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Green Foundry

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Green Foundry LIFE project

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Action B3 Test series of molds, cores and casts produced by inorganic and organic binder systems

Deliverable DeB3c Karhula Foundry implementing the inorganic binder system in everyday practices

Authors:
Karhula Foundry Oy
Meehanite Technology Oy
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Feasibility study on the implementation of inorganic binders in the production of Karhula Foundry

1. Backround

This feasibility study is made to assess the practicality of using inorganic binder systems in moulding process at Karhula Foundry. Karhula Foundry produces middle to large size special castings for global casting markets, mainly made of special stainless steels and irons. Weight range of produced castings is from 1 kg to 30 tons per piece.

Karhula Foundry has two moulding lines and hand moulding for large castings. Currently organic binder system is in use ie. phenolic Alphaset.

The feasibility of the implementation of inorganic binders instead of present organic binders is studied from economic, technical and environmental point of view.

Assessments and experiences in this report are from the tested inorganic binder systems and test casts carried out at Karhula Foundry in 2018-2020 as well as from the waste sand cleaning methods tested in this project. All results are reported in separate deliverables in actions:

- Action B1 “Emissions of different binder systems during small-scale test casts”,
- Action B3 “Test series of moulds, cores and casts produced by inorganic and organic binder systems” and
- Action B4 “Recycling options and sand purification of inorganic surplus foundry sand, high concentration organic waste sand and dusts”.

2. Economy of the inorganic binders

The cost of inorganic binders now available on market is known to be 15… higher than the cost of currently used organic binders in ferrous foundries (= furan, phenolic Alphaset and green sand).

One of the tested inorganic binder systems would require investments due to the need of drying at elevated temperature. This would mean construction of new ovens or other heating equipment such as hot air blowing line into moulding area. There would be also high investment cost for the present patterns and core boxes which are partly made of wood and resin. Resin patterns and core boxes would damage at the needed temperatures of 160…200 C°. Wooden patterns and core boxes are so good insulators that it was impossible

to get cores and moulds hardened and dried inside them. The patterns and core packages should be replaced by new ones made of metallic or other heat resistant material. Investment into sand drying system would costs about 0,5 million €. Patterns and core boxes for a typical products like pump housings in sizes of 0,1 to 2 tons and impellers in sizes in 30 kilos to a few hundred kilos (with 5-7 different core boxes) would cost c. 50. -100.000 € per product. Karhula Foundry produces average 1200 different products per annum. To replace all patterns and core boxes would be an investment of 60-120 M€.
The customers would never pay this.

The other two tested inorganic binder systems behave similar way as current Alphaset binder system, They are self-setting which means that they achieve the needed strength levels without drying at elevated temperature, and they would be usable in the present moulding lines without any new investments. This type of binders are the only ones possible to take into use in existing foundry by using existing wooden patterns and core boxes. These binders include some components, so, they are not 100 % inorganic. However, they could reduce organic impact by c. 80 %.

To be implemented on everyday practice inorganic binders must therefore give technical and environmental benefits to compensate higher initial cost. These aspects are addressed in next chapters.

3. Technical feasibility of inorganic binders in the production of Karhula Foundry.

Karhula Foundry has two moulding lines and hand moulding for large castings. The current binder system in use is phenolic Alphaset.
The melting capacity consists of 8 ton arc furnace and 8 ton, 1,5 ton and 0,5 ton induction furnaces. Karhula Foundry has an 8 ton AOD (Argon Oxygen Decarburization) converter for metal treatment.

The moulding sand is mainly pure high quality silica sand. For the most demanding castings the surfaces of moulds in contact with the melt are made of chromite sand. Sand is reclamed inhouse by mechanical vibrating table crushing system. Typical mixture in moulding is 70 % recycled sand and 30 % new sand.

The surplus sand has been disposed earlier locally, eg. by using it as a filler in local harbor area. Due to harmful impurities this surplus sand has been classified as waste and that's why is now prohibited by local authorities, and Alphaset surplus sand causes now a problem.

The moulds and cores are typically coated by alcohol-based zircon coatings.

The technical experiences from the tested inorganic binders:

- Three inorganic binder systems were tested
- One tested inorganic binder system requires drying at elevated temperature at 150…200 C°

- Two tested inorganic binder systems are of self-setting type behaving similar way as the current Alphaset binder system.

3.1 Experiences from the inorganic binder system nr. 1

The main challenge with this binder system was the need of heating to temperature of 160…200 C° for drying and for achieving appropriate strength levels. Drying of the test moulds was made in available small ovens which limited the maximum size of tests castings to 500 kg.

