

3.1. Introduction

The centrifuge tests were conducted on fine coal sample slurries to determine the performance of the novel dewatering aids on a different dewatering system. The centrifuges are high capacity equipment and they are widely used for classifying, clarifying and dewatering purposes. A separating force many times stronger than that of gravity can be provided in terms of a centrifuge. The centrifuge action, therefore, applies a large force onto the solid particles, which help solid liquid separation. These high forces usually tend to create maintenance problems. In spite of this, centrifugation is widely used in the dewatering industry since it is a continuous and fast operation and the centrifuges occupy a very small space compared to many industrial filters.

The centrifugation tests were conducted at Bird Machine Company using the lab-scale centrifuge units. The solid bowl and screen bowl centrifugation systems were tried on three different types of fine coal slurry samples in the absence and the presence of the novel dewatering aids. In addition to the centrifuge tests, vacuum filtration experiments were also performed on the same coal slurries to be able to compare the efficiency of these two methods on fine coal dewatering. It was observed that the presence of the dewatering aid helped to decrease the moisture content of the centrifuged cakes compared to the base tests conducted in the absence of any dewatering aids. The improvement in the dewatering efficiency of the centrifuges with the use of the novel dewatering aids developed at Virginia Tech was quite significant and the moisture contents of very thick cakes decreased satisfactorily. The results of the centrifuge experiments obtained at the Bird Machine Company's laboratories will be presented in this chapter and a brief comparison between the centrifugation and vacuum filtration techniques will be provided according to the results of the conducted tests.

3.2. Experimental Methods and Materials

Three different coal samples were used to conduct the centrifugation tests. All of the samples were flotation products from the operating coal preparation plants. They were all received in the form of slurry. The coal samples used for the analyses are listed below:

1. 28 mesh x 0 Pittsburgh No.8 coal, Feed to Disc Filters, from CONSOL Inc., U.S.A. (18.60% ash)
2. 100 mesh x 0 Pond Fines cleaned by flotation, Middle Fork Coal Preparation Plant, Pittston Coal Management Company, Virginia, U.S.A. (10.66% ash)
3. 28 mesh x 0 flotation product, Holston Coal Preparation Plant, Pittston Coal Management Company, Virginia, U.S.A. (9.3% ash)

Figure 3.1 shows the lab-scale solid bowl centrifuge, which is used to simulate the industrial scale solid bowl centrifugation operation in the laboratory conditions. There are four cylindrical units rotating around a vertical axis in the horizontal position in the equipment. One of the cylinders is used as the reference. There is a screen at the bottom of each cylinder unit and a filter cloth is placed on top of this screen to help the cake formation. The coal sample is thickened before feeding into the system, because the lab-scale centrifuge unit does not apply the thickening action itself. The solid density of the coal slurry is increased to 60-65% at the end of



Figure 3.1. Lab-scale solid bowl centrifuge unit.

thickening and then it is weighed and fed into the cylindrical units. The amount of the sample determines the thickness of the coal cake. The spin time and the G-force of the centrifuge are set to complete the centrifugation operation.

Figure 3.2 illustrates the lab-scale screen bowl centrifuge. This equipment was used to conduct the tests representing the screen bowl centrifugation application. It has a single cylindrical screen bowl, rotating around a vertical axis. In order to support the cake formation, a filter cloth fitting to the shape of the bowl is placed before feeding the sample. The coal slurry is pre-thickened as in the solid bowl centrifugation tests. The thickened samples are weighed at pre-determined amounts before placing into the bowl to form the desired cake thickness. The spin time and the centrifugal G force are set and the centrifuge is operated to conduct the experiments.

To determine the performance of the novel dewatering aids developed at Virginia Tech on centrifuge tests, Ethylene Glycol Monooleate (EGMO) and Polymethyl Hydrosiloxane (PMHS) were used as additives for centrifugation. To prepare the slurry for the centrifuge tests that were



Figure 3.2. Lab-scale screen bowl centrifuge.

performed in the presence of the additives, the dewatering aids were added into the slurries at desired dosages, which were contained in 5-gallon buckets. The slurries were conditioned by means of a dynamic mixer for 15 minutes. After the conditioning was completed, the slurry was thickened to increase the percent solid content of the sample and the prepared samples were subjected to centrifugation according to the previously explained procedures. The vacuum filtration tests, which were conducted to compare the effectiveness of the centrifugation and filtration operations on fine coal dewatering, were performed using the same techniques described in Chapter 2.

3.3. Experimental Results and Discussions

The first set of centrifugation tests were conducted on Pittsburgh No.8 coal sample slurry (28 mesh x 0). The sample was a flotation product from CONSOL Co. with 77.38-micrometer mean particle size and 18.60% ash content. This set of experiments was performed using the lab-scale solid bowl centrifuge unit. To compare the response of the coal sample to centrifugation in the presence of the additives, the novel dewatering aid EGMO was selected to be used. The tests were conducted in the absence and the presence of this reagent. To conduct the base experiments, the coal slurry was homogenized by mixing in the 5-gallon bucket it arrived in. Then, this sample was thickened using a large funnel by placing a filter paper in it. The solid content of the sample increased to approximately 60-65% at the end of the thickening operation. This sample was weighed and fed into the cylindrical containers of the centrifuge after placing the filter cloth on top of the screen section properly. The spin times were selected as 5, 15, 30, 60 and 120 seconds. The cake thicknesses were 0.5, 1.7 and 3.2 inches for the base tests. The centrifugal force was set to three different levels: 400G, 1500G and 2500G. In order to conduct the tests in the presence of the dewatering aid, EGMO was added into the slurry at a dosage of 2 Lbs./ton. The sample was contained in a 5-gallon bucket as in the base tests. To let the EGMO adsorb onto the coal surface, the slurry was conditioned by means of a dynamic mixer for 15 minutes. The conditioned sample was thickened and then used for the centrifugation. The cake thicknesses were 0.7, 1.6 and 3 inches for the tests conducted in the presence of the dewatering aid and the spin times were set to 5, 15, 30 and 60 seconds.

