BLOCKAGE REDUCTION TO INCREASE THE EFFICIENCY OF SLURRY APPLICATION

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Teagasc acknowledges the support of
Abbey Machinery Ltd. in the
financing of this project

ISBN 1 84170 090 8

December 1999

Teagasc
The Science of Farming and Food

EUROPEAN UNION
European Agricultural Guidance and Guarantee Fund

Teagasc, 19 Sandymount Avenue, Dublin 4

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SUMMARY

Discussions with farmers using band and injection slurry spreaders suggested that the rate of breakdown due to blockages, in these machines, was approximately one per day. This report shows how the use of an intake filter and a modified distributor on a band spreader can reduce this problem.

A set of obstacles was assembled on the basis of information from farmers and from literature. Ten classes of obstacles were selected, at random, and between size limits.

Two prototype filters, a commercial filter and an open pipe were tested while drawing slurry from an open tank to a tanker. During each test, obstacles were thrown into the slurry stream. Obstacles retained by the filter were counted afterwards. A second filter trial was organised to test the tendency of filters to clog. Obstacle tests with 3 prototype distributors and a control were conducted in a similar manner to the first filter trial but, in this case, preliminary tests were conducted in water and final tests in slurry. The initial tests identified the best prototype. This was then compared to the control distributor using slurry.

The open pipe allowed 80% of obstacles to pass while the filters allowed only 4 – 19% through. The new filters offered no improvement over the commercial unit. Filters required 16 hours agitation but the open pipe required 4 hours or less.

The best prototype had the same diameter as the control but had an obstacle trap attached at the side. In a test using obstacles and slurry, the control was obstructed by 56% of the obstacles while the prototype allowed only 21% to cause a blockage. Flow through the prototype was initially too large. Slowing down the rotor in the distributor and restricting the outlet from the obstacle trap with a single long pipe, connected to two nozzles, controlled the flow.

The results of the filter and distributor trials were combined. Of the seventy obstacles dropped above the filter, six passed through. Four of these caused blockages in the control distributor, but only one became stuck in the prototype. The blockage rate in the distributor and nozzles was significantly reduced compared to the original unit.

INTRODUCTION

There is widespread concern about the smells associated with slurry spreading. These are worst when a splash-plate spreader is used to apply the manure. They arise while the spreader is working, and afterwards when the more intense odours come off the field. This system is characterised by slurry thrown high in the air and by a field completely covered with manure. The odours are reduced if the slurry is placed gently on or below the surface of the ground. This reduces contact between the slurry and the air both during spreading and afterwards while the slurry lies in the field. Spreaders are available which offer improved environmental performance but they are more expensive and are more prone to blockage than splash plate equipment.

A second benefit is available if slurry is placed directly on or below the surface. When slurry is in contact with the air, ammonia can escape to the atmosphere. The greater the contact, the more ammonia is lost. This material is an atmospheric pollutant and contributes to acid rain. If it can be kept in the soil, it provides nitrogen for plants. This reduces the need for fertiliser and saves money on the farm. When slurry is broadcast with a splash plate spreader, most of the ammonia is lost, but if the slurry is placed below the surface, as in injection, then 95-99% of the ammonia is retained by the soil (Teagasc, 1991). However, this saving alone does not justify the added cost of the improved machine.

Band spreaders use small pipes to convey slurry from a central distributor to a large number of small diameter outlets, just above the ground. Injection spreaders are similar, but the material is injected into slits in the soil. The distributor and small pipes are common to both machines. These are prone to blockage by pieces of metal, plastic and wood that are found around the farmyard. If breakdowns from this source could be controlled, band and injection spreaders might become more competitive with splash-plate machines from a functional point of view. They are already superior in environmental respects.

The object of this project was to reduce blockages in environmentally-friendly slurry spreaders. We looked at filters and at a modification to the distributor, which allowed obstacles to escape. By this means, we showed how the rate of breakdown due to blockage of the distributor and outlets can be significantly reduced.

METHOD

Obstacles

Visits were made to 6 farms to witness work practices there and to discuss problems with handling slurry. This information was useful when choosing typical obstacles for use in trials. A list of 10 classes of obstacles was made up. One item was taken from each class for each set of obstacles. A total of 20 sets was prepared in a range of sizes. The size of each obstacle was chosen at random between limits. The smallest should just pass through a distributor while the largest would have difficulty passing through a 150 mm diameter pipe. One set of obstacles was used in each replicate in a filter or distributor test. These obstacles represented the objects found to have blocked slurry spreaders.