Heating caused some damages to resin patterns. If this inorganic binder system would be taken into everyday practice, all patterns and core boxes should be replaced by the ones made of metallic or other heat resistant material.

Other challenge was to find the right mixing time and the right recipe for the contents of the binder and the promotor. Estimation of the needed heating times was also difficult and ca. 25% of test moulds and cores broke during stripping because of improper drying and they could not be used for test casts.

When proper parameters for mixing time, recipe of binder and promotor, and heating times were found for the test moulds, the quality of moulds was comparable with current Alphaset moulds.

After the casting stainless steel into test moulds, it was found that significantly less fumes were emitted from these test mould compared to the fumes from the Alphaset moulds. Actually the difference is so big that we can say the moulds are fumeless.

The breaking of the moulds after cooling was easy and the present vibration equipment would suit to this binder system.

The quality of the successful test casts was good and comparable with the present castings made by using Alphaset binder system. In the moulds with cores the risk for gas bubble defects with inorganic moulds is diminished compared with Alphaset moulds, and the quality in this respect is even better.

For good surface quality both inorganic and organic Alphaset binder moulds must be coated.

3.2 Experiences from the inorganic binder system nr. 2

This binder system behaves similar way as the current organic Alphaset binder system in use, and it reaches the required strength levels at room temperature. The minimum room temperature for hardening is 10 C°. The binder itself is 100% inorganic material, but the hardener is organic ester mixture.

The main challenges in achieving the good quality moulds was to demonstrate the proper parameters for the mixing time and the contents of binder and hardener for the tested amount of sand batch. The hardening reaction must not start during the mixing or filling of the moulds, and the binder + hardener recipe must give the required strength levels. There are different formulas of harder for shorter and longer moulding time.

After founding the proper parameters for mixing time and the recipe of binder and hardener, the quality of moulds was found to be comparable with the current Alphaset moulds.

After the casting stainless steel into the test moulds, it was found that significantly less fumes were emitted also from these test mould compared to the fumes from the Alphaset moulds. Some more gas formation was expected with this binder system compared to the inorganic binder system nr. 1 due to the use of organic hardener and this was demonstrated by the chamber test made later. The results are addressed in the next chapter.

The shake-out of the moulds after cooling was easy and the present vibration equipment would suit to this binder system.

The quality of the successful test castings was good and comparable with the present castings made by using Alphaset binder system. In the moulds with cores the risk for gas bubble defects with inorganic moulds is diminished compared with Alphaset moulds, and the quality in this respect is even better.

For good surface quality both the inorganic binder system nr. 2 and Alphaset binder moulds must be coated.

3.3 Experiences from the inorganic binder system nr. 3

The compositions of inorganic binders are different in inorganic binders nr. 2 and 3. However, inorganic binder system nr. 3 also uses similar organic hardener as inorganic binder system 2, and therefore it behaves similarly compared to the current organic Alphaset binder system in us. The minimum room temperature for hardening is 10 C^{o}.

The main challenges also with this binder system in achieving good quality moulds was to demonstrate the proper parameters for the mixing time and the contents of binder and hardener for the tested amount of sand batch.

After founding the proper parameters for mixing time and the recipe of binder and hardener, the quality of moulds was found to be comparable with the current Alphaset moulds.

After the casting stainless steel into the test moulds, it was found that significantly less fumes were emitted also from these test mould compared to the fumes from the Alphaset moulds.

The breaking of the moulds after cooling was easy and the present vibration equipment would suit to this binder system.

The quality of the successful test casts was good and comparable with the present castings made by using Alphaset binder system. In the moulds with cores the risk for gas bubble defects with inorganic moulds is diminished compared with Alphaset moulds, and the quality in this respect is even better.

For good surface quality both the inorganic binder system nr. 2 and Alphaset binder moulds must be coated.

4. Environmental aspects of inorganic binder systems

The environmental aspects of inorganic binders are addressed and compered with the current organic phenolic Alphaset binder system based on the results from:

- Emission measurements in the chamber tests in Action B1 "Emissions of different binder systems during small-scale test casts"
- Results from the Action B4 "Recycling options and sand purification of inorganic surplus foundry sand, high concentration organic waste sand and dusts".

The results show that all inorganic binders will produce significantly less fumes in casting process. Additionally, the fumes do not contain toxic components. Surplus sand does not include environmentally harmful components. It maybe is possible to use directly as building and landfilling material. The only problem would be that it still is categorized as "waste".
So, we can say that concerning working conditions inside the foundry and the fume and smoke emissions from the foundry, inorganic binders will solve all problems.
Some specifications re. surplus sand need to be changed so that it can be used easier than today's surplus sands with organic binders residuals.

Proj.LIFE17ENV/FI/173