INSTALLATION OF A 'STATE OF THE ART' SLAG GRANULATION PLANT[1]

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Abstract

In February 2002, HKM contracted the VAI organisation to supply a new, 'state of the art' slag granulation facility. The project covered the design, supply, installation and commissioning of a new granulator for blast furnace 'B' at the HKM Ironmaking facility in Duisburg, Germany. The granulator technology was based upon the successful RASA design. From the outset of the project, the plant was to be designed to meet the latest environmental standards. To this end a condensation system was included to prevent the escape of sulphur bearing steam into the atmosphere. In addition, the VAI plant design carefully considered any operational problems experienced by HKM with their existing slag granulation facility on blast furnace 'A'. Additional labour saving features were included to ensure an efficient operation. This paper gives an overview of the plant design with particular attention being paid to the development of the condensation system and the steps taken to minimise the solids content of the recirculation water. A description is also included of the construction and commissioning phases of the project. Finally, data is included to illustrate the performance levels regularly achieved. Furthermore, the paper considers the RASA technology and gives an update on the various arrangements that can be provided to suit the needs of the blast furnace operator.

Key words: Slag granulation; Blast Furnace, Environment

INSTALAÇÃO DE UMA GRANULAÇÃO DE ESCÓRIA "ESTADO DA ARTE"

Resumo

Em fevereiro de 2002, a VAI foi contratada pela HKM para o fornecimento de uma nova planta de granulação de escória. O projeto abrangia concepção, fornecimento, instalação e comissionamento de um novo granulador para o alto-forno 'B' da planta de redução localizada em Duisburg, Alemanha. A tecnologia do granulador baseou-se na bem sucedida concepção RASA. Desde a fase inicial do projeto estabeleceu-se que a planta deveria ser projetada de forma a atender aos padrões ambientais vigentes. Para isso foi instalado um sistema de condensação para prevenir possíveis escapes de vapor de enxofre para a atmosfera. Além disso, todos os problemas operacionais experimentados pela HKM no sistema de seu alto-forno 'A' foram cuidadosamente analisados. Este trabalho fornece uma visão geral do projeto, dando ênfase ao desenvolvimento do sistema de condensação e às atitudes tomadas no sentido de minimizar a quantidade de material sólido na água de recirculação. Inclui-se ainda uma descrição das fases de construção e comissionamento do projeto. Por fim, incluem-se dados que ilustram o desempenho alcançado. Além disso, o trabalho apresenta a tecnologia RASA e várias disposições do sistema disponíveis atualmente, que podem ser fornecidos de forma a atender às necessidades do operador do alto-forno.

Palavras-chave: Granulação de escória; Alto-forno, Meio ambiente

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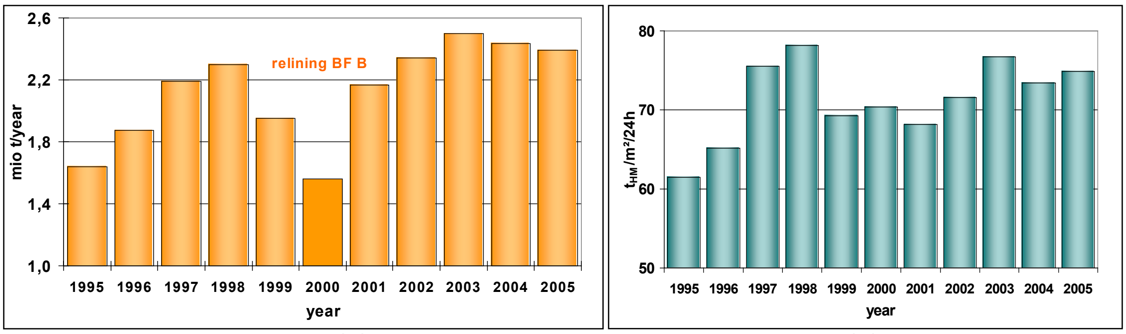
1 INTRODUCTION

HKM operates two Blast Furnaces, at their Duisburg plant in the heart of Germany's Ruhr industrial region, contributing to the production of more than five million tones of steel each year. A comparison of the main features of these two furnaces is shown in Figure 1.

