

Measures to prolong refractory lifetime in waste incineration plants

Dipl. Min. Till Osthövener, Project Manager; Dr. Wolfgang Kollenberg, Managing Director – Werkstoffzentrum Rheinbach GmbH, Germany

Motivation

From March 2003 until now investigations were carried out about the mechanism of corrosion within the casting of the waste incineration plant in Bonn/Germany.

The casting was done as a quality controlled process. Within this process there was a sampling of casted material for getting comparable results about their physical properties. Additionally, results about the comparison of streaked and gunned SiC masses are given.

The temperature of the casting while heating up was measured with thermocouples in the interior of the masses. The positive effect of external heating for a better drying process of the masses is shown.

The investigated materials are aluminarich-floating mass 90Wt%Al₂O₃ CA-bonded 2.0Wt%CaO; SiC90 as gunned and streaked mass silica sol/gel bonded and SiC90 as gunned mass phosphorous bonded. The samples were taken with the equipment of the casting company, so that there was no difference in the method of preparation of the labor material and of the casted material.

These samples were tested to get comparable results of different materials in respect to the special conditions in waste incineration plants.

Description of the methods of investigation

In the following, some test methods and their correlation to the actual situation in the process will be explained.

The intention is to get information about the physical properties from laboratory tests and to apply these results to the actual properties of the material in the plant. The following physical properties were chosen as being representative for a comparison: porosity; cold bending strength and hot/cold abrasion. The details of this choice are described in the following.

The effect of porosity

Components of the flue gas infiltrate the material by its open porosity, but it is important for the material to have this porosity, because of the quick change in temperature – corresponding with a high or even moderate thermal expansion within the material – will cause micro cracks which will only be stopped by micro and macro pores.

Measuring of strength

The strength was not tested as crushing strength as usual, but as bending strength of test bars with the dimension of 40 × 40 × 160 mm (EN993Part6). The bending strength is a parameter which qualifies the bending matrix within the fine grain of the ceramic structure while getting under tensile load. Our experience is that the bonding system within the ceramic matrix has a bigger effect on the strength and on the properties in use than the coarse grains themselves.

An additional effect is caused by the fact, that the temperature directly above the cooling tubes is at the most about 300 °C and the surface near the fireside is at about 1100 °C (depending on thickness of walls and thermal conductivity).

Thus the material above the tube will never exceed 300 °C. This is a fundamental point with respect to the drying and to get a ceramic bonding at higher temperatures.

Especially the phosphatic bonding system will get its final network strength as aluminaphosphate at temperatures above 500 °C. At lower temperatures there will be a condensing reaction and a release of vaporised water. Thus there should be a lack of strength directly above the tube when the bending system is of phosphatic nature.

Near the hatted pins there will be an estimated temperature of about 800 °C. The maximum tensile strength will be in this area of the casting. So the test method should be the test of the bending strength at room temperature after heating the material up to 800 °C. So we chose this temperature as representative for the material being under load. In this test we have not included aging and infiltration of the material.

Additionally a test with material shocked by temperature from 200 °C to 800 °C was done. In some cases the drying is not as efficient as desired. Surface areas, that are not directly in the radiation area of the burning aggregates while the system is heating up, will be exposed to a thermal shock when the waste is initially burning up.

Abrasion Tests

The results of the abrasion tests are giving hints for comparing and qualifying different or theoretically equivalent ceramic materials. The tests were done at room temperature and at 1200 °C. The test piece is exposed to a well defined bombardement with SiC Particles in accordance to ASTM C704-88. The results of this test only refer to the effect of the particle erosion of flue gas. The effect of changes in temperature and the presence of alkali oxides or changes in the redox potential within the surface is definitely not involved.

The testing procedure at room temperature will give hints on removability of the material at the time of replacement of the casting.

Especially the materials with high bending strength and a CA bonding system are showing a high resistance against sandblasting.

