

WHITE PAPER

Rudder Cavitation Damage Solved

Revised and updated, September 2013



**How to put a permanent end
to costly, repeated rudder repair
and replacement**

The Hydrex Group
www.hydrex.be



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Part I. Overview of rudder cavitation damage

As any shipowner knows, a ship's rudder is particularly prone to damage caused by erosion and corrosion. The problem features more prominently in high speed container carriers and other fast ships, which are more seriously affected than slower vessels.¹ However, it is a potential problem and hazard for all ships and boats.

This problem results in frequent, costly repairs to or replacement of this vital part of the ship's underwater equipment.

So far, the bulk of efforts to relieve this problem have not been fully effective.

Why the rudder?

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A ship's rudder, placed directly behind the propeller to give the ship maximum maneuverability, is particularly prone to erosion followed by corrosion. The erosion in this case is caused by hydrodynamic cavitation. Hydrodynamic cavitation is a phenomenon that accompanies turbulent fluids.² The turbulence in the fluid, in this case caused by the ship's motion through the water but more particularly by the action of the ship's propeller, results in areas of greatly reduced fluid pressure. (The physical laws involved are clear and well documented, but not relevant to this White Paper which is intended for shipowners/operators, not scientists.) Due to the low pressure, the water vaporizes. This causes small vapor-filled cavities or bubbles in the fluid up to about 3 mm in diameter. The cavities travel through the water and the pressure around them increases, causing them to collapse suddenly. The im-

plosion of the cavities is accompanied by a complex set of physical processes. It is the collapse of the cavities which is accompanied by very high pressure pulses, speeds and temperatures in the water, that cause the damage.

The forces involved are very large. It is as if the surface affected has been subjected to repeated, heavy blows from a hammer, as well as high temperatures. This causes what is known as cavitation erosion as the surface material, first paint and then steel, begins to flake away. This process can be greatly magnified by the presence of gravel or other hard particles in the water.

One need only examine a ship's rudder that has been subjected to cavitation damage to see that, whether one understands or subscribes to the theory, in practice very real damage is caused by this phenomenon. Rudders become deeply pitted; paint coatings and hard steel simply disappear; whole plates can fall off and the rudder practically disintegrate altogether, all as a result of this cavitation damage.

Cavitation is caused by the flows from the motion of the propeller, the cavities imploding on the propeller blades or being transported rapidly back to implode on the rudder surface. But the cavitation can also be caused by the turbulence around the rudder itself, and the collapse of the cavities can occur almost immediately after the cavity is created. So the rudder is subjected to cavitation damage from two main sources: the turbulence caused by the propeller and that caused by the water flowing over the rudder itself.

1 Jae-Moon Han et al., "Analysis of the cavitating flow around the horn-type rudder in the race of a propeller", CAV2001:sessionB9.005

2 www.arisdyne.com/vp/cavitation.htm accessed July 2011

Cavitation damage is not limited to the ship's rudder. The propeller is also subject to the phenomenon as are stabilizers, the vessel's hull and other parts of the under-water vessel where the water flows are particularly swift or turbulent. But the rudder is particularly prone to this phenomenon due to its position and form.

This process is gradual but not necessarily slow. In fact, it can occur in a remarkably short period of time. Sometimes six months is all it takes for serious rudder damage to be present. The first step is that the cavitation causes the paint coating on the steel to erode, eventually exposing bare steel. The erosion of the steel is then accompanied by the electro-chemical process of corrosion because the steel is no longer protected. The effect is multiplied as the cavitation continues and the erosion it causes is added to by the natural corrosion of bare steel exposed to water – the electro-chemical process and the oxidation which this brings about.

Attempted solutions

Rudder cavitation damage is a well known and extensively documented phenomenon. There is a vast amount of literature on the subject. High speed video has been used to capture the process of cavitation in action so that it can be studied. Computer programs have been developed to model the effects of cavitation and predict where the most damage will occur, depending on the construction and shape of the rudder. Many scientists have investigated the phenomenon and scientific papers on the subject abound.

There have been many attempts to prevent the damage caused by cavitation. In the main these attempts fall into the following categories:

1. Change the position of the rudder so that

it is not behind the propeller. This reduces cavitation on the rudder, but is impractical since the ship loses its maneuverability. The ideal placement of the rudder so that it provides maximum control of the ship is directly behind and in the wake of the propeller. The more rapidly moving water makes the rudder more effective. In other words, positioning the rudder so that it carries out its function in the best possible way renders it most liable to cavitation damage.

