BAND LUBRICATION TO REDUCE FRICTION LOSS IN FORAGE BLOWERS

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ABSTRACT

A low friction blower band and water lubrication for reducing the friction loss in forage blowers were investigated. A polyethylene band in a stationary forage blower did not significantly reduce specific energy requirement compared to a conventional steel band. Spray application of water at a rate of 170 L/h on the band of a stationary blower reduced the specific energy requirement by 26%.

When gum accumulated on a forage harvester blower band the use of lubricants at low flow rates (57 L/h) reduced the specific energy requirement of the total harvester by 15%. Addition of lubricants when forage moisture did not produce gum accumulation provided no reduction in specific energy. The use of a wetting agent and water lubricant did not result in a significant benefit compared to water alone. Water flow rates as low as 57 L/h prevented gum accumulation. **KEYWORDS.** Blowers, Friction, Lubrication.

INTRODUCTION

The forage harvester has become an integral part of today's dairy farm, because it links the forage in the field to the dairy cow on the farmstead. When harvesting forages in the form of silage, the entire harvesting and feeding system can be mechanized to reduce labor requirements. The risk of weather damage is less than with dry hay due to reduced field drying time. However, equipment and capital investments can be considerably higher compared to dry hay production. One part of this high cost is due to higher energy requirements.

The specific energy required of forage harvesters has been reported to fall broadly within the range of 0.7 to 2.2 kWh/t wet matter (O'Dogherty, 1982). The specific energy requirements can be divided into three basic areas. The crop unit, along with other drive train losses, accounts for about 20%; the cutterhead accounts for about 40%; and the blower conveying system accounts for the remaining 40% of the total energy used by the forage harvester (Blevins and Hanson, 1956; O'Dogherty, 1982; Persson, 1987). The current and most common conveying system is a blower/impeller. In practice, the blower/impeller is usually about 25 to 50% efficient (Totten and Millier, 1966). Robertson (1983) estimated that in terms of potential energy alone, the specific energy requirement to lift the material to the height of the discharge spout is about 2% of the energy requirement of the blower/impeller. Still, the blower continues to be used to convey the material from the harvester because of its low manufacturing cost, simplicity, reliability, ease of maintenance and adjustment, and high capacity.

Totten and Millier (1966) determined that the efficiency of the blower decreases as the coefficient of friction increases. The power used by a blower can be divided into three areas: particle movement or kinetic energy, friction energy and air movement (Blevins and Hanson, 1956). The friction energy portion is quite large. Totten and Millier (1966) predicted that 45% of the total blower energy requirement was due to friction when the forage coefficient of friction was 0.7. Numerous researchers have indicated that the greatest improvement in forage blower efficiency can be obtained by reducing the friction loss at the blower band (Chancellor, 1960; Pettengill and Millier, 1968; Totten and Millier, 1966).

Large friction loss in the blower can occur with some crops at certain moistures due to the accumulation of a gum like substance on machine surfaces. This gum layer is a waxy, gummy substance apparently made up of plant juices and cellular material from the forage (Finner, 1966). Finner (1966) also determined that legumes were more prone to gum accumulation than grasses and the most critical moisture range for gum accumulation from alfalfa was 40 to 55% (wet basis). Shinners et al. (1991) determined that a polyethylene surface reduced the coefficient of friction with alfalfa by an average of 7%. The use of water lubrication between several different surfaces and alfalfa reduced the coefficient of friction by an average of 67%. It is common practice to lubricate the band of stationary blowers in order to reduce friction loss. However, the flow rates used are unacceptable for forage harvester blowers because of the large volume of water that must be carried with the harvester.

The specific objectives of this research were to:

- Determine the effects of lubricant type, flow rate, and location with regard to the specific energy requirement of a stationary or a forage harvester blower.

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- Determine if using a polyethylene band in a stationary blower would reduce the specific energy requirement.

PROCEDURE

Initial tests were conducted using a stationary forage blower because the blower band could be quickly changed from steel to a polyethylene lined band. After initial success with low flow rate blower lubrication at the stationary blower, in-field tests were subsequently performed with the forage harvester.

The stationary blower was a Badger-Northland Model BN 2054. The blower diameter was 137 cm, paddle width was 20 cm and operating rotational speed was 540 rpm. Steel and polyethylene were used as band surfaces. Paddle clearance between both band surfaces was set to approximately 3 mm. Flat fan spray nozzles (0.19 L/min at 69 kPa) were placed at locations near the bottom half of the blower. Six nozzles were staggered on opposite sides of the blower in holders welded to the outside of the blower's side walls. They were positioned 3 cm from the band and at an angle toward the band so that the water sprayed directly onto the blower band. Three nozzles applied water before the blower feed inlet and three applied water between the blower inlet and outlet (fig. 1).

