Two percent points less moisture with XL-type high-performance vacuum disc filters

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Abstract. Coal producers around the world are striving to improve profitability, minimize impact on environment and reduce carbon footprint by reducing the energy demand. A crucial component for this is the availability of cost- and energy-efficient filtration technology. Beside filter presses, high-performance vacuum disc filters are state-of-the-art technology in the dewatering of fine coal concentrates achieving a moisture content in the range of 20 to 30% (ar). The design of the high-performance vacuum disc filters has already pushed the limits by reducing internal losses in the filter system to a minimum and by increasing rotational speed to a maximum. This results in highest productivity with a given amount of energy. Now, the XL generation of high-performance vacuum disc filters is focusing on moisture reduction. Therefore, the filtration area is doubled, which leads to a moisture reduction of 2–3% w/w, while the footprint is only 10% higher. And this can put vacuum disc filters back into projects where pressure filtration has been considered. High-performance vacuum disc filters are simple to operate, have higher reliability, lower down time and significantly lower CAPEX. And in particular the far lower CAPEX can make the difference of a project going ahead or not.

1 Introduction

Coal producers around the world are striving to increase the efficiency of their plants through improved processing methods. The focus here is on improving profitability, minimizing impact on environment and reducing the carbon footprint by reducing the energy demand. A crucial component for these targets is the availability of cost- and energy-efficient filtration technology.

Beside filter presses, high-performance vacuum disc filters are state-of-the-art technology in the dewatering of fine coal concentrates achieving a moisture content in the range of 20–30% (ar). They have the lowest energy requirements when residual moisture in the range of 21–30% is sufficient. However, there is an increasing requirement for lower moisture. The design of the high-performance vacuum disc filters (HPDF) has already pushed the limits by reducing internal losses in the filter system to a minimum and by increasing rotational speed to a maximum. This results in the highest productivity with a given amount of energy.

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2 High-performance vacuum disc filters

About 20 years ago high-performance vacuum disc filters as shown in Fig. 1. have made their way into CPPs (Coal Preparation Plants). These filters are designed for maximum solids throughput and run with slurry levels of up to 50% as shown in Fig. 2. This means that half of the filtration area is used for cake formation and the other half for cake drying.

Fig. 1. BOKELA high-performance vacuum disc filter BoVac Disc L176.

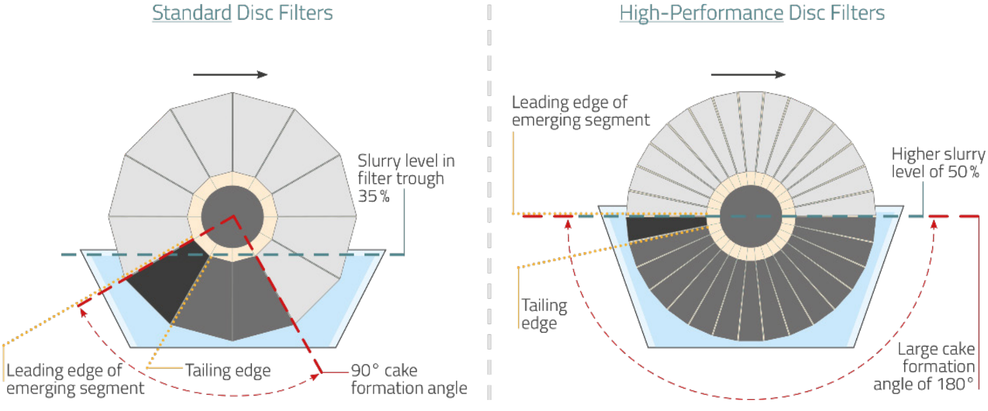
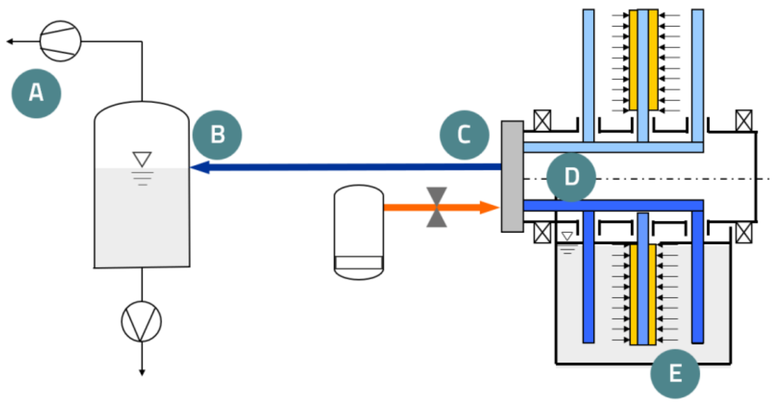