Results of the physical Tests

See **Figure 1**

Figure 1 shows the results of two high alumina-selffloating masses of the same quality (A+B). The bending strength is high in relation to the SiC-masses with bending strength lower than 6 MPa. (Phosphatic bonding/ streaked and gunned masses)

See **Figure 2**

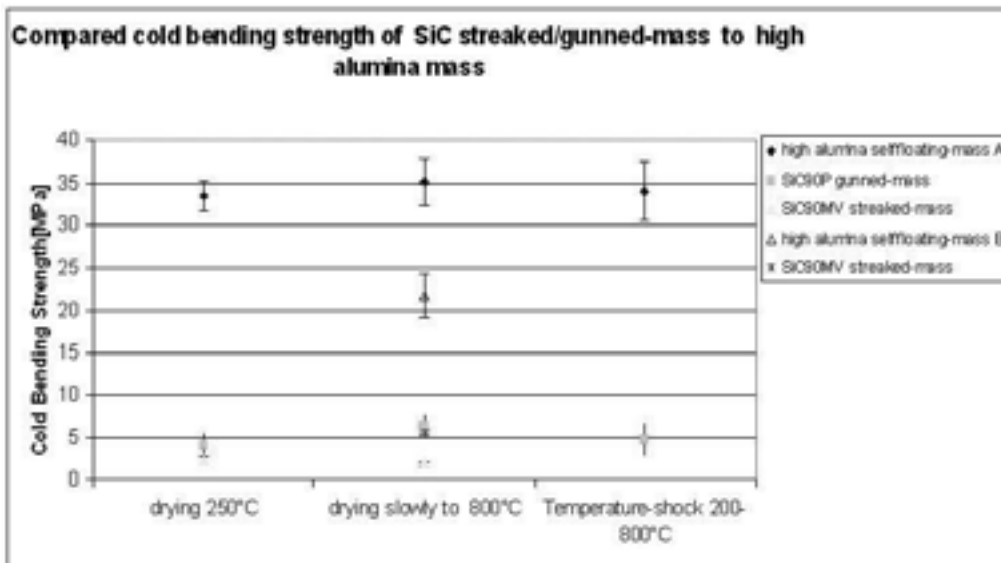


Fig. 1. Compared cold bending strength of SiC streaked/gunned-mass to high alumina mass

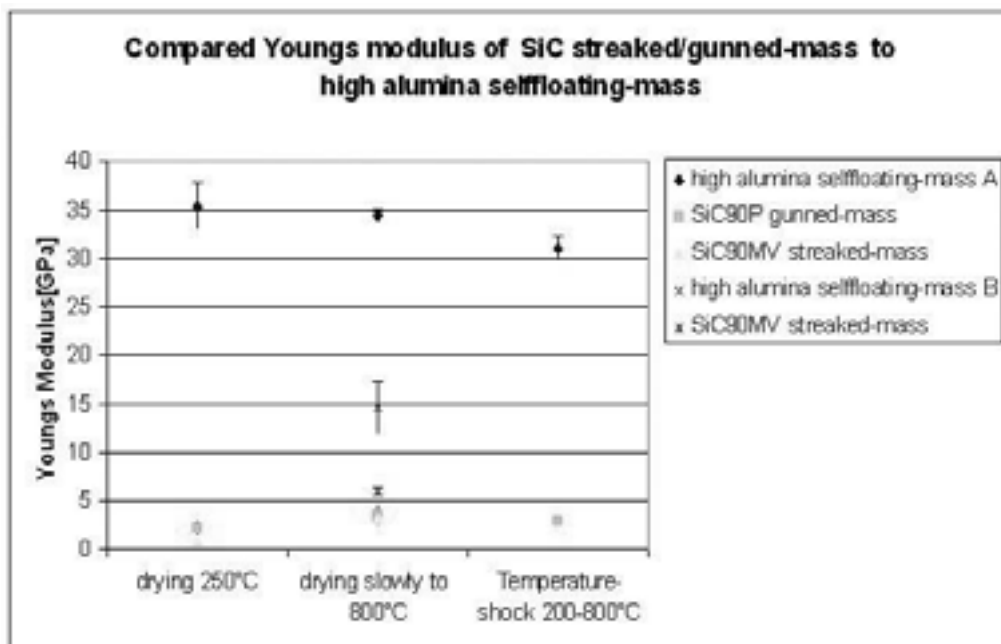


Fig. 2. Compared Youngs modulus of SiC streaked/gunned-mass to high alumina selffloating-mass

Figure 2 shows the results of two high alumina-selffloating masses of the same quality (A+B). The youngs modulus is high in relation to the gunned SiC-mass.

There are greater deviations in the Bending strength and in the youngs modulus of the same high alumina quality. The sampling was done at different revision cycles.

