ACHIEVING OPTIMUM FLOCCULATION USING THE FLOMIX HIGH ENERGY IN-LINE MIXER

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Abstract

This paper shares the experience of plant trials using the SNF FloMix high energy in-line mixer to aid flocculation of 'difficult sludge's' at two UK sewage treatment works. It aims to explore the gaps in performance that were identified at each site, and from there how the solution to those performance gaps were proved via plant trials using the SNF FloMix high energy in-line mixer. The payoffs identified are also reported. The paper is intended to give practical advice based on experience of 'making the polymer work' on plant as seen under laboratory conditions.

Keywords

Polymer split dosing, sludge dewatering, high energy in-line mixer, flocculation, FloMix

Introduction

The objective of commissioning/operation of any sludge dewatering process is to achieve performance targets in terms of sludge throughput, cake solids, return liquors, and polymer dosage. Typically, these performance targets will be to produce cake solids as dry as possible, return liquors as low in solids as possible, at the lowest possible polymer dosage.

Experience as a polymer supplier during commissioning/operation of a dewatering process that is not achieving the desired performance targets is that when this happens the polymer is the first variable that is questioned but to give the polymer a chance to work, it must be ensured that it is being applied properly by effectively incorporating it into the feed sludge.

Using the SNF FloMix high energy in-line mixer to aid incorporation of the polymer solution into the feed sludge has allowed significant improvements against performance targets during two full scale plant trials at sewage treatment works in the UK.

High energy in-line mixers are not new technology and there are several other types in the market, so what differentiates the SNF FloMix from the rest? Put simply the SNF FloMix high energy in-line mixer has been developed by a company who first and foremost are the largest manufacturer of polymer in the world, so we know about polymer. We have the technical expertise and know-how to optimise the application of polymer – 'make it work'.

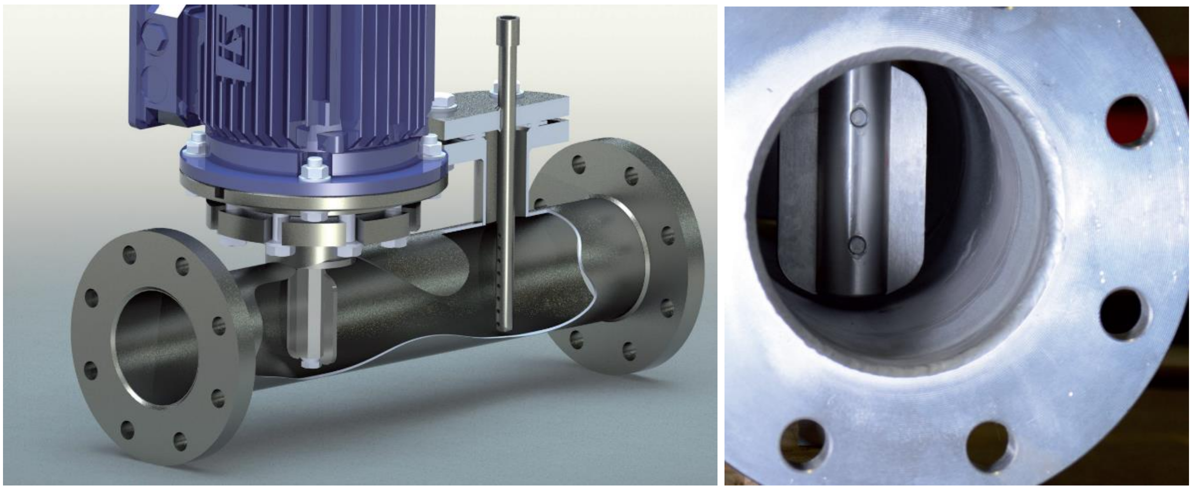

Figure 1: SNF FloMix high energy in-line mixer

Expert knowledge and the application of polymers is essential when preparing to trial a high energy in-line mixer. The significant increase in mixing energy may require a change in the polymer selection. If the polymer selection is not verified as the optimum selection for use in conjunction with a high energy in-line mixer, the trial may be unsuccessful, when actually if the high energy in-line mixer was used in conjunction with the correct polymer grade the trial may show significant performance improvements/benefits.

Through laboratory and plant trials SNF has established that as well as high energy mixing, split dosing of the polymer also can provide performance benefits.