Fig. 2. Slurry level and cake formation angle for standard disc filter and high-performance disc filter.

Furthermore, high-performance vacuum disc filters [1] are designed to minimize pressure losses by using

- trapezoidal filtrate pipes;
- pre-separation control heads;
- high perforated filter segments; and
- online cloth wash

Standard vacuum disc filters have significant pressure losses especially in coal concentrate applications. In these applications there are high filtrate flows in combination with high air flows. Due to the significant pressure losses of the standard disc filters, the -80 kPa pressure difference generated by a standard vacuum pump reduces to a pressure difference of -30 kPa to -50 kPa at the filter cake as Column E in Fig. 3 in line "Standard disc" shows. High-performance vacuum disc filters achieve a pressure difference at the filter cake of -65 kPa to -75 kPa as Column E line "HPDF Tech" in Fig. 3 shows.



Vacuum at	A Vacuum pump	B Receiver inlet	C Control head	D Segment outlet	E Filter cloth
Standard disc	-80 kPA	-70 ... -75 kPA	-55 ... -65 kPA	-45 ... -55 kPA	-30 ... -50 kPA
HPDF Tech	-80 kPa	-78 ... -79 kPa	-74 ... -78 kPa	-70 ... -76 kPa	-65 ... -75 kPa

Fig. 3. Pressure losses on standard disc filters and HPDF.

And this has a major impact on solids throughput as well as on cake moisture. Fig. 4 shows the moisture of a filtered coal concentrate sample at different vacuum levels.

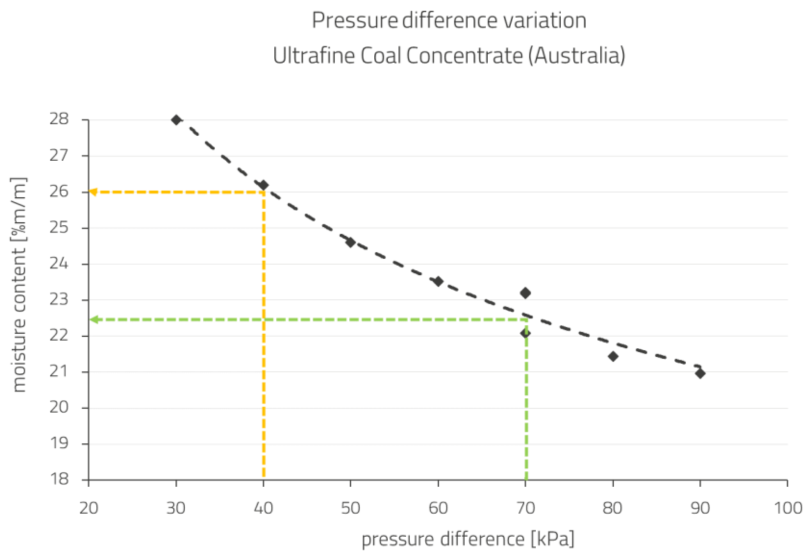


Fig. 4. Moisture of a coal filter cake produced at different vacuum levels.

