EXPERIENCES WITH MODERN DEWATERING TECHNOLOGIES IN FINE IRON ORE APPLICATION[1]

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Abstract
The demand for iron ore has increased dramatically in the last years and is forecast to remain on a stable high production level for years to come. It's expected that the world economy is facing a stable continuous growth of iron ore to 2 billion tonnes and more over the next decades[1)]. Furthermore it is expected that the existing and known high grade ore resources will decline, and the iron ore industry will be forced to implement more and more advanced beneficiation plants. As a consequence of the more complex benefication requirements, there will be a need for modern solutions for iron ore dewatering that are reliable mechanically as well as cost effective and with high capacity per unit at the same time. Conventional vacuum filtration methods have been the most prevalent in fine iron ore dewatering. Product quality needs, lower ore grades, complex mineralogy and energy costs have resulted in iron ore producers seeking better solutions for dewatering, in particular pelletizing feed. New advanced filtration methods have been introduced to the market. This paper describes, how these modern methods are answering the needs of the industry. Performance of advanced dewatering technologies (pressure filtration and ceramic capillary action filtration) for iron ore applications have been studied, and the findings are based on both industrial and pilot scale experiences on different materials. For example, the results show that the cake moisture content of iron ore pelletizing feed can be optimised more effectively by using modern filtration technologies. By selecting the most suitable and adjustable equipment, the effects of variations of feed material on down stream processes can be minimised and the possibilities of processing more difficult raw materials to high quality pellets are better. The Larox Corporation develops, designs and manufactures industrial filters and is a leading technology company in its field. Larox is a full service solution provider in filtration for separating solids from liquids. As such, this paper compares the new developments in this market area with the prevailing known vacuum filtration technology, but focuses on a comparison between capillary action filters and rotary vacuum disc filters (RVDF). The trade name Ceramec® is used to differentiate the Larox filter from the generic term.
Key words: Iron ore processing; Dewatering.

EXPERIÊNCIAS COM MODERNAS TECNOLOGIAS DE SECAGEM PARA APLICAÇÃO EM FINOS GRÃOS DE MINÉRIO DE FERRO

Resumo
A demanda por minério de ferro cresceu drasticamente nos últimos anos e a previsão é de que continue em alta no futuro próximo. A expectativa é de que a economia mundial mantenha o crescimento constante da produção de minério de ferro em 2 bilhões de toneladas ou mais para as próximas décadas[1]. Além disso, é esperado que as fontes existentes e já conhecidas de minério de alto teor diminuam e se esgotem, e que a indústria de minério de ferro será forçada a implementar técnicas cada vez mais avançadas de beneficiamento. Como consequência, há a necessidade de soluções mais modernas para a desaguamento do minério de ferro que sejam mecanicamente confiáveis e que apresentem simultaneamente custos compatíveis e alta capacidade por unidade. Os métodos de filtragem a vácuo convencionais têm sido predominantes no desaguamento de finos de minério de ferro. A necessidade de qualidade, de atender a mais baixos teores de ferro, mineralogia complexa e baixos custos com energia resultaram na busca, pelos produtores de minério de ferro, por melhores soluções de desaguamento, particularmente para o "pellet feed". Novos métodos de filtração foram introduzidos no mercado. Este trabalho descreve como estes métodos modernos respondem às necessidades da indústria. O desempenho dos processos avançados de desaguamento (filtração por pressão e filtração por cerâmica de ação capilar) para as aplicações em minério de ferro foram estudadas, e os resultados obtidos a partir de experiências piloto e industriais com diferentes materiais. Por exemplo, os resultados mostram que a umidade final na torta de "pellet feed" pode ser controlada de forma mais efetiva se usadas as tecnologias modernas de filtração. Ao selecionar os equipamentos mais adequados e flexíveis, os efeitos da variação do material alimentado nos processos subsequentes podem ser reduzidos e as possibilidades de processamento de materiais mais complexos em pelotas de alta qualidade são melhores. A Larox Corporation é líder mundial em tecnologia de filtragem desenvolvendo, desenhando e fabricando filtros industriais. A Larox oferece serviços completos e soluções em separação de sólidos e líquidos. Assim sendo, este trabalho compara os novos desenvolvimentos nesta área com as formas já conhecidas de tecnologia em filtração, porém o foco está na comparação entre os filtros cerâmicos de ação capilar e filtros de disco giratórios a vácuo (RVDF). O nome comercial Ceramec é usado para diferenciar o filtro Larox do termo genérico.
Palavras chave: processamento de minério de ferro, desaguamento.

