

OPTIMAL MIXING AND GRANULATION PROCESS FOR FINE UTILIZATION IN SINTERPLANTS*

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Abstract

Due the fast growing of pig iron and steel in the last years associate with some mineral resources changes (Hematite→Itabirite), has been checking the sinter feed degradation. The typical sinter feed (0.15;-6.3 mm) has become limited and the rapid growing production resulted in more and more fine ore (< 150 µm) availability in the market. The sinter plant operators are facing several new challenges since the mixing and granulation- and the sintering behavior of the fines containing mixtures often differs from the traditional sinter feed's behavior. The utilization of fines in the sinter plants might increase the process water consumption required for the mixing and granulation process or even the solid fuel consumption, which effects the operational cost of the plant significantly. The current study presents an overview about Outotec's laboratory facilities and competence regarding the mixing and granulation of fines in different equipments. The usage of high intensity mixers (HIM) – vertical and horizontal as well – showed to be the most effective, based in cold agglomeration tests in small scale, in case of fine ore handling. Permeability and particle size distribution curves are used to evaluate and demonstrate the efficiency of the different equipments. Outotec's "Know-How" with the different type of mixer and the modern laboratory facilities provide an excellent opportunities to optimize the mixing and granulation procedure and utilize up to 100 % pellet feed

Keywords: Sinter feed; Pellet feed; Permeability; High intensity mixing.

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1. INTRODUCTION

In 2015 the crude steel production was around 1.6 billion tons and almost 75 % of it was realized by the integrated steelworks using blast furnaces[1]. In this way, Outotec has been deeply looking for innovative sintering technologies, which provide the proper burden preparation for the iron making process. The research and development are aligned with the new trend; the mines are not able to satisfy the tremendously growing demands and minerals resources changes of the iron making market and deliver the required amount of conventional sinter feed (0.15;-6.3 mm). The high demand on the market contributed to the generation of large amount of iron ore fines (< 150 µm) during the mining operation and beneficiation procedure. The disadvantages of the fine utilization in the traditional sintering process are well known. According to their negative effect on the permeability, productivity and solid fuel consumption the usage of these ores is challenging for the operators. The bottleneck of handling fines in the sinter mixture is the mixing and granulation procedure. Principally the mixing procedure has three main goals. Firstly to mix the different type of raw material and ensure the homogeneity. Secondly, the optimal moisture content has to be set and lastly it has to be able to build up granules/nodules to ensure the required permeability of the sinter bed. [2] Although the mixing and nodulizing drums are widespread used in the practice because of their robust structure with low maintenance costs, they are not capable to solve the new problems with fines, when exceeding a certain fines fraction in the mixture. The preparation of the sinter mixture, containing up to 100 % fines requires accurate process lead and modern, automated equipment. There are several parameters, which have serious effects on the mixing procedure, such as variable mixing and granulation time, variable tool speed, water addition ratio in the different phases, amount of water and usage of binders. In order to be able to utilize as much fines in the plant as possible the right permeability, particle size distribution and moisture content needs to be optimized during varying of the above mentioned parameters. The vertical and horizontal high intensity mixers (HIM) have the necessary flexibility to optimize the agglomeration process. The qualitative evaluation of the sinter mixtures has also significant importance. Permeability and particle size distribution are the most commonly used measures in the practice. The mixing behavior of seven different ores in function of the moisture content was investigated by *Khosa and Manuel 2007*. According to their finding the optimum permeability – in Japanese Permeability Unit (JPU) – is between 40-60 JPU. The water addition has a positive effect, increasing effect on the permeability up to a certain point. After reaching a maximum JPU value further water addition already reduces the permeability. They characterized the mixtures by their size distribution before and after granulation as well [3].

The Outotec R&D center in Frankfurt Germany (FRC) has novel experience how to handle fines in different ways. The cutting-edge process design is to apply high intensity mixing separate for the mixing and granulation procedure. However, there has been other options investigated to handle fines in the agglomeration procedure, such as the implementation of pelletizing disc to generate minipellets (4-9 mm) or even normal pellets (9-16 mm). The so-called Hybrid Pelletization Sinter technology (HPS) separates the mixing procedure of the normal sinter feed from the fines. The fines are treated on separate discs and the produced pellets are led together with the sinter mix

into a common mixer[4] or even if the sinter feed is already mixed then into common nodulizer[5].