The standard vacuum disc filter provides a vacuum of about -40 kPa at the filter cake and thus the moisture will be 26% w/w. Due to the reduced pressure losses of the high-performance vacuum disc filters the vacuum at the filter cake is still about -70 kPa and thus the moisture is down to 22.5% w/w. This is 3.5% w/w points less moisture than the standard design disc filters which is the major reason why this filter type is used for ultrafine coal.

But not only the moisture is significantly improved on high-performance vacuum disc filters, also the solids throughput will more than double per 1 m² filtration area. A brief look into the filtration theory will explain why.

$$M_S = m_S \cdot A_f = \rho_S(1-\varepsilon) \cdot \sqrt{\frac{2}{\eta_L r_C}} \cdot \sqrt{\kappa} \cdot \sqrt{\Delta p} \cdot \sqrt{\frac{n}{60}} \cdot \sqrt{\frac{\alpha_1}{360°}} \cdot A_f \cdot 3\,600 \tag{1}$$

The above formula calculates the solids throughput of a rotational filter. The main differences between a standard vacuum disc filter and a high-performance vacuum disc filter are shown in Table 1.

Table 1. Differences between a standard vacuum disc filter and a high-performance disc filter

	Unit	Standard Disc Filter	High-Perf. Disc Filter
Maximum cake formation	[°]	90	150
Pressure difference at the filter cake	[kPa]	40	70
Rotational speed	[rpm]	0.5–1.0	1.0–2.0

The standard disc filter at its maximum rotational speed of about 1 rpm [2] is used as the 100% base line for the specific solid throughput. At higher speed standard disc filters are not able to discharge the cake completely and solids throughput cannot be increased further.

According to filtration theory, the pressure difference at the filter cake, the rotational speed of the filter and the cake formation angle all increase the solids throughput in relation to their square root. If the figures of Table 1 for the high-performance vacuum disc filter design are used, then the maximum solids throughput of the high-performance vacuum disc filter design will be 2.65 times that of the standard vacuum disc filter design as shown in Fig. 5.

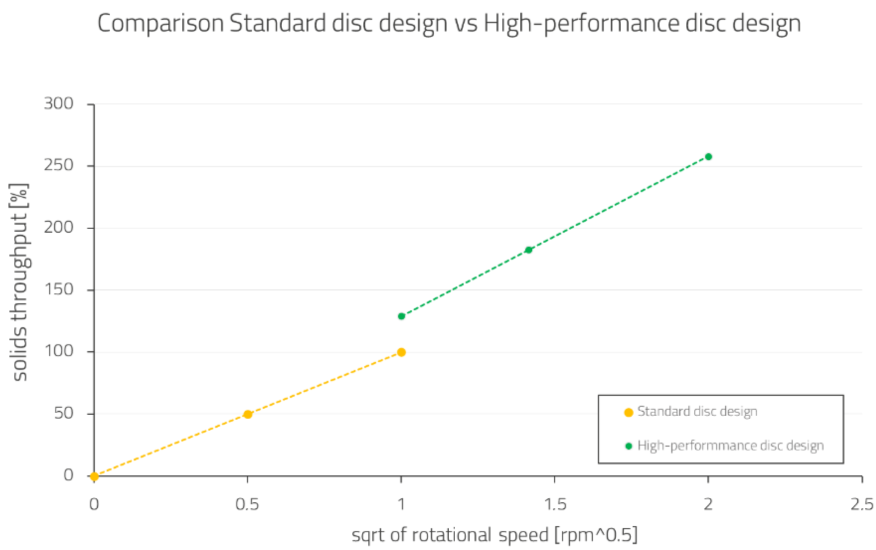


Fig. 5. Specific solids throughput vs square root of rotational speed.