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1 INTRODUCTION

1.1 Iron Ore Properties

Most iron ores mined today comprise the iron oxide minerals hematite, Fe_2O_3 (70% Fe); goethite, FeO(OH), (63% Fe); limonite, a mixture of hydrated iron oxides (up to 60% Fe); and magnetite, Fe_3O_4 (72% Fe).
Most of the world's important iron ore resources occur in iron-rich sedimentary rocks known as banded iron formations (BIFs) that are almost exclusively of Precambrian age (i.e. more than 600 million years old). BIFs occur on all continents. In many instances they are mined as iron ores, but most importantly they are the source rocks for most of the large high-grade concentrations of iron ore currently mined throughout the world.
The steel industry demands high quality (> 60% Fe) ore to decrease their slag production and increase steel quality and overall profit. For different steel making processes, the specification for impurities like SiO_2 varies from 1-5%. Where applicable, sinter feed for blast furnaces is the preferred raw material, the exceptions being North America and Sweden for example where only low grade ore is available and pellets are the choice to feed blast furnace[2)]. Thus, depending on the grade of the mined ore, different processes have to be installed.
In general it can be said that the filterability of fine iron ore depends on:

- Blain Index (particle size distribution)
- Content of ultra fine particles in the feed
- pH value (Zeta potential)
- Mineralogy (magnetite, hematite)
- Content of impurities (e.g. silica, clay etc.)

These characteristics also influence the capacity of available dewatering technology from up to 20 000 kg/m²h for a horizontal vacuum belt filter (HVBF) down to 250 kg/m²h for a pressure filter.

1.2 Pelletizing Feed

Fine iron ore which is used for pelletizing feed demands stable capacity and constant moisture content (the common target is between 8,5 – 9,5 w/w%), as well as low operational costs. The need for this narrow moisture target (+/- 0,2) is to minimize the use of bentonite and lime and to maximize green ball hardness during pellet production, thus keeping the operational costs at a profitable level (Figure 1).

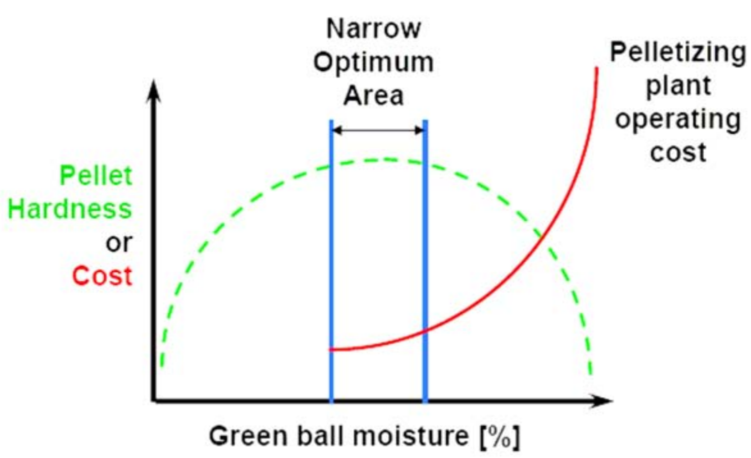

Figure 1: Optimal green ball moisture vs. operational cost and pellet hardness

The presence of fines in the feed for a pelletizing plant has a profound influence on the dewatering of iron ore slurries (i.e., reaching the right moisture content). A study was undertaken to understand "the influence of pH and the addition of model colloidal particles of a known surface charge to an iron oxide mineral slurry, and to investigate how these parameters affect a dead-end filtration process. Ceramic alumina membranes were used in the filtration experiments, and hematite was chosen as a model slurry. Amorphous silica was chosen as"[3)] the impurity. "It was shown that the fraction of small particles plays a decisive role in membrane fouling and pore-blocking mechanisms. Charged particles yielded a dense filtration cake with a high cake specific resistance, while the opposite was found to be true for uncharged particles. Electrostatic attraction between mineral particles and silica particles leads to partial immobilization of small particles, thus improving filtration performances. The capacity of the filter plates was found to be related to the combined medium and cake resistance."[3)] As the zeta potential of the particles differs according to the pH level (Figures 2a and 2b), there is no attraction between iron oxide and silica particles at higher pH level.