Split polymer dosing

Project background

A sewage treatment works had a Cambi thermal hydrolysis process (THP) plant for processing the sludge produced on site and imports received from satellite sites. The post-THP sludge was dewatered via filter belt press applications, with polymer injected just prior to an adjustable mixing/shear valve via a multi-point injection ring. Coinciding with increasing sludge feed solids from ~5% in 2007 to as high as 8-9% in 2013, the required polymer dosage to achieve the desired cake and filtrate performance targets had increased from ~7kg/tDS to ~12kg/tDS – an approximate 40% increase.

The concentration of the sludge is a parameter that will influence its dewatering ability. The higher the concentration of the sludge, the more difficult it is to mix in a viscous solution of polymer – even at a low polymer solution concentration. Solutions to this problem include: post dilution of the polymer, injecting the polymer further upstream, multiple injection points of the polymer, use of an in-line mixer. At this particular site splitting the polymer dosing to two separate points a significant distance apart was the preferred option in terms of cost and ease of modifying the existing polymer dosing regime.

Laboratory test work

A sample of post-THP sludge feed to the filter belt press application was collected on the 13th September 2013 for the purpose of flocculation and free drainage test work to be carried out under laboratory conditions. The objective of the test work was to investigate whether split polymer dosing could improve the performance of the polymer – ‘make it work’.

Methodology

300ml aliquots of sludge were conditioned with polymer solution in two stages and mixed using the high shear test method at 1000rpm for timed intervals at each stage. The sludge dry solids were measured at 8.90% and the polymer solution was prepared and dosed at a solution strength of 3g/l. The split polymer dosing ratio was adjusted in order to determine the optimum. The polymer dosage used in the test work was 1000ppm or ~11kg/tDS.

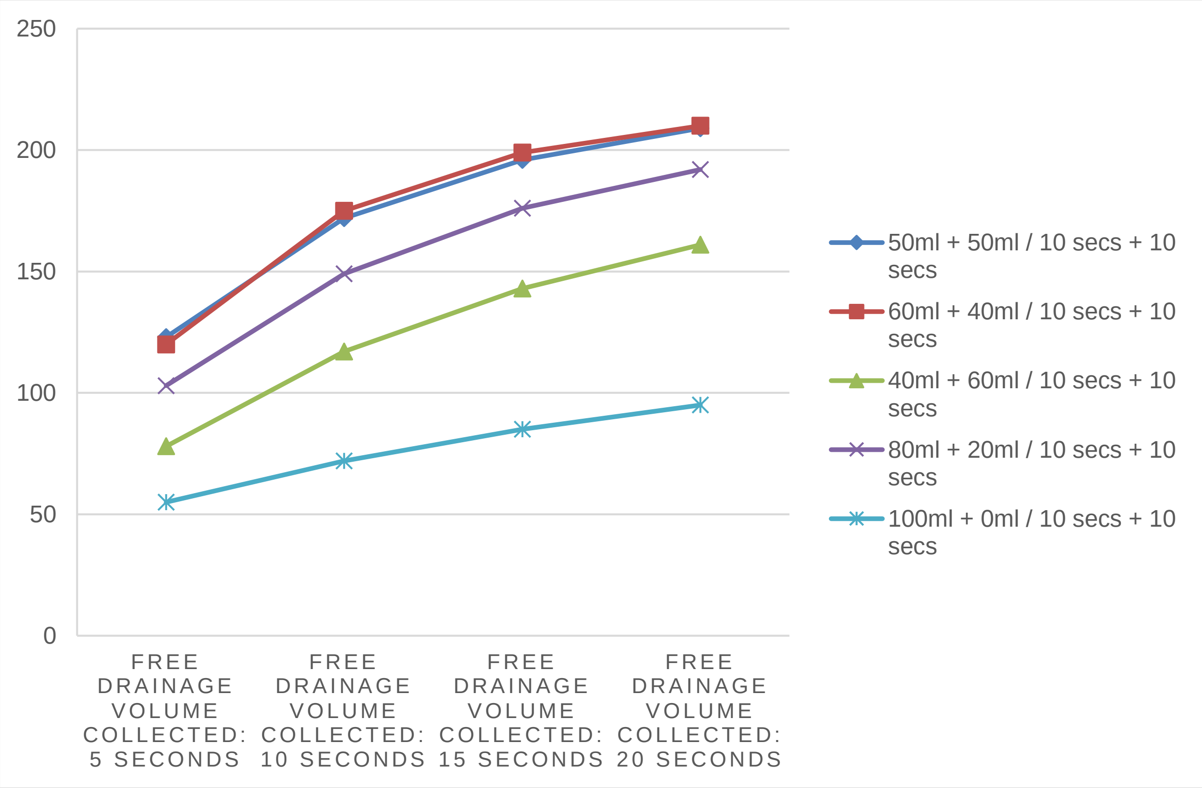

Figure 2: Free drainage results at different split polymer dosing ratios

The results showed that a split polymer dosing ratio of 50:50 to 60:40 provided the optimum free drainage performance under laboratory conditions. The 80:20 split polymer dosing ratio provided improved free drainage performance over the 40:60 split polymer dosing ratio, but solids capture (filtrate quality) was not as good.

