COATING TECHNOLOGY INCREASES PUMP PERFORMANCE

Jérémie Maillard
Belzona Polymerics Ltd, Claro Road, Harrogate, North Yorkshire HG1 4DS
Tel: +44 (0) 1423 567641 Fax: +44 (0) 1423 505967 email: jmaillard@belzona.com
www.belzona.com

BIOGRAPHICAL NOTE

Jérémie Maillard studied at the University of Lorient, France, and holds a combined Masters degree in Polymer and Composite Design / Mechanics and Materials Engineering, and more recently attained NACE Coating Inspector Level 2 – Certified. He is an engineer in the Technical Services Department at Belzona Polymerics Ltd. where he is responsible for business development and technical support within Belzona's European and North African markets.

ABSTRACT

Considering that that pumping systems account for 20% of the world's electrical demand and the cost of energy represents 95% of the cost to run pumping equipment, it is obvious that all industry would benefit from any solutions aimed at increasing pump performance.

Belzona Polymerics Ltd can call on more than 50 years experience of formulation and manufacture of cold applied coating for the protection of fluid handling equipment. Belzona®1341 Supermetalglide offers a unique hydrophobic surface coupled with high erosion/corrosion resistance, which reduces friction losses and thus the energy input required. Independent testing performed at the National Engineering Laboratory has proven that Belzona®1341 can increase the efficiency of new pumps by as much as 6%.

This paper will review the needs of the user and the corresponding development of the Belzona®1341 Supermetalglide Coating with respect to pump improvement and protection.

INTRODUCTION

Fluid handling equipment can suffer from several physical and mechanical problems, including general and/or localised corrosion, cavitation or reliability linked with poor efficiency or performance. All these parameters may affect the power consumption of the equipment, increasing considerably its lifetime running cost. Minimising performance deterioration is a major consideration for pump manufacturers and users.

One effective way, other than corrosion resistant alloys, to reduce the loss of equipment performance is to protect pumping systems using erosion/corrosion resistant coatings and in this area Belzona Polymerics Ltd has provided coating technology solutions for over 55 years within all industry sectors. The following paper is intended to introduce the need for pump coating and present the key benefits of a hydrophobic grade coating, such as Belzona®1341 Supermetalglide from an end user perspective.

ORIGIN OF PROBLEMS WITHIN FLUID HANDLING EQUIPMENT

We should start by recognising that it is virtually impossible to design a pump which is totally immune from in service deterioration. Typical problems encountered with pumps will be similar whether we look at heavy industries (i.e. oil and gas, power) or general utilities (i.e. water distribution). Pumping systems are designed to work at specific flow and heads, however, they are rarely running at full efficiency, which could be explained by different mechanisms, aside from purchasing an off the shelf pump where the intended service does not exactly match the Best Efficiency Point. Three main categories can summarise origins of pumps performance reduction. Mechanical losses due to friction in bearings, worn wear rings or seal problems. Leakage losses are explained by recirculation through wear rings, seals and balancing devices.

Energy losses, also called hydraulic losses, represent the majority of the efficiency reduction, highly relying on surface conditions. The metallic substrate is subject to erosion-corrosion, leading to its degradation. In order to offer a better understanding of the problems to be considered, we should consider the different forms of corrosion and erosion.

1) Corrosion

This section will review some of the main mechanisms of corrosion, in particular those which affect metals used in pumping systems, such as stainless steel, cast iron or bronze.

a. Uniform Corrosion

Uniform corrosion is most widely known as the oxidation of the entire surface, however, it also includes tarnishing, active dissolution and polishing in chemicals (especially acids), anodic oxidation and passivation. Passivation, or anodic polarisation, occurs with alloys such as stainless steels and aluminiums, where the surface oxidises, stabilising and preventing further corrosion.

Experience has shown that passivated alloys, such as aluminiums and stainless steels exhibit excellent resistance to corrosion in some immersed conditions, however, despite this passive oxide layer, when in close proximity to a more noble metal such as bronze, can still suffer bi-metallic corrosion.

b. Localised Corrosion

With this type of corrosion, certain areas of the metals corrode faster than others and it is in localised corrosion where the difference between oxidation and corrosion is seen. The process is accelerated as clear anodic and cathodic areas are defined, often with the corroded area invariably becoming increasingly anodic to the neighbouring cathodic area. It is one of the most problematic types of corrosion, and it is these forms of localised corrosion which often lead to component failure due to their severity. The various manifestations of this form of corrosion are as follows:

i. Bi-metallic Corrosion

When two metals of differing potentials are placed in solution and electrically connected together, a current flows between the two and electrons are given up by the metal with the greater potential – the anode. This principal is true for many types of corrosion, including uniform corrosion, where different potentials are present in the different grains of the structure. In the case of two separate, different metals, the results can be quite dramatic.