Blast Furnace	**A**	**B**
Year of construction	1973	1981
Last relining	1998	2000
Hearth diameter	10.3 m	11.0 m
Effective capacity	2,449 m^3	2,824 m^3
Charging equipment	Double bell with moveable armour	Rotating chute
Top pressure	2.8 bar	2.8 bar
Blast temperature	1,270 ^{O}C	1,320 ^{O}C
Tuyeres	30	30
Tapping holes	2	2
Capacity	2.5 million t/a	2.7 million t/a
Hot blast stoves		
Number	3	3
Dedusting		
Top gas dedusting	Ring-slot washer	Radial-flow washer
Casting-house d.	EP	EP
Slag removal		
Type	Granulation AJO	Granulation VAI-RASA

Figure 1. Comparison of Blast Furnaces at HKM's Duisburg Plant.

This paper deals with the contract to supply a granulation facility for Blast Furnace 'B'. The installation of the plant on Blast Furnace 'B' was required in order to complement the already existing facility on Blast Furnace 'A'. Typical performance of Blast Furnace 'B' over the last few years is indicated in Figures 2



(a) (b)

Figure 2. (a) HKM's Blast Furnace 'B' Annual Production. (b)Hearth Area Productivity

Based on the above typical performance of the Blast Furnace and the expected slag type and volumes, the plant requirements were defined by HKM. The actual slag quality for the period is shown in Figure 3.

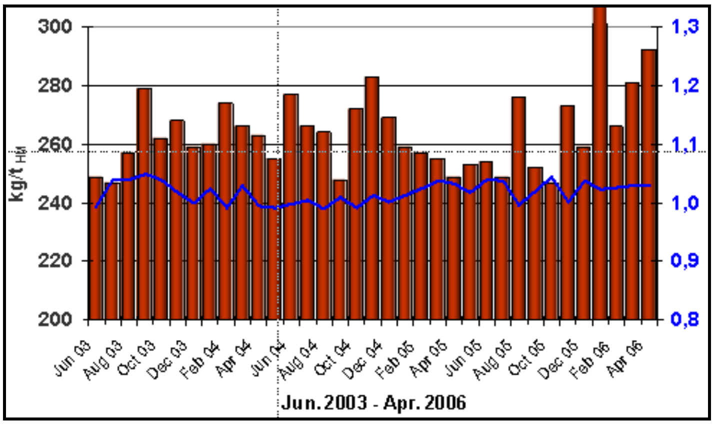


Figure 3. Slag Volume and Basicity, BF B.

Siemens VAI have previously worked with steel producers around the world in the design and development of slag granulation systems, and through a license agreement with the RASA Corporation of Japan have further increased access to the latest plan designs. Experience has included gravel dewatering, slurry pumping and screw/mesh rolls systems. At the time of the proposal for HKM, the favoured solution for producing a high quality marketable granulated slag product consisted of primary dewatering by a screw conveyor followed by secondary dewatering using a mesh roll filter. Because of environmental reasons the gaseous emissions had to be reduced. That's why we had to engineer a fully contained condensation system.

2 MATERIALS AND METHODS

2.1 Design

The project to design, supply, erect and commission a slag granulation plant at the HKM blast furnace 'B' using the RASA process technology was awarded by HKM in early 2002 on a consortium of two Siemens VAI group companies, led by Deutsche VAI (DVAI) based in Düsseldorf. DVAI were responsible for the overall project management, engineering, supply, installation and construction with the basic system design and key component supply being carried out by Siemens VAI.

The initial design concept was based on the successful plants built by Siemens VAI at the POSCO Gwangyang Works and at China Steel's Kaohsiung No.4 Blast Furnace. As indicated in Figure 4, after the slag is granulated at the spray box, primary dewatering is carried out using a screw conveyor. This conveyor removes the product granulate (~97% of slag input) whilst leaving the majority of the fine slag wool in suspension. The product granulate with about 25% water content is transported by conveyor to the final product dewatering area. The water from the slag basin is then further cleaned by passing it through a mesh roll filter which allows for the removal of the slag wool. The use of the screw conveyor for the primary separation process allows the plant to operate extremely well during periods of slag surge with a high availability.