The installation of pelletizing discs for an existing machine to support the already existing drum or even high intensity mixer is technically possible. Outotec has unique combined experience of implementation of pellet and sintering plants in order to evaluate plant layout and return over investment.

Outotec has unique experience with the handling of different type of ores and optimizing the mixing subsequently the sintering procedure as well. In the recent year's different type of iron ore fines were investigated and processed in the Frankfurt Research Centre (FRC) in Germany to provide optimal mixing, granulation and sintering solution for the clients. This paper demonstrates Outotec's facilities and findings regarding the mixing and granulation of fines in different equipments.

2. LABORATORY FACILITIES AND EXPERIMENTAL PROCEDURE FOR OPTIMIZATION OF IRON ORE FINES

2.1 Laboratory facilities

Outotec's novel approach in the fine processing is to find the most suitable-flexible equipment (or even equipment combination) and optimize the mixing, granulation and sintering process trying to keep the specific productivity and without increasing the solid fuel consumption. The Frankfurt Research Centre possesses the necessary equipment and professional staff to execute and evaluate mixing, granulation and sintering test with different type of fines and to aim the maximum possible fines utilization. The development of tailor made solution for each client ore are ensured by different mixer available. Four different type of equipment are available for the fine optimization. The highest flexibility has the vertical- and horizontal High Intensity Mixer (HIM). Figure 1 shows these type of equipments. High Intensity Mixers can be used not only for mixing but also for granulation purposes as well with variable retention time (mixing time), tool rotation speed and even the ratio of the water addition in the mixing and granulation phase can be set.

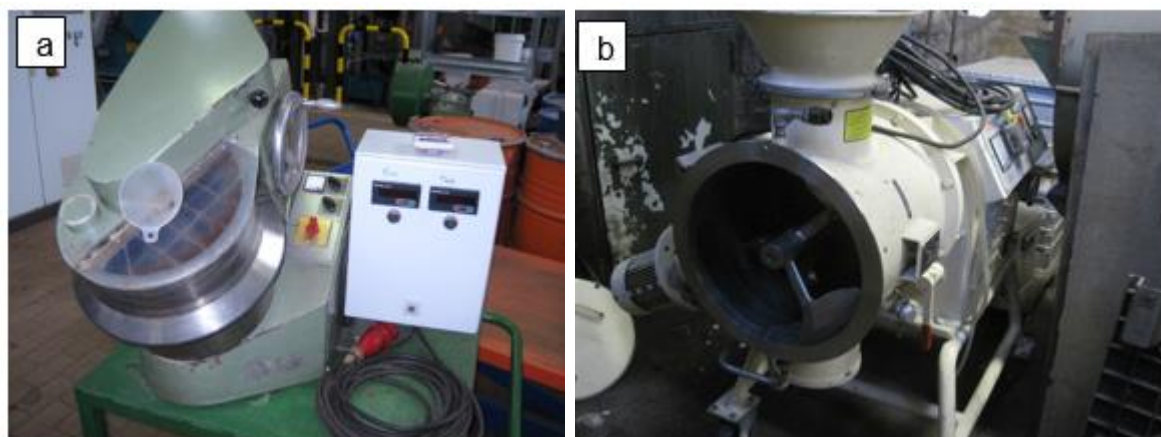


Figure 1. Vertical (a) and horizontal (b) intensive mixers

Different process designs can be tested in the Frankfurt Research Center such as the usage of drum type mixer or even pelletizing disc for special cases as well. Figure 2 represents the mixing and nodulizing drum (MND) and the pelletizing disc in FRC. After finding the best process and equipment parameters for fine utilization the mixtures needs to be sintered to verify the specific productivity and solid fuel consumption. The FRC has the necessary sintering pot facility to fulfill the clients' requirements and optimize the sintering process.