See **Figure 3**

The free floating high alumina mass is showing a low porosity of 12% (Sample A) and 18% (Sample B). The gunned masses is showing high porosities of >25%. One sample of the streaked SiC mass had only 21%.

The effect of burning the samples at 800 °C is low. The initial strength of CA bonded materials remains at a high level.

The low strength level of the phosphatic and silica sol/gel bonded SiC masses remains at low levels even at temperatures of 800 °C

See **Table 1**

The high alumina self floating mass shows a significant low level of abrasion at low and at high temperatures. Even after a thermal up-shock treatment from 200 to 800 °C there seems to be no effect in the abrasion rate.

Even after burning at 800 °C, the SiC material shows a very low resistance against particle bombardement. This effect is in accordance to the measured low level of bending strength.

The material with silica sol/gel bonding type raises its resistance against abrasion at 1200 °C to a very low level. This seems to be the positive effect of changing the bending type from silica sol/gel to a mullite bonding type.

SEM of high alumina self floating masses

The tested self floating material with a CA bonding type was running about 1 year in a high erosive area of the casting. The surface

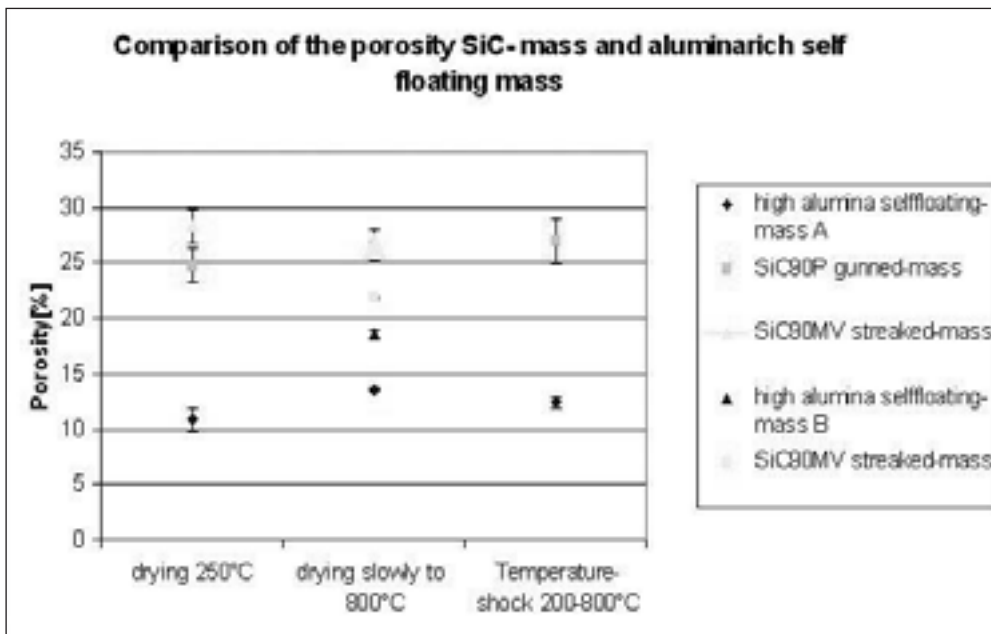


Fig. 3. Comparison of the porosity SiC- mass and aluminarich self floating mass

Tab. 1. Results of hot abrasion and cold abrasion tests

Pre Processing	Sample	Test Temperature [°C]	Loss of Material [cm ³]
After slow drying	SiC90 Silica sol/sel bonded	RT	34.3
After slow drying	SiC90 silica sol/gel bonded	1200	2.0
After slow drying	high alumina self floating	RT	1.0
After temperatur up shock 200-800 °C	high alumina self floating	1200	0.7
After slow drying	high alumina self floating	1200	1.2

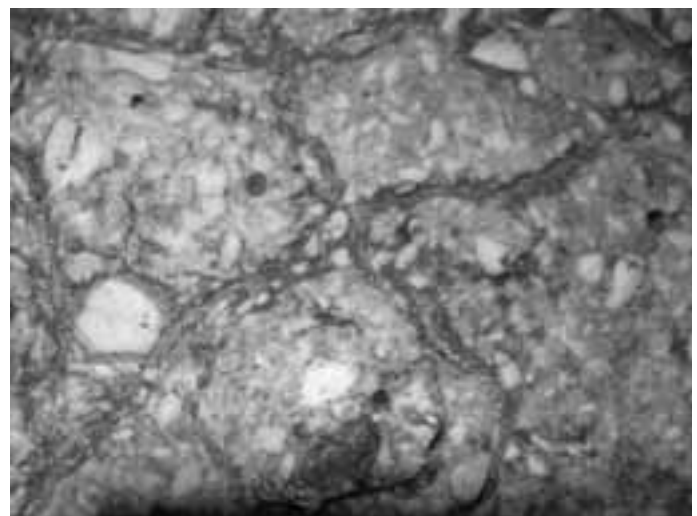


Fig. 4. Detail Image of self floating high alumina mass after 1 year. Total length is 6 cm