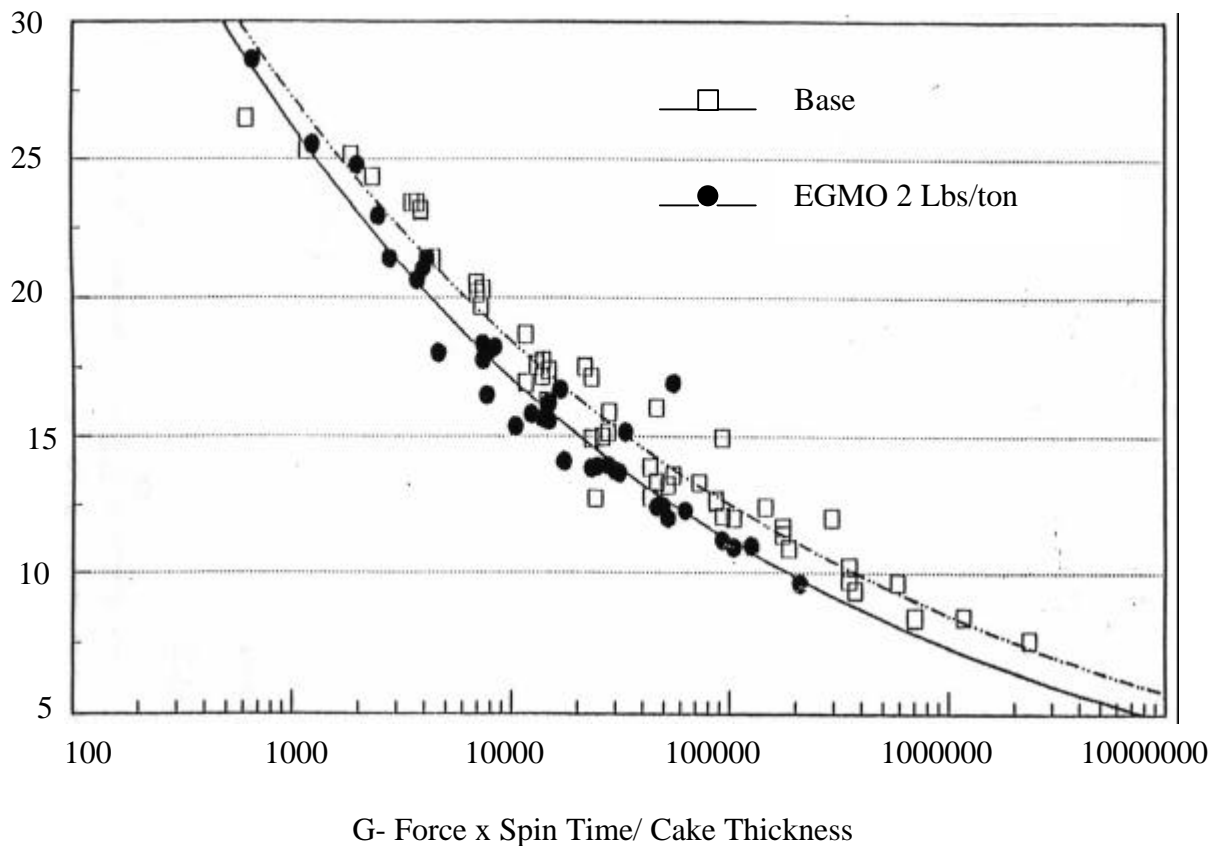


Figure 3.3. Results of the centrifugation tests conducted on Pittsburgh No. 8, (28 mesh x 0) sample slurry. The tests were performed using the lab-scale solid bowl centrifuge in the presence and the absence of the novel dewatering aid, EGMO. Reagent dosage was 2 Lbs./ton and the sample was conditioned by means of a dynamic mixer in a 5-gallon container for 15 minutes.

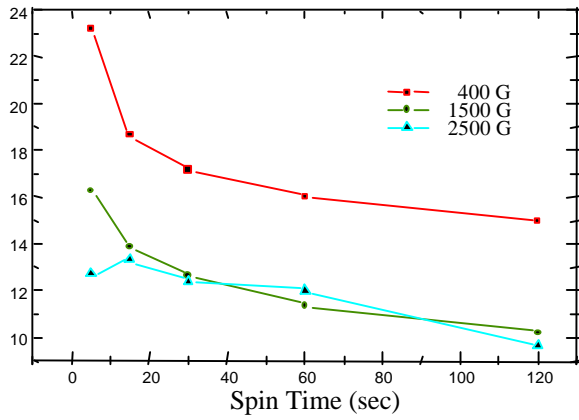
Figure 3.3 shows the experimental results of the tests conducted on the Pittsburgh coal sample using the lab-scale solid bowl centrifuge. The change in the cake moisture content was plotted against to a combined function of the applied G force, spin time and cake thickness as: G-Force (m/sec^2) x Spin Time (sec)/ Cake Thickness (m). According to this comparison, 2% points difference was observed between the results of the base experiments and the results taken with the addition of EGMO at 2 Lbs./ton into the coal slurry. To understand the effect of EGMO addition in increasing the efficiency of dewatering and the effects of the operational factors in centrifugation, the data represented in Figure 3.3 were resolved into separate figures as shown in Figure 3.4. This figure compares the results of the control tests (without EGMO addition) with