2. Redesign the rudder so that it is less affected by the flows and turbulence. Some inventors have developed a twisted rudder which is marketed and in use. The twist is an attempt to reduce the turbulence caused by the flow of the water from the rotation of the propeller by changing its angle of attack on the rudder. This has met with some success but has not eliminated the problem.
3. Strengthen the surface of the rudder to increase its resistance to cavitation erosion, often with some other metal. This has only partially relieved the problem, and can in fact be counterproductive if the combination of metals increases the electro-chemical/corrosion factor. The difference in potential between metals can cause very rapid corrosion to occur. Historically, the most dramatic example of this was perhaps the attempt to put copper sheathing on steel hulls to protect them from fouling. The proximity of the two metals resulted in very rapid corrosion of the steel. There have been attempts to reinforce the rudder with a stainless steel plate over the steel, only to have the welds or fasteners holding the plates in place corrode completely so that the plates simply dropped off.

There have been many attempts to devise a better protection system for the hull. Most of these have been ineffective. But not all of them.

4. Use cathodic protection systems to reduce the electro-chemical/corrosive effects. Since the corrosion only sets in after the protective coating has been eroded by cavitation, this is like putting a lock on the barn door after the horse has been stolen. It may reduce the corrosion, but it does not address the primary cause, which is the erosion damage caused by the cavitation.
5. Develop better coatings and rudder protection. It is in this area that the solution presented in this White Paper lies. There have been many attempts to devise a better protection system for the hull. Most of these have been ineffective. But not all of them.

Current practices

The most common practice is to use a conventional type of rudder, place it directly behind the propeller and coat it with a typical epoxy coating or antifouling scheme consisting of primer, epoxy coats, midcoat and biocidal AF paint; the rudder area is often also surrounded by a number of sacrificial anodes for cathodic protection. Depending on the design of the rudder, the usual cruising speed of the vessel and the presence or

absence of abrasive particles in the water, cavitation erosion sets in rapidly or not so rapidly; the paint is eroded away leaving bare steel; the steel is then subjected to the combined damaging effects of cavitation erosion plus corrosion; the rudder becomes pitted and damaged, usually in a specific pattern; inspection reveals the damage, hopefully before it is too late, and the rudder must be repaired or replaced before it disappears completely.

The repair usually consists of welding to restore and build up the surface where the metal has eroded or corroded away, followed by repainting. Plates may need to be entirely replaced. This usually takes the form of lengthy and expensive hot work performed in drydock. Alternatively, it can involve expensive, drawn out underwater repairs to the rudder to keep it functioning until the next opportunity to drydock the ship. Repairs done under water can only be considered a temporary measure since the steel and the welds must of necessity be left bare.

The vessel sails and the repaired rudder is subjected to further cavitation. Weaker now, the damage occurs more rapidly. Before too long the rudder must be replaced entirely.

This all adds up to a continuing economic



Typical repairs to a rudder that has suffered cavitation damage.

nightmare for the shipowner/operator. Dry docking is expensive in many ways, not the least of which is the off-hire time it entails.

Successful approach

One particular coating, a specially formulated glass-flake reinforced surface treated composite (STC) has been found to be extremely effective in completely preventing rudder cavitation erosion from occurring in the first place, thus breaking this vicious circle.

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This was an entirely practical solution, stumbled upon almost by accident by the manufacturer, since the coating system was designed for protection of the underwater ship hull and fouling control, not developed specifically for rudder protection. Observation of the coating system in action demonstrated that hull areas which are normally prone to cavitation erosion were successfully protected with this STC. There was no cavitation erosion where it normally would be expected to occur. This then led to its experimental application to rudders.

So far in the ten years that this system has been in use on many different rudders, not one has suffered any cavitation erosion damage. The rudders so treated have not even needed to be recoated with the STC, let alone repaired or replaced. At most some cosmetic

touch-up has been carried out during routine drydocking.

A byproduct of the STC without the glassflake has been used successfully to repair rudder pitting and other damage which has occurred due to ineffective protection. In cases where the steel was pitted but not completely worn away, the filler was used to build up and repair the pitting, before applying the STC to the entire rudder to protect it against future damage. This has also proved to be 100% effective.