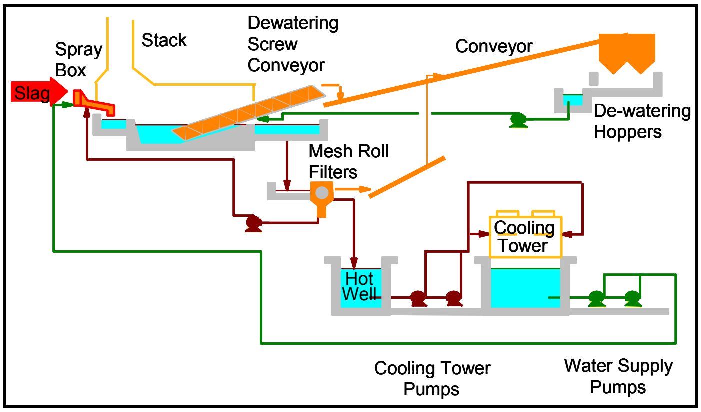


Figure 4. RASA-SVAI Wet Slag Granulation System Concept for China Steel's Kaohsiung No.4 BF.

This basic concept was the starting point for the design of the HKM plant at Duisburg, however there were a number of design changes which reflected the different operational experience and maintenance philosophy of HKM engineers and the local environmental regulations. Also, because of the existing blast furnace layout it was necessary to engineer a new plant arrangement which fitted within the restricted confines of the hot metal tracks without causing any interruption to the flow of hot metal.

The new features that required incorporating into the overall design were:

- The end section of the common slag runner to be copper
- An enclosed stack to prevent H_2S and SO_2 emissions
- A variable flow, constant pressure spray box with focused jets to optimize granulate quality
- Variable Voltage Variable Frequency drives on all the main pumps none of which incorporated standby drives
- A single mesh roll filter of increased capacity, specifically developed for this plant.

2.2 Copper Slag Outlet

The existing casthouse slag runner system required extending in order to provide the central feed to the slag granulation system and the last four metres of the new common section was designed to be a low maintenance copper stave. The design of this copper slag runner was based on the stave concept from blast furnace shell cooling systems. The arrangement was developed using finite element analysis (ANSYS) modelling, as shown in Figure 5 below, and consisted of a base stave on the bottom and two side staves.

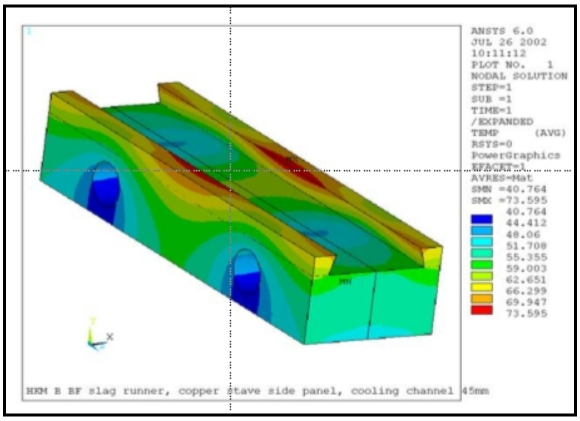


Figure 5. Thermal Analysis of Copper Stave for Slag Runner.

The water cooling channels were designed in order to obtain the formation of a solid slag layer over the length of the runner thus reducing the need for maintenance of the runner section immediately before the slag spray box.

2.3 Condensation Tower

As previously discussed, the original concept of granulation systems allowed atmospheric emissions from the stack and these can contain a relatively high H_2S content, approximately 200ppm. Therefore additional plant was required in order to greatly reduce this value and Figure 6 below shows the concept for the condensation system as developed with HKM.