The introduction of the high-performance vacuum disc filters into coal preparation plants was a good combination of getting a high solid throughput per filter and a comparatively low moisture. But nowadays CPPs are struggling with increasing fines rate. And the ultra-fines are the coal component with the highest moisture content. Therefore, CPP operators are looking for filters that provide an ultra-fine coal with less moisture in order to still achieve the required moisture target in the final sales product which is a mix of coarse, fines and ultra-fine coal particles. A reduction of 1–2% w/w moisture in the ultra-fines fraction can already make the difference.

3 Filter selection for ultra-fines filtration in a CPP in Australia

Like many other CPPs in Australia, an operation in the Bowen Basin is splitting the run of mine into a coarse, a fines and an ultra-fine fraction. The ultra-fine fraction at the beginning was not more than 16 % of the total coal. Therefore, the moisture of the ultra-fine fraction had to be <26.5% w/w in order to keep the total moisture <10.5% w/w. And the maximum amount of ultra-fine coal was identified to be 100 t/h. The biggest high-performance disc filter at that time was the BoVac Disc L176 with 176 m² filtration area. Laboratory tests [3] with the ultra-fine coal fraction (flotation concentrate) showed the following result.

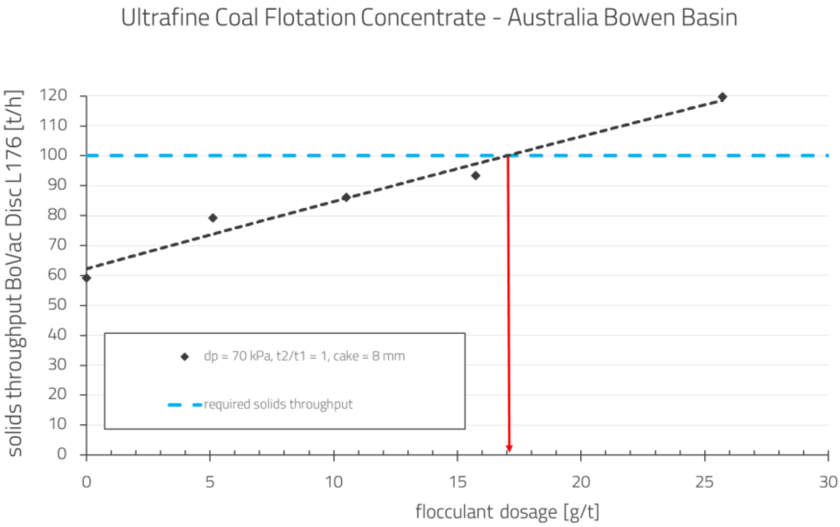


Fig. 6. Solid throughput of a BoVac Disc L176 HPDF vs floc dosage.

The target was to do the 100 t/h with one filter only. Therefore, the maximum area for cake formation as per Fig. 2 was used with 50% of the filtration area submerged in the slurry. The other 50% of the filtration area is used for cake drying. The definition of the dewatering ratio is "angle/time used for cake drying" divided by "angle/time used for cake formation". Each is 50% of the filtration area and accordingly the dewatering ratio is 1. This dewatering ratio of $t_2/ t_1 = 1$ is used in Fig. 6. It shows that the 100 t/h solids throughout can be reached on a single BoVac Disc L176 if at least 17 g/t of flocculant is added to the filter feed. But how about the moisture? This is shown in Fig. 7.