Due to its high glass content, this coating is extremely tough and resilient and has the added advantage of being an electrical insulator which successfully prevents electrochemical corrosion from taking place.

While the experiment with the STC has not yet been attempted on every type of vessel's rudder, and it remains to be tried on some of the really high speed ships, results to date show a potential final solution to all rudder cavitation problems.

This White Paper covers the problem of rudder cavitation damage in detail, and discusses the results and potential of using this type of coating system to completely prevent such damage from occurring, thus ending the recurring, expensive cycle of rudder cavitation damage, repair and replacement.

Part II. A short history of rudder cavitation damage and attempted solutions

Rudder cavitation damage is not new. Nor are attempts to resolve the problem. Naval architects, ship builders and scientists have been working on the problem since the current propeller/rudder combination came into use. There are references to cavitation observation experiments being carried out as early as 1895.³

The attempts to solve the problem since then have been many. As covered in Part I, they come under the broad classifications of

1. design changes to the ship and/or the rudder, or
2. efforts to contain erosion after the cavitation erosion has set in, or
3. attempts to “cavitation-proof” the rudder.

Judging from the literature available on the subject, much of the research in this area, however, has been an attempt to analyze and predict the potential damage to rudders which cavitation can cause. Methods of studying cavitation, describing cavitation, analyzing cavitation and observing cavitation abound. The problem is approached from many angles, but most of these angles seem to be different ways of describing the problem, rather than workable approaches to dealing with it effectively in the real world. In other words, solutions are scarce. This is well summed up in the following quote from a paper presented by J. Friesch at the Sixth International Symposium on Cavitation in Wageningen, The Netherlands, in 2006:

Rudder cavitation is a long recognized problem in shipping industry. Nevertheless, we are still far away from practical final solutions to improve the situation.⁴

The following statement occurs in the Final Report and Recommendations to the 24th ITCC (International Towing Tank Conference), “Erosion on Propellers and Appendages on High Powered/High Speed Ships”:

Although much is known about the bubble dynamics and material response, the problem of the prediction of prototype cavitation damage remains unsolved.”⁵

(Let alone, one might add, the full solution to the problem of rudder cavitation damage.)

Rudder design

Many attempts to solve the problem of cavitation damage have been by way of improved rudder design. While the problem of rudder cavitation damage is universal, the effects have been mitigated in varying degree through rudder design improvements.

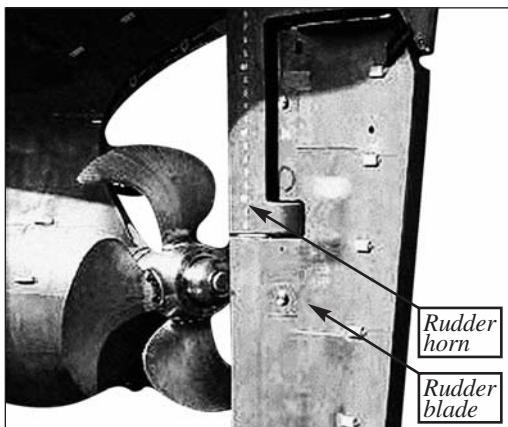
Types of rudder

A brief overview of some different types of rudder will help clarify this section of the White Paper.

3 MARIN, “Cavitation erosion,” <http://www.marin.nl/web/show/id=102629> accessed July 2011

4 Friesch, J., “Rudder Erosion Damages Caused by Cavitation,” Proceedings from Sixth International Symposium on Cavitation, Wageningen, The Netherlands, 2006

