APPLICATION TECHNOLOGY OF ANAEROBICALLY DIGESTED DAIRY SLURRY IN UPLAND FARMING

Tadashi Kishimoto, Kunio Nishizaki, Kazutaka Umetsu, Junichi Takahashi
Dept. of Agro-Environmental Science, Obihiro University of Agriculture and Veterinary Medicine, Inada-cho, Obihiro, Hokkaido, 080-8555, Japan

ABSTRACT

Some slurry handling and spreading systems have been introduced to ensure that the intended amount of nutrients in slurry is applied to the field. One unit of a disk type open slot injector with a gauge wheel for cutting depth control was used for experiments to determine the soil-machine interactions. Cutting resistance of a disk increased with increasing cutting depth of the disk. Motion resistance of a gauge wheel decreased with increasing cutting depth of the disk. This is thought that vertical load acting on the wheel decrease with increasing cutting depth of the disk, and the reduced vertical load to the wheel transferred to the disk.

Keywords: Injector, motion resistance, tillage resistance, disk

INTRODUCTION

The ordinance for the management and application of animal manure was issued in 1999, and the penalty will be imposed to farmers since 2004 for the protection of environment such as air pollution and water contamination. It regulates (1) the requirement of appropriate structures regarding the construction of facilities for storing slurry and manure, (2) the prohibition of dunghills piled up in the field, and (3) the prohibition of slurry stored in holding pond without waterproofed sheet. Then, some dairy farmers face the introduction of an adequate manure treatment system to their farms.

Biogas plant was introduced to Hokkaido as one of the methods to resolve the problems of manure treatments. This system adapts anaerobic fermentation and produces biogas. Though the initial cost of this system is quite high, the biogas generates heat and electricity through co-generation systems. However the same amount of digested slurry as raw slurry input to a digester was output to a slurry store after the fermentation.

Several systems for slurry application to upland and grassland fields have been introduced in European countries. The use of a slurry tankers and injectors in these systems has been also introduced recently into Hokkaido, Japan to treat the animal effluent including digested slurry as liquid manure. However, it is still in the trial use stage so suitable slurry handling and spreading systems for local use and their performance have not been obtained. Chambers et al. (2001) pointed out that adequate machinery was selected to give accurate slurry application. They also recommended selecting the right handling and spreading system to ensure that the intended amount of nutrients from slurry have been applied to the crop. They also described the details of slurry distribution systems.

In order to design or select a system suitable for the slurry application to grassland in Hokkaido, the factors of soil-machine resistance by the slurry tanker or the injector must be quantified to reduce the energy requirement. Factors affecting soil-machine resistance and their impacts on reducing energy requirements of slurry injecting implements were discussed by Kishimoto et al (2002). There are various types of injectors, and one of them is an open slot shallow injector. As the injector is suitable for slurry distribution to grassland (JOSKIN, 1999), one unit of open slot injectors is used for experiments to measure soil-machine resistance and to determine soil-machine interaction.

SLURRY SPREADING SYSTEMS

It is important that adequate machinery is selected to give accurate slurry application. Chambers et al. (2001) recommended selecting the right handling and spreading system to ensure that the intended amounts of nutrients from slurry have been applied to the crop. The following are the four main types of slurry distribution systems (Chambers et al. 2001).

Figure 1: Typical broadcast spreader

Slurry distribution systems

Broadcast spreader (splash plate or nozzles)

Figure 1 shows a typical broadcast spreader. The slurry is forced under pressure through a nozzle, often onto an inclined plate to increase the sideways spread.

Band spreader

Figure 2 shows a typical band spreader. The spreader boom has a number of hoses connected to it, distributing the slurry close to ground in strips or bands. It is fed

Figure 2: Typical band spreader

with slurry from single pipe, thus relying on the pressure at each of the hose outlets to provide even distribution. Advanced systems use rotary distributors to proportion the slurry evenly to each outlet.

Trailing shoe spreader

Figure 3 shows a typical trailing shoe spreader. This has a configuration similar to the band spreader with a shoe added to each hose allowing the slurry to be deposited under the crop canopy onto the soil. It is also possible to spread in growing crops without contaminating the crops.