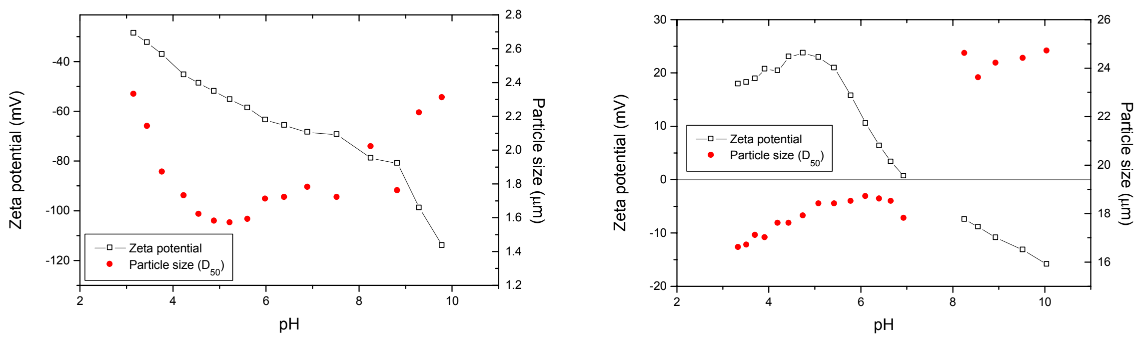

Figure 2a/b: Zeta potential vs. Silica particle size (left) vs. Iron oxide particle size (right)[3)]

Consequently, the silica as the lighter material moves first to the filtration medium and creates a slimy layer which blocks the filter medium pores for filtration, thereby reducing the filtration rate (Figure 3).

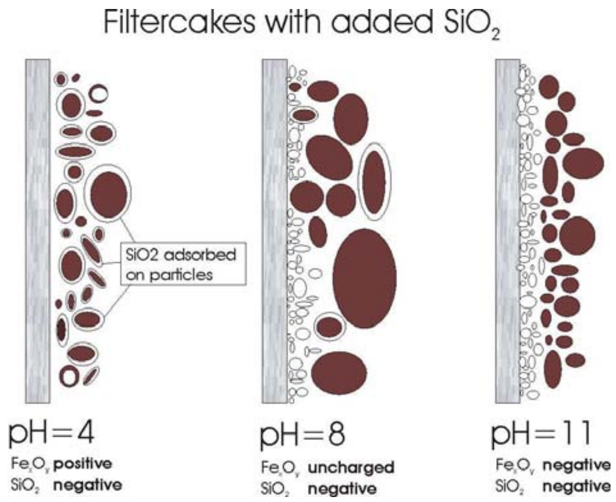

Figure 3: Attraction between iron oxide and silica [3)]

Experiences during tests with other iron oxide slurries have shown that this behaviour has to be studied carefully for different processes, because the rheology may differ from case to case and the optimum pH point may be different as well. Apart from silica, other impurities like clay can influence the ability to dewater iron oxide slurry as well and overcome the influence of pH adjustment. Often the process conditions that optimise benefication are very different from those which optimise filtration.

2 CERAMEC ACTION FILTRATION TECHNOLOGY

Why are the above study results and the Ceramec® equipment exciting? Well, although the technology was introduced into the market in the 80's of last century, it is a recent innovation in the iron ore industry. The development and introduction of capillary action filters with a filtration area of 144m² (Ceramec® CC-144) is a breakthrough. With the better understanding of iron ore dewatering and the mechanism of rheology mentioned above, the performance of this big unit can be optimized for high capacity production.