the results of the tests conducted by using EGMO at three different cake thicknesses. At each cake thickness, the cake moisture was plotted against the change in the spin time. The cake moisture contents were observed to decrease with the increased spin time and G force for all the tests as expected. For the thin cakes (~0.5 inches), as the G force increased from 400G to 1500G the cake moisture decreased by approximately 4% points for both the control tests and in the presence of the reagent. As the G force further increased to 2500G no more reduction in the cake moisture was observed for the base tests; however the cake moisture values continued to decrease in the presence of EGMO. At the end of the 60 seconds spin time, the cake moisture values were 16.06%, 12.00% and 11.36% for the base tests at 400G, 1500G and 2500G centrifugal force levels, respectively. When EGMO was added, these values reduced down to 15.16%, 10.97% and 9.58% using the same spin time. As the cake thickness was increased to ~1.7 inches, the increase in the G force started to be effective in decreasing the cake moisture even without EGMO addition. The 4% point reduction remained the same between the 400G and 1500G centrifugal force application for both control tests and the tests conducted with the additive. When the centrifugal force increased to 2500G, the cake moisture decreased by 1% point more for the control tests and by 2% points more with EGMO addition. For the ~3 inches thick cakes, the moisture contents of 20.31%, 15.15% and 13.33% were reached after 60 second spin time in the absence of any reagents at 400G, 1500G and 2500G centrifugal forces, respectively. The addition of EGMO decreased these values to 18.44%, 13.73% and 12.44%. As the cake thickness increased, the final moisture content values reached after centrifugation were higher but the effect of the dewatering aid was more significant in reducing the cake moisture. There was a 6% difference between the cake moistures obtained by using 400G and 1500G centrifugal force and 2% points more reduction was observed when the force was further raised to 2500G.

Figure 3.5 shows the superimposed results of the control tests and the tests conducted with EGMO on the Pittsburgh coal sample. At an approximately 0.5 inches cake thickness, there was only 0.5% point reduction at 400G and 1500G centrifugal force levels with the addition of EGMO compared to the base tests results. The difference increased to 2% at 2500G level.

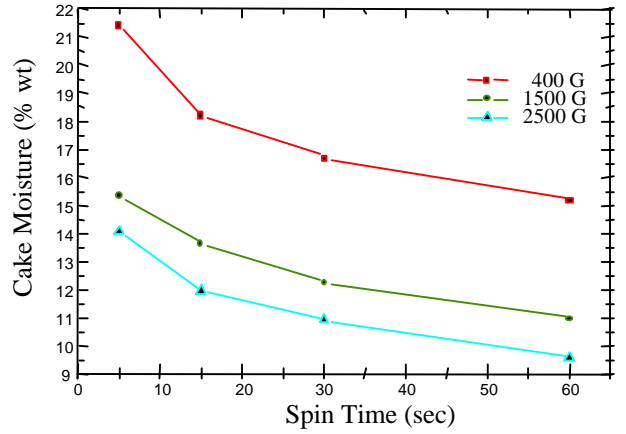
Control

Change in moisture content for 0.5 " cake

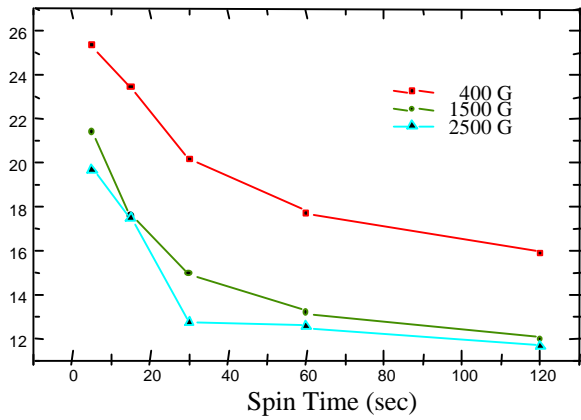


EGMO

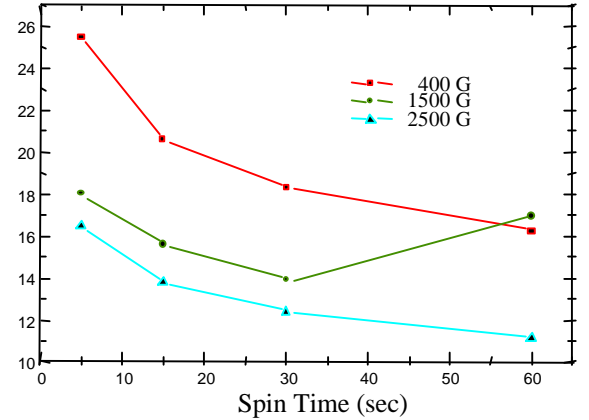
Change in moisture content for 0.7" cake