Filters

A common way to prevent obstacles entering a machine is to filter them from the slurry before the slurry enters the tanker. Three filters were tested in this project (Fig. 1) and compared to an open pipe which is the normal intake to a slurry tanker on Irish farms. The Abbey filter was the control and was made from sheet metal. It had circular holes, 30 mm in diameter. The Ring filter consisted of 4 concentric rings 50 mm deep and 10 mm apart and the Weldmesh filter was made from weldmesh with 22 mm square apertures. The ability of each unit, to exclude obstacles and to throw off accumulations of slurry fibre, was assessed.

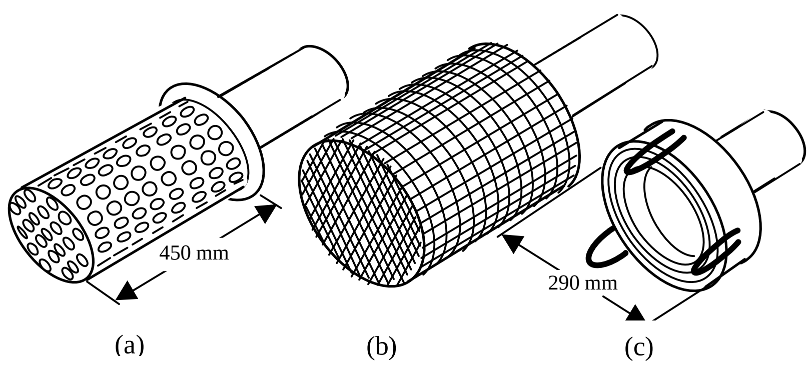

Fig. 1: The three filters tested in the obstacle trial: (a) Abbey filter, (b) Weldmesh filter, (c) Ring filter

Tests with obstacles were conducted in a 7 m^3 (1600 gal) tank on wheels (bowser) as in Fig. 2. Slurry was pumped from the tanker into the bowser. During a test, obstacles were dropped into the slurry directly over the filter as the slurry passed through it and back to the tanker. The bowser was then emptied completely and obstacles in the bowser were gathered. Any obstacle not accounted for was considered to have passed through the filter. The flow-rate of slurry was recorded.

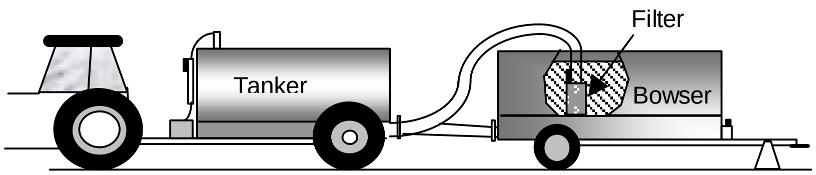

Fig. 2: Set-up for the filter trials with obstacles

The tendency for a filter to clog was assessed in a second trial. This was conducted using a 7 m^3 slurry tanker and a 450 m^3 slurry tank under the slatted floor of a cattle shed. A pump type agitator was used to mix the slurry. The construction of the tank did not allow complete circulation during agitation. Therefore only 25% of the tank was effectively mixed. The intake equipment used in this trial was the same as that used in the trial with obstacles, with one exception. A filter of wire mesh with 25 mm diameter apertures, on a steel frame, replaced the Weldmesh filter.

During a test, the slurry was agitated for 4 hours. When agitation stopped, the slurry tanker was filled three times with each filter and with the open pipe. Slurry was returned to the underground tank by a second pipe, taking care not to disturb the filter. This procedure was repeated three times.

Distributors

It was not possible to exclude all the obstacles using a filter. Therefore a prototype distributor was constructed which included an outlet for obstacles in the side-wall of the machine. Obstacles were collected in a small container or obstacle trap, while slurry passed to the ground, through one or more of the outlet pipes (Fig. 3). The inlet to the obstacle trap allowed slurry to flow in tangentially, generating circular motion. This supplied resistance to flow (Scotford, Cumby and Inskip, 1998) and provided a potential scouring effect to keep the outlet from the unit clean. A drain allowed the obstacle trap to be cleared of slurry. The bottom could then be opened and obstacles retrieved. The innovation was applied to a distributor from the 6 m bandspreader manufactured by Abbey Machinery Ltd. This had a hydraulic reversing valve as an additional feature, to improve chopping of obstacles by the rotor.

