FLEXISEEDER DRIVE MODULES:

AN OVERVIEW INCLUDING TECHNICAL SPECIFICATIONS

Flexi Technical Note - 001

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SUMMARY (ABSTRACT)

Drive systems are a pivotal component of plot and farm seeders as well as many other pieces of agricultural equipment. Drive modules which can be easily adapted, adopted and shared across a wide range of equipment, both for research and production, have considerable application for increasing efficiency and saving costs without compromising quality. This technical note introduces and provides technical specifications for two new Flexiseeder drive modules released at this conference, a **digital gearbox** and an **electrically powered, "vari-speed" mechanical drive,** developed jointly by John Brooks[1], S&N International[2], SLU[3] and BACD[5] under the Flexiseeder Project[7], and launched for use into the public domain.

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[7]www.flexiseeder.com. A voluntary user-group project of the Seed and Seed Drilling Technology Help Group: International Association for the Mechanization of Field Experiments / Global Institute and Agricultural University Internet Hub (IAU Trust).

INTRODUCTION

Plot seeders are only as good as their drive systems. The procurement and set up costs of drive systems constitute a significant proportion of the total cost of the equipment which they power. Their overall dimensions and flexibility in placement are major dictates of design. Anything which can be done to improve efficiency, affordability, flexibility and end-user comfort adds substantially to the overall "worth" of the machine.

Where end-users form part of the core product team, (which is a bottom up approach), drive modules can be designed and developed through the identification, assemblage and refinement of standard components which are readily available in the global market. Over the past eight months, this has been successfully demonstrated in applied ways through the two products (a digital gear box and an electrically driven "vari-speed" box) introduced and described in this technical note as case studies. By using this modular approach "drive" costs (including research and development costs) have been minimized and spread across a range of products / markets, thus turning an un-economic specialised product into something multi-purpose which could pay its own way and prosper.

Electric / digital drive systems are far more flexible than mechanical drives (shafts, sprockets and chains) and hydraulic drives**.** However, the up-take and use of electric drives / gearboxes on "affordable / intermediate technology" plot seeders and other research equipment has been hindered by cost and reliability issues compared with using chains, sprockets and shafts, and hydraulic drives. The advent of mass produced, reliable and affordable programmable DC stepper motors, reliable high frequency encoders and permanent magnet DC motors matched with a standard range of variators and gear boxes has changed this. This is demonstrated by the following case studies.

This technical note is one of six listed in the attachments prepared as additional technical background to Leuchovius et.al. (2008) and Stevens et al. (2008)[8].

CASE STUDY I: Development of the Brooks-S&N Electronic Gearbox

Perceived Need

Mechanical drive systems requiring chains, sprockets and shafts proved too restrictive for the design and development of new multi-purpose flexiseeders[9], both as plot seeders and as farm machines. At the same time, similar restrictions were being experienced in other research and production work taking place within the Flexiseeder project. Alternative drive systems were needed. Those available in the market were either too expensive, or failed to meet the reliability and precision expectations of the group. A search was made of the market for suitable high quality yet affordable "cross over technologies" able to be adapted to the group's needs.

Background

Prior to joining the Flexiseeder project, John Brooks had provided equipment for use in ISSF (International Skeet Shooting Federation) Trench shooting machines manufactured by Canterbury Trap International Ltd (Plate 1). AC motors were used to oscillate the trap continually on their simple / basic machine. For Olympic Trench events (including the up-

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[8] Covering the evolution and development of modular components of the Flexiseeder project, under the IAMFE / IAU Seed and Seed Drilling Help Group formed at IAMFE 2004 in St Petersburg.