Testing of the blower modifications was done in the summer of 1989 at the University of Wisconsin Dairy Instructional Center. Silo height was approximately 20 m. Trucks brought wilted, chopped alfalfa from the fields and emptied it onto a feeder apron, which fed the blower. The forage harvester which chopped the forage was set for a theoretical length of cut of 10 mm. The loaded feeder apron was weighed using platform scales on the four corners of the feeder apron. Input pto torque and rotational speed to the blower were measured using a torque transducer placed on the tractor pto shaft. Data were conditioned and stored on a datalogger at a frequency of 10 Hz. An average torque and speed were recorded at the end of each test and were used to calculate blower power requirement. Test run time was recorded by the datalogger and feed rate was calculated by dividing the material weight by the test run time. The average feed rate for all tests was approximately 27 t/h.

Water was applied to the blower band by the six nozzles connected to a centrifugal pump supplied by a water reservoir. The flow rate of water during each test was determined by measuring the volume of water consumed during each test and dividing by the test run time. At least three replicates were conducted for each experimental condition.

Subsequent tests were conducted using the lubrication techniques in the blower of a cut and blow forage harvester. Lubricants used were water alone or with a wetting agent, Tetrasodium EDTA (Jesco Resources, Inc., North Kansas City, MO). The wetting agent was diluted at a rate of 50 parts water to one part wetting agent at the recommendation of the manufacturer. The addition of a wetting agent was used to reduce the amount of water required for lubrication. Wetting agents are typically used for this reason in moistening cotton harvester spindles (Kepner et al., 1978).

The forage harvester used was a John Deere Model 3950. The blower diameter was 81 cm and paddle width was 15 cm. Paddle clearance with the band was set to approximately 3 mm. All tests were conducted with the forage harvester blower operating at 1000 rpm and the theoretical length of cut set at approximately 10 mm.

Four flat fan type nozzles, two on each side of the blower, were placed in a staggered position along the lower half of the blower housing. The nozzles were mounted approximately 19 mm from the blower band angled toward the blower band. Two nozzles were located before the feed inlet of the blower and two were located between the inlet and outlet (fig. 2). The four nozzles were supplied by a small electric powered diaphragm pump through a pressure regulator. A 57 L tank was placed on top of the cutterhead housing for storage of the lubricant. To obtain the desired flow rate, two sets of nozzles were calibrated at different pressures. Since the specific gravity of the wetting agent was very close to that of water, water only was used for the calibration. Flow rates of 57 and 228 L/h were used.

A torque transducer was placed between the tractor and harvester so the entire machine power could be

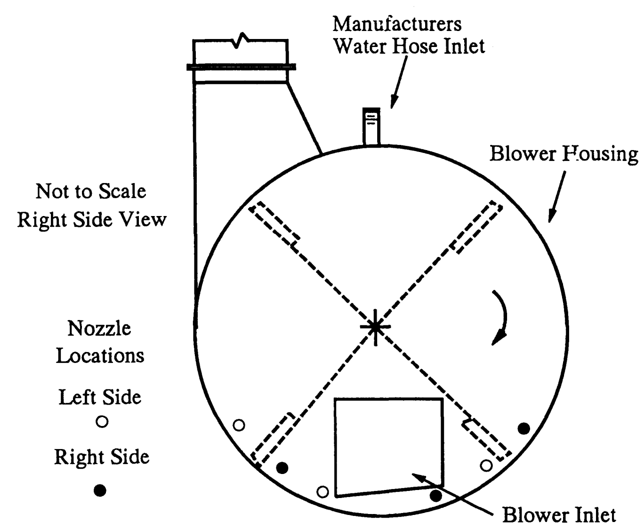

Figure 1–Nozzle location on stationary forage blower.

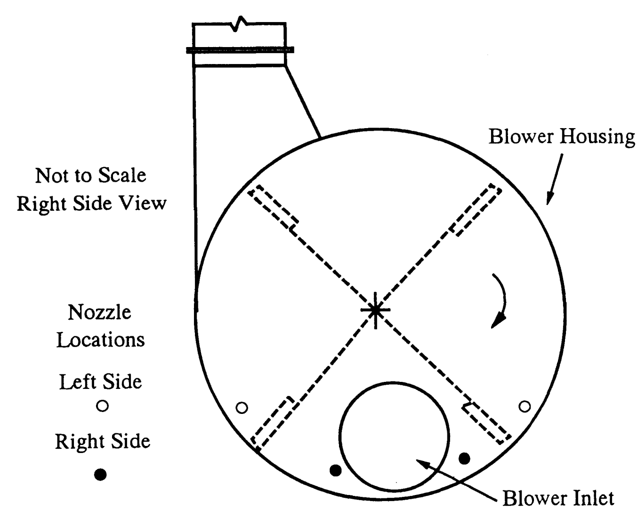

Figure 2–Nozzle location on forage harvester blower.

determined. Torque and speed measurements were taken at a frequency of 10 Hz and averaged for each run. These measurements, along with the start and end time of each run, were recorded with a datalogger. Power, feed rate and specific energy were determined using the same procedure previously described. The specific energies reported for the forage harvester represent total machine requirements.