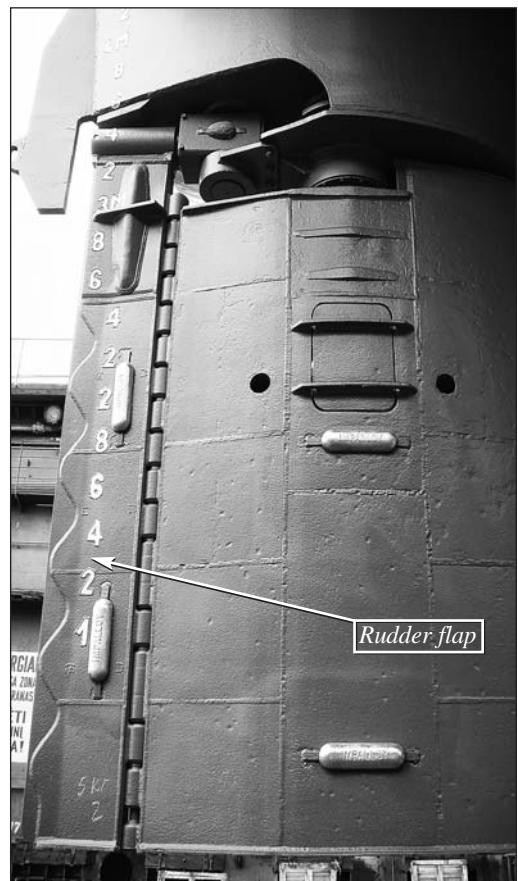
5 ITTC 2005 UK, “The Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships Final Report and Recommendations to the 24th ITTC



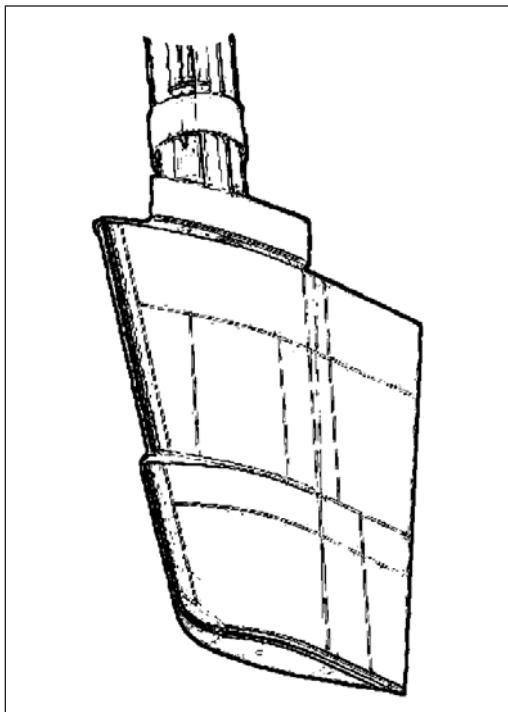
Semispade rudder



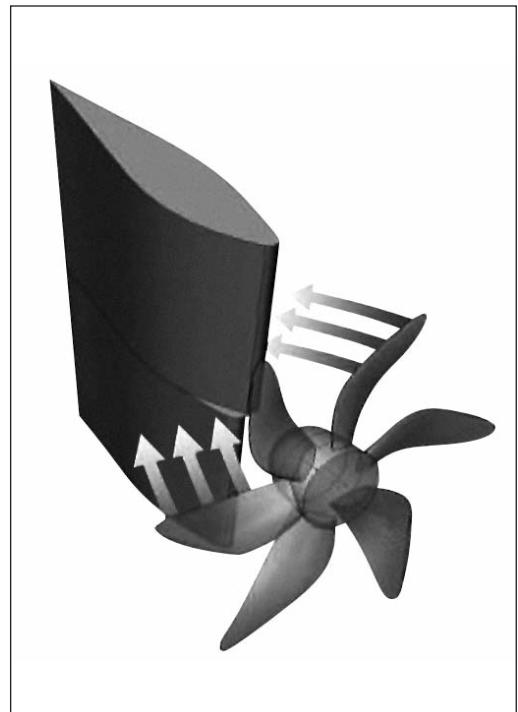
Full spade rudder



Flap rudder (full spade rudder plus a flap)



Twisted rudder



Twisted rudder

Rudder design and cavitation corrosion

The following extract from a very competent article by Mikael Grekula and Per Lindell, both project managers of ship design for SSPA Sweden AB, entitled "Cavitation Erosion Damage on Semispade Rudders" published in *The Swedish Club Letter* 1-2007⁶ describes some of the ways in which rudder design affects the potential for cavitation erosion:

Much of the cavitation problems related to the gap between horn and blade (B and C in Figure 1) can be avoided by the use of full spade instead of a semi-spade type of rudder. Furthermore, by twisting the leading edge of the rudder it can be better adapted to the rotational flow from the propeller and thereby suppressing cavitation induced on the rudder (A in Figure 1).