2.1 Filter Operation Principle

The operating principle of Ceramec® filters is simple as follows (Figure 4):

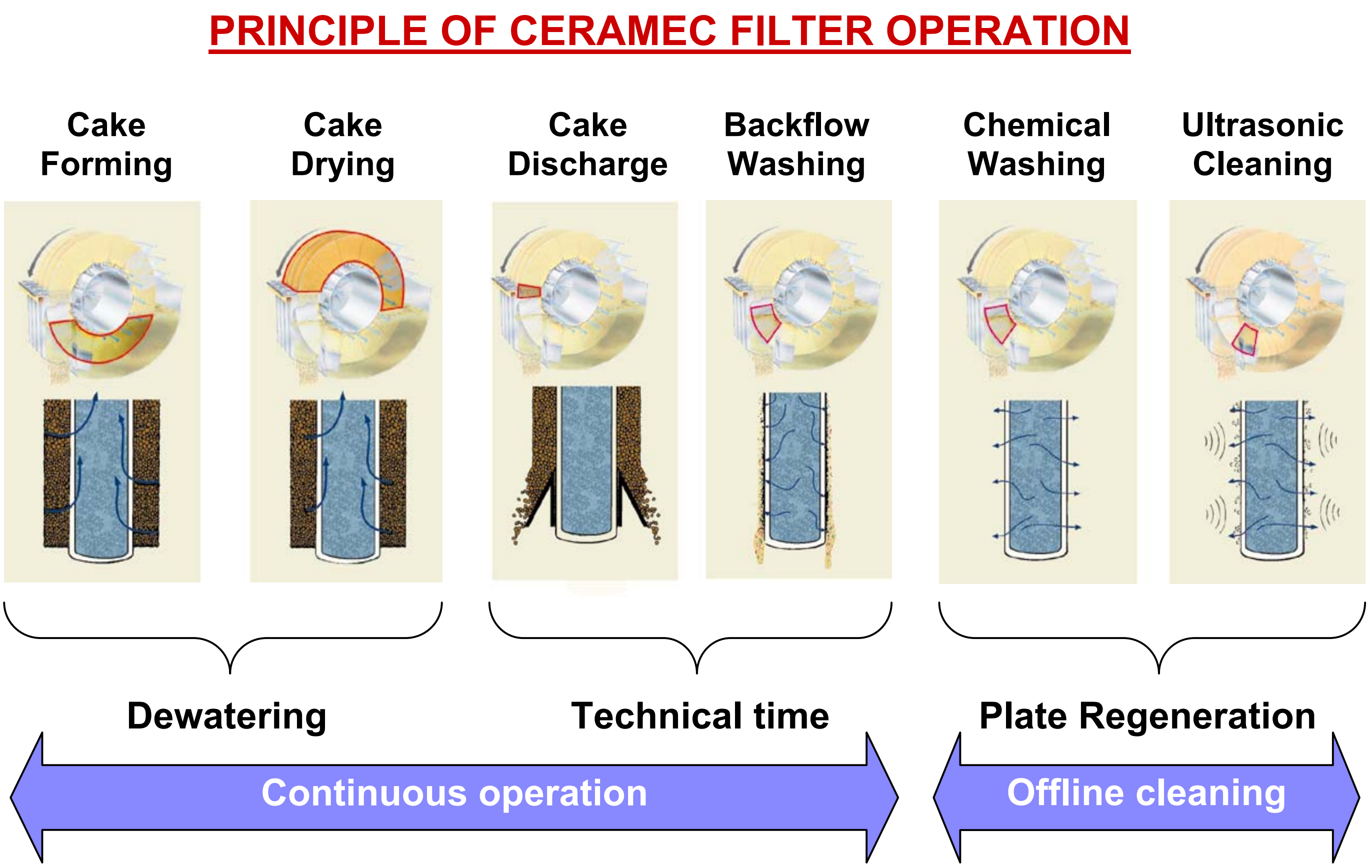

Figure 4: Operational principle of Ceramec® filter

1. Cake Forming

Cake forming takes place on the discs when they rotate through the slurry. Capillary action creates an extremely high vacuum level, which draws liquid through the discs into the filtrate lines. Solids build up rapidly on the external surfaces of the discs, and the micro porous structure prevents any solids from penetrating the disc surface. The filtrate drawn through the sectors is removed by a small (5.5 kW for 144m²) vacuum pump.

2. Cake Drying

As the discs rotate, capillary action continues in an uninterrupted manner across the disc surface until all free liquid is removed from the solids. No air penetrates the disc surface. The result is production of an exceptionally dry cake at a fraction of the energy required by conventional filtration techniques.

3. Cake Discharge

Scrapers remove the cake from the discs. A thin residual cake is left on the surface to protect against mechanical abrasion. This reduces maintenance requirements and extends the life of the discs. Continuous cake discharge is achieved without the need for a snap blow off.