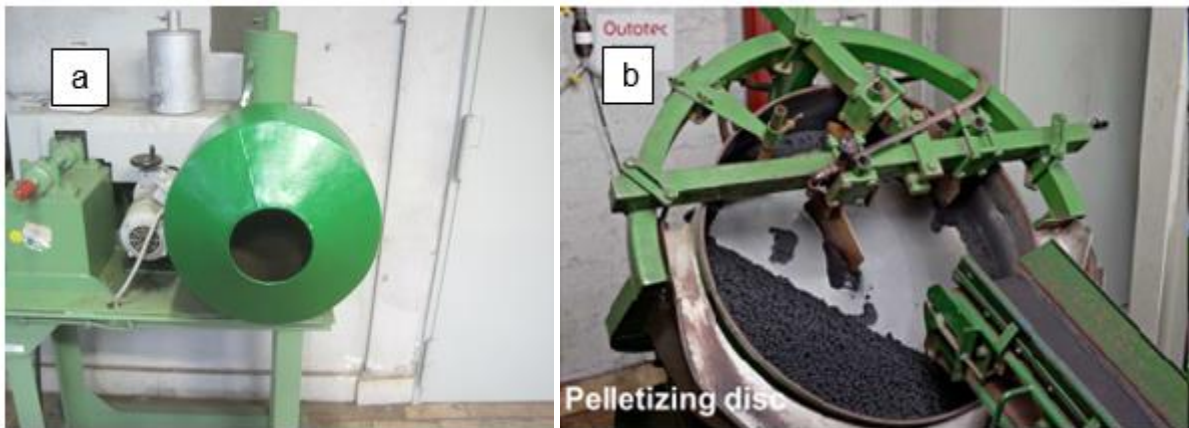


Figure 2. Drum type of mixer (a) and pelletizing disc (b)

Furthermore hot sintering tests are also necessary to produce the right amount of return fines to the agglomeration tests. Figure 3 represents the sintering pot facility in the FRC.

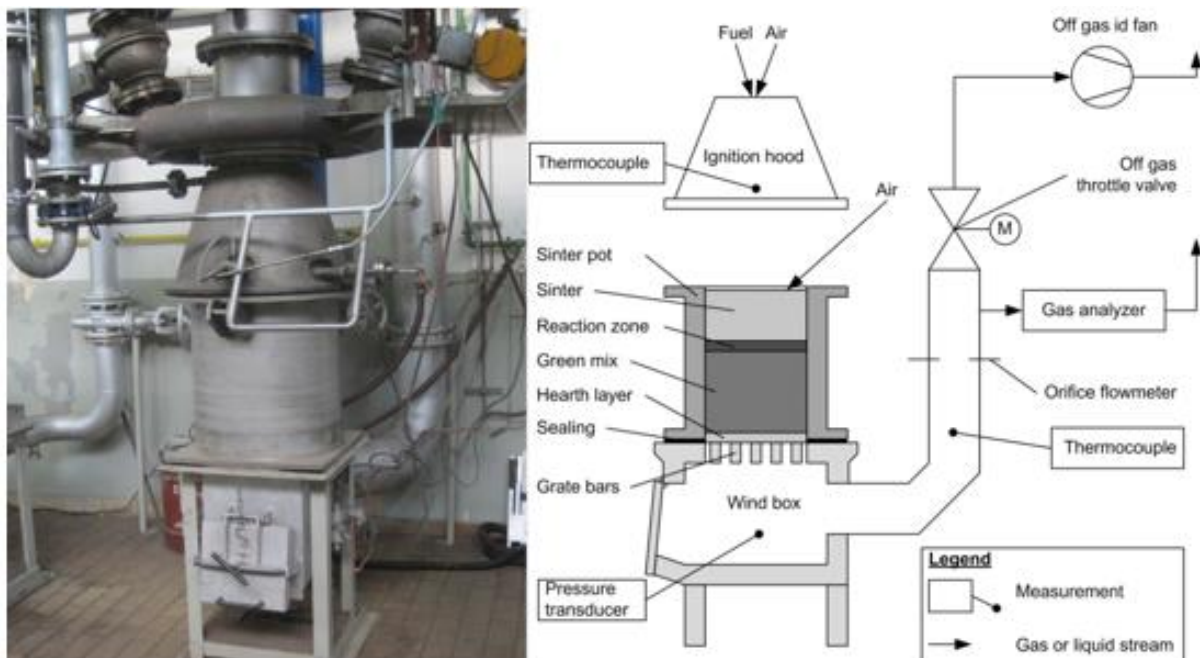


Figure 3. Left: Pot grate sinter test facility with ignition hood in place at Outotec R&D Centre Frankfurt, Germany. Right: Scheme of the sinter facility.