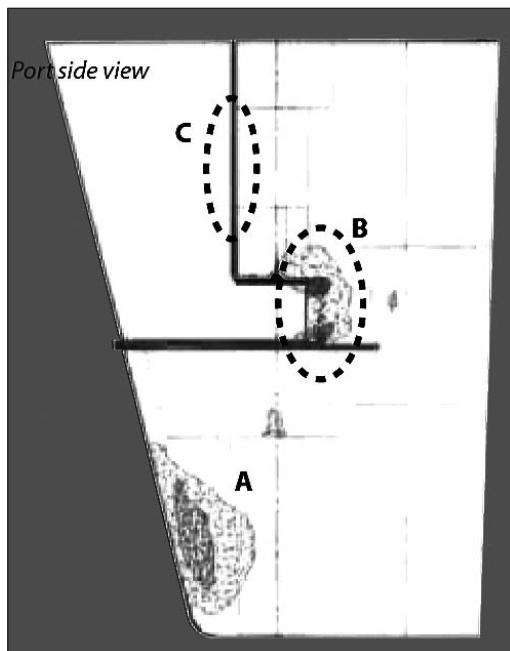


Figure 1 from the article "Cavitation Erosion Damage on Semispade Rudders" in *The Swedish Club Letter*.

Cathodic protection

It is not unusual to see several sacrificial anodes placed on various parts of the rudder.



Sacrificial anodes on rudder blade and flap to help prevent or reduce corrosion.

As already discussed, however, the cathodic protection system is aimed at preventing or slowing down corrosion and has no bearing on cavitation erosion at all, thus it is an attempt to deal with a symptom, not with a cause.

Cavitation proofing the rudder

The same article describes various attempts to make the rudder surface more resistant to cavitation erosion:

The cavitation erosion resistance can be increased by cladding with stainless steel or some other high tensile material at strategic locations. High tensile stainless steel is, compared to e.g. cast iron, considerably more resistant to cavitation

⁶ Mikael Grekula, Per Lindell, Project Managers, Ship Design, SSPA Sweden AB "Cavitation Erosion Damage on Semi-spade Rudders" *The Swedish Club Letter* 1-2007

and if the cavitation behaviour is unchanged by the implemented cladding, the time to failure is increased.

Solving an erosion problem is most safely done by changing the cavitation behaviour to avoid collapses on the structures. However, this is for different reasons not always possible at which the efforts often are only focused on armouring the structure. Therefore, if the cause of the damage – i.e. the behaviour of the cavitation – is not changed, the surface will still be exposed to the same mechanical strain by the cavitation.

The success of armouring measures depends on the aggressiveness of the cavitation and how the reinforcement is made. Since the mechanical strain remains, this type of measures may only be partially successful, still requiring continuous maintenance or recurrent repairs although the repairs are expected to be less extensive and less frequent.⁷

As mentioned above, at least one such attempt to use stainless steel to counter the

effects of cavitation was met with singular failure as the underlying steel and welds corroded and the stainless steel plates fell away, leaving the rudder itself completely exposed.

To date, as far as is known, only one type of coating has been able to withstand the forces of cavitation. All other coatings used and tried have simply been eroded, leaving the steel exposed, with all the consequences described earlier in this paper.

Of the various attempts to deal with cavitation erosion, only one has proved successful in all cases where it was applied. This approach falls under the heading of “cavitation proofing” the rudder by use of an appropriate coating which will not erode under the forces of cavitation.

⁷ Ibid.

Part III. A tested and proven approach to protecting a rudder from cavitation erosion

The ideal approach to cavitation erosion would be a protection of the rudder which prevented any such damage from occurring. Add to this a rudder design which is both efficient and which reduces cavitation as much as practicably possible, and one would have the solution.

To many who have researched in this field, this ideal approach might sound too good to be true. If they were told this already exists as a solution, they would be amazed.

Yet this solution does exist.

It is beyond the scope of this paper to discuss rudder design in detail. As has been shown above, advances in rudder design have been made which reduce the turbulence of flow caused by the rotation of the propeller and the angle of attack of the flows against the rudder. Different rudder forms suit different requirements. The maneuverability of the ship and the efficiency of the rudder form in terms of its ability to turn the ship without causing excessive drag are two other factors, besides reduction of potential cavitation damage, which must be taken into account in designing the rudder.

