USE OF SPINEL FORMING DRY VIBRATING MIXES IN 20-40 T CRUCIBLE INDUCTION FURNACES

Dr. rer. nat. Otto Krause, Klaus Rieke*,
Dörentrup Feuerfestprodukte GmbH & Co. KG, Dörentrup, Germany

1. Introduction

The use of dry vibrating mixes (DVM) has been customary practice in the steel industry for decades. It is mainly used in crucible induction furnaces. The steel industry is increasingly converting to these furnaces and therefore expanding the dry vibrating mixes market.

Main use is made of acidic dry vibrating mixes on a quartzite base or neutral dry vibrating mixes on a spinel forming base. Mixes on an andalusite or corundum base only play a marginal role.

The acidic mixes can be used to a limited extent here as their application temperature of 1650 °C is too low. Furthermore, they react very sensitively to slag which contains manganese so that it is very rapidly dissolved by it.

Therefore main use are the spinel forming mixes. This is the subject of this paper.

The spinel forming dry vibrating mixes contain

- Corundum (white fused alumina, fused brown alumina, tabular alumina)
- Magnesia (sintered magnesia, seawater magnesia, fused magnesia)
- Additives
- Chemical binders

Spinel is formed after the corundum-magnesia mixture is subjected to temperature impact. This is MA spinel with a melting point of 2130 °C.

This spinel is formed within a temperature range of 900 °C and 1200 °C, depending on the O_2 partial pressure. The MgO is hereby reduced to Mg. Mg has a strong affinity to oxygen. This process is reversed if the O_2 partial pressure should be subjected to even the slightest change, resulting in a new formation of MgO. MA spinel is formed however if Al_2O_3 should also be present.

This formation is initiated in the ground mix as a result of a reaction with the corundum, enabling the coarse grain to be dissolved also or surrounded in a coronal manner respectively (Fig. 1).

Up to now, the coronal formation of the spinel has not been proven with laboratory samples, but only with post mortem samples. It is possible that the inclusion of iron/steel is required. When Al_2O_3 is included, the MA spinel is able to absorb alumina almost completely. This enables both 78 and 90 spinel to be formed. The Al_2O_3 however is precipitated again as corundum when cooled down slowly. Tests performed on post mortem samples resulted in an Al_2O_3 content of 78 % in the MA spinel being measured on the hot side and 71 % on the cold side.

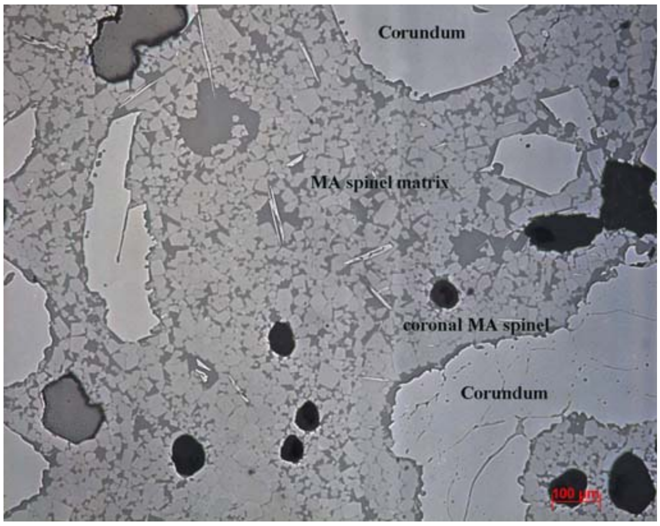

Fig. 1: Mircophoto from the hot side of the furnace wall.

2. Use and demands concerning refractory products

It is a known fact that the demands which are placed in refractory materials are permanently increasing. The temperature even exceeds 1800 °C in special cases. If the Mn content should then be too high, the result will be a rapid wear. A life time of 1 week in a 3 t crucible induction furnace is then deemed to be acceptable.

The furnace sizes have also increased up to 40 t in recent years. This results in increased pressure being applied to the furnace walls, for example. An additional parameter is the thermal capacity of the furnace, which increases considerably. This has a major effect on the refractory lining.

The DVMs, which still provide a good life time with crucible sizes of up to 10 t, show abnormal wear patterns with sizes of 20-40 t (Fig. 2).

Fig. 2: Photo of a severely damaged furnace wall from a 25 t crucible induction furnace

After a certain part of the campaign, the furnace wall starts to be covered by a web of cracks. If the furnace remains in operation, the cracks are scoured and the furnace wall is provided with a pin cushion like surface structure. At a later stage, the cushions start to flake off and wear occurs even faster. In this case, only a major repair can help or the lining campain has to be terminated.
Products with improved properties are in demand.