4. Backflow Washing

Filtrate is used to flush the discs after cake discharge. It removes residual cake and cleans the micro porous structure. Backflow washing helps the discs retain their exceptional filtration efficiency and ensures a long, trouble free life. Backflow washing is automatic and adjustable for each application.

5. Disc Regeneration

Instead of discarding the filter media, ceramic plates can be regenerated and the full permeability can be maintained. Periodic cleaning is performed automatically. The cleaning is done with the built-in chemical and ultrasonic systems automatically and without shut down of the filter.

3 CERAMEC® TECHNOLOGY AND ADVANTAGES

3.1 Process

The filtration principle of the Ceramec® capillary action filter starts with simple natural forces (Figure 5). The key idea is simple, and the lack of complex auxiliary systems and equipment means greater savings. The Young-Laplace law (Figure 6) describes the capillary phenomenon and quantifies how pores of a certain diameter cause a capillary effect due to the surface tension and the contact angle of the liquid.

Figure 5: Capillary force

$$\Delta p = \frac{4T \bullet \cos\theta}{D}$$

Fig. 6: Young-Laplace law

where:
Δp = bubble point pressure
T = surface tension
θ = wetting angle
D = pore diameter

With the correct pore size, air is prevented naturally from passing through the ceramic surface, ensuring minimal energy consumption. The vacuum of Ceramec filter is also very effective working at high altitudes, although the differential pressure which is the driving force for the filtration will be reduced accordingly and leads then to a slightly higher moisture in the product.

The bubble point pressure defines the over pressure needed to overcome the capillary force and subsequently drain a capillary. Basically the smaller the pore size, the bigger the bubble point pressure, but the higher the flow resistance.

Ceramec® filters consist of discs equipped with sectors. The basis of this construction is a porous substrate to drain the filtrate. On this substrate is located a thin membrane layer with much finer pores (average pore size is 0.7 µm). Due to the fact that the driving force is the capillary force of the small pores in the layer (membrane) on the ceramic discs, the vacuum pump is only used to drain the sectors, which means a small vacuum pump is needed compared with a RVDF. As the atmospheric pressure is not able to overcome the capillary force inside a Ceramec® sector, concerns about losing the vacuum in this system do not occur. Cake cracking is not an issue for this kind of filter and only marginally affects the filtration capacity.

Returning to the rheology of mineral slurries, tests have shown that the correct rheology for each different application has a huge impact on the filtration capacity. Tests were done on an iron ore flotation concentrate at a pH of 8,5, resulting in a very low filtration capacity using Ceramec® technology (< 100 kg/m²h). Changing the rheology of the material had a very high impact on cake production (Figure 7). By changing to pH 7 using acetic acid, a test filtration capacity between 1800 kgDS/m²h (residual moisture of 7,5 w/w%) and 5400 kgDS/m²h (residual moisture of 11,3 w/w%) could be obtained.