Next, additional mixing time following the second addition of polymer was tested under laboratory conditions.

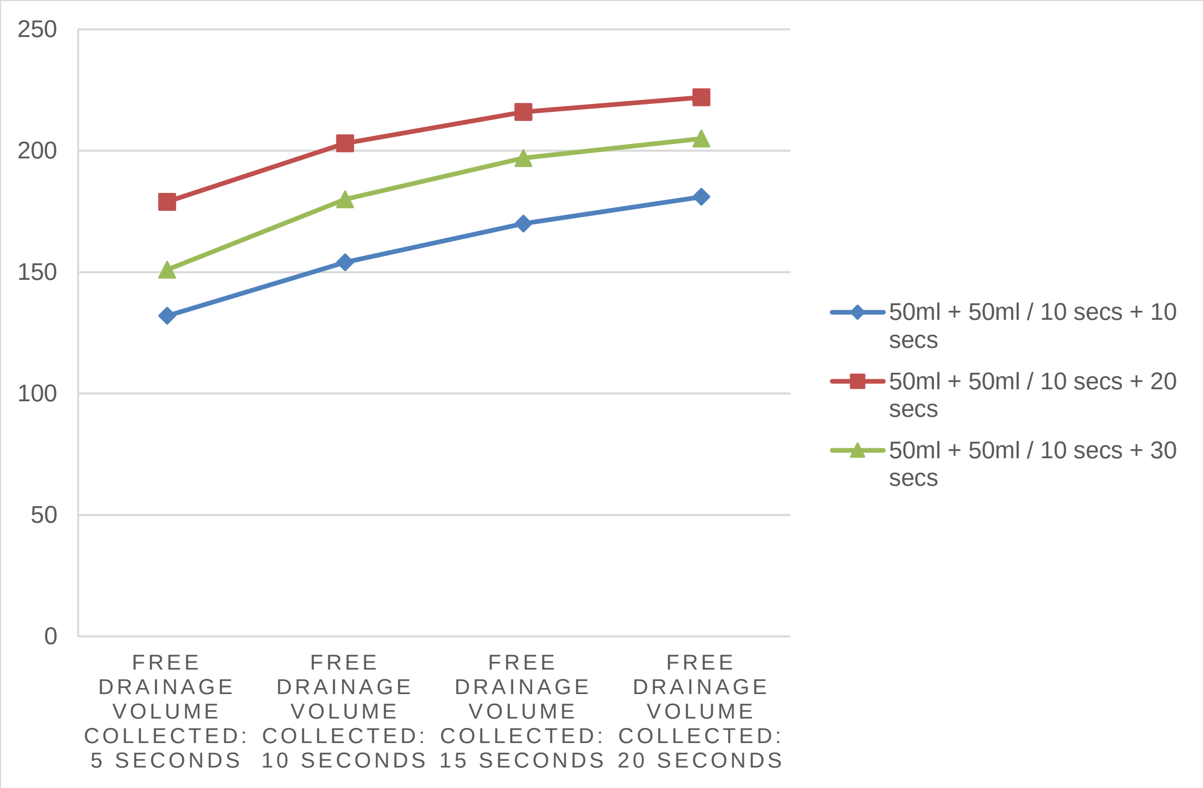

Figure 3: **Free drainage results of split polymer dosing ratios with additional mixing time**

The results showed that increasing the mixing energy further improved the free drainage performance under laboratory conditions. Too much mixing energy did result in a deterioration in free drainage performance, so optimisation of the mixing energy would be essential during plant trials.

Plant trials

The split polymer dosing on plant was applied by utilising a polymer dosing pump that belonged to a filter belt press that was out of service and operated in local control. The initial polymer injection was upstream of the filter belt press sludge feed pump, and the second polymer injection point at the usual position of the mixing/shear valve upstream of the filter belt press.

