grain stability rules. If the trimmed surface of the cargo is not fixed by bagged grain, huge mass of grain can be shifted sideway filling up the empty spaces of the hold and/or the empty spaces of the hatchcover panels above the free grain surface on the side of heeling due to rolling of the vessel on waves (Figure 1). As the consequence of this shifting, the centre of gravity of the vessel will translate sideway causing considerable initial heeling of the ship and reducing the residual dynamic stability of the vessel in a large scale.

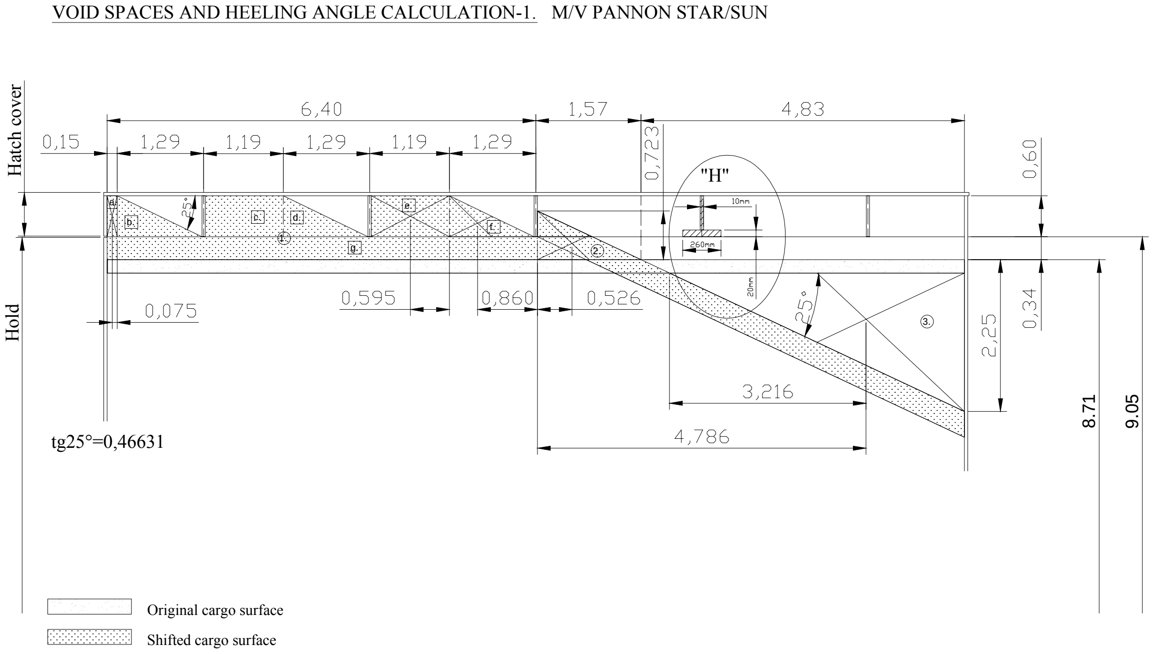

Fig. 1 Space and heeling calculation **Slika 1.** Određivanje prostora i nagibanja

To avoid this unfavourable phenomena one possible solution can be arranging of certain height bagged cargo on the trimmed grain surface. An other often used solution is to build temporary longitudinal grain bulkhead in way of the center line of the hold. The grain bags specially arranged on each other in a required height as per IMO [International Maritime Organization] rules – International Code for the Safe Carriage of Grain in Bulk – International Grain Code 1991, stabilize the cargo surface by local pressure load acting on the top of the trimmed free grain surface coming from the eventually distributed weigth of the bagged grain located above. In case of grain bulkheads, the potential quantity of the shiftable grain cargo is reduced by a strong temporary structures built in way of the center line of the hold, and is created from steel piles, heavy wooden boards, strong wire ropes and other strengthenings. A third potential surface stabilizatiton method can be to use a strong wire mesh putting onto the grain surface, which previously is to be covered by in minimum 75 mm over lapped strong clothes. Two layers of wire reinforcement mesh shall be laid on the top of the covering. The bottom layer is to be laid athwardship, and the top layer longitudinally. The wire mesh is to be properly fastened to the steel construction of the ship. The net openings of the wire mesh can not be less, then 150 x 150 mm.

