Procedure for thermally reductive conditioning of BOF (Basic Oxygen Furnace) slag for recycling the metal content and manufacturing highly reactive cement components

PRESS RELEASE

PR 0501 Klinkerweg

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Steelworks slag casting on the slag bed

LOESCHE GmbH is a medium-sized, internationally active company that last year celebrated the 111th anniversary of its founding.

In 111 years of the company's history, the name LOESCHE has always been associated with a great innovative capability that has significantly contributed to the success of the company worldwide. For decades LOESCHE has stood in particular for epoch-making developments in mill technology, which recently has also been signified by the phrase “GRINDING EXPERT” in the traditional LOESCHE theme. According to the demands of the market, LOESCHE is increasingly enhancing this still important field by developing complete processes. Providing complete solutions is becoming an ever larger part of LOESCHE's portfolio, which is also made clear in the new LOESCHE theme. “INNOVATIVE ENGINEERING” – this means much more than simply machine development. LOESCHE technology is traditionally found in the cement industry, steel industry, power plant construction, ore industry and minerals industry. In some of these fields LOESCHE is the global market leader.

In particular, since the introduction of the patented M + S roller technology in 1992/1993, the number of granulated blast furnace slag and cement mills sold has increased, even exceeding the 400 grinding units sold recently.

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The past successes can only be perpetuated and carried on into the future if the increasing market demands, which today also increasingly include sustainability and ecology, are taken into account by increased efforts in research and development. LOESCHE today does not just have a comprehensively equipped test center for grinding-related tests. Thanks to the company's farsighted vision, there is also a strong research team, which uses this test center for the practical implementation of creative ideas.

This research team processes complex tasks by combining profound knowledge of machine and process technology and extensive competence in the field of materials.

One outstanding process development that LOESCHE has initiated and that has been processed in close cooperation with the F. A. Finger-Institut für Baustoffkunde (FIB) at Bauhaus-Universität Weimar is the thermally reductive modification of steel slags for recycling iron and manufacturing “steelworks clinker”. The results achieved by LOESCHE and the FIB impressively reinforce the great success of this approach.

In contrast to the granulated blast furnace slag, original steel slag shows no appreciable binding behaviour after normal finish grinding. That is why the resulting slags in Germany have not been used previously in cement, but instead are used in road construction in unbound base layers or even in bituminous-bound base and cover layers. A significant portion must also be deposited. Against the backdrop of the preservation of resources, the current debate regarding reducing CO_2 and LOESCHE's experiences of being able to recycle higher metal contents from a siliceous matrix, a new research began to produce an innovative conditioning process for steel slags.

In a thermochemical procedure in a reducing atmosphere, the iron that is initially permanently bonded in mineral phases is transferred to an elemental, metallic form; this allows this iron to be separated and fed back into the process of steel production. By transferring the iron to its elemental form, the chemical composition of the remaining molten metal is changed such that the optimum range for the formation of cement clinker phases (clinker standard in the range of 90 to 105) is achieved in many cases without the addition of any corrective components. Consequently after the molten metal cools down, a material similar to (cement) clinker with a high reactivity (binding behaviour), which shows an alite content (tricalcium silicate) of up to 70 m%, is produced. Another important part of the procedure is the insight from LOESCHE and the FIB that MnO_2 reduced to MnO can be integrated into the alite grid, thus leading to stabilisation of this phase, which prevents the decay of alite into belite (dicalcium silicate) and CaO largely independently of the cooling.