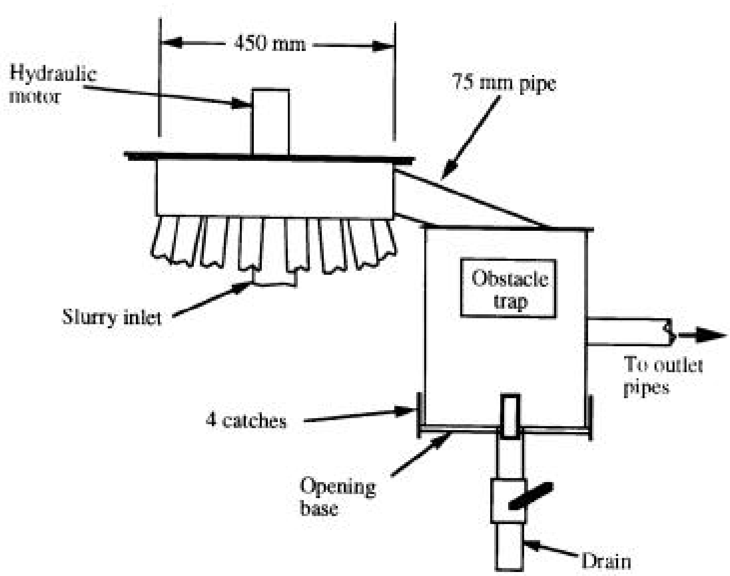

Fig. 3: Prototype VI distributor, with an obstacle outlet in the side and which is connected to an obstacle trap

The distributor (and obstacle trap) was made up in four versions. The first was a distributor by Abbey Machinery Ltd. with sixteen outlet pipes from the bottom of the unit and no side outlet. This was called "U" and was used as the control. The second version was identical to the first but had an outlet built into the side wall (V1). The third distributor had a track, 100 mm wide, between the outlets and the inside of the side wall. An outlet for obstacles was provided initially from the underside of the track (W), but this was later replaced with a side outlet to make the fourth version (V2).

The four designs were compared in a preliminary obstacle trial using water instead of slurry. The distributor was mounted on a frame over the 7 m^3 tank (or bowser) and the obstacle trap was connected to one side. Outlet pipes, boom and nozzles, similar to those found on an Abbey 6 m bandspreader, were installed under the distributor. Most of the nozzles discharged into the bowser, but the pipes connected to the obstacle trap discharged into a separate 1 m^3 tank. A slurry tanker was used to supply water or slurry and it had an obstacle-input unit mounted on its outlet pipe. This had two gate valves and it allowed obstacles to be inserted into the stream of water as it flowed to the distributor. Both tanks were weighed as a measure of flow-rate. The results were used to identify the best prototype distributor.

Final trials with the distributor focussed on two designs, the control and the prototype V1. As a clear conclusion was required, nine obstacle sets were used. The procedure adopted was the same as that for the trials with water, except that additional flow measurements were made during this test where time allowed. In previous tests with the prototype, the hydraulic oil flow-rate required for balanced flow of water was 10 l/min. When slurry was used an oil flow-rate of 22 l/min was required. As the tests proceeded, flow through the obstacle trap increased. This was attributed to the thinning of the slurry as it passed back and forth between the two vehicles. Consequently, hydraulic oil flow-rate was reduced for the last four tests.

The chopping capacity of the rotor was tested at two speeds. Samples of timber were pushed upwards through one of the outlets and into the distributor chamber, while the distributor rotated. A total of fourteen samples were used. The duration of chopping was recorded in each case.

RESULTS AND DISCUSSION

Obstacles

Our efforts to reduce blockages in slurry spreaders began with farm visits. Six common types of obstruction were identified. Wood was the worst offender, but plastic pipe, stones, silage, plastic sheet and straw also caused problems. Blockages occurred in spreaders between once per ten days and twice per day. A survey of contractors spreading slurry in the Netherlands extended the list of problem materials and indicated how, even with sophisticated blockage control equipment, breakdowns still occur (Somers and Huijsmans, 1995).

