

# New coatings for green sand moulding

## Introduction

*Sand inclusion related scrap caused by mould erosion is a significant problem in many production iron foundries, and quality concerns are increasing as castings sections become thinner and more complex.*

*Current green sand mould surface stabilisers are predominantly solvent-based and contain organic binders, which tend to burn-out during the casting process, and hence offer limited protection. In addition, such products normally require drying prior to casting, and this can result in the formation of scabs or other defects.*

*This paper highlights the benefits of an environmentally friendly, inorganic, water-based product, which acts as a surface stabiliser and reduces sand inclusion defects by the prevention of mould erosion. This new mould surface stabiliser does not require drying prior to pouring and has no adverse effect on green sand mould properties.*

Greensand moulding remains the most popular process for the production of long runs of iron and steel castings. However the nature of the sand chemistry and moulding operation renders the process prone to a variety of casting defects, which foundries routinely struggle to overcome.

High production foundries, especially those serving the automotive, heavy truck and hydraulic component markets, are increasingly under pressure to produce higher complexity components, whilst improving casting quality and reducing the overall cost of the component. Over recent years significant steps have been taken to improve the internally cored area of a component, by focusing on sand binders, sand additives and the core coating technology and application. The results being evident in superior internal surface finish, reduced re-work and lower scrap levels.

However, the technology utilised for the production of the greensand mould has changed little in the past few years and scrap and poor surface finish due to sand inclusions, caused by greensand mould erosion, is a significant problem which many high production iron foundries are now focusing on due to :-

- ❑ Thinner, more complex casting design → more aggressive pouring (faster & hotter)
- ❑ Demand for superior quality → improve casting integrity and surface finish
- ❑ Lower overall costs → reduce scrap levels and re-work requirement

Whilst conventional liquid refractory coatings and more recently the TRIBONOL<sup>\*</sup> process have proved successful in reducing or eliminating sand burn-on and metal penetration defects in greensand casting applications, these coatings are not generally effective against defects related to sand expansion or mould erosion. The products typically used to prevent mould erosion are solvent based products based on phenolic resins.

Phenolic resin based products are applied to the mould surface by spraying, and are normally dried using an in-line heater, the dried coating produces a surface hardening effect and seals the mould surface, preventing subsequent drying out of the mould surface. The use of solvent-based phenolic surface hardeners does have its limitations due to the following :-

- ❑ The mould drying process can effect the greensand mould surface strength and potentially increase the occurrence of scabbing and associated defects within the cast component.
- ❑ Phenolic resins are organic and start to break-down at around 200 °C, therefore the breakdown of strength of the coated surface during casting can be rapid, resulting in a friable surface more prone to erosion.

- ❑ The solvent-based product is applied by spraying which will create a fine mist of solvent. With increasing awareness of health, safety and the environment issues within the foundry, this is increasingly unacceptable from personal health issues through to Volatile Organic Compound (VOC) emission regulations.

Discussions with production iron foundries in Japan, North America and Europe, confirmed the need for an environmentally friendly greensand coating or “mould surface stabiliser”, which would help in achieving a near net shape casting, free from mould erosion or expansion related defects. Foseco noted these broad requirements and implemented a project to develop an optimised product, which would not suffer from the limitations associated with current practices or solutions.

This paper provides an introduction to the benefits of a greensand surface stabilising coating – HARDCOTE\* W100, and details the use of the product by referencing a number of case-studies from around the globe.

#### Development

Foundries currently employ a number of innovative solutions to try and overcome problems associated with mould erosion and sand inclusion defects, which typically result in costly scrap or casting re-work. Some of the common techniques include :-

- ❑ Solvent based phenolic binder surface hardeners
- ❑ Water-based refractory coatings, dried with infra-red heaters
- ❑ Special facing sands, applied to specific areas or the whole mould face
- ❑ Replacement of greensand mould face with core packages
- ❑ Petroleum based sprays to prevent mould face drying

The following critical criteria were considered important during the product design and development work, to ensure that the finished product would be a more practical and effective alternative to current methods :-

- ❑ Environmentally friendly – no solvents or restricted raw materials to ensure the product can be produced, transported and used without compromising health, safety and environmental regulations.

- ❑ Prevention of greensand mould erosion.
- ❑ No detrimental effect on greensand system – the control of the greensand system is of the utmost importance in ensuring that castings are produced consistently and reliably with a minimum of scrap and re-work, it is essential that external products which may become incorporated into the greensand system do not have a negative effect on the fine balance of the greensand system.
- ❑ Product application – high production greensand foundries are highly automated systems, any bottlenecks within the system will considerably effect the productivity and effectiveness of the foundry. The proposed product application system should fit within the greensand moulding line without creating new bottlenecks, or compromising the automated nature of the foundry.
- ❑ Cost effective – the purpose of the product is to reduce overall production costs by eliminating scrap or the need for re-work operations.

The product developed to meet these requirements was HARDCOTE W100.