If we compare the potentials of cast iron with bronze in flowing sea water, we see typical potentials of -0.61 V for the cast iron compared to -0.23 V for the bronze [1]. Specific attack will occur because the cast iron is the cathode, compared to the anodic bronze.

ii. Deposit Corrosion

Deposit corrosion occurs under or around a discontinuous deposit on a metallic surface. In sea water, gaskets, fittings, and marine growth are primarily the cause of propagation, leading to pitting. This form of corrosion shares similarities to crevice corrosion.

iii. Pitting

The most probable causes of pitting corrosion are defects in the surface of the alloy, which may be either in the smoothness of the surface, or the internal structure of the alloy. In both cases there is small localised corrosion, leading to oxygen depletion. Corrosion is propagated as the greater area outside of the pitted area, which has ready access to oxygen, becomes cathodic despite its being of the same material.

iv. Selective Dissolution

In certain alloys, the more active element can become corroded away, and a good example is the graphitisation of iron, where the iron corrodes in preference to the (non-corroding) carbon, and dealuminification in some brasses.

2) Erosion

The high fluid velocities encountered in fluid handling equipment contribute to the rapid degradation of the components. In addressing the solution for erosion problems it is important to be able to diagnose the erosion sub category.

a. Impingement

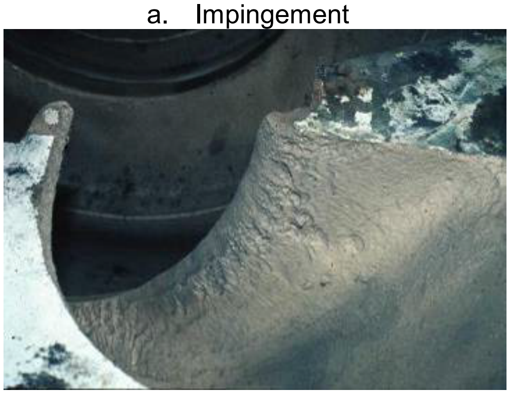
Fig 1 – impingement erosion

Impingement is caused solely by high velocity fluid flow, and its effect on the substrate, such as in this example where high fluid velocities are occurring due to high pressure to low pressure leakage.

b. Entrainment

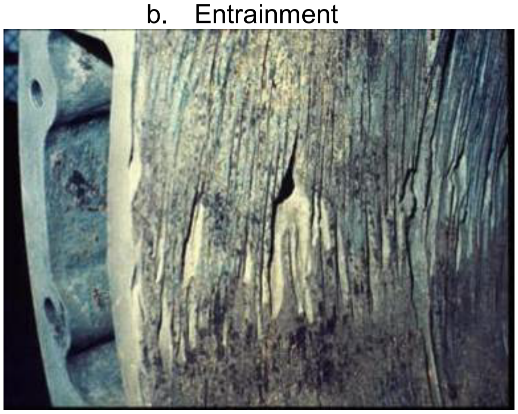
Fig 2 – entrainment erosion

When silts and gravel are carried up in the fluid stream they are said to be entrained. This type of erosion causes greater material loss than impingement alone for the same given fluid velocity.

c. Cavitation

Fig 3 – cavitation (impeller)

Cavitation occurs as a result of a pressure difference in the fluid and can be found on either pump body or impeller, although it is most commonly observed on the impeller, in particular the low pressure surfaces. This picture shows cavitation on impeller blades and on the adjacent surfaces. It is recognized by "peppering" of the surface with many small pits, caused by the implosion of the vapour bubbles onto the substrate.

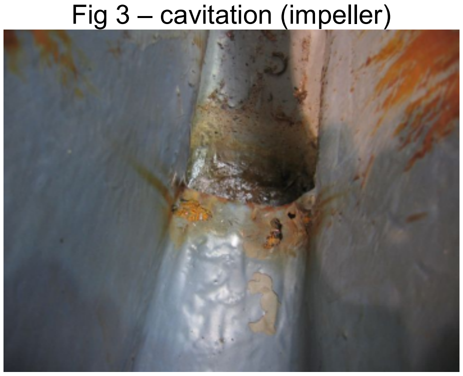

Fig 4 – Cavitation to pump cutwater

3) Erosion - Corrosion

Most metals are not naturally found in their pure state, but in an ore, often oxidised, and this is the state that a pure metal will aim to revert to. The effect of the combined action causes the "protective", stable or passivated layer of oxide to be removed, and then re-oxidise. This cycle repeats itself until the material is fully stable, and can result in accelerated complete degradation of the unit.