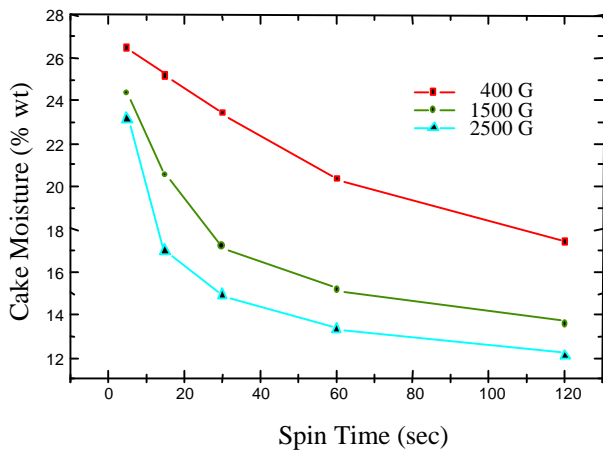
Change in moisture content for 1.7" cake



Change in moisture content for 1.6 " cake



Change in moisture content for 3.2" cake



Change in moisture content for 3.0" cake

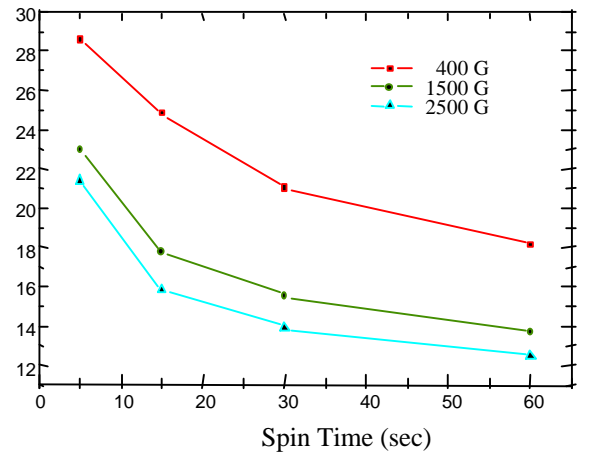


Figure 3.4. Resolution of the centrifuge tests results on Pittsburgh coal sample.

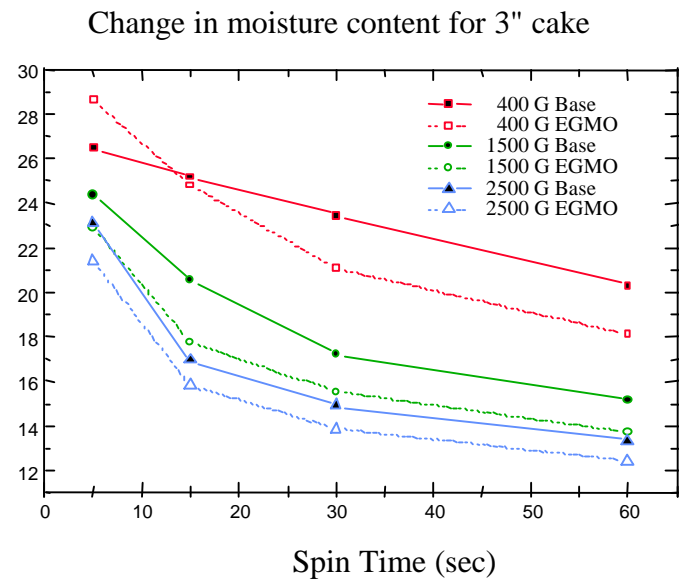
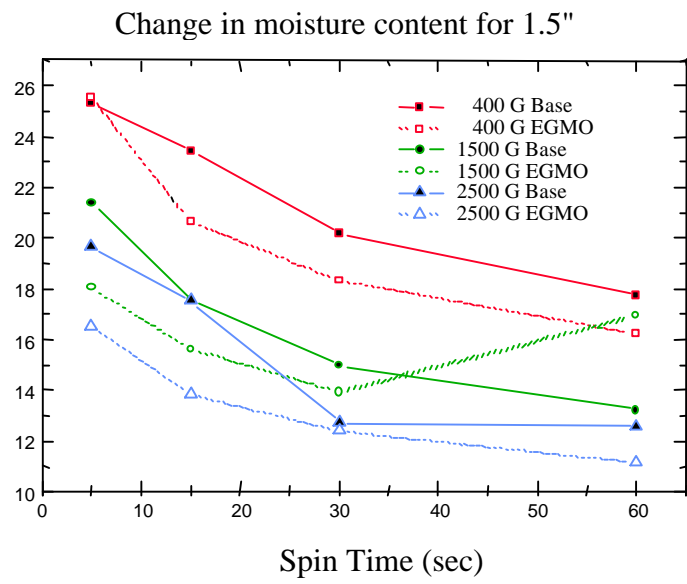
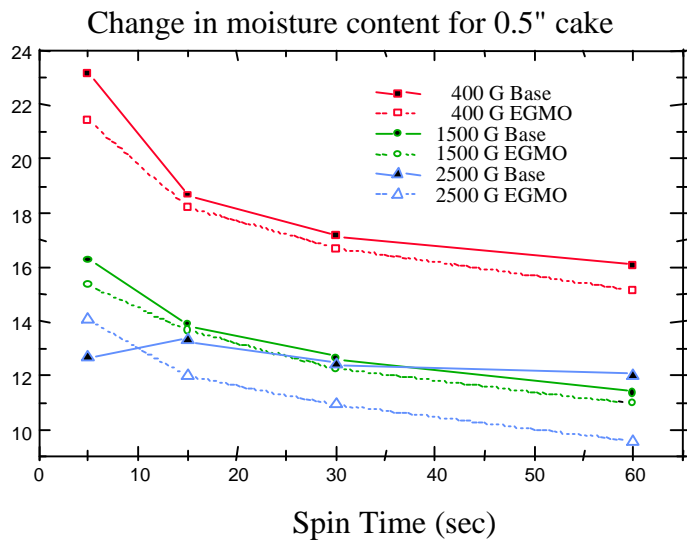


Figure 3.5. Superimposed results of the control tests and the tests conducted in the presence of EGMO (2 Lbs./ton).