Each of these potential solutions is accepted by IMO, but both of them – either arranging bagged cargo on the trimmed free grain surface, to build up strong longitudinal grain bulkheads in way of the center line of the hold, or using wire meshes – are really expensive, time consuming and uncomfortable.

If no protection against shifting is used in the hold, for further stability checking the shifted centre of gravity of the cargo is to be determined considering that the heeling angle of the inclined grain surface is 25° to the base line of the ship. The heeling moment due to cargo shifting highly depends on the geometry hold and on the actual stowage factor of the transported grain cargo. In most of the cases – especially in case multipurpose general cargo vessels having one big size rectangular shape hold – carrying bulk grain cargo of relatively small stowage factor (abt. 1,20 – 1,40 m^3/t), and if no protection used against cargo shifting, the sideway translation of the centre of gravity of the vessel is so big, that the regarding IMO grain stabiliy requirements can not be complied with.

The world patented idea, which will be briefly accounted below compairing to the bagged grain. grain bulkhead and meshing methods, offers a much easier and cheaper technical solution to solve the free grain surface stabilization problem. The idea was worked out by the patent-holder, Mr. Dániel Hadházi, who is naval architect, and shipping technical expert, actually working as associate professor at the Aircraft and Ships Department of Budapest University of Technology and Economics. The essence of the new proposed technical solution is to use air-cushions between the trimmed grain surface and the closed hatchcover panels to stabilize the free grain surface during the voyage of the ship.

2. Theory of the new surface stabilization method for sea-going grain cargo transport

When the grain cargo is already loaded into the hold, the grain surface is to be properly trimmed, and covered by canvas cloth for separation. Then required number and size of air-cushions are to be laid down on the surface (Figure 2). The number of the air-cushions depends on the geometry – length and breath – of the hold, and on the height of the remaining void space between the trimmed cargo surface and the lowest structural elements of the hatch cover panels. Before closing the hatchcovers the flexible filling pipes of the cushions are to be connected to the compressed air system located and arranged on the outer side of the hatch-coaming. If the height of the void space above the trimmed grain surface is high, the air-cushions can be laid down even in two layers on each other.

After closing the hatchcovers the air-cushions are to be filled up by compressed air. The pressure in the air chambers of the cushions can be adjusted by local regulators. The expanding cushions will fill up the gap between the trimmed grain surface and the lowest steel construction elements of the hatchcovers closing and blocking all those spaces, where the grain could be shifted due to the rolling of the ship (Figure 3, 4). In case using two layers of air-cushions, before closing the hatch covers the lower air-cushions are to be pressed up. The hatchcovers can be closed and secured following this. Only when all of these operations are over can be pressed up the upper air-cushions having the function to fill up the still remained void space between the lower air-cushion and the closed hatchcover panels.