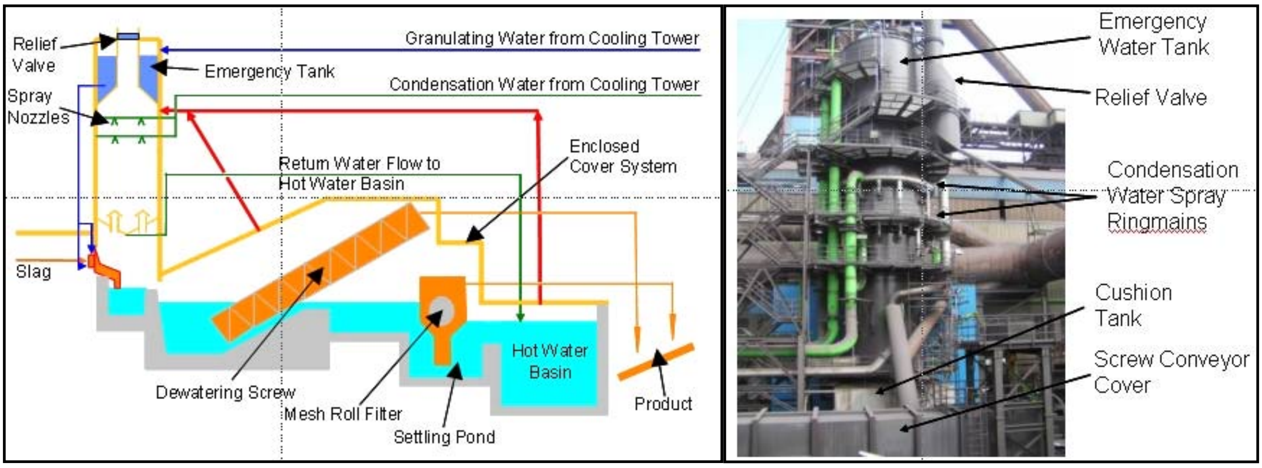


Figure 6. (a) Basic Design Concept for Condensation System. (b) View of Condensation Tower

The emission requirements meant that all equipment had to be enclosed and thus the screw basin, settling pond and hotwell were all provided with removable covers. The settling pond was used for tertiary separation of the product and was incorporated in this design as the request of HKM. The cover to the settling pond utilized hydraulic actuation in order to reduce downtime during cleaning operations. Most condensation systems rely on restricting the entrainment of air with the slag as it runs into the spray box slag runner and creating a closed system. A completely closed system is not possible with the RASA-VAI system due to the addition of air via nozzles on the mesh roll filter which allow separation of the product from the filter mesh. Therefore, by arrangement of the system vapour flows the sulphur reactions are controlled in order to prevent any H_2S emission with the product or in the cooling tower.

The water required for the condensation system runs as a separate line from the cold water basin to the tower itself. Variable flow control of the water to the tower ensures complete coverage of the spray tower through the four rows of spray heads. The return water is then collected in the base of the tower and gravity fed to the hot water basin where it mixes with the returned granulating water from the screw and mesh roll filter prior to being pumped through the cooling tower.

2.4 Variable Flow Spray Box

At HKM, in order to maintain an approximately fixed water to slag ratio, the spray box orifice was designed to be variable. The automated control of the spray box opening, used in conjunction with the supply of the granulating water at a constant pressure, enabled good control over the flow rate and by accurately tuning the process control system a water to slag ratio of a minimum of 5 to 1 was consistently obtained.

2.5 VVVF Drives

After discussions with HKM on their previous experiences it was decided that redundancy of pumps was not required. Therefore, single pumps of 100% capacity were utilized and the variable water flowrates necessary to maintain a fixed water to slag ratio were obtained using VVVF drives, thus giving additional gains in power consumption when operated at flowrates below the design rating.

2.6 Single Mesh Roll Filter

Figure 7 illustrates the basic arrangement of the drum filter. At HKM with the variable water flowrates it was decided to provide a single larger filter (DF6 type). The overall capacity of the DF6 is similar to two DF4's but requires excellent control to avoid overflow directly to the settling pond.

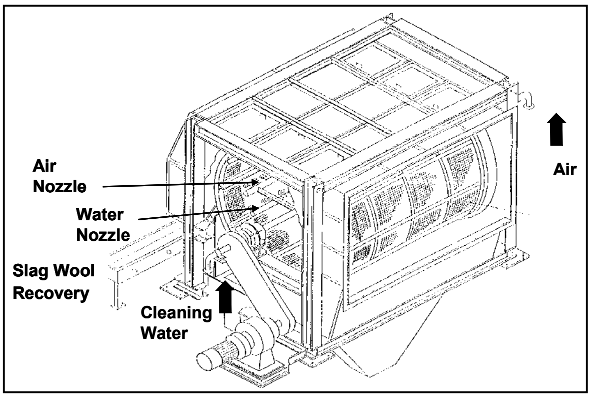


Figure 7. Mesh Roll Filter.

2.7 Installation & Commissioning

After a rapid design phase starting in February 2002, the start of the civil phase of construction occurred towards the end of August 2002 with mechanical erection starting early in the New Year of 2003. Cold Commissioning began in May 2003 giving an overall project duration of 16 months to start up.

Commissioning went well with only minor issues with the sequence control being identified. This achievement was testament to the quality and endeavour of the site team and, as during construction, a close cooperation with the HKM personnel. The commissioning of the water system control logic was extremely important in achieving a balance of the water flows through the various basins utilizing the pump VVVF drives. The time invested in obtaining consistent control reduced the likelihood of control trips during initial operation and thus enabled the plant availability to be maintained at a high level from the beginning of commercial operation. Figure 8 shows the installation of the screw conveyor carried out.