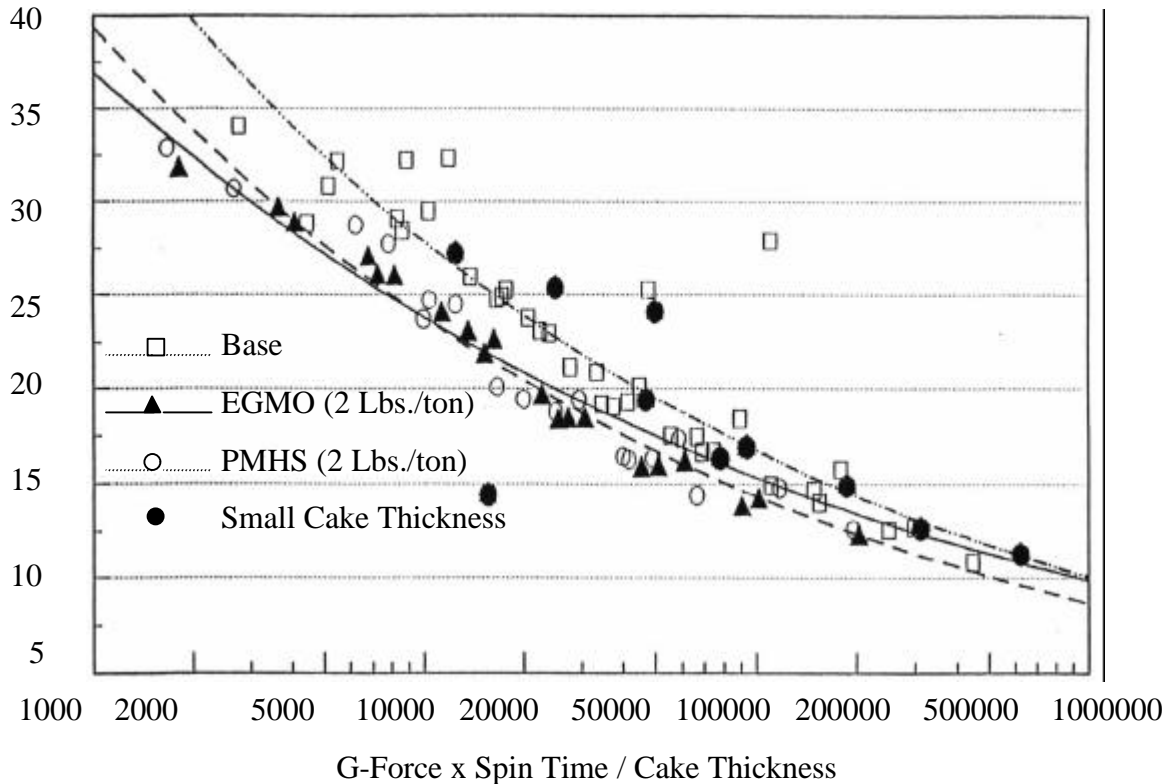


Figure 3.6. Results of the centrifugation tests conducted on Middle Fork (100 mesh x 0) coal sample slurry. The tests were conducted using the lab-scale solid bowl centrifuge in the presence and the absence of the dewatering aids. EGMO and PMHS were used at 2 Lbs./ton dosages. The sample was conditioned by means of a dynamic mixer in a 5-gallon container for 15 minutes.

For the thicker, 1.5 and 3 inches cakes the difference between the results of the tests conducted in the absence and the presence of the dewatering aid was about 2% points lower under all the tested spin time and G force conditions. The centrifuges have a high performance of creating low moisture content cakes even without using any additives since the forces applied on the particles is very high. As a result there was a lesser difference between the moisture contents of the coal cakes produced with or without the dewatering aid compared to the vacuum filtration analyses. Using high G force (2500G) and long spin time (120 seconds), the cake moisture contents of 10-12% were reached without using any reagent. On this particular sample, the presence of the dewatering aid was not very effective due to the high ash content of the coal (18.60%), which was unfavorable for the dewatering of fine coal.