2.2 Mixing and Granulation Process Development

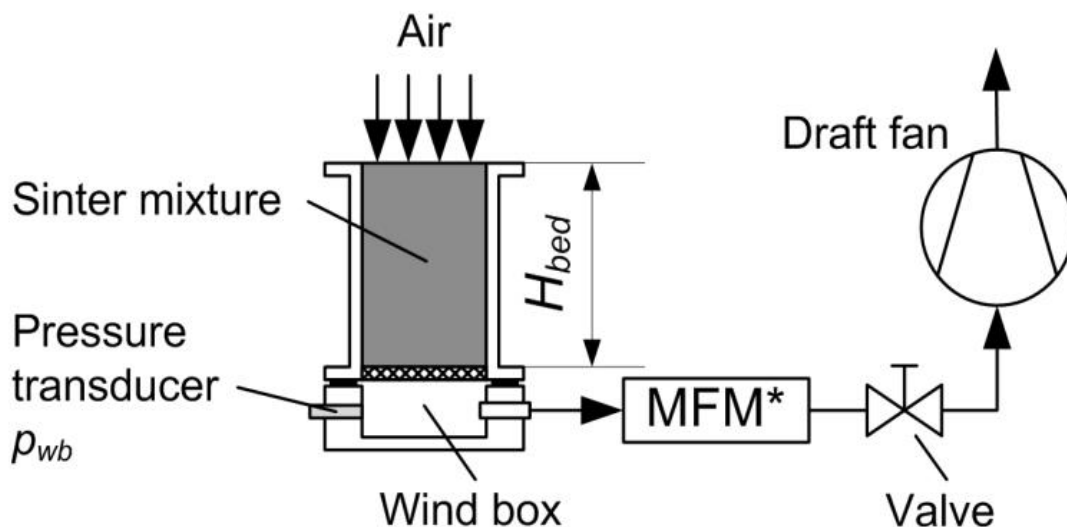
In the first step the sinter mix composition, basicity and other above mentioned process parameters has to be defined. The mixing and granulation tests are carried out in different equipments or even in the combination of them. The execution of the tests bases on Outotec long year experience. In order to optimize the combination of the examined parameters Outotec implies his scientific competence to set up a proper test matrix. The evaluation of the results requires to determine the following parameters:

- Moisture content – before and after agglomeration
- Permeability

Normally the target sinter mix permeability for iron ores is between 40-60 JPU after granulation. This ensures the stable sintering process and product quality. The permeability is measured by the following schematic setup in Figure 4. The sinter mixture is filled in a cylinder by a highly permeable grate. The air will pass through the sinter mixture with the volumetric flow indicated by the mass flow meter (MFM). The permeability value is calculated according to Eq. 1 at a volumetric flow of 400 L_{Norm}/min at ambient conditions.

$$JPU = u \left(\frac{H_{bed}}{p_{wb}} \right)^{0.6} \quad \text{Eq. 1}$$

Herein, u indicates the superficial gas velocity through the sinter mixture, H_{bed} the height of the sinter mixture, and p_{wb} the pressure inside the wind box. The superficial gas velocity calculates from the volumetric flow through the grate surface.



*MFM: *Mass flow meter*

Figure 4. The schematic setup the permeability measurement

Averaging the permeability values of several repetitions delivers the final value. Closing the valve and refilling the cylinder prior to each repetition allows avoiding compaction effects due to drying and draft.

- Particle size distribution

Usually the mixture is dried out at 100 °C for a certain time to a defined moisture level. At the desired moisture the mixture is screened by using sieves of 10 mm, 8 mm, 5 mm, 2.8 mm, 1 mm, and 0.5 mm. The probe is completely sieved by 30 circular movements of the stack. Slight hitting the sieves can loosen minor deposits on the sieve grates. After sieving the remains of each particle size range has to be weighed. This allows the determination of the mass fraction per particle size bandwidth. Important is to check the development of the mass fractions between 1-5 mm before and after granulation. After the evaluation of the results hot pot grate tests are recommended to determine the specific productivity and solid fuel consumption.