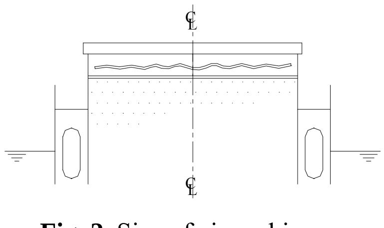

Fig. 2. Size of air cushion

Slika 2. Veličina zračnog jastuka

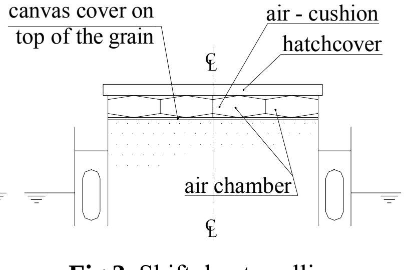

Fig 3. Shift due to rolling

Slika 3. Pomaci uslijed valjanja

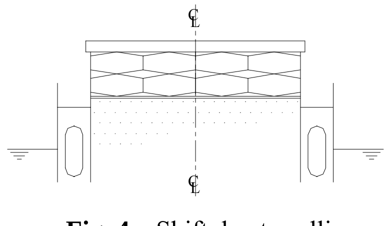

Fig. 4. Shift due to rolling

Slika. 4. Pomaci uslijed valjanja

Each air-cushion is devided into air-chambers ensuring the safe operation of the system in case of leakage. According to preliminary calculation and considering the already existing experimental results, 0,10 - 0,15 bar (1 – 1,5 t/m^2) in the pressurized cushion chambers can ensure the required surface stabilization effect. During the voyage, pressure gauges indicate the adjusted and constant pressure level in the cushion chambers showing the safe operation of the whole system.

After arrival, in the destination port before opening the hatchcovers, first the air is to be released from the cushions. The suction of the compressed air could be carried out by using vacuum pumps, which will be connected to the same flexible pipes, which were used to press up the cushions in the loading port. When the air is already released, the hatchcovers can be opened, and the cushions can be easily rolled up and removed from the hold. After these operations the discharging of the cargo can start immediately.

3. Laboratory experiments

In the laboratory of the Aircraft and Ships Department at Budapest University of Technology and Economics was built an experimental tool for studying, analylising and cheching the operation of this air-cushion type free grain surface stabilization system in way of static heeling and dynamic rolling of the ship. The construction and the dimensions of the experimental tool can be seen on Figure 5 and 6. The experiments were carried out by the patent-holder and the co-authors of this article.

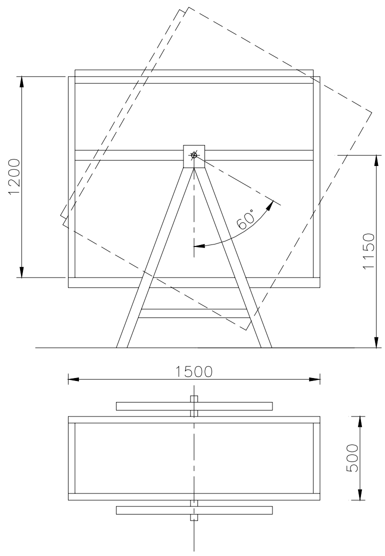

Fig. 5. The idea of the experimenta tool

Slika 5. Zamisao alata za pokuse

Fig. 6 The tool its

Slika 6. Sam alat

The experimental tool is a special size box supported by a stay. The box is connected to the stay through bearings, whiches allow it to turn around a virtual axis. The box is the model of a short cross section of a regtangular shape cargo hold. The breadth/height proportion of the box is similar to the real multipurpose general cargo ship hold breadth/height proportions (1,35:1). The total closed volume of the box is abt. 0,90 m^3. The front wall of the box was made of 4 mm thick plexi glass to ensure the visual checking of the inner part of the box during the experiments allowing to take photos and videos of the grain surface behaviour in differnt conditions. The box was covered by a stiffened flat plate fastened by bolts to the flanges going around at the upper edge of the box. The stiffeners of the flat plate represent the overhanging steel structural elements of a „real" hatchcover (Figure 7).

Fig. 7. Stiffening of the hatch cover **Slika 7.** Ukrepljenje poklopca grotla

The inclination of the box was carried out by an excentrically located portable mechanical car lifter. The heeling angle of the was measured by a plumb-line. The maximum inclination of the box was 58°. For the dynamic experiments the car lifter was removed, and the box was swinged by hand.

The air-cushions were created of strong plastic material using adhesive technology. The air-cushions designed for 0,2 bar over pressure. We used two sets of them, devided into three air-chambers each. The air-chambers were provided by non-return valves and through flexible plastic pipes were connected to a ped operated pump used for pressing up them. The pressure inside the chambers was measured by manometer. From each chamber the air could be released individually. The geometrical dimensions of the air-cushion were a slightly smaller, then the inner sizes of the box allowing the cushions to move free on the top of the trimmed grain surface, without any side wall friction (Figure 8).

Fig. 8. Air cushions **Slika 8.** Zračni jastuci

For the experiments we used bulk grain of 1,32 m^3/t stowage factor having 27,2° slope angle.