[9] Equally suited to zero (eco) tillage, reduced tillage and conventional cultivation.

coming Olympics in Bejing), 15 of these simple traps would have been required for each bunker layout. Instead, one multi-purpose trap machine with combined position control to tilt, yaw and also reposition in the traverse plane, replaced the traditional 15 trap layout. This new system is programmable to emulate the nine different ISSF tables for height and angle as described in the international rule book. The system has a design registration and patent pending. John Brooks Ltd was therefore invited to join the Flexiseeder project. It was from this background that the Brooks – S&N electronic gearbox originated as a cross-over design using integrated motion control

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Canterbury Trap
International Ltd

www.canterburytrap.co.nz

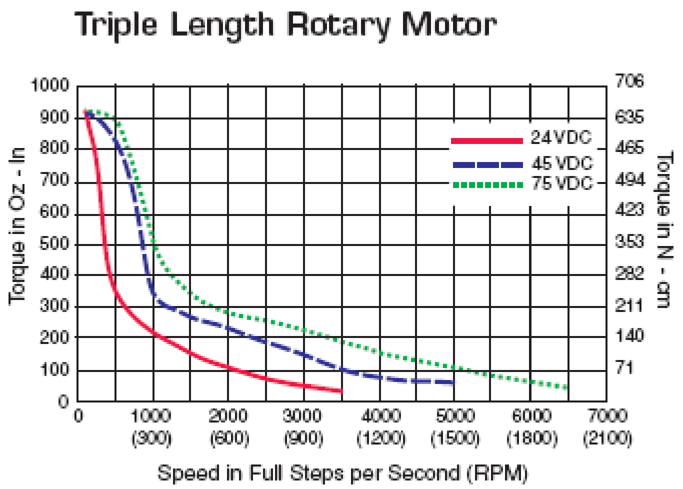
Plate 1. Olympic skeet launcher from which integrated motion control technologies were extended into the Flexiseeder project.

Product Development and Release

Unit Specifications: In the past, a separate Position Controller or PLC, Drive and peripherals would have been used. Over the last few years manufacturers have developed products which combine the motor, drive and control electronics in a single unit. This Integrated Motion Control Solution reduces the number of components required. The result is a less expensive, product.

In the multi-component solution, each component must be mounted into an enclosure, with wire and cabling run between the various components. By implementing an integrated solution, the assembly labour can be reduced to mounting and interfacing a single component. So there is often a cost saving here as well.

The maximum torque of a stepper motor occurs around zero rpm. They are available in different frame sizes and lengths. The longer versions offer more torque, although there is a sharper drop-off as the RPM increases (see graph below) . Supply voltage has a significant impact on the available torque as well.



Bench testing: Static torque measurements were taken by J Brooks Ltd with the assistance of S&N International Ltd using a range of different metering devices (including an Accord Cell Wheel, and Oyjord cell wheels). Against this, suitable gearbox ratings and ratios were calculated based on the range of land speeds and plot lengths anticipated in different countries. Testing was then carried out under load with two different gearbox ratios and 12V then 24Vdc supplies.

Spreadsheets were used to both calculate and record torque test results, the selection of encoder and motor resolutions and calibration factor used in the controllers program. While automating machines, determining the operating ranges for different conditions is pivotal since these affect the choice of encoder and motor resolution. It proved necessary to use a 24V supply, particularly at the higher motor rpms, which relates to shorter plot lengths and faster land speeds. *Since most tractors run 12V systems, the unit comes with a 12/24V converter with sufficient output capacity to drive 2-3 motors.*

Bench testing in John Brooks Ltd workshop, Christchurch, New Zealand. www.johnbrooks.co.nz

“Smart” Stepper Motor

www.mdriveplus.com

Control box, Mk2

(Shower proof)

Digi-gearbox retro-fitted to early Oyjord cell wheel

Encoder

(10,000 pulse / rev)

Encoder mounted top left behind steel protector

"Brooks Drive" Worm Gearbox and mounting torque arm fitted to base of S&N Flexiseeder cell wheel assembly[10].

Digi-gearbox retro- fitted to Accord Cell wheel as test bed.