This paper concentrates not on the design of the rudder but on its protection, because it is potentially the most effective approach. Given perfect protection, concerns about rudder form diminish or disappear and one can simply choose the best rudder form for a specific type of ship and know that it will not be subject to cavitation damage because it is protected.

Ideal rudder protection

As has been mentioned, there is a type of coating which has been in use for ten years and which has proven to be "cavitation damage proof" on the Rudders to which it has been applied over that time period. Aside from some minor touch-ups, none of the Rudders that were properly prepared and coated have had to be recoated, even after eight years. None of them have suffered from cavitation damage since the coating was applied. For those shipowners and operators who have tried this coating for their Rudders, the cavitation damage problem ceased to exist.

The coating is a specially strong variation of a glassflake reinforced hull coating. By changing the formula of the glassflake reinforced hull coating, a tougher, more resilient version results which is better suited to protecting Rudders from cavitation damage.

In terms of preparation and application requirements, the coating is not particularly demanding. The surface must be grit blasted to remove any previous coating and create an adequate anchor profile and surface cleanliness, ($75\mu\text{m}$ and SA 2.5). It is applied in two coats. But normally at newbuild or when an existing coating is being replaced, two coats each of about 500 microns thickness are applied adding up to a total of at least 1000 microns dry film thickness (DFT).

The second coat can be applied approximately three hours after the first one, allowing very rapid completion of the

coating job. The curing time is minimal (the vessel can leave drydock 24 hours after the final coat). The coating has very low VOC content.

This rudder protection system consists simply of two homogenous coats. No primer, no epoxy, no tie-coat, no AF.

Once applied and cured, the coating, technically known as a Surface Treated Composite or STC, forms an extremely tough and durable surface which will continue to protect the rudder for the full service life of the ship without the need for replacement.

Using the special filler resin to repair cavitation damage

It was found experimentally that a byproduct of the STC coating which proved so effective in protecting rudders from cavitation erosion, could also be used successfully to repair a badly pitted rudder, as long as the damage

has not gone too deep. The technique used is as follows:

1. Grit blast the rudder as already described.
2. Apply a full coat of the filler and allow it to cure.
3. Spray the filler on the pitted, damaged parts as thickly as possible.
4. Spread the filler, when it has thickened somewhat, into the pitting and damaged area. Let that cure.
5. Spray on a final coat of the STC and permit it to cure.

If the pitting is very bad, then the sequence can be altered so that the filling of the pitting is repeated. In any event, the last step is a final full coat of the STC.

These steps result in the repair of a rudder which has not suffered too extensive cavitation damage. It has been carried out successfully on a large number of damaged rudders, none of which has needed further



Some of the rudders coated with glassflake reinforced STC.

repair or repainting since the rudder was repaired and recoated. If the damage is too extensive however, then welding will be needed to repair the steel before the filler and STC are applied.

100% success rate

Since this approach to rudder repair and protection was first discovered and applied in 2004, a large number of rudders have been successfully repaired and/or recoated in this fashion, using the glassflake reinforced STC. Since the original application, some 110 rudders have been repaired and/or coated on a wide variety of ships: cruise ships, cargo vessels, container carriers, ro-ro cargo ships, a cable layer, a dredger, crude oil tankers, research vessels, ice-going ships and ice-breakers, tugboats, a reefer, passenger ferries, bulkers and others.

In all cases, the application was successful. None of the rudders so protected have suffered from cavitation damage at any point since application.



Part IV. Case study

Founded in 1893, Ernst Russ is a Hamburg based, family owned shipping company. For close to 120 years, Ernst Russ has been offering customers the highest standards in ship management. The ER Fleet Manual, introduced by Ernst Russ long before international standards were developed, is continuously updated and exceeds all standard requirements and regulations. The company has a fleet of ten vessels including five ro-ro cargo ships. Due to their higher propeller revs, it was the rudders of the ro-ro cargo vessels that suffered particularly from cavitation damage.

Grzegorz Giriat is Superintendent of Ernst Russ, responsible for the five ro-ro ships. Those ships were built in 1999. The rudders were originally coated with a standard epoxy coating. Grzegorz Giriat explains, "During the first intermediate docking, between two and three years from launch, we observed that we already had extensive cavitation damage on the rudders."

In an attempt to remedy the situation, a special doubler plate was installed on the most affected parts of the rudder. The ships sailed again.