Figure 3: Typical trailing shoe spreader

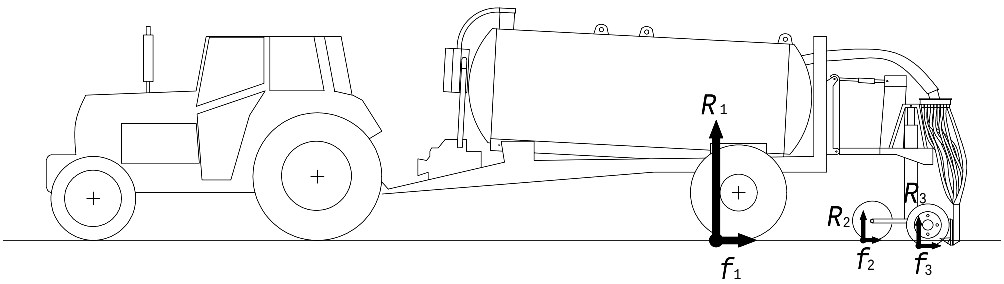
Injector

Slurry is injected under the soil surface. There are various types of injectors but each fits into one of two categories. One of them is open slot shallow injection for up to 50 mm depth. The other is deep injection for depths greater than 150 mm. Figures 4 and 5 show the shallow and deep injectors respectively**.**

Figures 4: Typical shallow injector

Figures 5: Typical deep injector

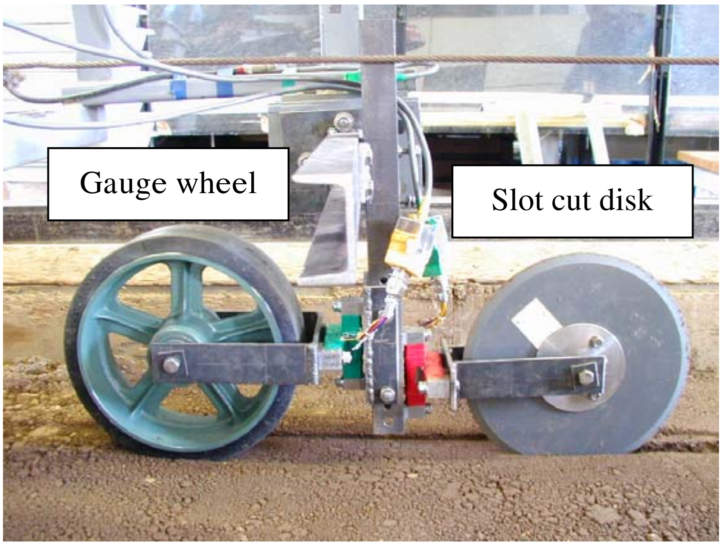
Materials and Methods



Figures 6: The schematic diagram of external forces acting on a shallow injector and a tanker

Figure 6 shows the schematic diagrams of external forces acting on an open slot injector and tanker. The gauge wheel and slot cut disks of the injector come in contact with grass as the injector is usually operated on the grassland. The resistance between these parts and grass is produced. In this study, the magnitude of these resistances, f_2 and f_3 in Fig. 6 are measured.

Figure 7 shows the experimental unit of an open slot injector. Experiments were conducted on an indoor soil bin which contains loam. The composition of the loam was 48.0 % sand, 37.5 % silt and 14.5 % clay. Preparation of the soil for experiments was done by rotary tilling, compacting and leveling after adding adequate water for desired moisture content. Moisture content of the soil was about 13 % in wet base. Average cone index of the soil in 10 cm depth was 760 kPa. The forward velocity of the tested device was adjusted to the 0.17m/s. Cutting depths of the disk are set at 2, 4, 6 and 8 cm. Additional weight of 40, 60 and 80 kgf is applied to the unit.



Figures 7: Experimental unit of shallow injector

RESULTS AND DISCUSSION

Figures 8 shows the measured cutting resistance of the disk *FHd* and motion resistance of a gauge wheel *FHw* at a 60 kgf additional weight. The absolute value of cutting resistance of a disk increased with increasing cutting depth of the disk. The absolute values of motion resistance of a gauge wheel decreased with increasing cutting depth of the disk. However, the disk cutting resistances at 2 cm as shallow depth are not significantly different.
Figure 9 shows the measured vertical load acting on the disk *FVd* and the gauge wheel *FVw* at a 60 kgf additional weight. The vertical load acting on the gauge wheel decreased with increasing the cutting depth. The vertical load acting on the disk increased with increasing the cutting depth. This phenomenon is almost similar when the additional weight increased. The interaction between the injector unit and soil is explained by the phenomena that the reduced vertical load to the wheel transferred to the disk.

