Improving animal traction technology


Photo: Paul Starkey

Diversifying operations using animal power

Improving the efficiency of an animal-powered gear to meet the requirements of different machines

by

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Abstract

The use of animal traction as an energy source for agricultural operations is one step in the mechanisation of agriculture in developing countries. An animal-powered gear, based on a double-friction wheel transmission, can be used to drive various machines (cereal mill, rice huller, oil press, etc). Based on the torque and speed requirements of these machines, and the power available from typical draft animals in Africa, the University of Hohenheim, Germany, has carried out research to determine the optimal configuration of the power transmission to achieve the best efficiency for a given combination of animal and machine. Using a 100 mm rough friction wheel with a pressing force of 500 N, an efficiency of more than 90% was obtained.

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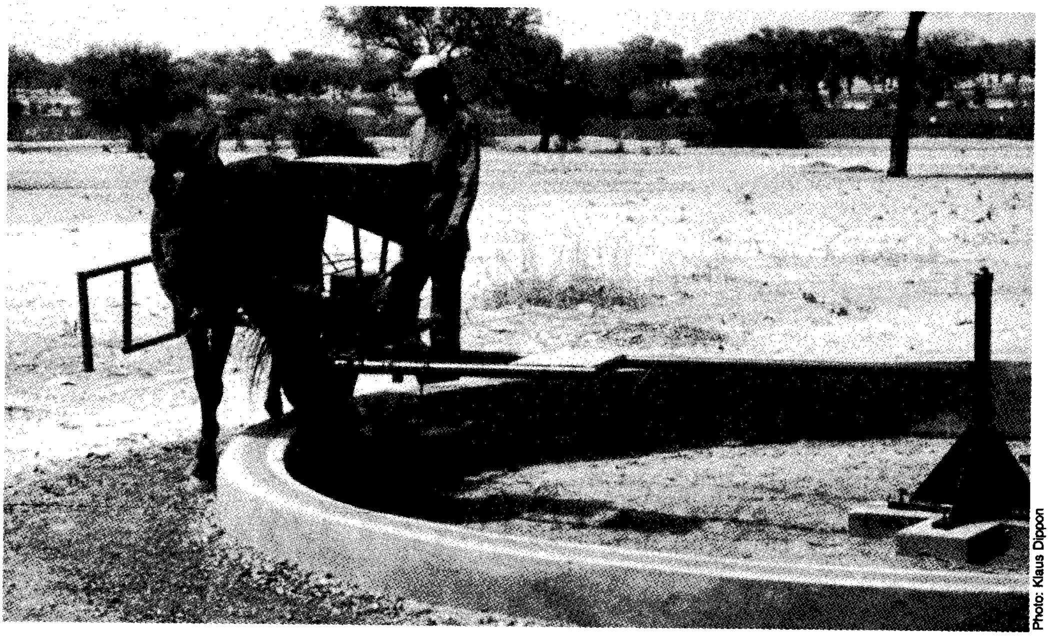
Objectives

The "Documentation, improvement and dissemination of animal-powered technology" project, sponsored by GATE (German Appropriate Technology Exchange, a division of the German agency for technical cooperation—GTZ) has introduced animal-powered machines in some West African countries (Burkina Faso, Mali, Niger, Senegal, Sierra Leone) and in Zambia (Franzke, 1991; TDAU, 1990). These machines should be used for mechanising agricultural operations in remote areas.

Most project activities focus on the use of animal-powered gears in cereal grinding mills (Photo 1) and water lifting devices. Using animals as a "motor" for cereal mills should relieve women of the strenuous work of pounding and reduce the time they spend each day making flour: to produce

Photo 1: An animal-powered mill being pulled by a horse in West Africa



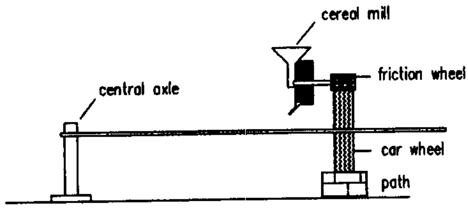


Figure 1: Drive unit of the animal-powered gear

the weekly flour requirement of a typical Zambian rural household takes about two hours of pounding a day (Löffler, 1990). The aim of the project is not to introduce animal traction where it is unknown, but to encourage the use of existing animals.

In Africa 90% of the draft animals are used for soil tillage (Busquets, 1986). Because this is a seasonal operation the animals only work for 40 days a year, on average. If animal traction is known and practised, the introduction of animal-powered gears allows animals to be used for longer periods, which should improve the economics of animal keeping.