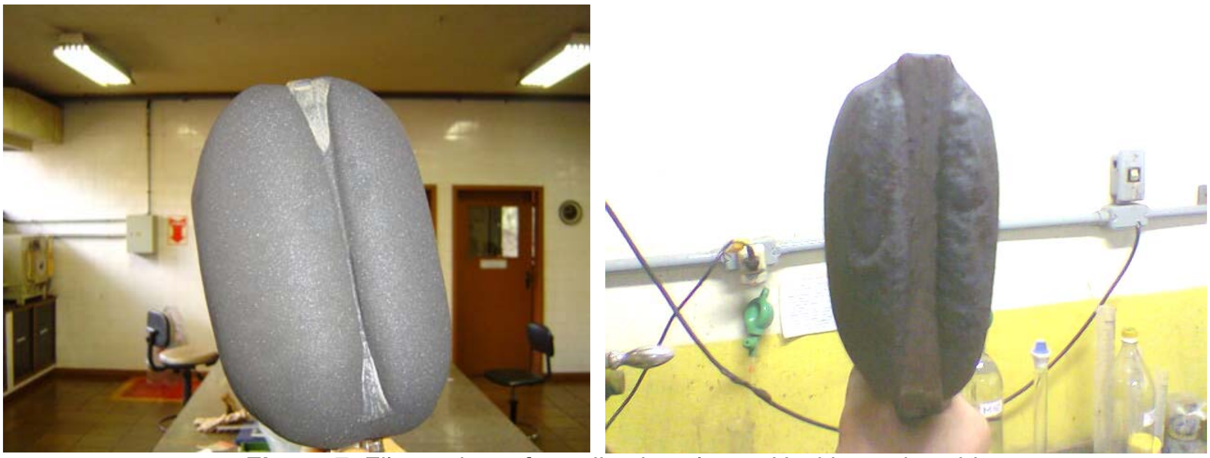

Figure 7: Filter cakes after adjusting slurry pH with acetic acid

Apart from the influence of rheology, the Ceramec® filter produces a crystal clear filtrate compared to the RVDF (Figure 8). The dry solids (DS) content of conventional vacuum disc filter product is typically around 1 – 3 w/w% compared to the Ceramec® filter with an average of 20 mg/l. Hence, plant water recovery using the advanced Ceramec® technology is much higher and water can be easily re-used, e.g. for the cooling circuit of a power plant. Also the losses of fines are reduced due to Ceramec® technology, which would result in fines accumulation in the thickener leading to more difficult thickening and huge tailing dams.

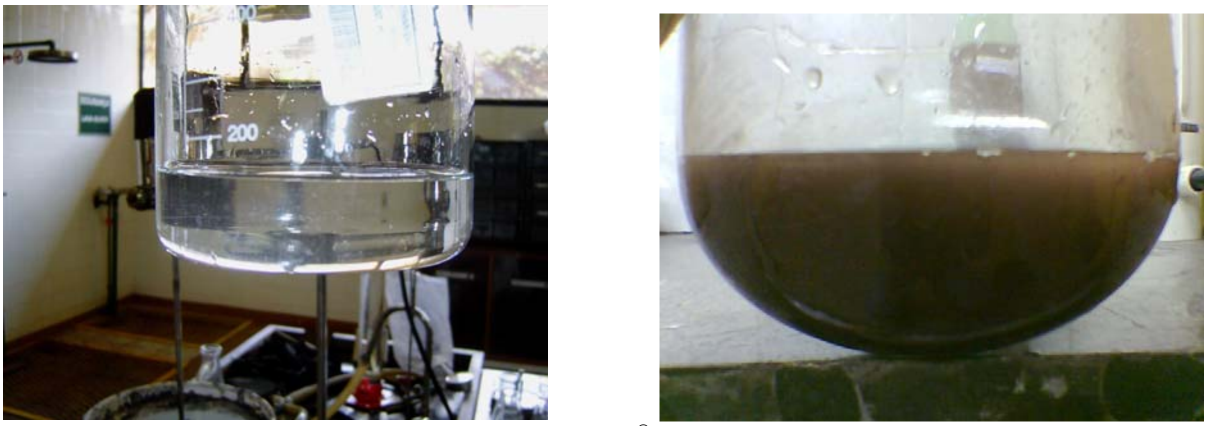

Figure 8: Filtrate clarity - Ceramec® filter (left) and RVDF (right)

3.2 Technical Advantages of the Ceramec® Filter

The Ceramec® filter is delivered as a “plug and produce” filter, which requires only pipe connection, power supply and connection to the plant PLC if necessary. Otherwise all features like the vacuum and filtrate pump, the air separator, the filtrate

tank and the local PLC are mounted on the filter rig. Also all necessary instrumentation and valves are included.
Maintenance for this advanced filter technology is very easy, and, because there are only bolted sectors installed which can be regenerated in place, the sectors have a much longer life time than a single filter cloth. Given an operational time of about 800 - 1000 h per cloth, this results in a long down time for RVDF every second month. Ceramec® filter installations have shown that, with the recommended regeneration cycles, the life time of sectors is more than three years. In iron ore applications it is common practice to regenerate the sectors twice a day. This is done fully automatically and through a completely closed system and needs only approximately one to two hours per day. Compared to RVDF, this means much less down time for the filtration installation, which means higher availability and less maintenance manpower.
Due to the small vacuum pump size, the noise levels at filtration plants utilizing Ceramec® filters are minimal. Besides that, there is minimal need for power sub-stations, as the overall installed motor power for a 144m² filter is only 110kW. In addition, the cabling is much cheaper compared to RVDFs. Compared to the low motor power installation requirements for Ceramec® filters, even a single vacuum pump for a 100m² RVDF requires up to 500kW of installed motor power. The main reason for the high power requirements in iron ore filtration by RVDF is the high porosity of an iron ore cake and the subsequent high vacuum loss that occurs with air passing through the cake and filter cloth, because no capillary effect occurs. Only with huge vacuum pump installations a vacuum of approximately 0,5-0,7 bar can be reached. The situation is even worse when the cake cracks, resulting in loss of vacuum. For Ceramec® filters, no loss of vacuum is possible as no air can come through the filter medium. This also results in better cake moisture reduction using Ceramec® filter technology as shown in Figure 9.