CONVENTIONAL SOLUTIONS TO ADDRESS THESE PROBLEMS

All of these deteriorations will greatly reduce the efficiency with which the pump is running. It is important to find solutions to reduce these effects and to extend the lifetime of equipment.
Pump manufacturers have been looking at different ways to reduce corrosion and erosion damage onto metallic substrate, which we will investigate.

1) Material selection

In addressing the erosion-corrosion problem, the first consideration is always the material. One possible way to reduce the rate of deterioration is to select the best material suited for specific operating conditions.

a. Conventional materials

Conventional materials such as cast iron are generally used whenever possible due to cost implication. However, their resistance to erosion–corrosion is relatively low, implying a quick degradation of the substrate.

b. Stainless Steel

Stainless steels are extensively used for their resistance to general corrosion, through the creation of a protective passivation layer. Providing this passive film stays undamaged, corrosion rate will be very low. However, if the film is damaged and the environment does not favour rapid film repair, then localised corrosion can occur.

By understanding the principle of the oxidation / reduction process, it is clear that the noblest metals are more likely to be protected against corrosion, but no metals are completely immune against erosive and corrosive attack.

As stated earlier, the usual criterion for the choice of a particular material, or combination of materials of construction will be cost, provided that the materials have sufficient physical properties to function within the environment. However, this design ethic can cause more problems than it solves, particularly if the equipment is to be immersed in an electrolytic solution. The resultant bi-metallic corrosion, which will inevitably ensue due to the different metals used, will lead to the premature failure of the equipment.

Over many years attempts have been made in areas of fluid flow to select specific materials with corrosion resistant properties and also to try to match up galvanic potentials to minimise the difference and thus galvanic effect [2] however ultimately when using only metals there will always be a compromise either in performance or cost.

2) Coating Technology

The only way to greatly reduce erosion–corrosion effects is to isolate the metal surface from its environment. For fluid flow situations, there is a wide range of factory applied coatings, including PTFE, FBE and rubber linings, but a more limited range of options available to the designer which can be field applied or repaired in situ. It is the latter that we will now review:

a. Glass Flake Coating

Historically, glass flake coatings have been used and specified for the protection of fluid handling, processing and storage vessels. They have good corrosion protection properties and with correct selection of binder, have a good chemical resistance.

Nevertheless, glass flakes systems do have many drawbacks. The level of Volatile Organic Compound (VOC) through solvents as well as styrene may be a serious health and safety issue. The polymerisation process involved in curing process of glass flake system leads to shrinkage causing the bond line to be permanently stressed. The adhesion, cavitation and impact resistance are relatively poor and in comparison with conventional solvent free epoxy system, their general erosion resistance is lower. Glass flake systems are notoriously brittle and easily damaged during routine maintenance of equipment.

Glass flake are also high build, typically 1.5 – 2mm thick. This could cause flow restriction in critical areas affecting performance characteristics. In terms of performance, this thick glass flake coating will shift the efficiency curve to the left. This will improve the efficiency of a pump which is operating left of Best Efficiency Point (BEP) but will reduce efficiency of pump operating at or to the right of BEP.

If we compare for example the 2mm thickness of a glass flake coating on a 100mm pump inlet, we see a reduction of the cross section area of approximately 8%; and flow rate is highly influenced by the cross sectional area.

b. Modified Solvented Epoxy Coating

Modified solvented epoxies are very versatile in use, as they can be designed with many different properties, depending of the binders used. Generally, they offer good resistance to erosion–corrosion. Epoxies can be modified using phenol, coal tar and hydrocarbon resin to give special properties, e.g. better chemical resistance, better penetration, improved water resistance and so on. One drawback with solvented epoxy coatings is that they contain large quantities of solvent, which is associated with health and safety problems. The content of solvent also implies shrinkage, thus stress within the coating. Poor immersion resistance of modified solvented epoxies may limit their use within fluid handling equipment.