Table 1: Operating conditions 08/10/2013

Plant Settings Before Optimisation			Plant Settings Following Optimisation	
Sludge flow m3/hr	11.52		Sludge flow m3/hr	11.52
Sludge solids %	8.77		Sludge solids %	8.77
Polymer solution concentration g/l	3.74		Polymer solution concentration g/l	3.74
Polymer dosage kg/tDS	11.03		Polymer dosage kg/tDS	8.22
Split polymer dosage ratio	45:55		Split polymer dosage ratio	60:40
Cake solids	27.2		Cake solids	27.3
Filtrate return solids mg/l	1350		Filtrate return solids mg/l	828
Mixing shear valve setting	Minimum		Mixing shear valve setting	Maximum
			Polymer dosage reduction %	25
			Filtrate return solids reduction %	39

Table 2: Operating conditions 16/10/2013

Plant Settings Before Optimisation			Plant Settings Following Optimisation	
Sludge flow m3/hr	11.52		Sludge flow m3/hr	11.52
Sludge solids %	8.62		Sludge solids %	8.62
Polymer solution concentration g/l	4.41		Polymer solution concentration g/l	4.41
Polymer dosage kg/tDS	12.69		Polymer dosage kg/tDS	6.81
Split polymer dosage ratio	50:50		Split polymer dosage ratio	65:35
Cake solids	29.18		Cake solids	28.41
Filtrate return solids mg/l	636		Filtrate return solids mg/l	430
Mixing shear valve setting	Minimum		Mixing shear valve setting	Maximum
			Polymer dosage reduction %	46
			Filtrate return solids reduction %	32

Initial attempts at optimisation on plant indicated that an increase in the concentration of the polymer solution would allow for more effective alterations to be made to the polymer dosage. The concentration of the polymer solution was increased to 5g/l.

Table 3: Operating conditions 28/10/2013

Plant Settings Before Optimisation	
Sludge flow m3/hr	12.1
Sludge solids %	8.73
Polymer solution concentration g/l	5
Polymer dosage kg/tDS	12.94
Split polymer dosage ratio	85:15
Cake solids	29.37
Filtrate return solids mg/l	1124
Mixing shear valve setting	Maximum

Plant Settings Following Optimisation	
Sludge flow m3/hr	12.1
Sludge solids %	8.73
Polymer solution concentration g/l	5
Polymer dosage kg/tDS	9.01
Split polymer dosage ratio	75:25
Cake solids	27.9
Filtrate return solids mg/l	804
Mixing shear valve setting	Maximum
Polymer dosage reduction %	40
Filtrate return solids reduction %	28

Table 4: Operating conditions 31/10/2013

Plant Settings Before Optimisation	
Sludge flow m3/hr	11.34
Sludge solids %	9.21
Polymer solution concentration g/l	5.25
Polymer dosage kg/tDS	11.23
Split polymer dosage ratio	80:20
Cake solids	25.21
Filtrate return solids mg/l	596
Mixing shear valve setting	Maximum

Plant Settings Following Optimisation	
Sludge flow m3/hr	11.34
Sludge solids %	9.21
Polymer solution concentration g/l	5.25
Polymer dosage kg/tDS	9.04
Split polymer dosage ratio	75:25
Cake solids	29.13
Filtrate return solids mg/l	434
Mixing shear valve setting	Maximum
Polymer dosage reduction %	20
Filtrate return solids reduction %	27
Cake solids increase %	15

Table 5: Operating conditions 03/12/2013

Plant Settings Before Optimisation	
Sludge flow m3/hr	12.31
Sludge solids %	8.44
Polymer solution concentration g/l	5.34
Polymer dosage kg/tDS	18
Split polymer dosage ratio	65:35
Cake solids	26.71
Filtrate return solids mg/l	914
Mixing shear valve setting	Midway

Plant Settings Following Optimisation	
Sludge flow m3/hr	12.31
Sludge solids %	8.44
Polymer solution concentration g/l	5.34
Polymer dosage kg/tDS	11.96
Split polymer dosage ratio	55:45
Cake solids	27.26
Filtrate return solids mg/l	642
Mixing shear valve setting	Maximum
Polymer dosage reduction %	34
Filtrate return solids reduction %	30
Cake solids increase %	2

Summary of results

Polymer overdosing was occurring due to a lack of mixing between the feed sludge and the polymer solution.

Increasing the mixing energy by setting the mixing/shear valve to provide maximum shear significantly improved free drainage performance on the gravity zone/top belt of the belt press, which allowed the polymer flow/dosage to the secondary injection point to be reduced.

When the split polymer dosing ratio and mixing energy were optimised the results of the plant trials suggest that on average a 33% reduction in dosage/polymer costs was achieved, and a 31% reduction in solids returned to the STW for retreatment.