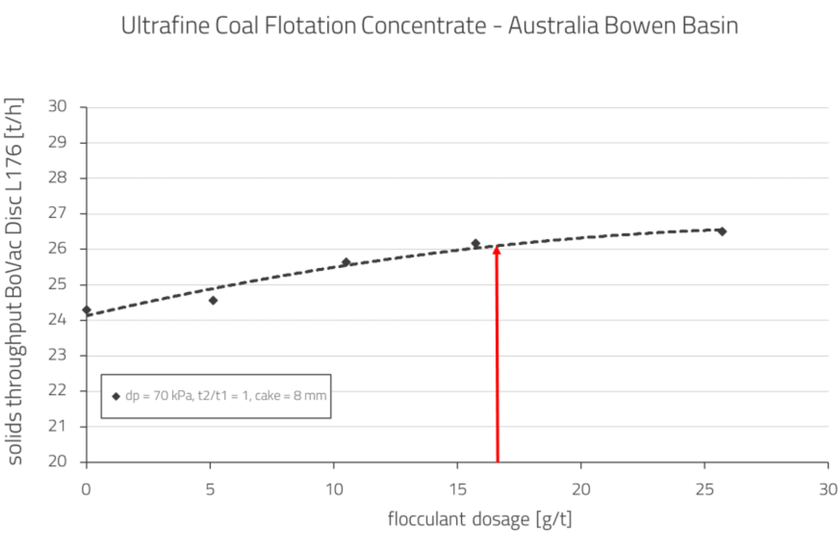


Fig. 7. Moisture of a BoVac Disc L176 HPDF vs floc dosage.

Typically, the moisture increases with increasing amount of flocculant addition. And Fig. 7 confirms that very well. The maximum permitted moisture of 26.5% w/w permits to run the filter with up to 25 g/t flocculant. Therefore, the selection of a BoVac Disc L176 high-performance vacuum disc filter was the right decision.

4 Current situation with more ultra-fines requiring lower moisture

Over the last years the amount of ultra-fines has increased from 100 t/h to 120 t/h in the CPP while the total coal capacity remained at 630 t/h. As a consequence, the total moisture of the combined flows of coarse, fines and ultra-fines has exceeded the 10.5% (ar) moisture limit reaching almost 11% (ar). In order to get back to less than 10.5% (ar) moisture, the new maximum permitted moisture for the ultra-fines is 24% w/w. But the existing BoVac Disc L176 filter is producing a moisture of 26.2% w/w. What can be done?

One option would be to buy and use a pressure filter. Pressure filters would get a moisture of <20% w/w. But the investment cost for this filter type would be high. And there would be more cost for all the ancillaries, the extra new building plus new piping, cabling and electrics.

A second option would be to increase the dewatering time t_2 on the existing vacuum filter. On a rotary type filter this is possible by increasing the dewatering ratio which is the quotient of cake dry time t_2 divided by cake form time t_1 as shown in Fig. 8.

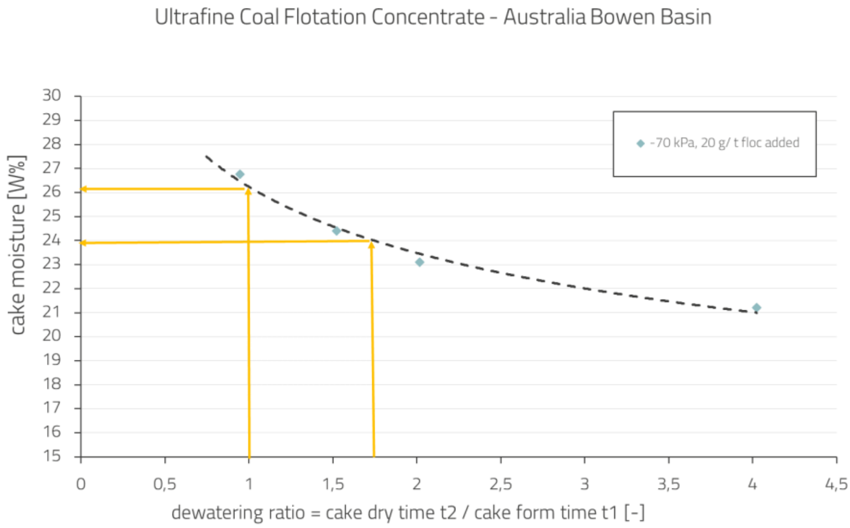


Fig. 8. Moisture of a BoVac Disc L176 HPDF vs dewatering ratio.