c. Thermosetting Polyurethane Coatings

Design allows these to be stiff or flexible as required, offering good curing at low temperatures, cavitation and impact erosion resistance. Their disadvantage, however, tends to be in long term immersion as some can be moisture sensitive, tending to absorb water more readily than other coatings. Applying at a greater thickness helps to overcome this problem, and there have recently been developments in diffusion resistance to provide systems which avoid these shortfalls.

d. Modified Solvent-Free Epoxy Coating

Modified Solvent-free epoxies offer similar benefits as solvented epoxy coatings, such as resistance to erosion–corrosion and chemical resistance. The key benefit of solvent free material eliminates associated health and safety problems whilst also reducing the shrinkage to a negligible level. There is also significant scope to work with the properties of the coating and required service parameters, modifying for strength, flexibility, corrosion and erosion resistance, and temperature and chemical resistance. Resistance in immersion is generally excellent which offers long term protection for fluid handling equipment.

Solvent-free epoxy coatings, such as those developed by the author organisation, are applied at a relatively low thickness, about 500 microns, which do not lead to interference with the fluid flow, compared to glass flake coating for the majority of pumping situations

It has also been observed in pump-jet installations [3] that in certain situations where dissimilar metals were in contact with flowing high speed sea water, users have chosen solely cathodic protection, however, this is not the total solution. Use of a combined coating and cathodic protection gives optimum protection where there is a risk of foreign body entry (very common in pump-jets), however, for most pumping situations selection of the correct coating system is sufficient in terms of protection.

DEVELOPMENT OF BELZONA®1341 SUPERMETALGLIDE

Recognising that solvent-free epoxy coatings are one of the most relevant and adaptable systems for protection against erosion–corrosion in pumps, Belzona®1341 Supermetalglide was developed based on this chemical backbone. This offers a coating specifically designed to meet the key service requirements of the pump, i.e. immersion, corrosion, erosion and cavitation resistance, excellent adhesion, flexibility, and ease of application and maintenance. Also, being a solvent-free coating, health and safety risks are reduced during application and most importantly the coating will not be stressed.

A fluid passing through a hydraulic passage is subject to resistance caused by friction and viscosity. Hydraulic losses represent most of the efficiency reduction (9% for a mixed flow pump to 20 % for a radial flow [4]), coating technology will help in reducing those losses, therefore increasing pumps performance.

1) Surface properties

The energy losses can be reduced by designing a coating system which should have a smooth surface and be resistant to erosion–corrosion effects. Additionally this coating system should have a low electronic affinity for water molecules, i.e. hydrophobic material, thus delaying the onset of turbulent flow and consequently reducing skin friction.

Belzona®1341 Supermetalglide is specifically designed as hydrophobic, smooth surface coating with low surface energy and abrasion resistant fillers. The technology produced an ultra smooth surface that reduces the boundary layer of the pumped fluid and reduces the internal turbulence in the flow, thus increasing hydraulic efficiency.

Even polished metal pump surfaces are found to be relatively rough when examined under high magnification. Further surface roughening can result from erosion-corrosion or cavitation effects, thus causing a reduction in efficiency of the system.

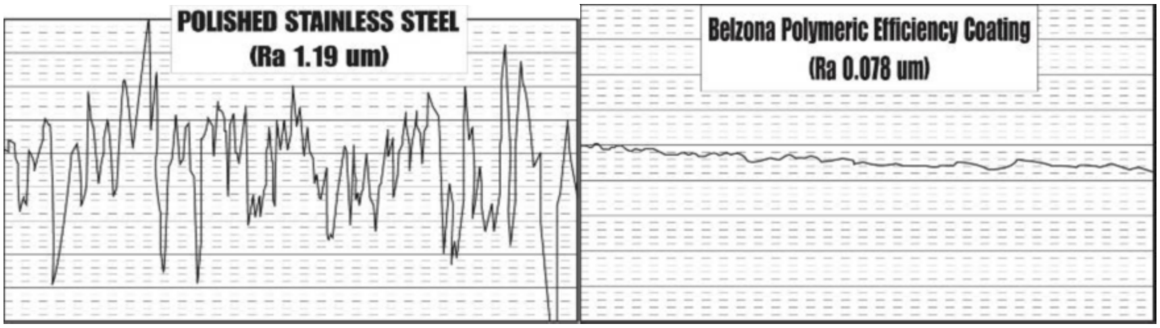

Fig 5: Roughness comparison between polish stainless steel and Belzona®1341 Supermetalglide ([5]Talysurf Surface Inspection, Leeds University, 1989)

The smoothness on the surface of this type of coating is more than 15 times greater than polished stainless steel (Fig 5). When applied to fluid flow equipment, this type of coating has been proven to improve hydrodynamic performance by increasing overall efficiency through reducing power consumption, increasing fluid flow rate or pressure.