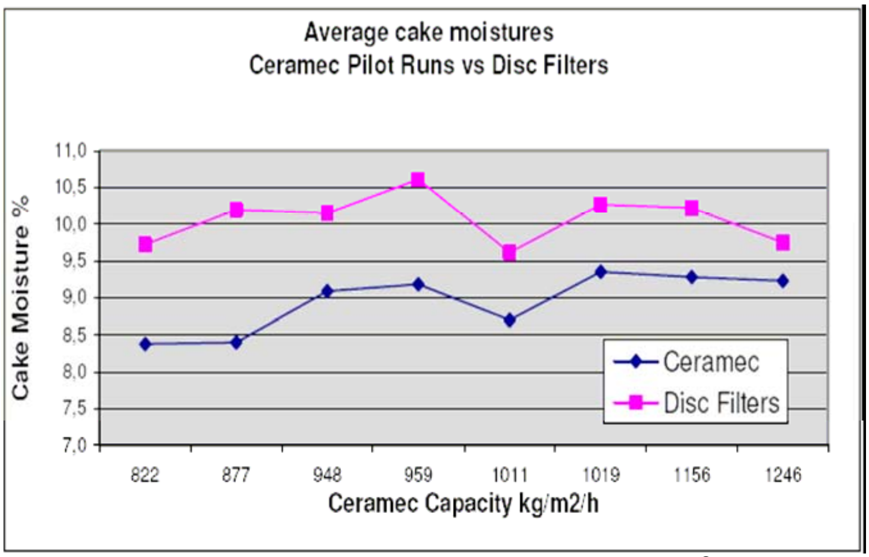

Figure 9: Cake moisture - RVDF vs. Ceramec®

Another high power requirement for RVDFs is for the “snap blow” aspect of their operation. RVDFs use a high intensity back flow of air to discharge the cake. In comparison, the Ceramec® filter uses a scraper discharge for effective and low energy cake remove.

All in all, the installed power for Ceramec® filters is typically about 10% of that for a RVDF installation. This results in much lower CAPEX and OPEX for Ceramec® filters. Looking at OPEX, there is a huge difference considering spare parts, power price per unit, water price, compressed air costs and labour costs for maintenance. Operating cost calculations for comparable filter sizes end up being approximately 8 times lower for the Ceramec® solution. Based on Brasilian water, energy and labour prices, the OPEX for Ceramec® filters is about 0,10 EUR/tonDS, compared to about 0,75 EUR/tonDS for RVDF.

4 SELECTION OF FILTRATION EQUIPMENT FOR IRON ORE FINES

For fine iron ore slurries different filtration technologies can be used. A wide range of vacuum and pressure filtration (PF) equipment is available and well established in the market. Selection of the right technology depends on the slurry properties in addition to CAPEX and OPEX. Based on field experience, the following diagram is helpful for rough selection of the right filtration equipment (Figure 10).
Slurries with a low Blain Index can be easily filtered with conventional vacuum technology. HVBF can be the right choice if high tonnages at a low Blain Index have to be handled and the dewatering is easy. For Blain Indices between 500 and 2500, different dewatering technologies can be used. Roughly three areas can be defined for different Blain Indices. At the lower end is a small range RVDF and a vacuum belt filter can be the right choice to handle the coarse material. In the mid range for low moisture content and low CAPEX and OPEX, the capillary action filter covers a wide range of fine iron ore dewatering tasks. For very fine material and slurries containing high amount of impurities, e.g. clay or similar, the best choice for iron ore dewatering is moving towards pressure filtration equipment. Compared to vacuum equipment, pressure filtration tends to be a batch process rather a continuous process.