"Then it was 2004 when we went to the drydock in Antwerp," says the Superintendent. "All the vessels were in drydock. The doublers hadn't helped. I would say the situation worsened a bit because the gap between the hub and the rudder was reduced by the doubler plates. Cavitation is a well-known phenomenon. It's known there has to be a certain distance between the hub and the rudder. If that distance is not sufficient then

the cavitation will be worse." It was.

During that 2004 docking, Ecospeed [the glassflake reinforced STC used to protect the rudders now reformulated as a separate, special coating specifically for rudders and underwater gear, Ecoshield®] was applied experimentally on the *Elisabeth Russ*. The application was close to the end of the docking. There was only time to grit blast the rudder and apply two coats of Ecospeed. The pitting and damage from the cavitation was not repaired but the paint simply applied over it. This was the test.

The trial was successful beyond all expectations. When the ship next came out of the water in 2007 it could be seen that, despite the last minute application, no further cavitation damage had occurred.

As a result, the rudders of the remaining four ro-ro ships were coated with Ecospeed, all with similar results. Based on this the bulbous bows of all the ships were also coated with Ecospeed since these vessels trade in the ice and the traditional coating in use was not holding up in these conditions. The ships have the highest Finnish ice class. Ecospeed has also been used to protect one of the stabilizers. Only budgetary constraints have prevented the company from blasting the hulls of all five ships and coating them all with Ecospeed.

None of the rudders have sustained any further cavitation damage. They have been touched up where the paint was chipped or scraped, but the cavitation damage to the rudders ended with the first application of Ecospeed.

The most recent drydocking of the *Elisabeth Russ*, the first vessel to be so

None of the rudders have sustained any further cavitation damage. They have been touched up where the paint was chipped or scraped, but the cavitation damage to the rudders ended with the first application of Ecospeed.

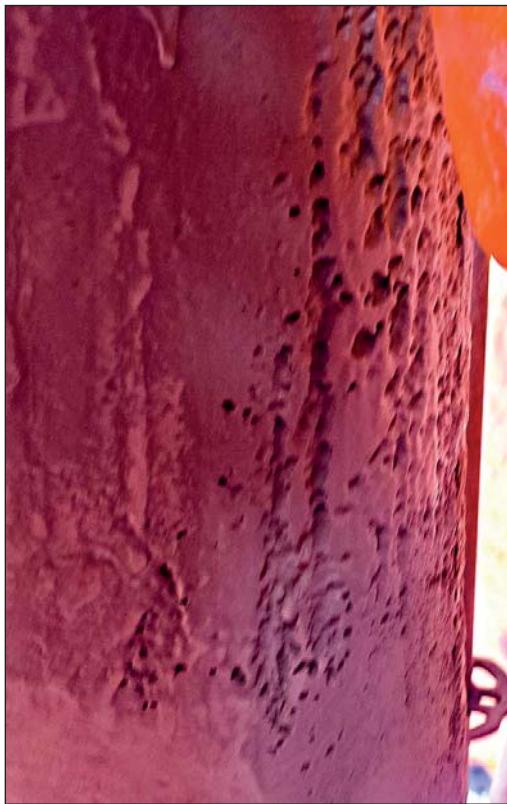
coated, in 2011, confirms that the original Ecospeed protection applied in 2004 is still holding firm and the rudder is intact, free from cavitation damage.

The Superintendent confirmed that not having to carry out hot work on the rudders when the ships were in drydock has saved the company a great deal of drydock expense.

"In general everybody is looking to be in drydock as short as possible and to get all the work done as quickly as possible," explains Grzegorz. "Additional hot work on the rudder inevitably results in some collisions with other jobs. I would say for me it is quite

clear. Had we not applied Ecospeed on the rudders, we would certainly have extensive work to do in drydock. Even replacing the doubler plates is a lot of work."

The *Elisabeth Russ* played a particularly important role in the development of Ecoshield for rudder cavitation damage protection. She was the first ever in a long line of successful rudder-specific applications of the coating. An experiment that validated the use of the STC for protection against cavitation.



The rudder of the *Elisabeth Russ* when first coated with Ecospeed in 2004 (left). In the 2011 drydocking Superintendent Grzegorz Girjat points out the original cavitation damage which was simply coated over with Ecospeed in 2004 (right). No further cavitation damage has occurred to the rudder since the original protection at that time.