Filters

Filters are used in handling slurry but are not always successful. Where the liquid is thin or free-flowing, as in the case of pig slurry, a filter can be quite effective. However, most farms in Ireland have slurry from cattle or cows, and this is often thick with plenty of fibre. It forms a crust on top if it is left undisturbed for a few weeks. In its virgin state this material will quickly clog a filter. Many hours of agitation are needed to homogenise cattle slurry and reduce the viscosity to the point where the slurry could flow easily through the 30 mm holes in a filter.

Table 1 shows how the three filters compared to the open pipe. A total of 80 obstacles were used in each test, the same obstacles for each filter. The open pipe allowed 80% of these to enter the tanker. Using any of the filters gave a significant improvement over the open pipe. The performance of the Ring filter was worse than that of the other two, but the difference between the Abbey and Weldmesh filters was not significant. This result suggests that a slurry filter, such as the Abbey or Weldmesh units, can exclude approximately 90% of the obstacles it is likely to meet.

During the trial with obstacles and filters, a layer of fibrous material accumulated on the intake. This was removed from the filters after each test so the fibre did not build up sufficiently to upset the trial. We carried out a second trial to compare the filters in a situation where they were not cleaned after each fill. A second parameter was introduced, namely degree of agitation, to give an indication of the amount of agitation required when using a filter or an open pipe.

The graph in Fig. 4 shows how flow-rate varied during the trial. After the initial four hours agitation, flow-rate through the open pipe has peaked, but flow through the two filters was still very slow. A further 8 hours of mixing brought a substantial improvement in flow through the filters, but the open pipe showed little change. The final agitation period brought only a small improvement in flow in the filters. The Abbey filter reached the efficiency of the open pipe and the Mesh filter came close to it. The Ring filter is not shown as it became blocked early in each test.

Table 1: Percentage of obstacles passing an intake filter in slurry (%)

Obstacle type	Open pipe	Abbey	Ring	Weldmesh
Silage	100	0	0	0
Wood	75	0	0	0
Slurry crust	88	0	0	0
Ear tag	88	25	50	0
Metal	50	25	38	0
Cattle hair	100	0	38	13
Stone	25	0	13	0
Plastic sheet	100	13	50	25
Plastic pipe	88	13	0	0
Syringe	88	0	0	0
Mean	80	8	19	4

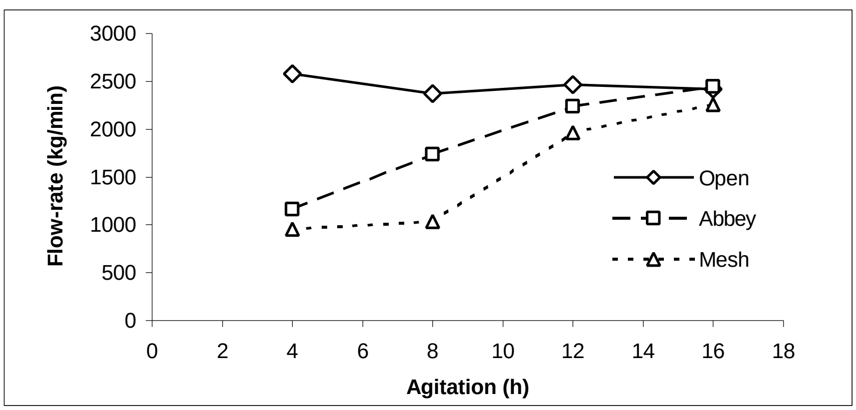

Fig. 4: Average flow-rate through the open pipe, the Abbey filter and the Mesh filter during prolonged filling

The filter trials are summarised in Table 2. The open pipe allowed most of the obstacles to pass into the tanker. Neither of the prototypes showed a significant improvement over the commercial unit so they offer no reduction in the blockage rate of spreaders.

Table 2: Summary of the performance of the open pipe intake and of three filters

Variable	Open	Abbey	Mesh	Rings
Obstacles passing (%)	80	8	4	19
Peak flow-rate (kg/min)	2,580	2,450	2,260	400
Average filter cleanings (kg/test)	-	4.7	18.0	1.9

Distributors

Once an obstacle is in the distributor, the only way out is through a distribution pipe where a blockage may occur. In this project, we explored the possibility of providing a relatively large outlet in the side of the distributor to allow obstacles to escape. They flowed from the obstacle outlet to a small tank or obstacle trap, which retained the obstacles as the slurry flowed away to the distribution pipes (Fig. 3).