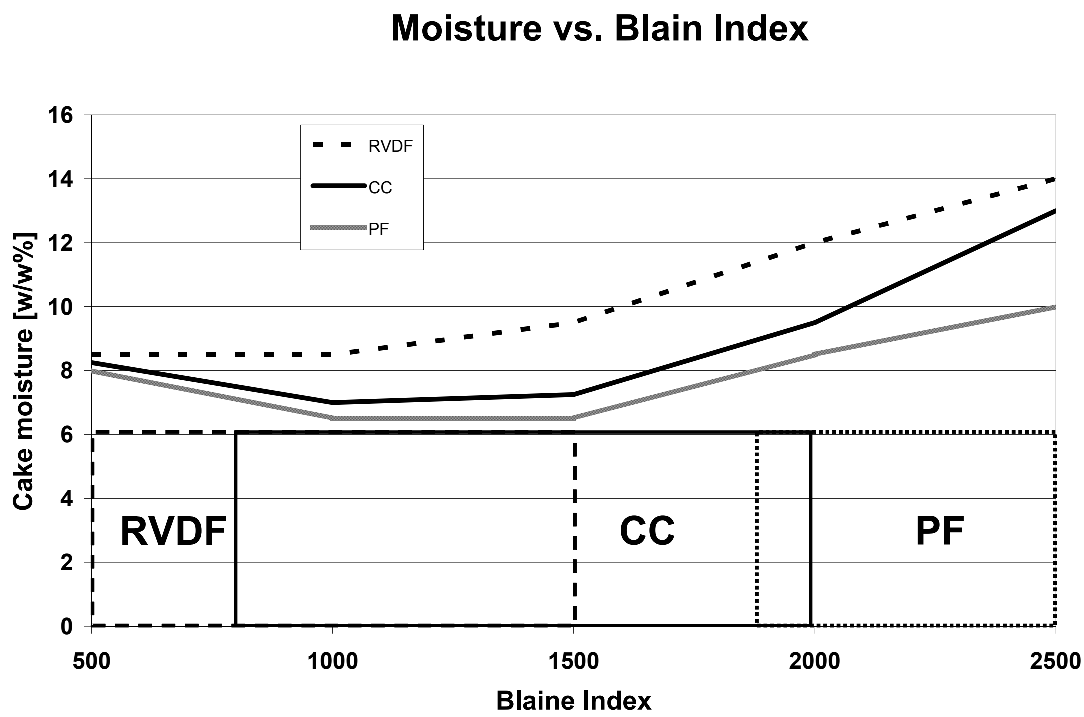

Figure 10: Rough selection of filtration equipment

5 CONCLUSION

The large quantities of low grade iron ore around the world are forcing the iron ore industry to upgrade ore for the steelmaking industry. This requires benefication and there is a tendency towards finer grinding. Thus reliable dewatering solutions are demanded, but at the same time they should require low capital investment as well as low operation cost.

From the CAPEX point of view, the ranking between pressure filtration and vacuum filtration is clearly in the favour of vacuum filtration. Only for finer and highly contaminated products do the product recoveries of pressure filters justify the higher investment costs.

With respect to vacuum filtration technology, a distinction between horizontal and vertical vacuum filtration equipment can be made. Vacuum belt filters like RB-SV should be considered for heavy material in the coarser grinding range.

In the wide range between heavy coarse and very fine material, use of Ceramec® and RVDF technologies predominate.

In addition to the well known and commonly used vacuum disc filters, a reliable and low operating cost filtration solution with a large filtration area for high capacity and stable product moisture content has been developed and will be steadily improved according to process demands. This filter is called the Ceramec® capillary action filter, which guarantees stable capacity and good moisture results with low capital investment and operation costs and easy maintenance and monitoring.

The Ceramec® filter also has other remarkable advantages, because it is a plug and produce solution including features such as a small installed vacuum pump, easy online monitoring and continuous steady product characteristics. The automation features of this technology allow completely independent cake forming and drying control. The low vacuum pump requirements reduce the investment costs, because all the required features are mounted on the filter rig itself and no additional cabling work and transformers are needed.

The effective and reliable construction enables easy maintenance and provides the lowest operating costs, because no cloth changing is needed and the ceramic plates last for years.

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