Discussion

It may have been possible to further improve the performance of the filter belt press application by using a high energy in-line mixer to apply the polymer to the feed sludge rather than injecting the initial dose of polymer upstream of the sludge feed pump. But with a >30% reduction in polymer dosage achieved using this setup at relative ease and minimal cost the customer was happy not to investigate any further potential improvements via the use of a high energy in-line mixer.

What we found out about post-THP sludge – mixing is critical! Post-THP sludge is typically 5-6% DS (and at this particular site can be higher than 9%) and ‘soup like’/viscous, so it is more difficult to mix in a viscous solution of polymer.

When flocculating a post-THP sludge the polymer takes longer to ‘activate’. What is meant by activate is the time taken for the polymer to start working and free water to be released from the polymer conditioned sludge. Increasing the mixing energy speeds up the activation time.

Injecting the initial dosage of polymer further back prior to the sludge feed pump provided increased activation time and increased mixing energy.

Split polymer dosing in conjunction with the SNF FloMix high energy in-line mixer case study 1

Project background

A UK sewage treatment works has a Cambi THP plant where the post-THP sludge is processed by filter belt presses. The polymer was originally injected into the sludge feed pipe-work, some 3-4 meters before the flocculation tank prior to the gravity zone/top belt of the filter belt press. The flocculation tank is fitted with a fixed speed stirrer and provides a residence time of between 3 and 4 minutes depending on throughput.

The post-THP sludge processed is high in dry solids (+5%) and following commissioning it became apparent that there was insufficient energy to provide adequate sludge/polymer mixing via the original polymer injection/mixing arrangement. Some improvements were made when these were upgraded to the multipoint injection ring and mixing/shear valve – as shown below:

Figure 4: Polymer multipoint injection ring and mixing/shear valve on sludge feed pipe work

However, even with this improvement, the polymer dosage remained high at ~16kg/tDS and throughput low at 12-13m3/hr against expectations of 10kg/tDS and throughputs in the region of 18m3/hr.

Further tests both onsite and in the laboratory indicated that further mixing was still required. The site agreed to trial a basic prototype of the FloMix high energy in-line mixer.

Plant trials

The prototype FloMix unit, with a single polymer injection point into the body of the mixer, was installed on one of the filter belt presses into the sludge feed pipe work downstream of the mixing/shear valve. Trials determined that a 50:50 polymer dosage split between the mixing/shear valve and the prototype FloMix unit provided the optimum results.

The additional energy provided by the split polymer dosing ratio and prototype FloMix unit increased the efficiency of the sludge/polymer incorporation allowing the throughput on the filter belt press to be increased by up to 30% - providing a corresponding reduction in polymer dosage of the same amount. The increased throughput, in the long term could provide other cost benefits such a reduced filter belt press run time and wear.

Previous trials both using post-THP sludge from this site and as previously reported in section 2 had determined that residence time (activation time) following polymer addition was also a major factor in obtaining optimum performance, and therefore in light of these results a 'spend to save' proposal was jointly put forward to:

1. Install the commercial release version of the FloMix high energy mixers on all 4 (No.) filter belt presses, including dual polymer split dosing.
2. Increase the size of the flocculation tanks on all 4 (No.) filter belt presses.

The payback period based on polymer usage savings alone was estimated at no more than 18 months.

Permanent solution

The FloMix units have now been installed on all 4 (No.) filter belt presses in the same configuration as the original trial – in between the mixing/shear valve and the flocculation tank - as shown below:

Figure 5: FloMix unit installed on plant between the mixing/shear valve and the flocculation tank

The polymer flow is split at a 50:50 ratio, as determined in the earlier trials using the prototype FloMix unit, between the mixing/shear valve and the FloMix high energy mixer and is controlled by rotameters (the control could be upgraded to be automated if required). There are two polymer addition points at the FloMix high energy mixer – a multipoint injection ring upstream of and a single point into the body of the high energy mixer. The injection points are controlled manually without rotameters.

During the commissioning period it became apparent that for optimum results the process required the split polymer dosing and maximum mixing energy at both the mixing/shear valve and the FloMix high energy mixer, but the fixed speed stirrer in the flocculation tank was proving to be detrimental to performance – breaking down the well-formed flocs as they went onto the gravity zone/top belt of the filter belt press.