3. EXPERIMENTAL RESULTS

This chapter demonstrates the current results and findings gained in the processing of fines. As the main challenge in the sinter plants is to find the optimal process parameters for handling fines, Outotec executed several test campaigns with different type of fine (< 150 µm) iron ores in order to investigate their mixing and granulation behavior. The amount of the iron bearing material and the basicity of the mixture were held constant during the experimental work. The efficiency of the different mixing and granulation (nodulizing) equipments and the effect of water addition were examined in function of the fine content. The aim of the test works were to compare the applicability of high intensity equipments with the traditional drum type of mixer. The proper permeability setting during agglomeration is essential for the sintering process, and in this regard, the benefit of high intensity mixing is unambiguous. The usage of HIM allows the operator to set the required permeability (40-60 JPU) between the applicable ranges of iron ores irrespectively of the fine content, Figure 5 (a). On the other hand the mixing of fines with a drum type mixer allows to set only the lower range of the acceptable permeability in the mixture. Similar tendency can be seen with the moisture content. As figure 5 (b) represents, increasing fine content in the mixture requires significantly more water to set the target permeability (~ 50 JPU), the benefit of the high intensity mixing solution is evident, generally it requires about 1 % less water than the drum.

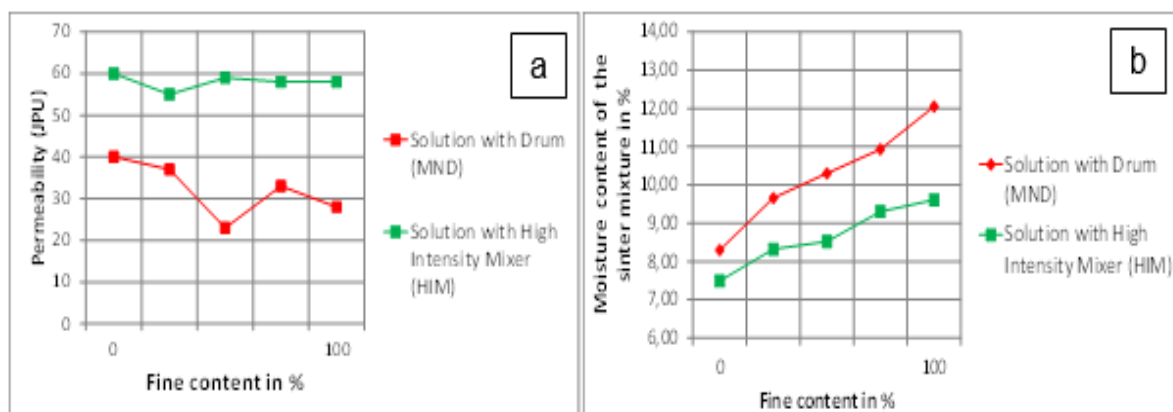


Figure 5. Sinter mix Permeability (a) and moisture content (b) in function of the fine content

The easiest way to evaluate the granulation efficient is to investigate the development of the size fraction before- and after granulation. The most interesting range of size distribution is between 1 -5 mm, where the granulation process –formation of nodules – is the most effective. On this basis the next stage of the investigations was based on the comparison of the two above mentioned solution regarding granulation efficiency. Both, 100 % conventional sinter feed and 100 % fines containing mixtures were processed in a high intensity mixer HIM and in a drum. In the first step the mixing procedure were executed with the same mixing time and water addition ratio, it was followed by the granulation procedure. Small amount of samples were taken before- and after the mixing and granulation stage as well. The samples were dried out and properly screened to be able to see the changes in the mass fractions of the respective size ranges. The Figure 6 represents the results using drum type of mixer and nodulizer. As the dark blue curve shows, the drum type of mixing and nodulizing solution is sufficient in the proceeding of conventional sinter feed. The mass fraction between 1-5 mm had been increased from 18-20 % up to 30-35 % during granulation (see orange line), which shows the strong granulation capability of the drum with conventional sinter feed. On the other hand the proceeding of fines points out different results –see light blue curve. The increase in the mass fraction between 1-5 mm is negligible, however the mass fraction between 5-8 mm –which has less importance in the traditional sintering process – increased drastically. This is because the MND tends to roll pellets of hardly controllable sizes. It can be highlighted as a kind of balling effect of bigger size fractions instead of generating nodules from smaller fractions. As a result, the smaller fractions remain ungranulated in the sinter mix. On the other hand - as discussed in the introduction – this range exactly match to the requirements of micro pelletizing. On this basis, Outotec can also provide sustainable solutions for hybrid sintering, where the fines can be handled with drum type of solutions separate from the normal sinter feed and in a later stage they will be lead and sintered together.

