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SWEREA MEFOS EXPERIENCES ON DRY BLAST FURNACE SLAG GRANULATION

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Introduction

Dry granulation of blast furnace slag (BF-slag) both enables an efficient heat recovery and an environmentally friendly route for production of Ground Granulated BF-slag (GGBS), without the use of water and the consequent drying. Swerea MEFOS (MEFOS) has during the period 2012-2014 been running a project financed by the Swedish Energy Agency, SSAB Europe (SSAB) and SSAB Merox (Merox), with the aim to develop a dry slag granulation process (DSG) applicable to BF-slag. DSG has been investigated since the mid 1980´s, covering air granulation, rotary granulation using spinning disc or spinning cup, cooling drum and the Merotec method[1-3]. The most recent development has been on air granulation and Rotary Cup Atomisation (RCA)[4-6]. This paper summarizes the main results of five DSG trials that have been performed with BF-slag using an industrial test-rig erected at SSAB in Luleå.

Set up of the industrial test-rig

Five industrial trials have been performed using an industrial test-rig erected at SSAB, shown in Figure 1. The test-rig, designed for 100-200 kg/min, is equipped with a tundish (about 3 m^3), hydraulic stopper control and a hydraulic moveable slag launder. The strategic position of the rig makes it possible to also test BOF-slag.

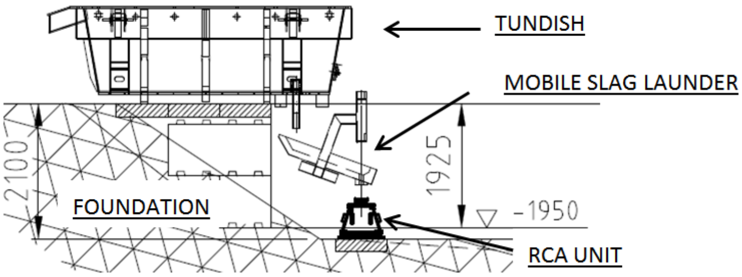

Figure 1: The industrial test-rig at SSAB works in Lulea

The tundish nozzle (ID 65 mm) is made of alumina-carbon. The ramming, launder and exit launder nozzle (ID 40 mm) are made of high alumina castable. The RCA unit consist of a frequency controlled 2kW electrical engine, protected by a steel sheet casing and a granulation cup connected to the engine shaft by cup holder, cooled with pressurized air, see Figure 2.

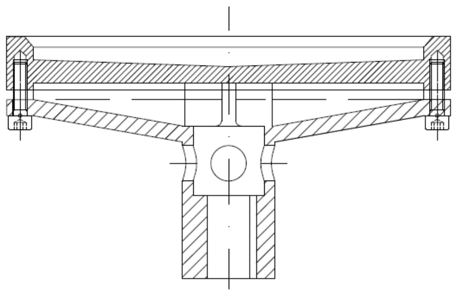

Figure 2: Design of the granulation cup (SSAB TOOLOX) and holder (OD 250mm)

Pre-heating of the casting nozzle and the slag launder was done with oxy-fuel burners. The BF-slag was transported to the granulation test-site by the slag carrier train in 34 ton slag pots. After pre-tilting, the slag in the pot was directly poured into the tundish. The slag flows to a safety dich during the time when the flow is adjusted with the stopper. The launder is then moved into the slag stream and transferred via the launder to the rotating disc. The process was monitored by temperature measurement, level control and by high speed film. Evaluation of the granules includes chemical composition, glass content, grindability, cement properties, etc. The tundish was emptied in the end of the tests via the safety dich.

Results and discussions

Summary of test results

The temperature of the BF-slag in the 5 tests varied between 1330 °C and 1400 °C. The BF-slag flow was estimated to between 100 and 150 kg/min (corresponding to a stopper position of +15 to +20 mm) and the speed of the rotary cup was adjusted between 600 and 1800 rpm. Most of the granules were collected at a distance of 3 to 4 m from the centre of the cup.

The high velocity film exposures of 3000 frames/s are shown in Figure 3 below. The formation of the granules can be summarized into two stages, first radial stringers are formed at the cup edge and curves back due to the velocity decrease as they move out from the edge. Secondly the slag stringers are disintegrated into slag granules. The particle velocity was calculated based on the travelling distance of the particles (ΔS= S3-S1 =62 mm), giving a particle velocity equal to 15.5 m/s (0,062 m/0.004 s). The speed at the cup edge was calculated by equation (1),

$$v = r \cdot \varpi \, , \tag{1}$$

where ω is the angular velocity and r is the radius, to 19.6 m/s at 1500 rpm ((1500/60)*0,25*π). The difference between the cup speed at the edge and the particle could be attributed to slippage of hot slag on the cup surface.