The fixed speed stirrer in the flocculation tank was disabled resulting in results of –

1. Sludge throughputs in excess of 18m3/hr – an increase of 28%
2. Polymer dosage rates of 9-10kg/tDS – a reduction of 25-30%
3. Cake solids consistently above 26%

Split polymer dosing in conjunction with the SNF FloMix high energy in-line mixer case study 2

Project background

A UK sewage treatment works uses powder polymer to aid dewatering of post-THP sludge via filter belt presses. Originally this application used polymer supplied by a competitor of SNF. The polymer was injected, as is typical for a filter belt press, as a single stage via a multipoint injection ring before a mixing/shear valve a couple of meters upstream of the filter belt press. As performance in terms of cake solids and polymer dosage were nowhere near the targets agreed for handover of the site from the Principal Contractor to the water company, SNF were invited to site to make recommendations to improve performance and trial FloPam (SNF brand name) polymers.

Polymer screening test work carried out under laboratory conditions suggested that an SNF polymer with a different charge density to the incumbent competitor product would provide improved performance. Split polymer dosing was also investigated under laboratory conditions and again suggested that it would improve performance – large robust flocs were able to be produced with greater water release.

On plant it was agreed to trial splitting the polymer dosing using rotameters to allow an initial injection of polymer upstream of the sludge feed pumps, with the rest of the polymer injected at the usual location of the shear/mixing valve upstream of the filter belt press.

Although the split polymer dosing using this set up produced improved results in terms of allowing the polymer dosage to be reduced and cake solids increased, injecting a proportion of the polymer before the sludge flow meter was causing issues with the PLC control of the polymer dosing. The polymer dosage is calculated via solids loading onto the belt using a solids density monitor on the sludge feed line coming out of the sludge buffer tanks to the sludge feed pumps. Adding a flow of polymer into the sludge before the sludge flow meter was resulting in an inaccurate sludge flow being relayed to the PLC by the sludge flow meter.

Therefore, it was decided to move the first polymer injection point downstream of the sludge flow meter. The sludge feed pipe work was modified and another mixing/shear valve was installed approximately 20 meters upstream of the original mixing/shear valve before the filter belt press. The first polymer injection point was downstairs of the press hall and outside of the building.

Again this polymer dosing arrangement allowed a reduction in polymer dosage and increase in cake solids. The negative point of installing another mixing/shear valve was that excessive back pressure was now being exerted on the sludge feed pumps causing the stators to wear out very quickly. With this in mind the customer requested that SNF should evaluate whether the use of the FloMix high energy in-line mixer could provide performance improvements and reduce polymer consumption.

Plant trials

The trial compared the FloMix high energy in-line mixer installed on filter belt press No. 1 against the existing set up of 2 (No.) mixing/shear valves on filter belt press No. 2. The first stage of the trial involved replacing the mixing/shear valve downstairs of the press hall and outside of the building with the FloMix high energy in-line mixer trial skid. It was agreed that the unit would then be moved upstairs into the press hall and used closer to the filter belt press. The trial was conducted over the period of 16th February to 10th march 2016. Optimisation of the filter belt press and the FloMix high energy in-line mixer was carried out by SNF technical specialists, with independent analysis of feed sludge, polymer solution, cake and filtrate carried out by AquaEnviro.

Figure 6: **FloMix high energy in-line mixer trial skid unit installed downstairs and outside of the press hall**

The trial identified that the FloMix high energy in-line mixer was able to provide the following performance improvements –

1. The polymer dosage was reduced by at least 23% on filter belt press No. 1, and over 25% on filter belt press No. 2.
2. Cake solids were maintained between 26-28% (~1%DS higher than the "control" belt)
3. A 50% reduction in filtrate suspended solids

The annual savings in polymer costs alone at this site were estimated at over £130,000.

The optimum performance was achieved when the FloMix high energy in-line mixer was positioned downstairs from the press hall and outside of the building some 20 meters upstream of the original mixing/shear valve before the filter belt press, with the following settings:

> 75% of the polymer dosed at the FloMix high energy in-line mixer and the remaining 25% of the polymer dosed to the existing mixing/shear valve.
>
> The FloMix high energy in-line mixer was operated at maximum speed (50Hz).

Positioning the FloMix high energy in-line mixer trial skid upstairs in the press hall as a replacement for the mixing/shear valve (just upstream of the filter belt press), but still split dosing polymer to the mixing/shear valve downstairs and outside of the press hall, produced poor performance results.

The mixing/shear valve was replaced upstairs in the press hall and the mixing/shear valve downstairs and outside of the press hall was fully opened. Trials with this set up and the addition of 20 meters of temporary pipe work between the FloMix high energy in-line mixer trial skid and the mixing/shear valve close to the filter belt press did not produce the same improvement in performance compared to when the FloMix high energy in-line mixer trial skid was positioned downstairs and outside of the press hall. This particular set up was trialled, as a permanent installation of the FloMix high energy in-line mixers would be considerably more convenient in terms of the installation and future maintenance if they were sited upstairs in the press hall. In order to install the equipment upstairs in the press hall ninety degrees bends from the FloMix high energy in-line mixer trial skid to the temporary pipe work had to be used, which may have altered the flow/shear dynamics.