Each test run was approximately 60 m in length and the mass of forage collected ranged from 180 to 450 kg. A sample from each run was taken to determine the material moisture content using the oven dry method (103° C for 24 h, ASAE Standard S358.1, ASAE, 1991). At least five replicates were conducted for each experimental condition.

Moisture content of the crop varied throughout a test. In order to reduce the effect of varying moisture, the specific energy of the forage harvester was adjusted using empirical moisture compensation equations as outlined in Engineering Practice EP502 (ASAE, 1991). These equations bring all feed rate and specific energy measurements to a common moisture content of 65% wet basis (w.b). This procedure reduced data scatter as a result of varying crop moisture when compared to data on a wet or dry matter basis (Linde and Bowen, 1988).

Statistical analysis of feed rate and specific energy data was conducted using either a one way or two way analysis of variance. If a test was repeated different days and or with a different cutting, then a two way analysis of variance was conducted. The least significant difference (LSD) indicate no statistical difference at a probability of 5%.

RESULTS

STATIONARY BLOWER TESTS

A series of tests were conducted to determine how the location of water application in a stationary blower affected the specific energy requirement . The locations tested were:

1. Before and at the material inlet location.
2. At the material inlet and before the blower outlet.
3. On top of the blower band (manufacturer's water inlet hose connection).

The first two application locations were achieved by supplying water to selected nozzles as previously described. Only a steel blower band was tested.

There were no significant differences between energy requirements for any of the water locations (Table 1).

TABLE 1. Stationary blower energy requirements as affected by lubricant flow rate and location

Lubricant Rate and Location	Moisture Content (% w.b.)	Wet Basis Specific Energy (kWh/t)	Number of Tests
Before Feed Inlet (125 L/h)	43.7	0.89	3
After Feed Inlet (125 L/h)	44.0	1.03	4
Manufacturers Hose Inlet (434 L/h)	41.3	1.04	3
LSD		0.37	

However, the water applied before the material inlet led to the lowest average specific energy. Perhaps the water applied before the inlet was able to act as a lubricant for a longer distance along the blower band than the water applied closer to the blower outlet. Water applied on top of the blower band was likely mixed with the incoming forage and was unable to lubricate the band as directly as water applied at the band. Addition of water at the top of the blower band required a much greater flow rate relative to the forage throughput to prevent plugging of the blower pipe. Water applied at the top kept both paddles and band relatively free of gum accumulation. The nozzles at the side locations kept only the band free of gum accumulation.

Tests were conducted to determine how varying the water flow rate affected specific energy. Water flow rates of 0, 141, and 220 L/h were used. Water was applied to a steel band both before and after the blower inlet using the side mounted nozzles. The results show that the amount of water had little effect on the specific energy, but any water lubrication reduced energy requirements relative to no water (Table 2). However, this test showed no statistical difference between the energy requirements with and without water lubrication. It was observed that only slight gum accumulation occurred in this test.

A second test was conducted to determine if water application could significantly reduce the specific energy requirement of the blower when gum accumulation was present. Water flow rates of 0 and 170 L/h were used. Water was applied to steel and polyethylene bands both before and after the blower inlet using the side mounted nozzles. During this test, significant accumulations of gum were observed to have occurred with both types of band surfaces. This problem was so acute that the blower pipe often plugged when water lubricant was not applied. Data from test runs where plugging occurred was discarded. The addition of water lubricant reduced the blower energy requirement by an average of 26% (Table 3).

No significant energy advantage was found when comparing the polyethylene and steel bands. Significant gumming occurred on the polyethylene band when no water lubrication was used. If gum accumulation occurs, such that the forage drags along a gum layer rather than the band surface, the type of surface beneath the gum layer is irrelevant.