Table 1 shows the ratio between resistance to vertical load at a slot cut disk and a gauge wheel. The ratios of the gauge wheel at the same additional weight are thought to be almost constant even the disk cutting depth increases. This shows that the influence of the motion resistance to the total resistance is almost constant. However, the ratio of the disk at the same additional weight significantly increases as the cutting depth increases. This shows that the disk cutting resistance mainly affects the increase of total resistance.

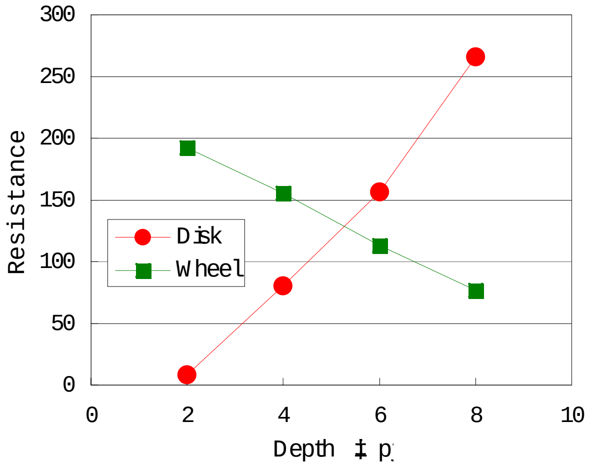


Figure 8. Relationship between disc cutting depth and resistance at 590 N additional weight

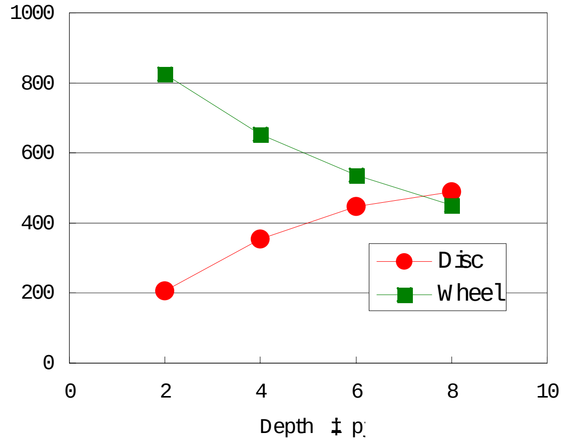


Figure 9. Relationship between disc cutting depth and vertical load at 590 N additional weight

Table 1: Ratio between resistance to vertical load at slot cut disk and gauge wheel

Depth (cm)	Disk *FHd/FVd*			Wheel *FHw/FVw*		
	Additional weight					
	392 N	589 N	785 N	392 N	589 N	785 N
2	0.071	0.040	0.057	0.200	0.233	0.295
4	0.164	0.226	0.149	0.221	0.238	0.264
6	0.288	0.350	0.483	0.213	0.211	0.265
8	0.485	0.544	0.726	0.229	0.170	0.306

The disk sides contact area to the soil may increase as the cutting depth increases. This shows that reducing the resistance produced by the friction between the disk and the soil may be effective to reduce total resistance acting on the injector unit.

CONCLUSIONS

One unit of a disk type open slot injector with a gauge wheel for cutting depth control was used for experiments to determine the soil-machine interactions. Cutting resistance of a disk and motion resistance of a gauge wheel were measured in loam at different disk cutting depth and various vertical loads. The following conclusions were drawn from the experiments

1. Cutting resistance of a disk increased with increasing cutting depth of the disk.
2. Motion resistance of a gauge wheel decreased with increasing cutting depth of the disk.
3. This is thought that vertical load acting on the wheel decrease with increasing cutting depth of the disk, and the reduced vertical load to the wheel transferred to the disk.
4. The influence of the motion resistances to the total resistance is thought to be almost constant.
5. The ratio of the disk at the same additional weight significantly increases as the cutting depth increases.
6. The disk cutting resistance mainly affects the increase of total resistance.

REFERENCES

1. CHAMBERS, B., N. NICHOLSON, K. SMITH, B. PAIN, T. CUMBY & I. SCOTFORD, 2001. **Managing Livestock Manures Booklet 3 Spreading systems for slurries and solid manures**. Ministry of Agriculture, Fisheries and Food. London, UK. pp18
2. JOSKIN, 1999. JOSKIN **Technical skills within**, JOSKIN, Soumagne, Belgium. pp19
3. KISHIMOTO, T., WAY, T. R., JUN, H. & K. NISHIZAKI, 2002. **Factors of soil-machine resistance and soil compaction at the operation of animal effluent application, In: Greenhouse Gases and Animal Agriculture** (Eds: Takahashi, J., Young, B. A.), Elsevier Science, Amsterdam, The Netherlands, 323-330