2) Independent testing

Recognizing with Belzona®1341 Supermetalglide we had developed what appeared to be a very high performance coating, it was necessary to independently test the product to see if our theories were correct. Initially laboratories were used; subsequently various pump manufacturers tested in-house for use on their own pumps.

a. National Engineering Laboratories – 1989

The testing of Belzona®1341 Supermetalglide was carried out under strict independent laboratory conditions using the fluid flow test facilities of the National Engineering Laboratories (N.E.L.) who, as part of the U.K.'s Department of Trade and Industry, represent the most comprehensive pump test facilities of their type available anywhere in the world. [6]

In this case, the test vehicle chosen was a single stage, end suction centrifugal pump with 10 inch suction and discharge branches.
The pump, in uncoated condition, running at 1300 rpm was found to deliver 875 m^3/hour at 26.5 meter head with an overall peak efficiency of 83.5% (see fig 6).

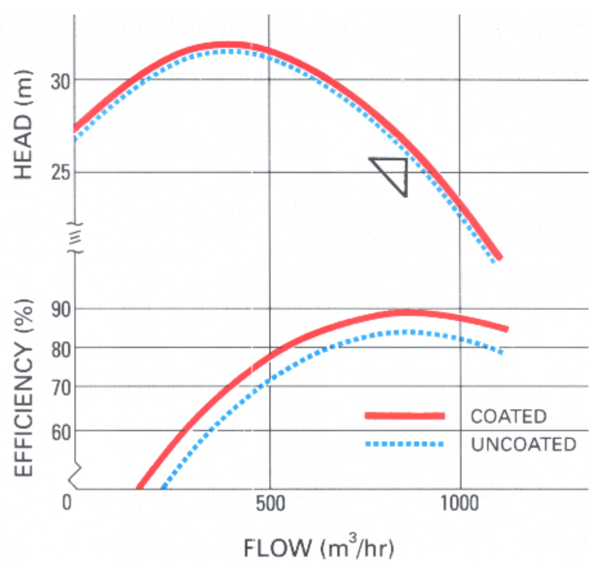

Fig 6: N.E.L. performance curve

The pump tests were carried out using a typical closed-loop system with a series of flow/ head/power readings taken across the full flow range from 10% to 125% to give an accurate performance curve using calibrated test instrumentation traceable to national standards.

Testing of the Belzona®1341 Supermetalglide coated pump gave a maximum 6% increase in the peak efficiency. Also, there was little change to the pump head/flow characteristics with the peak efficiency duty coinciding with that of the uncoated pump.
Meanwhile, at this peak efficiency point, the power reduction has been measured at 5.1kW at duty point. Assuming a 5,000 hour operating cycle/annum, the power savings over this period would amount to 25,400 kWh.

This demonstrated that the Belzona®1341 Supermetalglide coating offer pump users (designers, manufacturers, end users) various different possibilities:

- Increase in head delivered
- Increase in flow rate
- Reduction in power consumption
- Improvement in efficiency across the whole duty range.

For example, a manufacturer may want to offer Belzona®1341 Supermetalglide as

- an “optional extra” to customers seeking higher performance, or
- to allow the use of cast iron over stainless steel for competitive (cost) advantage, or
- to enhance an aspect of a pump if it is short on promised deliverables.

Furthermore, to the user, the above properties are of benefit but the key advantage through the use of a coating on iron or steel is that the pump will not suffer in service deterioration through corrosion, and original planned deliverables can be maintained.

b. KSB Omega Pumps – 1994

In 1994 following testing carried out at KSB’s Bremen works on four OMEGA pumps with sizes 250-480, the manufacturer recorded an improvement in efficiency from 84% to 86.9 - 87.5% [7].

3) Case histories

a. ITT Lowara Pump – 2008

Recently, Belzona®1341 Supermetalglide was tested by Pump Supply and Repair Group on new 150-250 single stage ITT Lowara pumps. Results have shown a power consumption reduction of 7% (1.1kW) at the Best Efficiency Point. Similar results have been measured on the whole duty range.