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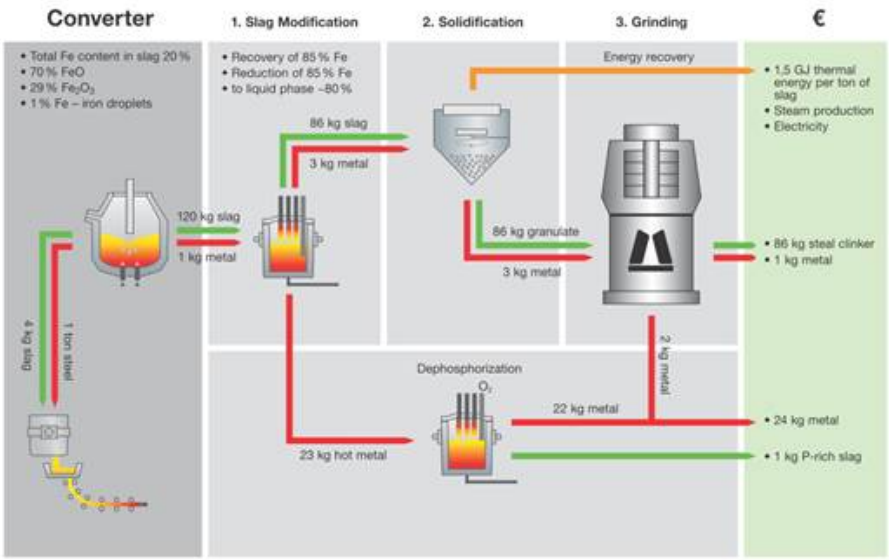
The hydraulic mineral binder manufactured on the basis of this procedure can be used as a composite material for cement or as an independent clinker material in accordance with the

experience of LOESCHE. Two procedures for conditioning have been registered for a patent, which largely differ in the respective cooling process for the remaining molten metal. The first procedure provides for slow cooling over more than 15 minutes, which can be implemented primarily as passive, dormant cooling. A second conditioning process is based on fast cooling through additional measures in less than 15 minutes.

The basic structure of the procedure can be taken from the following diagram. The mass flows are related to 1 t of poured steel slag.



Principle representation of the thermally-reductive process for the modification of LD-Slag, recycling of the metallic content and creation of a "steelworks clinker

The individual stages of the procedure have already been tried and tested on an industrial scale. LOESCHE's partner for the entire procedure is the company Primetals Technologies/Linz, Austria, which has industrial-scale plants for reduction and fast cooling based on patented procedures in its product range.

The remaining iron (approx. 8 - 10 %) that is still in the "steelwork clinker" can be separated in a LOESCHE mill. The separation procedure for this, which has also been patented by LOESCHE, has been successfully in operation for approx. 6 years to recycle stainless steel from stainless steel slags in a recycling plant in Belgium.

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To verify the idea envisaged by LOESCHE back in 2009 of thermally reductive treatment of LD slags, smelting trials with test material from a German steel works in the arc furnace of the *Bundesanstalt für Materialforschung und -prüfung* (BAM - German Federal Office for Material Research and Testing) were ordered in 2011 by LOESCHE/FIB. All chemical and mineralogical tests were carried out at the FIB in Weimar, which also managed the further development of the procedure in terms of materials.

LOESCHE has made international patent applications for the two procedures for conditioning steelwork slags and for the formation of a hydraulic mineral binder with fast and slow cooling. These two conditioning procedures have already led to national patents in some cases.

Based on the activities within the framework of the smelting trials, the BAM, represented by the Federal Republic of Germany, brought a lawsuit against LOESCHE three years later for the complete transfer of all rights to the patent applications made and the patents already granted. The legal uncertainty that this created led to the need to suspend the further development and implementation of these two highly interesting conditioning procedures for more than three years. The legal dispute was conclusively decided in December 2017 in front of the Munich *Oberlandesgericht* (Higher Regional Court). That decision confirmed that the second conditioning procedure - the fast cooling - was the sole property of LOESCHE. In relation to the first conditioning procedure - slow cooling - a third of the ownership was conceded to the BAM, represented by the Federal Republic of Germany.

After the end of the legal dispute with the Federal Republic of Germany, the activities relating to the implementation of the two procedures on an industrial scale could be resumed by LOESCHE. Here the second procedure is considered by LOESCHE to be more economical, since the fast cooling can be carried out in facilities, in which heat recovery is also possible.

In the coming years the aim will be to successfully implement the procedure into industrial practice. Innovations of this kind not only lead to high-quality use of a secondary material that has previously barely been suitable for any use, but also ensure LOESCHE's international competitiveness and thus jobs in German medium-sized companies.

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