4. Static experiments

The aim of the static experiments were to very the efficiency of the new surface stabilization idea among laboratory conditions. For the static tests the box was filled up to two different levels:

- the height of the void space between the trimmed grain surface and the lowest point of the cover siffener is two times of the thickness of the pressed up air-cushions (2 x 144 mm),
- the height of the void space between the trimmed grain surface and the lowest point of the cover siffener is egual to the thickness of the pressed up air-cushions (144 mm).

First we inclined the box without air-cushions measuring the heeling angle of the free grain surface. The results can be find in Table I.

Table 1 Heeling angle measurements **Tablica 1** Mjerenje kuteva nagiba

	Static experiments	
Denomination	$H_{void\ space}$ = 288 mm	$H_{void\ space}$ = 144 mm
The grain surface starts to incline	≈ 28°	≈ 30°
The inclined grain surface reaches the hatchcover	≈ 52°	≈ 39°
Heeling angle of the inclined grain surface at the maximum inclination of the box (58°)	≈ 30°	≈ 28°
Turning back the box, the grain surface starts to backslide at	≈ 9°	≈ 11°
Residual heeling angle of the grain surface at 0° inclination of the box	≈ 22°	≈ 19°

The photos of Figure 9, 10 represent the findings above.

Fig. 9 Experimets

Slika 9 Pokusi

Fig. 10 Experiments

Slika.. 10 Pokusu

Repeating the experiments with air-cushions it became clear, that the proposed stabilization method can work, since either using one or two cushions – depending on the required height of the void space –, the surface of the grain stayed in place keeping the centre of gravity of the cargo in the center line of the hold. (Figure 11, 12 and 13, 14) Considering even the maximum inclination angle of box, only a very small quantity of grain could shift sideway filling up only the small gaps between the individual air-chambers. The residual heeling angle of the grain surface at 0° inclination was practically less, then 1°.

Fig. 11 Experiment **Slika 11** Pokus

Fig. 12 Experiment **Slika 12** Pokus

Fig. 13 Experiment **Slika 13** Pokus

Fig. 14 Experiment **Slika 14** Pokus

During the experiments the over pressure in the air-chambers was 0,1 bar. Since the proposed method tries to stabilize the free grain surface by a vertical pressure load similarly to bagging methom, the over pressure in the cushions was determined ensuring the same surface pressure load like it would be deriving from the minimum required height of the bagged grain as per IMO rules. As per the International Code for the Safe Carriage of Grain in Bulk – International Grain Code 1991 if bagging is used for stabilizing the surface the topped off tightly stowed bagged grain is to be extended to a height of not less than one-sixteenth of the maximum breadth of the free grain surface or 1,2 m, whichever is greater. Instead of grain, other suitable cargo exerting at least the same pressure can be used. Considering that the stowage factor of the bagged grain is abt. 1,40 m^3/t, the pressure on the base area of 1 m^2 x 1,20 m high cube made of a material of this stowage factor is abt. 0,857 $t/m^2 \approx$ 0,1 bar.

Checking the consequences of accidental leakage of the air-cushions, we repeated the experiments releasing the air systematically first from the outer, then the middle air-chamber(s) of the cushion(s) on the inclined side of the box. The leakage, of course decreased the efficiency of the surface stabilization process. Below the leaked air-chambers the grain surface became amorf, and no exact surface inclination angle could be measured, however the sideway shifted cargo volume was much less, then it would have been without air-cushions. On Figure 15 and 16, respectively can be seen the consequances of the leaks in case of using one or two air-cushions.

Fig. 15 Experiment **Slika 15** Pokus

Fig. 16 Experiment **Slika 16** Pokus

An other special problem of the method can be, if the pressure acting on the surface of the grain „goes through" the cargo straight down to the bottom of the hold increasing the local pressure on the bottom structure. For checking this phenomena we measured the deflection of the bottom plate of the box by a micrometer located in the middle of the outer side of the bottom plate (Figure 17).