The construction of the disseminated animal-powered gear is well adapted to rural conditions in developing countries. Most of the components are obtained from the local market, the only ones imported being high quality bearings which reduce frictional losses and guarantee continuous operation. Skilled local blacksmiths and craftsmen are capable of manufacturing the power transmission, and even the grinding stones of the cereal mill will be made locally in the near future.

Optimisation of the power transmission

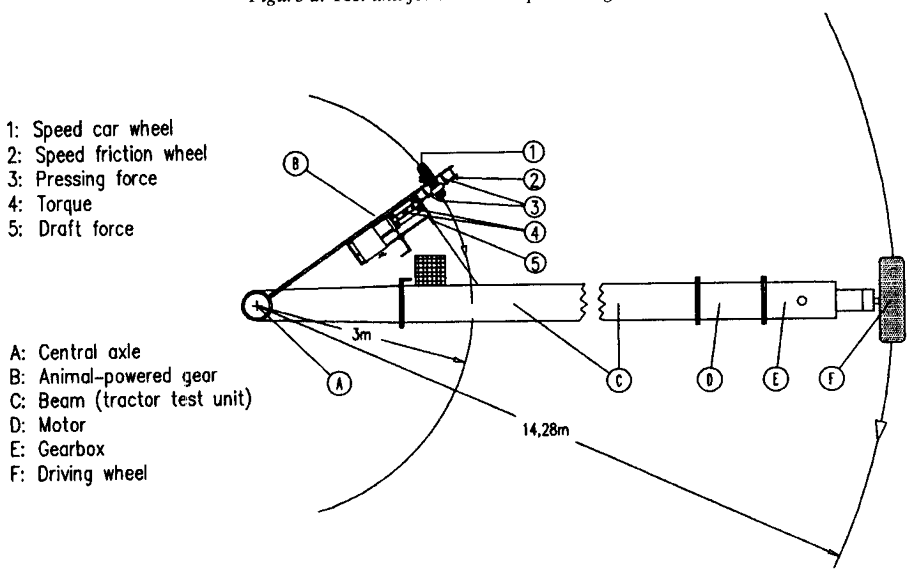
Based on the analysis of the working performance of the actual model of the animal-powered gear and the intention to drive other machines with this system, one has to think about the most suitable friction wheel combination. Figure 1 is a general sketch of the drive unit of the animal-powered gear.

By changing the diameter, material and surface of the friction wheel, one can influence the main parameters (speed and transferable torque) of the power transmission depending on the pressing force between the two wheels. This was the main idea behind subsequent investigations at the Institute of Agricultural Engineering of the University of Hohenheim, Germany. The main aim was to identify at a given power (animal) the best combination for a specific case. Furthermore one should be able to give some information about the highest efficiency which can be achieved when operating a machine at a known speed and torque.

Test unit

To obtain realistic results, a copy of the animal-powered gear now in use was fabricated. It was powered by a tractor test unit which already existed on the camp of the institute. The animal-powered gear was mounted to the pivot of the tractor test unit. They were connected by a rope with integrated load cell. A torque transducer was attached to the output axle of the friction wheel. Next to this, a brake was placed to simulate the loading of the

Figure 2: Test unit for an animal-powered gear



power transmission. Between the axles of the wheels another two load cells were installed to measure the pressing force between them. The speed of the wheels was measured using two generators mounted on the axles of the wheels. All tests were carried out at a velocity of 1.1 m/s of the tractor test unit beam. Construction and arrangement of these components are shown in Figure 2.

Parameters investigated

The tests are based on the parameters listed below:

- surface (smooth, rough)
- diameter of friction wheel (60, 80, 100, 120 mm)
- friction wheel material (steel, wood)
- pressing force (300, 500, 1000, 1500, 2000 N)

Starting from the 120 mm friction wheel used in the actual animal-powered gear only smaller diameters were tested. Mounting wheels with smaller diameters will increase the speed available for the attached machine and also cause a smoother running at a reduced loading. The pressing force is directly proportional to the transferable power and was investigated in a range typical for animal traction.

During the test the brake was tightened continuously until the friction wheel slipped on the car wheel. All data were collected with an analog data logger and afterwards evaluated by suitable hard- and software.