Figure 3.6 illustrates the centrifuge tests results conducted on the Middle Fork (100 mesh x 0) coal sample using the solid bowl centrifugation technique. This sample was a flotation product of the tailing pond coal, processed by the Pittston Coal Management Company. The ash content of the sample was 10.66%, and the mean particle size was 25.53 micrometer. The tests were conducted both in the presence and the absence of the dewatering aids. Two novel dewatering reagents, EGMO and PMHS were tried on this sample. The reagent dosage was kept constant at 2 Lbs./ton and the coal slurries were conditioned for 15 minutes in 5-gallon buckets by means of a dynamic mixer. The centrifugal force was again adjusted to 400G, 1500 G and 2500G levels. The cake thicknesses were selected as 0.5, 1.5 and 3 inches, and the spin time periods were set to 10, 20, 40 and 80 seconds. It was clearly observed that, both EGMO and PMHS helped decreasing the cake moisture compared to the tests conducted in the absence of any dewatering aids. Between these two reagents, EGMO was observed to perform better at lower G force ranges and PMHS was more effective at high G force ranges compared to the base tests results. It was expectable that at high G force levels centrifugation was quite effective in reducing the cake moisture even without addition of the reagent. However, it is important to note that, the centrifugal force is desired to be kept low for the industrial applications because of the abrasion problems faced at high G forces. At low G force levels, 4 to 5 % reduction in the moisture content was achieved using the novel dewatering aids with respect to the base results. As the G force increased, the difference decreased to ~2% for EGMO and to ~1% for PMHS. Some deviations were observed in the presence of PMHS at very low cake thicknesses as represented in Figure 3.6 by the solid circles.

Figure 3.7 represents the results of the tests conducted on the Holston coal sample (28 mesh x 0). This sample was the flotation product from Pittston Coal Management Company. The mean particle size of the sample was 33.56 micrometer and the ash content was 9.3%. On Holston coal sample screen bowl centrifuge tests were conducted by using the lab-scale screen bowl centrifuge. To determine the effect of the dewatering aid in cake moisture reduction, EGMO was used for the tests at a dosage of 2 Lbs./ton. The spin time periods were chosen as 10, 20, 40, 80 and 120 seconds and the centrifugal force values were set to 400G, 1500G and 2500G

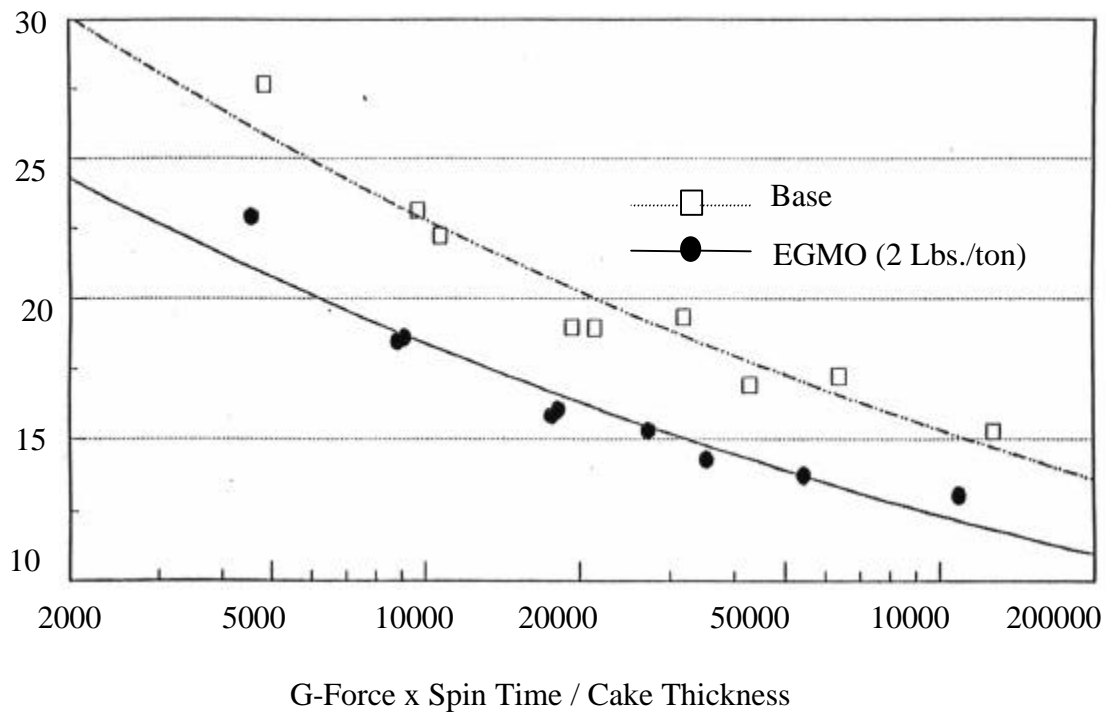


Figure 3.7. Results of the centrifugation tests conducted on Holston (28 mesh x 0) coal sample slurry. The tests were conducted using the lab-scale screen bowl centrifuge in the presence and the absence of the dewatering aid, EGMO at 2 Lbs./ton. The sample was conditioned by means of a dynamic mixer in a 5-gallon container for 15 minutes.

as in the previous tests. The cake thicknesses were approximately 0.5, 1.5 and 2.5 inches. The screen bowl centrifuge was observed to perform more efficiently in fine coal dewatering based on to the results obtained on the Holston coal sample slurry. The cake moisture values of 3% to 5% points lower than the base experiment results were achieved in the presence of EGMO. The better performance of the screen bowl centrifuge can be attributed to the special design of the equipment which is more suitable for the dewatering purposes compared to the solid bowl centrifuges. In addition, this particular sample was more suitable to dewatering in terms of the ash content and the particle size distribution.