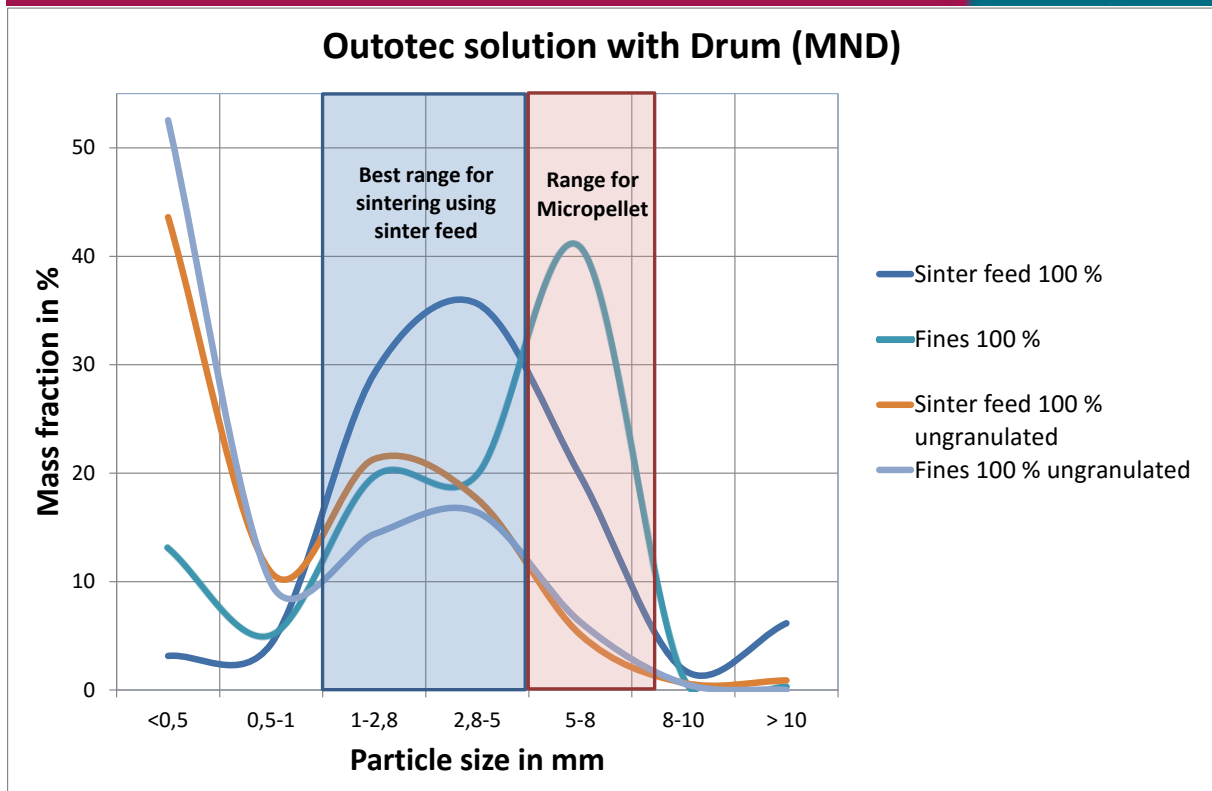


Figure 6. Mass fraction in function of the particle size distribution using drum type of mixing and nodulizing (MND) solution

The similar procedure was executed in the high intensity mixing solution as well. Figure 7 indicates the results of the tests. Similar to the previous figure, the dark blue curve represents the changes in the mass fractions during the granulation procedure using sinter feed. The advantage of HIM is evident. The mass fraction between 1-5 mm had been increased from 18-20 % up to 40 % during granulation, which confirms the excellent efficiency of high intensity mixing using sinter feed. In contrast with the drum type of mixer (MND), the HIM is able to handle the fines and shows positive results in the mass fraction between 1-5 mm, as the light blue line indicates. The increase in the granulation efficiency with fines is significant. The mass fraction increased from 15-18 % up to 25-30 % in the monitored size range of 1-5 mm.