Part V. Conclusion

Rudder cavitation damage is a constant expense and interruption to ship-owners and operators.

Increasing numbers of high speed container carriers and other vessels have magnified the problem since they suffer from cavitation more than lower rev, slower ships.

Most attempts to solve the problem have proved unsuccessful, as evidenced by the continuing need for frequent repair or replacement of rudders.

Rudder design has mitigated the problem somewhat but far from solved it.

Most coatings generally fail to provide adequate protection and usually erode.

The use of cathodic protection systems has no effect on cavitation erosion even if it does reduce the subsequent corrosion damage.

The use of a specially formulated glass-flake resin surface treated composite, strengthened specifically for rudder protection, Ecoshield, has proved 100% effective in protecting rudders from cavitation. Of the 110 rudders so protected to date, none has suffered from further cavitation damage and none has needed to be recoated. The first experiment with Ecospeed on rudders was carried out in 2004 on the *Elisabeth Russ*

as described in the case study in Part IV above. Therefore the protection has proved that it will last close to seven years at least, although it is expected to last for the entire service life of the vessel to which it is applied.

After years of testing and development, Subsea Industries, a Hydrex company, launched Ecoshield® in 2013, a special formulation of its well known Ecospeed hull coating. Ecoshield is designed specifically for use on rudders, bulbous bows, stabilizer fins, Kort nozzles and other underwater gear which requires special protection. Ecoshield puts an end to rudder cavitation damage.

By protecting the steel of the rudder from erosion due to cavitation, the expensive and interruptive cycle of cavitation - erosion - corrosion - repair - replacement is ended.

Experiments with the fastest military vessels are still to be conducted, but all the evidence available to date indicates that Ecoshield will be just as effective on these vessels, even if a thicker application is required.

Shipowners and operators can consider the problem of cavitation damage to rudders to be solved. The solution simply remains to be implemented on all ships afloat to make this vexing problem a thing of the past.

Your next step?

Since extensive rudder damage can be quite hazardous, it is recommended that shipowners/operators arrange for regular inspection of the rudder. This can be done underwater and need not be relegated to drydock.

If damage is evident it can be repaired temporarily with the ship still afloat without serious interruption of operations and schedule. This can be done with the aim of keeping the ship in service until the next scheduled drydocking.

At the next drydocking, get the rudder thoroughly repaired (or replaced if the damage is too extensive). Then have the rudder grit blasted and coated properly with Ecoshield.

Further inspections will show that the cavitation damage will not recur.

If in doubt about this solution, then shipowners/operators should experiment with the rudder on a single ship to be sure of its workability before extending the solution to the entire fleet.

To find out more about Ecoshield and Ecospeed, visit the following websites:

www.ecospeed.be
www.ecospeed.us

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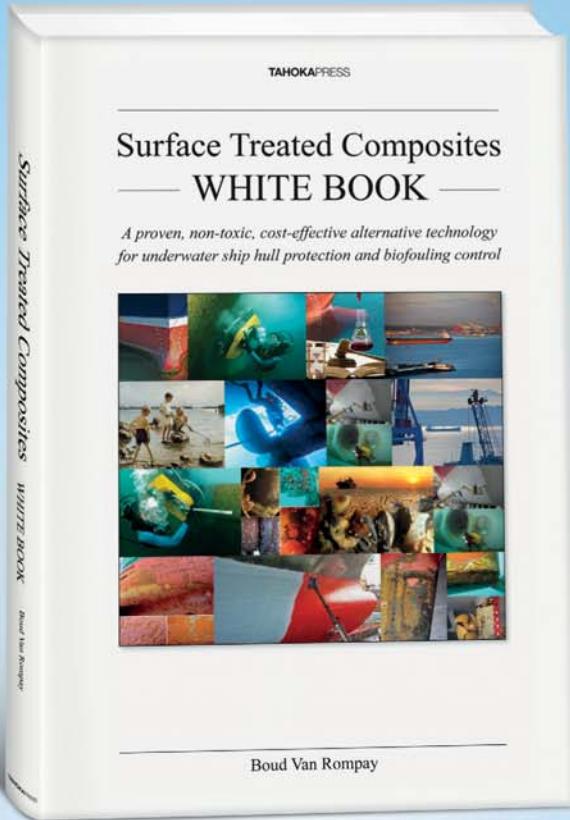
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