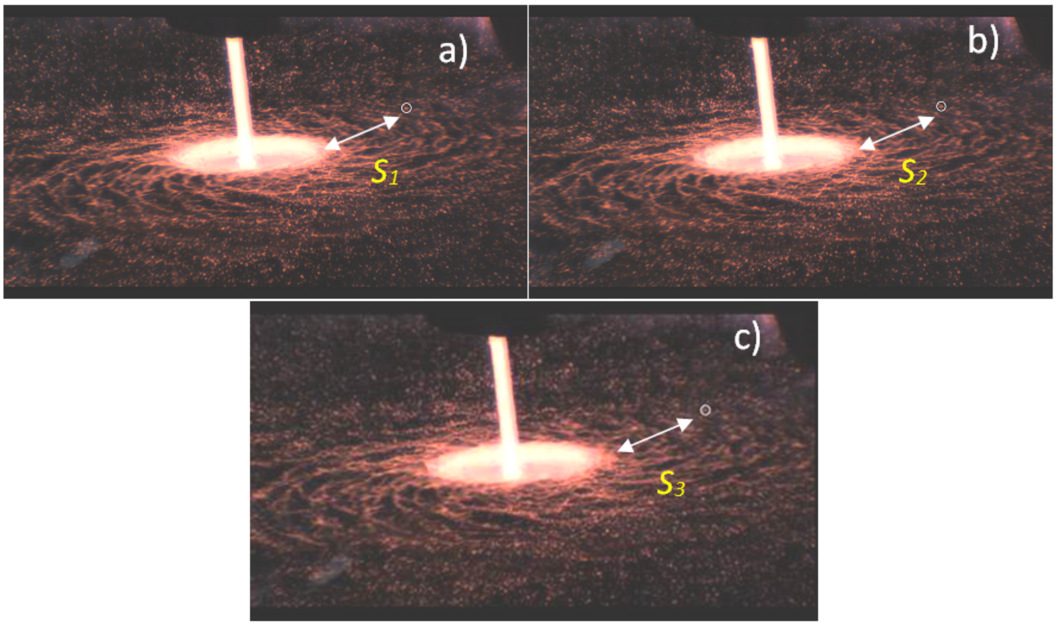

Figure 3: High velocity film exposures at 3000 frames/s and a cup speed of 1500 rpm

Important findings of the trials are summarized according to the following:

- The test rig is well suited for granulation of BF-slag.
- A controllable slag flow to the centre of the cup was achieved.
- The RCA seems to be a robust process capable of handing large variations in slag flows.
- The temperature drop of the slag in the tundish compared to the temperature in the BF-runner is at least 100 °C, which affects the process.
- Flow control using the stopper was preferred as plugging occurred when attempts was made for using smaller nozzles (ID 30 mm), when aiming for the target BF-slag flow of 100-200 kg/min.
- Pressurized air was sufficient for cooling, no wear of the granulation cup made by SSAB TOOLOX was observed after the tests.
- Slag wool was only observed at both low slag flow and high cup speed.

Properties of dry granulated BF-slag

The morphology of the BF-slag granules is shown in Figure 4. All of the granules (<3 mm) are not fully rounded particles as some of them are partly connected by a thin string. A possibly explanation could be high slag viscosity.

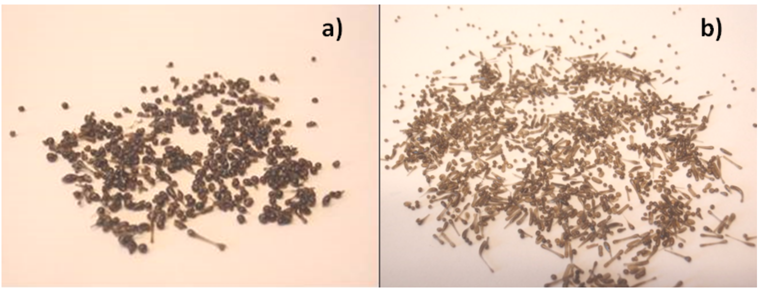

Figure 4: Morphology of the granules, a) 1.4-2.0 mm and b) 0.7 – 1.0 mm

The glass content, determined by polarization microscopy, was in general 98 % and the grindability of the granules was comparable with water granulated BF-slag. The initial binding time for a 50/50 mixture of dry granulated BF-slag and test cement (Norcem) was higher than both a 50/50 mixture of wet granulated slag and Norcem and 100 % of Norcem. The compressive strength after 28 and 91 days was also higher for the dry granulated slag mixture.

Table 1: Result of reactivity test and the measured compression strength

Binding time (EN196-3), min	50/50 dry/Norcem	50/50 wet/Norcem	100 % Norcem
	220	180	135
Compressive Strength (EN196-1)			
7/28/91 d, MPa	30.5/56.3/68.4	25.5/50.8/65.1	41.8/50.5/56.9

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