If the cake form time is kept constant and the cake dry time is 1.75 times higher, then the moisture reduces from 26.2% w/w down to slightly less than 24.0% w/w. This would exactly fulfill the new moisture requirement of maximum 24% w/w. But what does this mean for the solid throughput?

In order to get the dewatering ratio from 1 to 1.75, the rotational speed has to be reduced to 57% of the previous speed and 43% of the cake formation angle has to be blocked off adding bridge blocks into the control head. This reduces the solids throughput of the existing BoVac Disc L176 filter to 60 t/h as shown in Fig. 9.

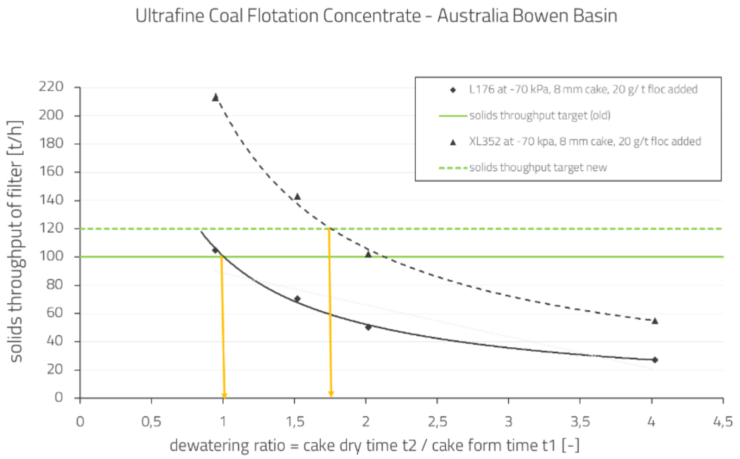


Fig. 9. Solid throughput of a BoVac Disc L176 HPDF vs dewatering ratio.

Now the new maximum permitted moisture of <24% w/w can be reached but the solids throughput of the BoVac Disc L176 filter would drop to 60 t/h. But 120 t/h ultra-fines need to be filtered now. This means that a second BoVac Disc L176 is required now. Besides the filter and its ancillaries, this will further require a building extension with extra piping, cabling and electrics. Is there a less costly option?

5 New XL-series of high-performance vacuum disc filters

The high-performance vacuum disc filters are very successfully used in alumina refineries, where they run with speeds of up to 6 rpm, solid throughputs of up to 1,400 t/h and filtrate capacities of 1,200 m³/h. However, in CPP applications the rotational speed is <2 rpm and the solids throughput <200 t/h. With this reduced capacity, the design of the high-performance filter could be modified for CPP applications. The core parts like the control head and the internal piping were still kept the same. But the disc diameter was increased from 5.6 m to 6.4 m and the number of discs was increased from max. 4 to max. 6. This resulted in a doubling of the filtration area per filter from 176 m² (BoVac Disc L176) to 352 m² (BoVac Disc XL352). The BoVac Disc XL352 is currently the biggest vacuum disc filter on the market and is already successfully running in copper and zinc tailings applications. And the footprint of the XL352 is only slightly bigger compared to the footprint of the L176 as Fig. 10 shows.

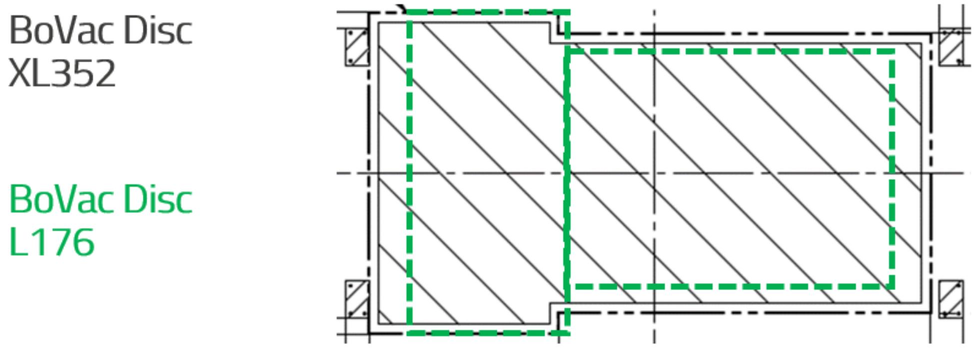


Fig. 10. Footprint of BoVac Disc L176 and BoVac Disc XL352.