#### Product Characteristics

##### Environmental

The product is a water-based coating which contains a selection of special refractory filler materials and an inorganic, high-temperature stable binder. The product is classified as non-hazardous and contains no SARA 313 reportable materials. It is to be applied by spraying, and the inhalation of the atomised material should be avoided. However, it poses no fire or explosion risks, it contains no volatile organic compounds (VOC’s), and the evaporation products are non-harmful.

##### Defect Elimination

Greensand mould erosion can be caused by a number of factors :-

- ❑ Poor running and gating design
- ❑ Turbulent mould filling
- ❑ Poor greensand mould strength

The instances of mould erosion can be limited by designing the defect out of the process, by optimising the running and gating systems to ensure a non-turbulent filling of the mould cavity, and ensuring that the metal flow does not directly impinge on areas of the mould causing increased localised stresses. The flow of metal into the mould cavity can be significantly improved by the use of filters, to ensure turbulence within the metal is reduced to a minimum, however, this optimisation is not always possible due to the casting design, or the limitation of the moulding box size.

The greensand system itself is very sensitive to changes and must be controlled very precisely to ensure optimum moulding properties, yet the production pressures on automated lines can often result in the sand within a system reaching temperatures above the recommended ideal. This will often be observed as a poor, friable mould surface which will increase dramatically the potential for mould erosion. Increases in mould erosion due to reduced mould surface strengths can also be brought about by extended periods between moulding, closing and casting, this time period can be significant on larger or more complex castings where a large number of cores need to be assembled. During this time period there is a tendency for the mould surface to dry out and for green strength to be reduced, resulting in a friable surface.

For the prevention of mould erosion by the use of a mould coating, the requirement is for the improvement of the following parameters :-

- Increase mould surface green strength.
- Increase mould surface hot strength.
- Prevent surface drying.

#### Mould Surface Green Strength

To measure the beneficial effects on the mould surface green strength a simple test was devised, shown in Figure 1.

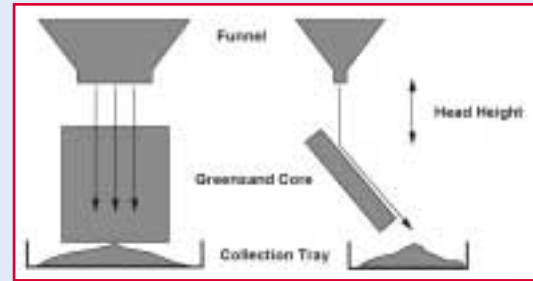


Figure 1: Green Strength Mould Erosion Test

The test was carried out allowing a known quantity of sand to fall from a pre-determined head height onto a freshly made greensand core. The difference in the quantity of poured sand and collected sand was measured, and defined as the erosion value. (i.e high erosion values represent low surface green strength).

The test was carried out on coated and un-coated cores, with the coated cores having various application rates of the HARDCOTE W100 applied, the results are shown on the graph in Figure 2. The graph shows that an optimum application rate is achieved at between 50 and 100 grams per square metre of mould surface.



Figure 2: Effect of coating application rate on Surface Green Strength

To assess the benefits of the coating in preventing erosion due to surface drying, the erosion value was calculated for coated and un-coated cores, after they had been left to air dry for set periods of time, the results are shown on the graph in Figure 3. Although the erosion value increases with time the effect of the coating is very significant when compared with the un-coated cores, and the application rate should be increased to a maximum if the time-delay before casting is excessive.

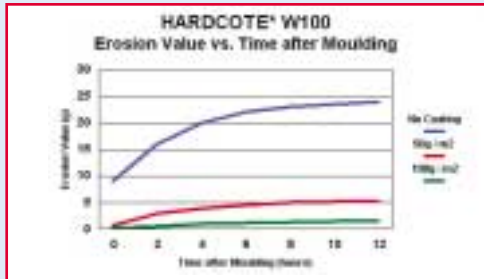


Figure 3: Effect of air drying on Surface Green Strength

### Mould Surface Green Strength

To measure the effect of the coating on hot strength of the mould surface, two separate tests were employed. In the first a coated and un-coated greensand core is placed in an oven at 1400 °C for five minutes, and then the resultant core surface observed, shown in Figures 4 and 5. The un-coated core shows minor cracks on the mould surface, and mould friability is very evident when the core is subject to simple sand erosion testing. The coated core, however shows a smooth defect free surface with strong skin hardness.



Figure 4: Cracking at high temperature on un-coated greensand core



Figure 5: Smooth stabilised surface at high temperature on coated greensand core

The second evaluation test is a simple impingement test casting, shown in Figure 6. The metal is poured down the central running system and is diverted directly onto the greensand mould surface, at point 'A', un-coated greensand and point 'B', coated greensand.