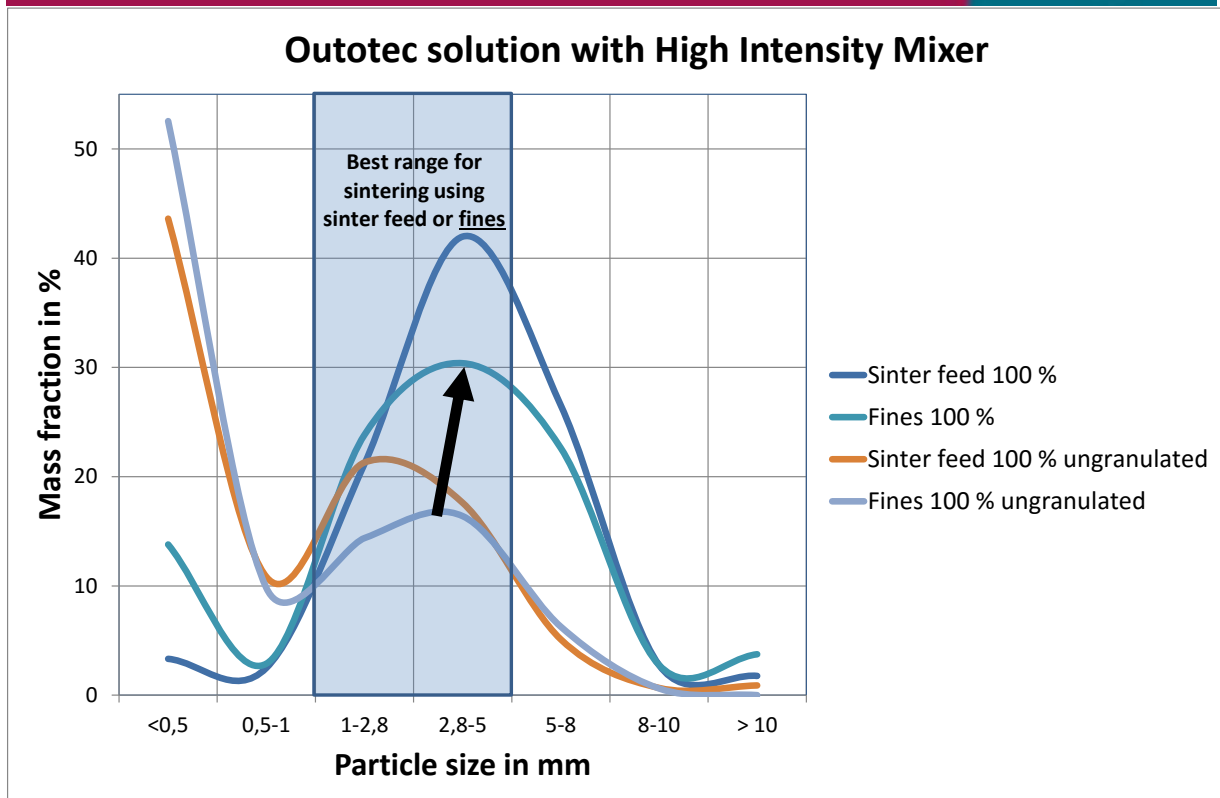


Figure 7. Mass fraction in function of the particle size distribution using high intensity equipments as mixing and nodulizing solution

4. CONCLUSIONS

Outotec can find the tailor made solution for every plant and iron ore blend based on the expertise and facilities available at the Frankfurt Research Center. The increasing amount of fines in the sintering process, the need of improving the mixing and granulation process – traditionally done by mixing and nodulizing drum (MND) - becomes substantial for reliable production. Outotec has introduced (vertical/horizontal) High Intensity Mixers (HIM) for both, the mixing and granulation (nodulizing) process. In this case the following advantages shall be highlighted:

1. HIM solution provides compact layout, up to 30 % in the raw material transport distance can be saved compared to the conventional MND solution;
2. HIM's provides excellent mixing and granulation effect, thus optimum moisture, material distribution and subsequently permeability of the feed mix;
3. The application of the HIM's, fraction of fines (< 150 μm) can be utilized very easily. However the prediction of how much fines can be processed, remains the subject of test works. Generally it can be stated, that the processing of a high amount of fines in a sinter plant is feasible, but to avoid the loss of productivity and the increase of solid fuel consumption (according to the higher moisture content in the mixture) proper agglomeration and sintering tests are necessary;
4. HIM's provides a large process flexibility to the plant operator. By varying the tool speed and retention time of the mixed material inside of the equipment, the mixing as well as the granulation can be optimized according to the used

material and own requirements. Thus it is possible to handle a variety of different raw material in one equipment.

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