The FloMix high energy in-line mixer trial skid was repositioned downstairs and outside of the press hall again but this time to serve filter belt press No. 2, and filter belt press No. 1 became the control. Once again it was possible to achieve the optimum results on the filter belt press which had the FloMix high energy in-line mixer trial skid serving it, with a reduction in polymer dosage of between 2 and 3kg/tDS.

At a polymer dosage of 10kg/tDS the performance of the control filter belt press (No. 1) without the FloMix high energy in-line mixer trial skid serving it was unstable. Any slight fluctuation in carrier water pressure or feed solids caused belt flooding and loss of solids out of the sides of the bottom belts onto the floor of the press hall. Under normal unsupervised running conditions, the Site Ops left the polymer dosage set at 11kg/tDS.

Filter belt press No. 2 served by the FloMix high energy in-line mixer trial skid operated smoothly at a polymer dosage of 8kg/tDS. The filtrate quality was again improved when compared with the control filter belt press (No. 1), but the improvement in cake solids produced was not as distinct, possibly suggesting that a difference in belt cloth age maybe contributing to the difference.

Trial results

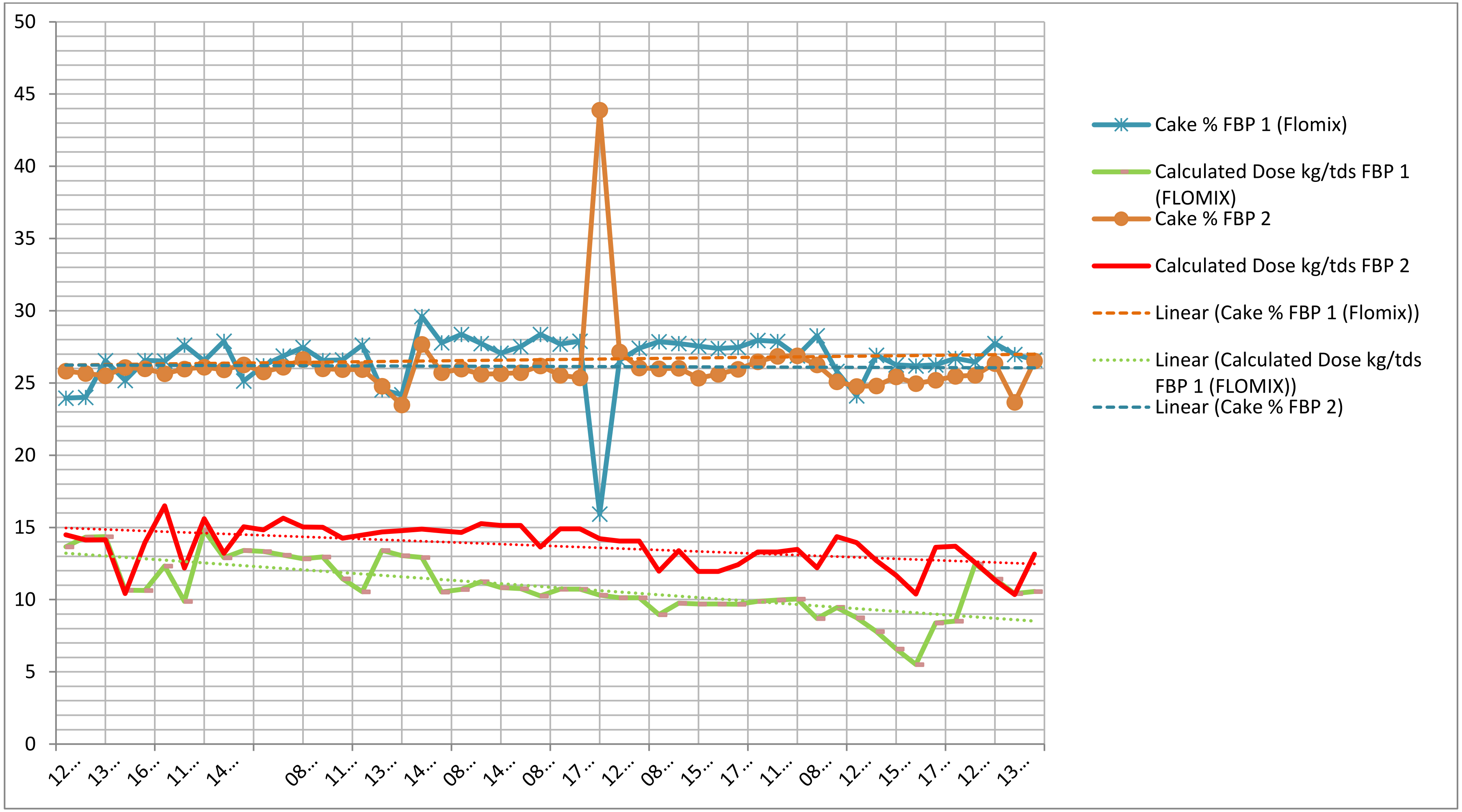

Table 6: **Results of FloMix trial on filter belt press No. 1 **note: there are anomalous cake solids results on 21.2.16 at 08:50am***

Discussion

The reason for the improved performance when the FloMix high energy in-line mixer trial skid was positioned downstairs and outside of the press hall compared to when it was positioned upstairs in the press hall with the same length of pipe work between the two polymer injection points is unclear. In theory the 'activation' time for the polymer was the same. The difference in performance was most likely due to how the temporary pipe work was installed to the FloMix high energy in-line mixer trial skid when it was upstairs in the press hall. Ninety-degree bends had to be used which may have altered the flow/shear dynamics compared to the swept bends on the permanent pipe work when the unit was installed downstairs and outside of the press hall.

As discussed earlier in this report in case study No. 1 – at a similar UK sewage treatment works with the same sludge treatment process, post-THP sludge dewatered via filter belt presses, the mixing/shear valve is prior to the FloMix high energy in-line mixer, and both are positioned within a few meters of the filter belt press. This set up is providing improved performance.

The post-THP sludge at the UK sewage treatment works described in case study No. 2 contains a high proportion of SAS from another nearby sewage treatment works. This SAS is from a BNR treatment process and suspected to contain a high level of soluble phosphorus, which is believed to cause a deterioration in dewatering properties – the polymer consumption will increase and the cake dry solids produced will be lower.

Conclusions