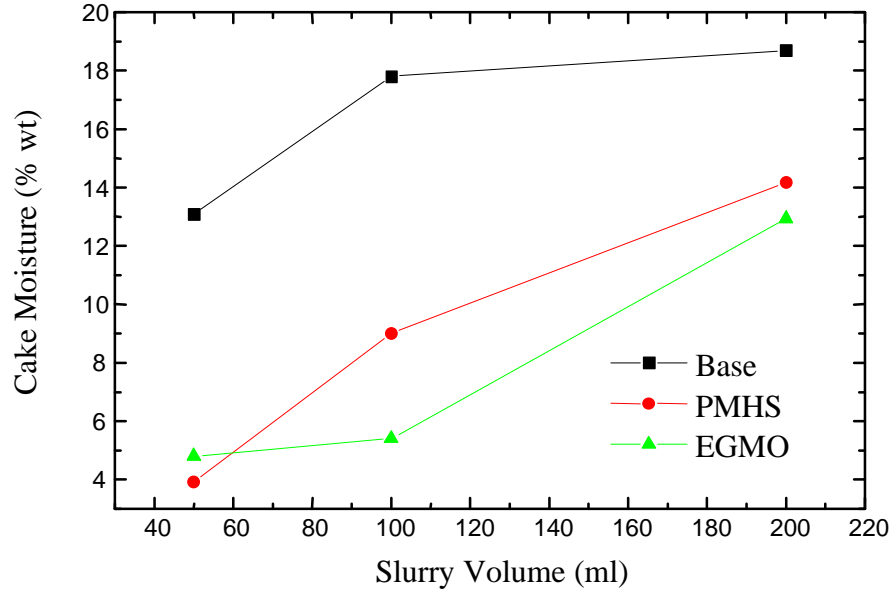


Figure 3.8. Results of the filtration tests conducted on Middle Fork sample slurry. The experiments were conducted at three different slurry volumes (cake thicknesses). Reagents A and E were used as the dewatering aids each at a dosage of 2Lbs/ton. The vacuum was set to 28 inches-Hg and the drying cycle time was 5 minutes for all the tests.

To compare the efficiency of the centrifugation and the vacuum filtration techniques in fine coal dewatering, some vacuum filtration tests were conducted simultaneously with the centrifuge tests on the Middle Fork and the Holston coal samples. The Pittsburgh coal sample was a fairly bad sample and no vacuum filtration tests were tried on it. Figure 3.8 shows the results of the vacuum filtration tests conducted on the Middle Fork coal sample (100 mesh x 0). The sample slurry had 24.4% solid content originally. The tests were performed at three different cake thicknesses. To arrange the cake thickness 50, 100 and 200 ml sample slurries were used, which formed approximately 0.1, 0.2 and 0.4 inches thick cakes, respectively. The vacuum pressure was set to 28 inches-Hg for all the tests. The tests were performed both in the absence and the presence of the dewatering aid. The novel dewatering aids EGMO and PMHS were used like in the centrifuge tests performed on the Middle Fork coal sample. The reagents were added into the coal slurry at 2 Lbs./ton dosages as in the centrifuge analyses. The samples

collected into 250-ml flasks were conditioned for 2 minutes by hand shaking to let the reagents adsorb onto the coal surface. The drying cycle time was set to 5 minutes for all the tests. As it is seen in Figure 3.8, the cake moisture was the lowest at 0.1 inches cake thickness and increased with the increasing cake thickness. For 0.1inch thick cake the addition of EGMO decreased the cake moisture to 4.8%, which was 13.10% in the absence of any dewatering aids. At this thickness PMHS reduced the cake moisture further down to 3.93%. When the cake thickness increased to 0.2 inches, the base cake moisture content increased to 17.80%. With the addition of EGMO and PMHS, 5.4% and 9% moisture content values were reached, respectively. The effect of the reagent usage diminished for the thicker cakes. At a thickness of 0.4 inches, there were only 4 to 6% points reduction in the cake moisture in the presence of the reagents compared to the base value (18.69%). The cake moisture contents of 12.93% with EGMO and 14.17% with PMHS were attained.

The comparison between the vacuum filtration and centrifugation tests results that were obtained using the Middle fork coal sample showed that for both tests as the cake thickness decrease and the applied dewatering force increase, cake moisture contents can be reduced to the minimum values. However, the difference between the base values and the results obtained in the presence of the dewatering aids were larger for the vacuum filtration application compared to the centrifuge tests results. As it was mentioned before, this can be attributed to the ability of the centrifuges to decrease the cake moisture to very low values at high G forces without using any reagents. As it is shown in Figure 3.6, the moisture contents between 5 to 10% were obtained with centrifugation at fairly high G force values regardless of the dewatering aids were used or not. The vacuum filtration tests gave cake moistures of 4-5% in the presence of the dewatering aids for 0.1 inch thick cakes. However, the drying cycle time was long (5 minutes) and the vacuum pressure was set to a relatively high value (28 inches-Hg). In addition, the cake thicknesses were very low for vacuum filtration analyses compared to the thicknesses used in the centrifugation tests. Although, the application of very high G forces for the centrifugation is not common in centrifuge dewatering because of the abrasion that create maintenance problems, the results obtained with centrifugation was very successful considering the high cake thicknesses of the filter cakes.