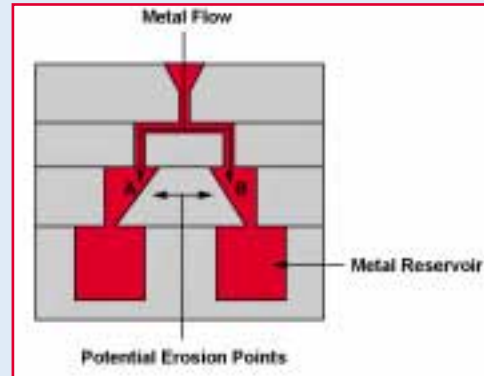


Figure 6: Metal Impingement Test Casting

After solidification the casting is visually inspected at points 'A' and 'B' and assessed for signs of erosion. Photographs of the test castings are shown in Figures 7 and 8, and show significant mould erosion on the un-coated mould, whereas the coated mould is significantly smoother and defect free



Figure 7: Point 'A' – casting produced using an un-coated Mould



Figure 8: Point 'B' – casting produced using a Coated Mould

### Effect on the Greensand System

The product itself is a combination of inert refractory fillers and an inorganic binder. Tests have indicated that this will have no effect on a greensand system, due to the relative inertness of the individual components and the very low addition rates that will result from this products usage. Monitoring of greensand systems where this product has been utilised on a continual basis in Japan, has shown no detrimental effect on the system.

### Product Application

The product is supplied as a milky white liquid with a viscosity of 400 to 600 mPa, and should be used without any further dilution, by spraying. The ideal application rate is between 50 and 100 grams per square metre, and this can be easily achieved by correct setting of the spray unit and an application time of between 6 and 8 seconds. The effect of this rate of coverage on the greensand mould surface is to give a slightly tacky feel when touched.

The material can be effectively applied by manual operation, see Figure 9, or by automatic operation, see Figure 10.

The material once applied by spray, does not need a further drying process due to its fast air-drying characteristics. This is both beneficial from a time restraint perspective, no additional capital cost of drying equipment, and will also prevent mould surface damage associated with excessive heating.

### Cost Effectiveness

Experience to-date has shown that HARDCOTE W100 application is capable of providing various cost benefits to the foundry, most notably :-

- Reduction in scrap levels
- Reduction in re-work
- Elimination of solvent-based coatings, leading to environmental, health and safety advantages
- Improved quality of surface finish, lettering and numbering



Figure 9: Manual Application



Figure 10: Automatic Application

Typically, the optimum application of HARDCOTE W100 results in a significant reduction in sand related scrap, commonly by as much as 70 to 80% of the normal scrap levels without application. The savings associated with such substantial scrap and re-work reduction will normally offset the modest additional material costs of the coating application.

### Case Studies

#### Pipe Fitting Foundry - Japan

The foundry is producing ductile iron pipe fittings with weights of up to 80kg, produced on a horizontally split, jolt-squeeze moulding machine. The time between moulding and casting is between ten and thirty minutes. Mould erosion of both the cope and drag lead to a poor surface finish on the exterior of the casting (Figure 11), and a scrap rate of approximately 6%.



Figure 11: Casting surface from un-Coated Mould



Figure 12: Casting surface from Coated Mould

HARDCOTE W100 was initially applied by manual spraying, and showed promising results with significant improvement in surface finish, shown in Figure 12. The promising results were followed by the introduction of an automated spray unit, applying the coating to both the cope and drag, and analysis of casting results has shown a reduction in scrap rate from 6% to 1.5%.

#### Toowoomba Wheel Products - Australia

The foundry is producing wheel components for the truck and heavy vehicle market. On one particular component, a 70kg 5-spoke wheel hub casting, there were problems with severe mould erosion and resultant metal penetration, shown in Figure 13, due to the use of a direct pouring method. Instead of re-methoding the component, and the resultant decrease in yield, HARDCOTE W100 was applied manually at a rate of 90 grams per mould. The result, shown in Figure 14, shows a dramatic improvement in casting quality, with reduced finishing and machining times. The benefits were further realised in reduced production costs and shorter lead times.



Figure 13: Wheel Hub casting with un-Coated Mould

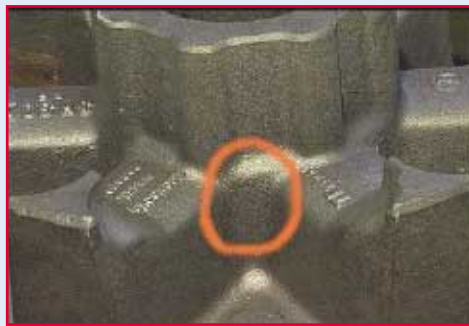


Figure 14: Wheel Hub casting with Coated Mould

### **Conclusions**

As foundries strive to produce more complex castings with thinner section thickness, the requirements placed upon the moulding media is increased to new levels. Failure within the moulding media, during the casting operation will result in increased levels of re-work and scrap. Within the costing systems of the modern foundry, it is essential to control costs, especially the variable costs, as fluctuations can mean the difference between a profit and loss on a particular job. Both scrap and re-work are significant components of the overall cost, and by maintaining these at minimum levels, they can have a very beneficial effect on the balance sheet.

It is for these reasons that investment in processes which minimise scrap and re-work, is essential. The innovations described in this paper, have focused on one such process, a process aimed at improving the as-cast quality of a component, a process which can, with a limited on-cost, significantly reduce the total component cost.

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