Results

The most important parameter which characterises the power transmission is its efficiency. It is determined as the quotient of the power (P_{ab}) measured at the axle of the friction wheel and the input power (P_{zu}):

$$\eta = \frac{P_{ab}}{P_{zu}} = \frac{M_d \cdot n_{fr} \cdot 2\pi}{F_z \cdot V_R}$$

where:

M_d = torque (Nm)
n_{fr} = frequency of rotation of the friction wheel (revs/min)
F_z = draft force (N)
V_R = velocity of the beam (m/s)

Figure 3 shows the pattern of the efficiency against tractive force. For all configurations tested, the curves have a comparable pattern. It can be described as a parabolic function. Increasing the pressing force will smoothen the curve and the range of a high efficiency gets larger. For practical use, high pressing forces cause a huge draft power range of comparable efficiency. However, the maximum value is significantly lower than that with low pressing forces. As illustrated, the highest

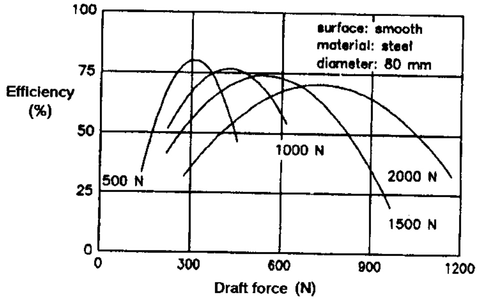


Figure 3: Efficiency of the 80 mm friction wheel at different pressing forces

efficiency of 81% for an 80 mm friction wheel at 500 N decreases to 69% at 2000 N pressing force.

Regarding the influence of the surface, one notices that the efficiency of rough surfaces is on the average 10 to 15% higher than the other ones. The maximum value of 92% was measured for the rough 100 mm friction wheel.

Taking into account all parameters, the 100 mm wheel shows the best efficiency.

If different machines should be powered, one has to consider the different torque requirements. As shown in Figure 4, the main difference in the curve pattern of torque against draft force for different diameters is the gradient of the straight line. In general the bigger the diameter the higher the gradient. The pressing force has no influence on the gradient but determines the maximum value of the transferable torque.

The best efficiency at a sufficient torque is worthless if the animal cannot provide the required draft force. Considering the pattern for the 100 mm friction wheel for different materials shown in Figure 5, a pair of oxen with a tractive force of about 1200 N can be used in all configurations. Hence the use of a donkey with a draft force of at least 250 N is limited to a pressing force of 450 N for the rough friction wheel. A wooden friction

Figure 4: Transferable torque at rough surface

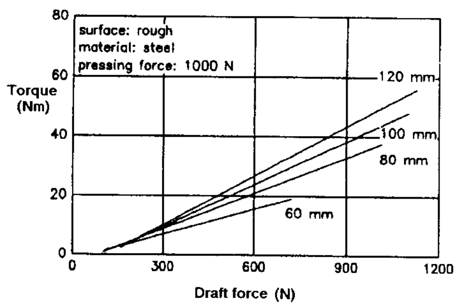


Table 1: Friction wheel combinations for a donkey with 250 N tractive power

	Diameter (mm)	*Pressing force (N)*	*Efficiency (%)*	*Torque (Nm)*	*Frequency of rotation (revs/min)*	*Draft force (N)*
Smooth surface						
1	60	500	64	3.9	303	217
2	100	500	84	9.1	182	225
3	100	300	71	7.1	182	198
4	120	300	75	5.4	152	124
Rough surface						
5	60	500	81	5.3	303	214
6	60	1000	81	6.7	303	226
7	80	500	89	6.5	227	293
8	120	500	77	12.8	152	251
Wooden surface						
9	60	500	79	6.8	303	284
10	60	1000	74	6.2	303	286
11	100	500	87	8.0	182	193

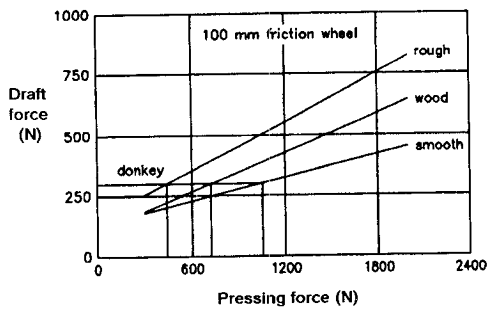
wheel increases the pressing force to 700 N; using smooth friction wheels, one can apply a pressing force of more than 1000 N.

Concerning the practical use of this investigation, it is possible to select the best friction wheel based on the measured data. For this selection the power of the animal has to be known.

As an example, Table 1 shows all the friction wheel combinations investigated for a donkey with a tractive force of 250 N. For a supposed torque requirement of the machine of 7 Nm at a speed of 300 revs/min, combinations 1, 5, 6, 9 and 10 are valid. Taking into account the efficiency, the only practicable solutions are combinations 5 and 6.

Normally, the measurement of the pressing force in remote areas is not possible. Using a spring balance or people of different weights standing on the pivot mounted machine to adjust the pressure are simple methods to get information with a sufficient accuracy of the real pressing force.

Figure 5: Draft forces of the 100 mm friction wheel at the highest efficiency



Conclusion

The investigations have provided information on how to achieve the most efficient power transmission. The greatest efficiency was obtained with a 100 mm rough friction wheel. The most efficient pressing force depends on the draft force provided by the animal.

Acknowledgements

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