The obstacle duct had a diameter of 75 mm and is sloped downwards to prevent obstacles flowing back into the distributor. The duct was connected to the top of the trap and set to one side to generate circular motion inside the vessel. This helped to keep the side outlet clean. The drain allowed the trap to be emptied of slurry before opening the base to remove obstacles. Several versions of the outlet were constructed. The arrangement that worked best consisted of a single pipe from the side of the trap to a T-piece connected to two nozzles. This allowed flow from the obstacle trap to be matched with flow from the pipes connected directly to the distributor.

The first distributor test was a preliminary trial to differentiate between design options, so only four replicates were used in each test. This was not sufficient to guarantee significant differences between prototypes. However, the results of these tests, along with other information gathered during the trial, allowed us to choose the design most likely to succeed. During a test, obstacles were placed in the stream of water flowing from the tanker to the bowser. In the distributor, the rotor threw obstacles into the obstacle trap, or chopped them into pieces small enough to pass into the outlet pipes. Some of these lodged in the nozzles, while others passed into the bowser. Failing this, obstacles remained in the distributor until the end of the test.

The result of this trial is given in Table 3. The obstacle trap caught a substantial number of obstacles, especially when attached to distributor prototype V1. While the differences between prototypes were not significant, prototype V1 with a small distributor and a side outlet suffered the lowest number of obstructions. It was also the cheapest option. The next best distributor, prototype V2, caused extreme damage to obstacles during the test. This suggested that obstacles and slurry sat for a while in the pocket at the end of the long rotor. At the obstacle outlet this large quantity of material moved slowly towards the duct and suffered repeated blows from the rotor. In prototype V1, there was less room for material to lodge, so obstacles could accelerate more quickly into the duct. If this analysis is correct, prototype V2 was not a good design and should not be developed further. Prototype W, with a track and a bottom outlet, gave a poor performance. This is consistent with expectation as obstacles passing through the bottom of the distributor have little benefit from the centrifugal force applied by the spinning rotor. Therefore, prototype V1 was selected for further development.

Table 3: Percentage of obstacles held by selected parts of the prototype spreader during preliminary trials with water

Obstacle resting place	Distributor type			
	Control	V1	V2	W
1. Obstacle trap	0	28	25	8
2. Distributor	43	17	35	50
3. 50 mm pipes	13	8	5	0
Blockages per test (2+3)	55	25	40	50

The prototype V1 was compared to the control in the final trial. In Table 4, the proportion of obstacles causing obstruction in the two distributors is given. In this list, only obstacles that reached the distributor are considered, as some items became trapped in the 100 mm pipe leading up to the distributor. A total of 56% of the obstacles entering the control were later found in the distributor or in the nozzles. This is two to three times the blockage rate in the prototype and the difference is significant. During the trial, two obstacles escaped from the obstacle trap and lodged downstream at the T-piece and in one of the nozzles attached to it. This is probably avoidable and future development should seek to eliminate the problem.

Table 4: Percentage of obstacles, reaching the distributor, which caused an obstruction in the distributor tests with slurry

Obstacle type	Obstructions (%)		
	Control	Prototype VI	Difference
Silage	63	37	26
Wood	56	14	41
Slurry crust	50	20	30
Ear tag	67	20	47
Metal	67	0	67
Cattle hair	25	20	5
Stone	60	18	43
Plastic sheet	50	25	25
Plastic pipe	78	56	22
Syringe	50	0	50
Mean	56	21	35 +/ -12

During the preliminary tests with obstacles, water flow through the nozzle, attached to the obstacle trap, was at least twice as fast as that through the other pipes attached to the distributor. We were obliged to correct this, as uniform distribution of slurry in the field is a high priority. The final design used a control valve on the hydraulic oil supply from the tractor and a control on the outlet from the obstacle catcher. The latter consisted of a 50 mm pipe connected by a T-piece to two nozzles. This reduced the flow-rate of slurry while maintaining the pipe cross-section. The operation of the combined system is illustrated in Fig. 5. As the flow-rate of hydraulic oil increased, the speed of the rotor and the flow of slurry from the obstacle trap rose also. At the crossover point, the rate of flow from a nozzle connected to the trap equals the average flow through the nozzles connected to the distributor.