Fig. 17. Deflection of the bottom plate **Slika 17.** Progibi podne ploče

Pressing up the air-cushions above the grain surface no additional deflection of the bottom plate was experienced. This means, that the inner friction among the grain seeds, and the friction between the seeds and the side walls of box, respectively can compensate the pressure load acting on the surface, and no additional pressure load appears on the bottom of the hold.

The pressure in the air-cushions act not only the trimmed grain surface, but the air-cushions being supperted by the lower structural elements of the hatchcover, tries to lift up the cover reducing the sealing efficiency of the panels. In the real life after closing the hatchcovers the panels should be secured for sea voyage. During the laboratory experiments the flat plate cover of the box – representing the hatchcover of a hold - was fixed by bolts. This type of securing proved to be enough to keep it in place. Due to the very special construction of the box the deflection of the cover plate was not measured. However, the heavy weight and the strong steel structure of the hatchcovers probably can take the upward pressure load of the air-cushions without any failure, and the securing elements can keep the panels in place ensuring the watertightness of the closure, the problem must be checked later during the industrial experiments.

4.1. Dynamic experiments

The aim to carry out dynamic experiments was to check the efficiency of the proposed stabilization method in case rolling the box. This dynamic experiment was only for information, since the dynamic analogue between the model and a „theoretical real ship" could not be properly ensured. The box was swinged manually with a rolling period abt. 2,7 sec. No considerable grain volume shifting was experienced even in case of using intact or leaked air-cushions. However to study the dynamic behaviour of the grain surface is also important, is good to know, that on the sea the grain is shifted sideway mainly because of the big heeling angle due the rolling of the ship on waves, and less because of the dynamic mass forces acting on the grain seeds.

5. Ventilation of the cargo

The grain cargo surface can be ventilated via vent-holes located between the air-chambers of the cushions, as it can be seen on Figure 19. The required size, diameter and number of the vent holes ensuring the proper ventilation and the still safe operation of the cushions are to be determined with the industrial experiments. In case of using air-cushions for surface stabilization, forced ventilation is to be applied blowing fresh air continouosly to the open space above the air-cushions up to the inner side of the hatchcover panels. The construction and the technical details of the hold ventilation system should be designed depending on the size and the position of the air-cushions used considering the minimum required quantity of air to avoid the deterioration of the cargo quality during the time of sea transport.

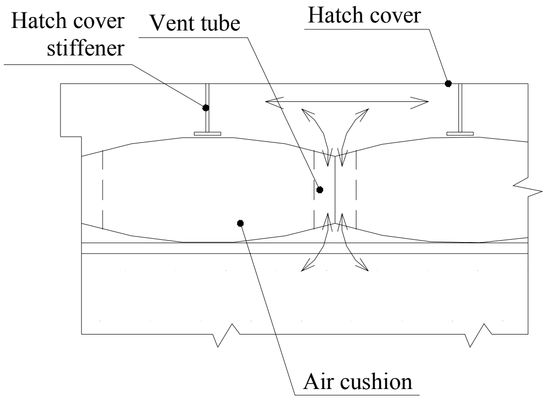

Fig. 19 Ventilated via vent-holes **Slika 19.** Prozračivanje

6. Conclusions

The results of the static and dynamic experiments are very reassuring and make us optimistic, that the offered solution – to use air-cushions for stabilizing the free grain surface – can work among real conditions as well. However the process is still in an experimental phase – only the theory itself was checked in a specially developped laboratory tool –, it seems to be effective, easy to use, comfortable, and definitely cheaper, then those other methods – bagged grain, grain bulkhead, wire mesh – which are widely used nowdays in the shipping practice. Of course, the process is to be checked among real sea transport conditions as well.

The process can be used only in that case, if IMO will approve it. Steps will be done in the near future to inform the International Maritime Organisation about this new proposal, asking for the authority's opinion about this potential stabilization method, and if the authoruty can accept it, applying for its approval, respectively,.

If this stabilization process will be approved by IMO, an other important and urgent aspect of the project will be to find a manufacturer to develop the industrial size air-cushions and to work out the safe and economical operation of the whole system among industrial sea shipping conditions.