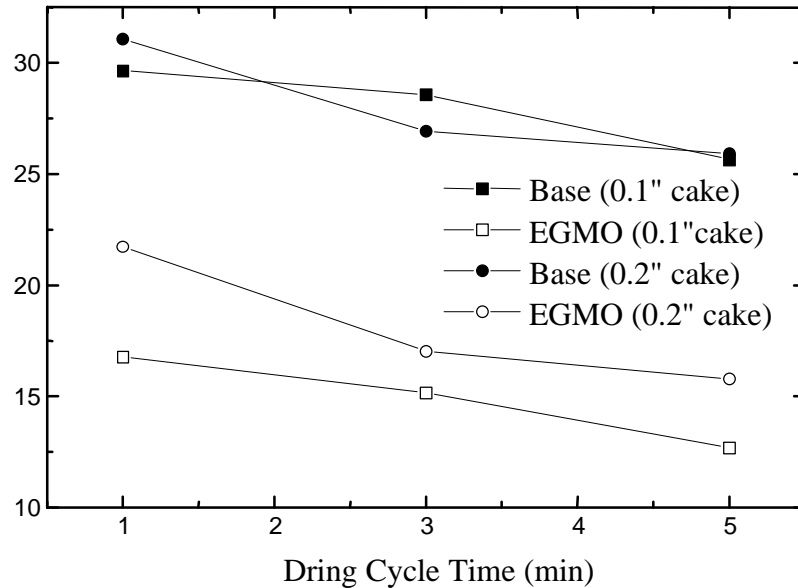


Figure 3.9. Results of the filtration tests conducted on Holston (28 mesh x 0) sample slurry. The experiments were conducted at three different drying cycle times and at two different cake thicknesses. Reagents A was used as the dewatering aid at a dosage of 2Lbs/ton. The vacuum was set to 28 inches-Hg.

Figure 3.9 illustrates the results of the vacuum filtration tests conducted on the Holston coal sample (28 mesh x 0). The percent solid content of the original sample slurry was 19.30%. The tests were conducted at two different cake thicknesses and varying drying cycle times. EGMO was used at 2 Lbs./ton dosage as the dewatering aid. The cake thicknesses were 0.1 and 0.2 inches obtained by using 50 ml and 100 ml sample slurries. The vacuum pressure was set to 28 inches-Hg for all the tests. The same sample slurry conditioned to conduct the centrifuge tests by means of a dynamic mixer (15 minutes) was used to perform the vacuum filtration tests. This gave the advantage of keeping the consistency between the vacuum filtration and centrifugation tests in terms of the adsorption of the reagent onto the coal surface. The base moisture content values for 0.1 and 0.2 inches thick cakes were neighboring at all the drying cycle time periods. Increasing the drying cycle time from 1 minute to 5 minutes decreased the

cake moisture without any dewatering aid addition from ~30% to ~26%, respectively. In the presence of EGMO, cake moisture values decreased approximately by 10% for 0.2 inches thick cake and by 12-14% for 0.1 inches thick cake. After 1 minute drying, the cake moisture contents of 21.73% and 16.79% were reached for 0.2 and 0.1 inches cakes, which decreased to 18.80% and 12.70% at the end of 5 minutes drying period. The results of the centrifuge tests and the vacuum filtration tests conducted on the Holston coal sample were more consistent. This was most probably due to the utilization of the screen bowl centrifugation technique on this coal sample and the low ash content of the sample slurry. The efficiency of the screen bowl centrifuge was better than the solid bowl centrifuge in reducing the cake moisture. The screen bowl centrifugation technique helps the drainage of the excessive moisture out through the perforated sections of the bowl.

3.4. Conclusions

1. The usage of the novel dewatering aids developed at Virginia Tech helped to decrease the moisture content of the fine coal sample slurries in centrifugation applications. The efficiency of the novel reagents was closely related to the quality of the coal sample. On the Pittsburgh coal sample the usage of dewatering aid slightly improved the tests results. This was due to the high ash content of this particular coal (18.60%). Although the Pittsburgh sample was relatively coarse (-28 mesh) it was a bad sample due to the high ash content and the addition of EGMO decreased the cake moisture only by 2%
2. The improvement of the centrifuge dewatering in the presence of the novel reagents was very significant on good quality coal samples. The moisture contents of the filter cakes of the Middle Fork and the Holston coal samples were decreased successfully in the presence of the additives. There was approximately 4 to 5% reduction in the cake moisture contents compared to the results obtained in the absence of any reagents. Both of these samples had low ash contents. Although their particle size distributions were comparably fine, the novel reagents reduced their moisture contents. This implies that the ash contained in the coal slurry decreases the efficiency of the dewatering aid very severely. On the other hand, the novel reagents are capable of decreasing the moisture contents of very fine size coal efficiently when it is a good quality sample.

3. The centrifuge operation was very successful in decreasing the cake moisture even at very high cake thicknesses. However the improvement diminished as the G force became very high. At such a high energy input, an excellent dewatering can be achieved by centrifuges even without the usage of any chemicals.
4. Between the two centrifugation techniques used to conduct the tests at Bird Machine Company's Laboratories, the screen bowl centrifuge was observed to be more suitable to fine coal dewatering. This was due to the special design of this type of centrifuge, which improves the drainage of the water through the screens, so that the cake moisture can be further reduced.
5. The performance of the centrifugation and the vacuum filtration techniques on fine coal dewatering were observed to be similar at the same cake thicknesses. On the good quality coal samples, the moisture contents of the coal samples were reduced to reasonably low values. This observation indicates that the novel dewatering aids can be used for both systems effectively.