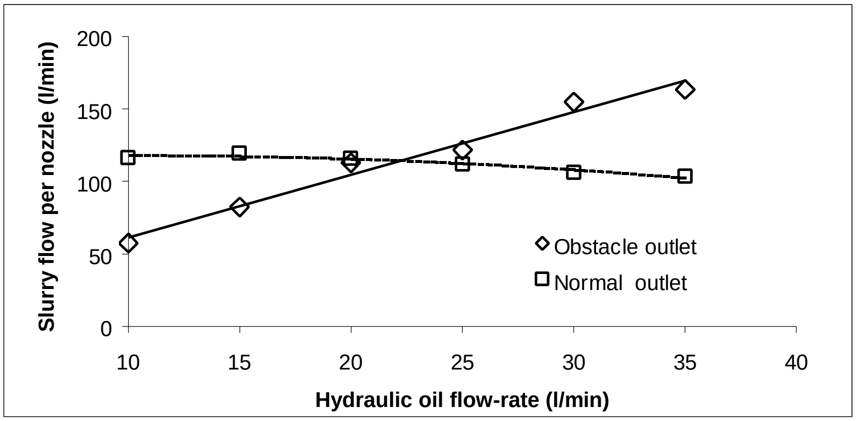

Fig. 5: Effect of oil flow from the tractor on the flow-rate of slurry from the obstacle outlet and from normal outlets

In Fig. 5, the effect of changing part of the set-up is illustrated. In Fig. 6 the variation of flow during an average replicate is described. Flow through the nozzles connected to the distributor and from the obstacle trap is plotted against cycle time. Initial pressure in the tanker was too high. This caused a high flow from the distributor and low flow from the obstacle trap. Flow-rates converged briefly but moved apart again as the tests proceeded. After the initial deviation, air pressure in these tests was almost constant. Therefore, it is likely that the reduction in depth of the slurry, in the tanker, gave rise to the reduction in flow-rate through the distributor towards the end of the test.

The plot of flow-rate through the obstacle trap is almost a mirror image of the corresponding plot for the distributor. As one line rises, the other falls. Evidently, there is competition for slurry in the distributor. Perhaps the variation is caused by changes in the level of slurry in the outlet pipes. This may affect pressure in the distributor and hence the partition in flow. Alternatively, the pumping action of the rotor may account for this effect. Pumping slurry through the rotor requires power from the hydraulic motor. If the flow-rate reduces, less power is consumed and the rotor speeds up. This would increase the feed to the obstacle catcher. Whatever the mechanism behind the variation, if it is to be avoided, control of the vacuum tanker must be improved. While the variation in flow is not perfect, it is close to the normal range for bandspreaders.

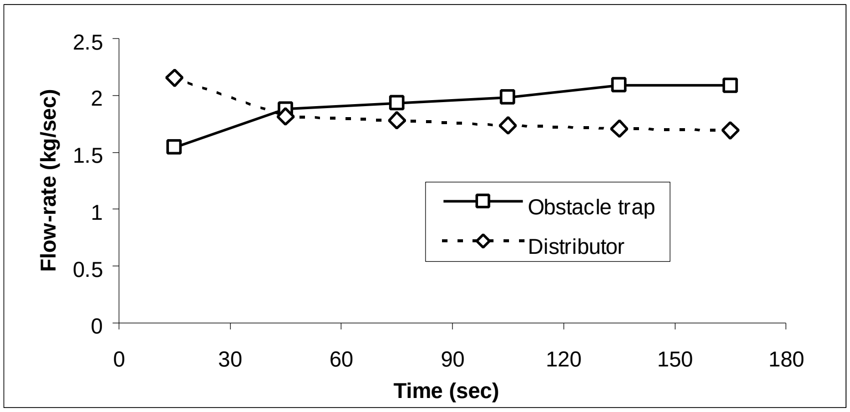

Fig. 6: Flow-rate of slurry from the distributor and from the obstacle trap nozzles plotted against cycle time

The test of chopping capacity of the rotor gave only outline information. At a rotor speed of 400 rev/min, softwood and hardwood up to 36 mm were chopped, although at the largest size chopping took 5 seconds. When the rotor speed was reduced to 150 rev/min, one hardwood sample of 32 mm and a second of 36 mm were chopped. However, three other samples of hardwood, of 36 mm diameter, could not be severed. No further tests were performed, due to the risk of damaging the machine. The bolts, holding the chopping plate in place, had already shifted. This test suggested that the rotor could chop virtually any timber that could fit into the outlets and that adequate capacity was retained at the speed required by the obstacle trap. Speeds between 230 and 250 rev/min were recorded during the distributor test with slurry. The speed of the rotor might be increased above this level if greater resistance to flow could be generated in the obstacle trap. This could be accomplished, in part at least, by extending the outlet pipe between the trap and the T-piece.