Figure 8. Installation of the Screw Conveyor.

3 RESULTS

3.1 Start-Up

The first slag tap was taken on 17th June 2003 and the initial hot commissioning period was relatively uneventful. Figure 9 below shows the first product granulate emerging from the screw conveyor outlet and it was immediately noted to be of high quality. The main target of this period was to refine the instrumentation feedback in order to improve the control system prediction of the slag flowrate. This calculated slag flowrate was then used to control the spray box water flowrate in order to maintain a steady water to slag ratio and thus good quality granulate of the correct particle size. Some control refinements made to further improve the system included adding a rate of temperature change factor in order to ensure water flow increases led any slag flow increases. The sequence logic functioned very successfully and a balance of the hot water flows was rapidly achieved allowing fine tuning of the level control to be carried out.

Figure 9. Granulate From The First Slag Cast As It Is Discharged From The Screw Conveyor Outlet.

The month long performance test was successfully completed on 12th September 2003. During the test period the guaranteed availability of greater than 97% was comfortably achieved with a power consumption of less than 10 kWh per ton of slag. The product granulate had a glassy content greater than 95% and a grain distribution of more than 95% between 0 and 3mm.

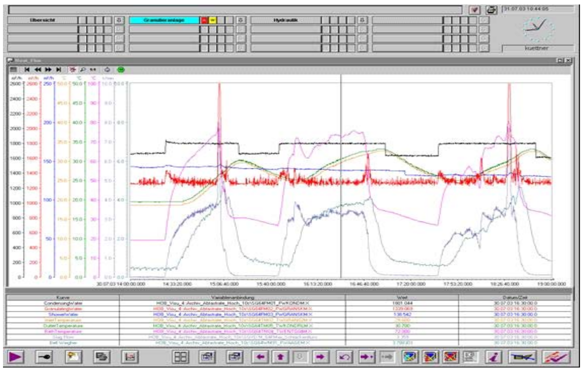


Figure 10. Operating Data From The Start Up Period.

Figure 10 is a trend of operating data from three casts carried out on the 30th July 2003. It shows the general repeatability of the system with maximum bath water temperatures attained of approximately 75 OC with slag rates of the order of 4 t/min.

3.3 Maintenance & Operation

After completion of the performance tests HKM assumed responsibility for the plant operation with continued support from the Siemens VAI organization. The first 18 months of operation have demonstrated the robustness of the plant equipment. This philosophy included ensuring all parts of the system were easily accessible for maintenance, reducing the number of moving parts in the water system and including ceramic or stainless steel parts where necessary to reduce the interruptions due to wear.

The latest development of the dewatering screw conveyor, incorporating the design modifications from previous installations and an improved lifting device, has proven very successful at HKM. The concept of being able to handle large quantities of slag with minimal maintenance has been ably demonstrated, with the design capable of accepting short term peaks of over 10 t/min.

The continued operation of the plant is indicated in figure 11, where it should be noted that no adjustments have been made for periods of low demand in the market and external plant maintenance which have occasionally led to the granulation facility being under employed.

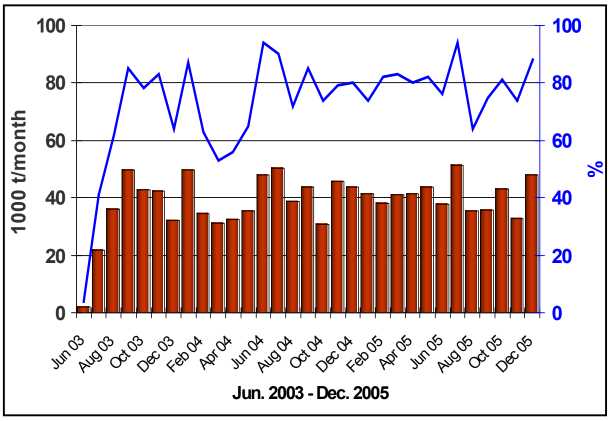


Figure 11. Slag Granulate Production Since Initial Operation.

4 CONCLUSION

The successful start up of the slag granulation plant was due to the good co-operation established between all parties during the course of the project. The granulated slag product is consistently of a high quality. The granulation plant achieved the requirements to continue the reductions in the level of H_2S emissions and also its current operation at high availabilities demonstrates the robustness of the screw dewatering process.