Now, instead of buying a second BoVac Disc L176 filter, the CPP can replace the existing BoVac Disc L176 with a BoVac Disc XL352. According to Fig. 8 and Fig. 9, this filter would separate the 120 t/h of ultra-fines at a moisture of slightly less than 24% w/w. It would fulfill the new capacity and moisture requirement. And the replacement can be realized with some minor modifications to the building and the conveyor connection. This is a very cost-efficient solution. Finally, the vacuum air requirement needs to be checked.

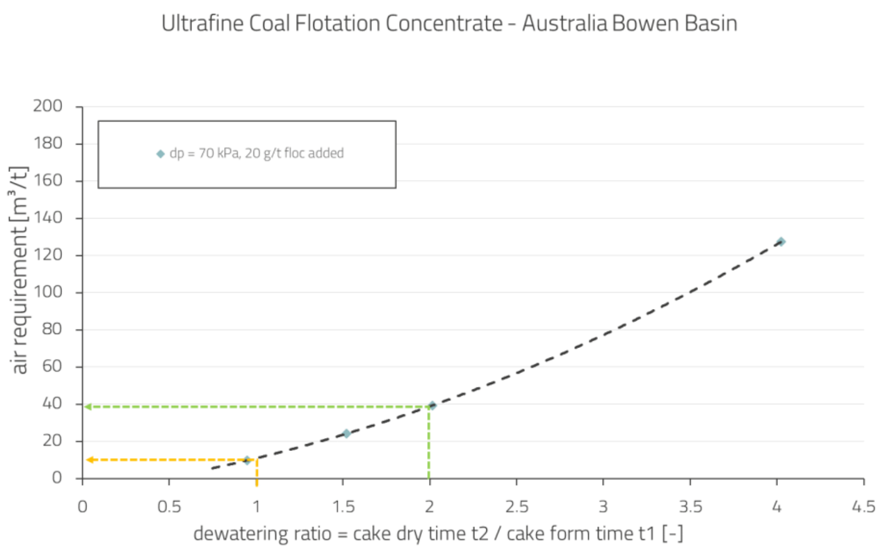


Fig. 11. Vacuum air requirement vs dewatering ratio.

Fig. 11 shows, that the vacuum air requirement increases from 10 m^3/t to 40 m^3/t. This is an increase of the electrical power consumption for the vacuum pump from 0.25 kWh/t to 1.0 kWh/t. Plus another 20 kWh for the extra 20 t/h of ultra-fines. The existing vacuum pump was sized for more than 10,000 m^3/h suction flow and is already big enough for the increased vacuum requirement of 120 t/h x 40 m^3/t = 4,800 m^3/h.

Overall, this is a very cost-effective way of reducing the moisture by 2.2% w/w points. The new filter can be installed within the existing building. This would certainly be the option with the lowest capital investment.

6 Conclusion

The upgrade of the BoVac Disc L176 high-performance vacuum disc filter to the BoVac Disc XL352 high-performance vacuum disc filter offers the opportunity to coal preparations plants to reduce the moisture of their ultra-fine coal fraction by about 2% w/w points or more. CCPs which already operate vacuum disc filters of smaller size can simply replace these vacuum disc filters with the BoVac Disc XL352. This requires more vacuum air capacity, some beam changes in the building and a new hopper to connect to the existing conveyor. A building extension is not required. Piping and cabling remain as well almost unchanged. Therefore, it is a very cost-efficient way of reducing the ultra-fine coal moisture.

References

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