Filter and Distributor

A filter and distributor are complementary devices for controlling blockages. It is appropriate that they should be tested in combination. In this case, such a test would need to be conducted in the field. This would make it very difficult to get obstacles to the distributor. If obstacles were put into the slurry before loading, some obstacles would lodge in the tanker. Inserting obstacles on the move is difficult and expensive. Therefore, a computer option was adopted. Data from obstacle tests with filters and with distributors were combined on screen to indicate which obstacles would pass a filter and cause a blockage in the distributor or nozzles. The Abbey filter was used as it gave the best overall performance. Seven obstacle sets were suitable, as they had been used in all three of the relevant tests.

The 70 obstacles had been dropped over the filter, but only 6 passed through. Of the 6 obstacles passing the filter, only 1 had caused a blockage in prototype V1. This was a piece of plastic sheet 590 x 88 mm wide. Four obstacles stuck in the control distributor; an ear tag, 2 pieces of metal and the same piece of plastic as was held in the prototype. This result is consistent with previous comparisons between the distributors.

The prototype was effective in reducing the number of breakdowns to approximately 40% of the level in a typical commercial spreader. This achievement was obtained at a cost. An obstacle trap must be added and an additional unit is required to control the flow of hydraulic oil. However, the development increases the competitiveness of the bandspreader in relation to the splash-plate spreader. This may prove to be a more important consideration than the incremental cost. The trials with filters show how their performance is affected by the duration of agitation. This information is supportive of filters generally, as it quantifies, in this case at least, the degree of agitation required for a filter. We showed that in a typical slurry tank, filters required over 4 times as much agitation as an open pipe to achieve the same flow-rate. In these trials, the prototype filters did not improve on the performance of the commercial unit.

Further developments

The VI distributor, is in prototype form and would accommodate a number of possible improvements. These could enhance its performance and make the machine more reliable. The most important addition to the prototype is a flow control for the hydraulic oil supply. Without this, flow-rate from the obstacle trap will vary depending on the tractor, how it is operated and on the consistency of the slurry. Secondly, the obstacle trap needs to be refined. The base should be improved so that slurry does not spill on the person who opens it. Also, the drain should connect into one of the outlets, to avoid spillage. Perhaps, at the end of a run, slurry could be discharged from the trap remotely and obstacles tipped out on the ground, before the tanker leaves the field. At present, obstacles in the trap can escape through the main outlet in the side of the unit. This should not happen as it places two nozzles at risk of obstruction. The problem could be overcome in two ways. A baffle, ahead of the outlet, combined with the circular motion of the slurry in the trap, would deflect obstacles from the outlet. At the end of a run, the slurry in the trap drops to the level of the outlet. Floating obstacles then have the opportunity to escape. This problem might be averted if the outlet pipe, at the side of the trap, were at an upward angle.

On a more basic level, the possibility of improving the removal of obstacles from the distributor may exist. These trials indicate that neither a bottom outlet for obstacles, nor a track, inside the distributor wall, gives the best performance. Perhaps the obstacle outlet itself could be improved. The current outlet has a round cross-section but the distributor rotor is rectangular. A square duct, the same height as the rotor, would reduce obstruction and may allow obstacles through more easily. Increasing the cross-section area of the outlet could allow more obstacles to escape, but the flow-rate of slurry would also increase.

CONCLUSIONS

- The prototype VI distributor with an obstacle trap is more efficient at disposing of obstacles than the original control. It uses no additional moving parts.

- The flow-rate of slurry from the obstacle trap must be kept in check. Two controls are used. An additional valve, which restricts the flow of hydraulic oil to the distributor, slows down the rotor. A single pipe, connected to two outlets, restricts the flow of slurry to the ground.

- The chopping capacity of the rotor, in the prototype distributor, need not be reduced. If necessary, most of the flow control required can be generated in the outlet from the obstacle trap. This would allow the rotor to spin at a speed close to its maximum.

- The prototype filters do not offer better performance than the Abbey filter.

- Filters required sixteen hours agitation, but the open pipe required four hours or less to achieve the same throughput.

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