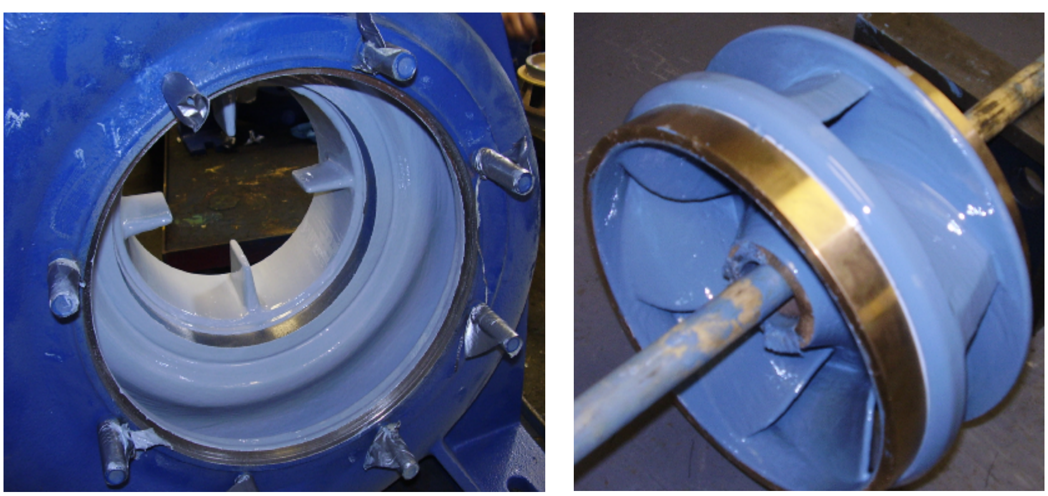

Fig 7: ITT Lowara Pumps before testing

b. Sterling Fluid Systems' Halberg SiHi – 1992

In 1992, this Belgian chemical plant cooling water pump was coated with Belzona®1341 Supermetalglide. The capacity of this equipment, running 24 hours a day, is 5000 cubic meters of water per hour. During a maintenance shutdown in 2004, the pump was inspected and found to be still in excellent condition, despite the salty water and the years of operation (Staining is from untreated components in the system). As illustrated in this picture, 12 years after the initial application, this pump was still offering added benefit to the longevity of the Belzona®1341 Supermetalglide application with a 7% increase in efficiency as measured by increased output that has been documented by the end user.

Fig 8: Belzona®1341 Supermetalglide after 12 years service

CONCLUSION

We have seen that in-service deterioration is possible through mechanical, leakage and hydraulic losses. Of these, leakage and hydraulic losses can be addressed through material selection, or the use of performance coatings to provide the pump with protection against damage through bi-metallic or general corrosion, or erosive effects such as cavitation.

Use of the correct performance coating has been shown to not only improve the performance of the pump compared to its "as new" condition but to maintain this throughout its life with minimal maintenance of the coating necessary. Preventing bi-metallic corrosion under wear ring seats can prevent leakage from the high to low pressure side (on split casing pumps for example) and general corrosion can be halted in the main body of the pump and impeller.

In particular over the last two decades Belzona®1341 Supermetalglide has proved itself to have appeal with both the end user and many of the world's major and specialist pump manufacturers due to its ability to address performance improvement in power consumption, head, efficiency and effectiveness, in original equipment manufacture as well as refurbishment situations.

REFERENCES

[1] FW FINK et al, "The Corrosion of Metals in Marine Environment", Battelle Memorial Institute, DMIC Report 254, Distributed by NTIS AD-712 pp7,13 (1970)

[2] H TIETGEN, "Experience gained with plastic materials in hull repairs", Germanischer Lloyd, 1982

[3] G BOWERS, "Theoretical and Practical Aspects of Erosion-Corrosion Control and Repair in Waterjet Installations", Waterjet Propulsion III, RINA 2001

[4] J HOWARTH, "Pump efficiency/power consumption", ESR Technology, 2007

[5] "Talysurf Surface Inspection of Steel, Belzona® Ceramic S-Metal and Belzona® Supermetalglide", Leeds University, 1989

[6] Dr DA BEL, "Efficiency Tests on a 10-inch centrifugal pump before and after the application of a coating", Report Ref 432/88 BEMO/01, National Engineering Laboratory, 1989

[7] EVERMANN, "Innenbeschichtung von OMEGA Pumpengehaeusen mit Belzona® SUPERMETALGLIDE" (Internal coating of OMEGA Pump casings with Belzona® SUPERMETALGIDE), KSB, 1994