Split polymer dosing and the use of the FloMix high energy in-line mixer provides significant performance improvements in terms of polymer dosage, cake solids, and return liquors when used to achieve optimum flocculation for filtration applications dewatering post-THP sludge.

The fact that there seems to be no generic set up for split polymer dosing and the use of a high energy in-line mixer means that working with polymer experts to identify the optimum set up and polymer grade that best suits the individual sludge and/or dewatering process is essential.

Results achieved using the FloMix high energy in-line mixer indicate that de-watering performance improvements on other 'difficult sludge' types such as a high dry solids mixed raw sludge, which can be difficult to effectively incorporate a viscous polymer solution into, or a thickened SAS that is then sent to be dewatered may be achievable.

Another potential use for the FloMix high energy in-line mixer is to replace the traditional mixing/shear valves on dewatering applications that require them to be set at maximum shear to achieve the optimum results. The back pressure exerted on the sludge and/or polymer dosing pumps from mixing/shear valves can cause pump stators to wear out quickly, which can be costly in terms of spares and process downtime. As the stators wear out the flows delivered by the pumps will also reduce, in turn reducing the throughput capable by the dewatering application potentially causing a backlog of sludge stocks waiting to be dewatered.

SNF would be interested to trial the FloMix high energy in-line mixer on a centrifuge dewatering application to investigate if an increase in mixing energy can improve performance, or if optimum mixing energy is already provided by the centrifuge itself. Ideally this would be on a centrifuge processing post-THP or a high dry solids mixed raw sludge i.e. a sludge that by its nature would be difficult to incorporate polymer solution into. If a trial is of interest to anyone reading this paper, please get in touch with the author using the details at the top of the first page.

Finally, in waste water treatment, sludge dewatering represents one of the most expensive stages. The present trend is clearly a reduction in sludge volume by increasing the dry solids content. In line with this trend SNF has developed a wide range of polymers with much higher molecular weight and structure level leading to higher polymer solution viscosity. The use of these polymer types should allow a lower polymer dosage to be achieved, but leads to a much higher demand in mixing energy. Therefore, in order to achieve a reduction in polymer usage by using high molecular weight polymers it must be ensured that they are effectively incorporated into the feed sludge. The FloMix high energy in-line mixer can be used in conjunction with high molecular weight polymers to ensure optimum flocculation is achieved to provide advantages such as reduction in polymer dosage, higher drainage speed leading to a higher dry solids output, and improved filtrate quality providing lower return suspended solids back to the sewage treatment works.

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