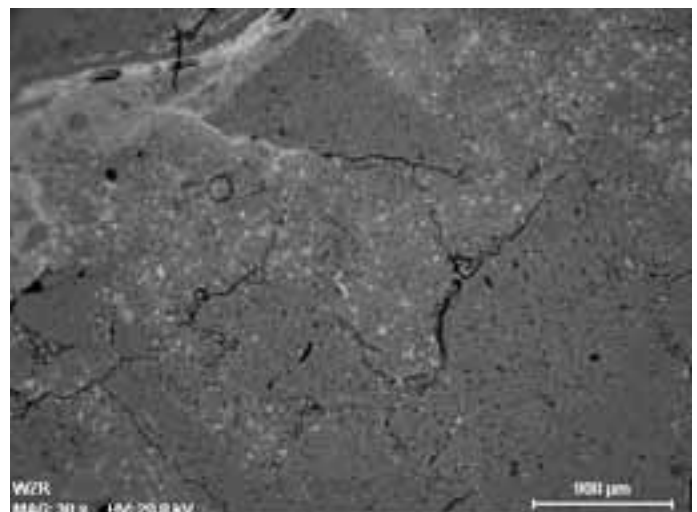


Fig. 5. SEM of the structure of self floating high alumina mass after 1 year in use

gave a very well impression of a good abrasion resistance. There was nearly no abrasion but refilling of surface near cracks.

See **Figure 4**

See **Figure 5**

The SEM shows the coexistence of refilled and not refilled microcracks (upper left area). There seems to be no effect of crack growing by thermal expansion of the filling material. So the material is able to keep its structure and probably its physical properties without additional inner cracks. There was no visible corrosion effect at the surface of the tube just below the sample.

Measuring of the Temperature within the casting

The investigated plant is equipped with a characteristic prismatic bar, exposed directly to the fire. The burners are placed above this bar. Waste ignition is performed by radiation of the burning aggre-