When water alone and the water/wetting agent mixture were applied on the blower band of a forage harvester, specific energy requirements were not affected (Table 4). However, these tests were conducted when material moisture did not produce appreciable gum accumulation in the blower when the harvester was operated without lubricant. Finner (1966) indicated that alfalfa gum

TABLE 2. Stationary blower energy requirements as affected by lubricant flow rate

Lubricant Rate and Location	Moisture Content (% w.b.)	Wet Basis Specific Energy (kWh/t)	Number of Tests
0 L/h	42.0	0.95	6
141 L/h	42.5	0.84	6
220 L/h	44.5	0.84	6
LSD		0.16	

TABLE 3. Stationary blower energy requirements as affected by lubricant flow rate and band surface material

Lubricant Rate and Location	Moisture Content (% w.b.)	Wet Basis Specific Energy (kWh/t)	Number of Tests
0 L/h Steel	55.0	1.07	6
170 L/h Steel	55.0	0.78	6
0 L/h Polyethylene	53.5	1.12	8
0 L/h Polyethylene	54.4	0.84	6
LSD		0.27	

TABLE 6. Energy requirements with lubricants at common flow rates with gumming present in forage harvester blower

		Moisture Adjusted		
Lubricant Rate	Moisture Content (% w.b.)	Feed Rate (t/h)	Specific Energy (kWh/t)	Number of Tests
None (0 L/h)	50.8	17.9	2.10	6
Water Only (57 L/h)	50.2	19.1	1.78	6
Water+ Wetting Agent (57 L/h)	47.3	16.7	1.74	6
LSD		2.8	0.23	

accumulation was generally not a concern at moistures above 55% (w.b).

Table 5 presents results when the material moistures produced a significant amount of gum accumulation in the blower. In this test, gum accumulation of approximately 2 mm thickness was observed on the blower band. A type T thermocouple was attached to the outside of the blower band, midway between the inlet and outlet. When no lubricant was used, a temperature rise of almost 38° C above ambient was measured. When the lubricants were used the measured temperature rise was approximately 7° C above ambient. The water only lubricant decreased the specific energy requirement by 10% while the water/wetting agent mix decreased it 13%. There was no significant difference in specific energy between the two lubricants.

TABLE 4. Energy requirements with lubricants applied when gumming was not present in forage harvester blower

		Moisture Adjusted		
Lubricant Rate	Moisture Content (% w.b.)	Feed Rate (t/h)	Specific Energy (kWh/t)	Number of Tests
None (0 L/h)	59.5	18.0	2.11	12
Water Only (228 L/h)	57.3	16.1	2.06	12
Water + Wetting Agent (57 L/h)	56.9	16.1	2.09	12
LSD		1.7	0.11	

TABLE 5. Energy requirements with lubricants applied when gumming was present in forage harvester blower

		Moisture Adjusted		
Lubricant Rate	Moisture Content (% w.b.)	Feed Rate (t/h)	Specific Energy (kWh/t)	Number of Tests
None (0 L/h)	47.2	16.1	2.01	12
Water Only (228 L/h)	43.8	15.6	1.81	12
Water+ Wetting Agent (57 L/h)	41.7	15.8	1.75	12
LSD		0.9	0.09	

When each lubricants was applied at 57 L/h and significant gum accumulation occurred, the water/wetting agent mix reduced the specific energy requirement by 17% while the water alone produced a 15% reduction (Table 6). Again there was no significant difference using the two lubricants, even at the reduced flow rate. The wetting agent was expected to allow the use of a reduced flow rate and still prevent gum accumulation. However, when both lubricants were applied at the lower flow rate of 57 L/h, the reduction in specific energy was similar for the two lubricants. There was no advantage to using the wetting agent, because only a low flow rate of water (57 L/h) was required to reduce blower gum accumulation and friction loss.

Overall forage harvester specific energy requirement was reduced 15% by blower lubrication when gum accumulation was present. If the blower accounts for about 40% of the total machine energy, then the blower energy requirement was reduced 35%. This was similar to the results obtained with the stationary blower.

SUMMARY AND CONCLUSIONS

The application of moderate flow rates of water as a lubricant on the blower band had the most favorable effect on reducing the friction loss at the band of a stationary blower. Friction loss was reduced because the lubricants prevented gum accumulation on the blower band.

Using nozzles to direct water onto the blower band reduced the specific energy requirement by 27% for a steel band when gum accumulation was present. When testing the location of the application, it was found that when water was applied at or before the location where the material entered the blower, the same improvement was achieved with much less water than when water was added through the top of the blower as is currently the practice. Lining the blower band with polyethylene proved to be insignificant in reducing the friction loss because gum accumulation was observed on this material.

Application of a lubricant did not significantly affect the energy requirement of a forage harvester when gum accumulation was not present on the blower band, . When gum accumulation was present, a flow rate of water lubricant at 57 L/h reduced the specific energy requirement by 15%. The use of a wetting agent as a lubricant proved to have no advantage compared to water alone.

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