3. Wear behaviour of the DVM in crucible induction furnaces

The wear of the furnace lining is the most frequent cause of crucible induction furnaces breakdowns. The furnace walls are designed with a wall thickness of 120 mm for example and can be described as follows after the charge for sintering:

Sintered zone	10-20 mm
Fritted zone	20 mm
Loosening zone	80-90 mm

The thickness of the furnace lining has changed after 1/3 of the furnace travel. The furnace wall then has the following approximate zones distribution:

Worn part	20 mm
Sintered zone	20 mm
Fritted zone	40 mm
Loosening zone	40 mm

The furnace will have broken out after a wall thickness reduction of approx. 40-60 %. That means there is a wear of 48-72 mm in our case.
The existence of a loosening zone is important at the end of the furnace campaign as this is required in order to press the furnace out. The reducing of the furnace lining until sintering has been fully completed is not economical as it can then no longer be pressed out. The manual breaking out which is then necessary is time consuming and results in production losses.
If the loosening zone at the cold end of the furnace wall has already been hardened, normally we are able to detect the formation of spinel in most cases. This means that the temperature at the cold side has achieved a minimum of 1000 °C.
A product had to be developed which provides a resistance to chemical wear which is as high as possible, in addition to it having a very good thermal shock resistance (TSR). The sintering capability is to be as low as possible, i.e. it should only be applied at high temperatures. On the other hand, there is a risk that the sintering zone is too weak so that it could be eroded by chemical wear too rapidly, without it being able to regenerate itself. This behaviour is correlated by the observation made that a mix has a good appearance up to a certain number of charges and then reduced to a minimum residual thickness within a few charges.

4. Test results

Various DVMs were tested in order to determine the influence of the ferrostastic pressure. The test samples which were prefired at various temperatures displayed various values, i.e. the higher the prefiring temperature, the higher the D-Max values and the lower the shrinkage (Tab. 1).

Tab. 1: Dilatometer tests conducted in a hood type furnace with a load of 0.01 N/mm²

Quality	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
Prefired Temp. [°C]	1400	1400	1400	1650	1500	1650	1650	1500	1700
D-Max [%]	0.73	0.7	0.77	1.05	0.99	1.01	1.11	1.26	1.26
°C	1050	1024	1029	1362	1276	1300	1450	1574	1650
1000	0.73	0.70	0.77	0.84	0.81	0.84	0.85	0.85	0.84
1100	0.71	0.66	0.75	0.92	0.89	0.92	0.93	0.94	0.93
1200	0.47	0.38	0.56	0.99	0.95	0.98	1.00	1.03	1.01
1300	-0.28	-0.47	0.01	1.04	0.97	1.01	1.07	1.11	1.09
1400	-1.50	-1.75	-1.02	1.05	0.91	1.00	1.11	1.18	1.15
1500	-3.07	-3.31	-2.22	0.99	0.69	0.93	1.10	1.24	1.22
1600	-4.08	-5.37	-3.34	0.72	-0.11	0.72	0.93	1.25	1.22
1700				-0.77	-2.43	-0.37	-0.07	0.97	1.26

From the table, it is clear that the maximum elongation of the differently composed mixes is similar but that the temperatures differ greatly from each other. At a prefiring temperature of 1650 °C, the shrinkage is relatively small at 1700 °C, whereby the newly developed DVMs are not subjected to any shrinkage at all. An interesting aspect is however that with low prefiring temperatures (1400 °C), shrinkages of > 2 % were measured at 1500 °C. One therefore has considerable shrinkages in the rear section of the furnace wall.
It was observed that the post mortem samples had been subjected to cracks in the real furnace wall section which were in part gaping and which were not filled with metal. (see Pict. 2).
The technological values were obtained from test samples (see Tab. 2).

Tab. 2: Technological values

	density green	**density fired**	**expansion**	**CCS**
	[g/cm³]	**[g/cm³]**	**[%]**	**[N/mm²]**
Nr.		**1500°C**		
1	2,86	2,52	3,80	3,10
2	2,88	2,61	2,80	9,08
3	2,98	2,76	2,27	17,28
4	2,91	2,61	3,07	7,44
		1600°C		
1	2,86	2,48	4,40	4,30
2	2,87	2,59	3,00	9,99
3	2,99	2,69	3,20	16,55
4	2,90	2,56	3,60	7,96
		1700°C		
1	2,86	2,43	5,00	5,50
2	2,87	2,59	3,07	12,10
3	2,97	2,63	3,53	15,45
4	2,91	2,54	3,93	12,86

The new developments (2, 3, 4) have slightly higher green bulk densities and clearly improved bulk densities. The expansions are reduced and the cold crushing strengths (CCS) are clearly increased.
The improved expansion and the CCS have a beneficial effect on the life times, whereby the susceptibility to cracks is also reduced.

5. Summary

After generally observing DVMs, it was possible to demonstrate the microscopic formation of the hot side of the furnace wall with Fig. 1.

The tests carried out with regard to the expansion behaviour of the DVMs when subjected to low loads showed that a good refractoryness is advantageous for the shrinkage behaviour of the DVMs in the rear section of the furnace wall.

The technological values of the new developments have especially been achieved in the expansion behaviour and the resistance.

The new qualities have already proven themselves in use. It was possible to increase the life time by up to 20 %.

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