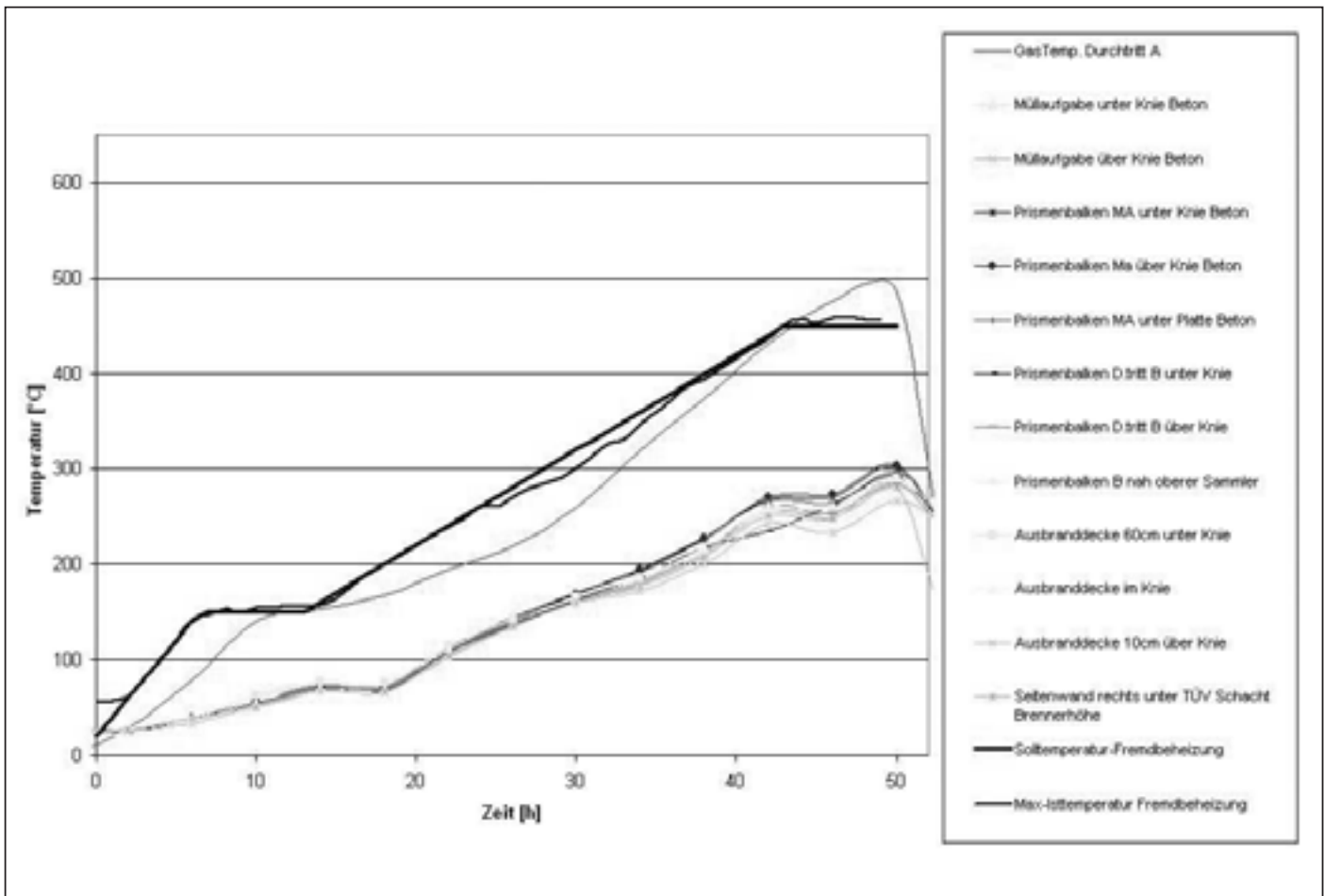


Fig. 6. Results of the temperature measurement with external heating

gates. There are casted areas placed in the shadow of direct radiation which cannot be dried properly. The drying of these areas is done by the backward heating of the tubes with temperatures of 300 °C at most. Unfortunately, some of the areas in the radiation shadow of the burner are the areas with the maximum exposure to the waste fire.

Temperature was measured by flexibly inconel mantled thermocouples NiCr/Ni with an outer diameter of 1.5 mm. They were placed through a hole of 2 mm in the vertical plate of the tubes up to the level of the hatted pins. Now they are about 1cm below the surface of the casting.

Results of temperature measurement

See **Figure 6**

The temperature deviation in the interior of the casting is more homogeneous when externally heated, because preheated air (up to 500 °C) is blown into the vessel. Using external burning aggregates has the advantage of minimizing the amount of preheated secondary air.

The result of this procedure is that the energy of heating is distributed in a homogeneous manner over all casted surfaces of the vessel. This is intended by the manufacturer of the refractory material, who requires that the temperature ramp is in accordance to his specifications.

Measures of Quality Controlling

During the casting works, several items have been documented: the materials deployed and their storage life, the accordance to data sheets, the handling instructions, the engaged machinery and the cleaning instructions. Photographs of critical areas have been tak-

en. All the investigations presented above are an integral part of the quality control concept.

Summary

The investigation of a high alumina CA-bonded self floating mass in areas of high erosion rate in the casting of waste incineration plants showed that this material can compete with the traditional casting of SiC-masses.

It has porosities of 12 to 18% and a cold bending strength above 20MPa even without burning.

The investigated gunned and streaked SiC masses are showing results in bending strength below 6 MPa at porosities far above 20%. The material has higher abrasion rates in a laboratory testing than the high alumina mass. This is caused by the phosphatic bonding system which has not the initial strength of the CA-bonding type which is homogeneously settled over the whole thickness of the casting.

One disadvantage is the resistance against sandblasting in the attempt of removal and a possible corrosion of the tube wall in the area of the anchors with contact to the fire side over a longer life time.

Future Works

The effect of external heating on the refractory material will be observed in detail further on. During the future revision works, material - even in good condition - will be sampled in order to find out the causes for long term stability.

The author acknowledges the MVA Bonn staff for their very good cooperation and for opening the enabling the sampling during revision work.

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