Plate 2. Brooks – S&N digital gearbox developed and released into the public domain during May 2008 under the Flexiseeder project.

Programming: Only 25 percent of the available programming capacity has been used so far. There is plenty of scope for adding additional functionality in the program. For example this could include linear variable dosing or variable spray volume delivered over a plot, or a starting cone when seeds are released.

Controls: The Electronic gearbox ratio is set using simple thumbwheel switches with a potentiometer adjustment, to compensate for land wheel diameter differences. Motor direction and Run switches are provided. These could in future be replaced by a digital display and keypad panel (HMI).

Motor: Stepper motors were used[11] since they are inherently a positioning device, robust in design with the added advantage of having no commutator or brushes. Micro-stepping and refinements in current modulation techniques have enhanced torque performance and smoothness of rotation. These motors will operate from a low – voltage dc power supply (12 to 75 volts). A "Smart" NEMA 34 stepping motor is used with on-board electronics and +12 to +75 VDC micro stepping drive and controller. By applying innovative techniques to control current flow through the motor, resonance is significantly dampened over the entire speed range and audible noise is reduced. The micro-step resolution of up to 51,200 steps/revolution helps significantly when operating in a variable speed control mode.

This product combines a full-featured controller with motor and driver. The unit includes I/O Lines, an Analog Input, encoder Input, and RS485 serial communications port. The latter is used for connection to a PC via USB or RS232 converters. Windows based Software is provided for Parameter Setup and Application programming.

Gearbox: A simple J Brooks worm type right-angle drive box[12](15:1 ratio) is married to the stepper motor using a coupling flange. Planetary gearboxes are normally used with small to medium stepper motors. However for this application, <u>a less precise and costly solution</u> proved adequate.

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[10] Note: 15.1 ratio worm gearbox used for digi-gearbox and 7.5:1 ratio box used for direct mechanical drives

[11] While DC motors would normally be the traditional choice we required a position sensor mounted on the motor (eg: an encoder).

[12] For the Trap shooter they have the added advantage of self locking, avoiding the need for a brake (in ratio's above 50:1).

Encoder: An Eltra brand encoder providing 10,000 pulses per revolution of the input shaft, mounted on the land wheel is used to provide the speed reference. Unlike a traditional tacho-generator, it can also be used for calculating the distance traveled/position if required.

CASE STUDY II: Development of the Brooks-S&N "vari-speed" electric drive

Perceived Need

Twelve and 24 Volt DC electric motors including modified 12 vehicle generators (dynamos) run as motors have been used for many years to power mechanical distributors fitted to Oyjord and other plot seeders. This has been done to provide added flexibility for placing and operating cone units and/or positioning and seating the operator(s), independent of the dictates of direct mechanical drives.

For successful operation, particularly using 12 Volt motors, relatively heavy (1/4 up to 1/2 HP) motors are required. This is needed to deliver adequate torque especially at lower speeds (600 to 800 rpm) where the motor is slowed electrically below its optimal operating speed[13]. Substantial torque is required while dispensing heavier seeds and fertilizer at higher than normal rates, such that impellor speed is maintained through the initial shock of product hitting the impellor. Impellors have usually been cast as a solid block from aluminium then machined and balanced by drilling holes in the base of the unit.

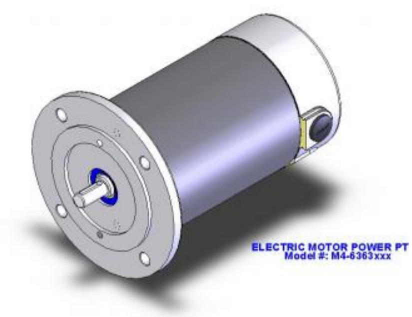
A vehicle dynamo drives clockwise, whereas historically, the impellors of Oyjord distributors have been designed and engineered to rotate counter clockwise. Initially this was overcome by using belts for the final drive. Last year, the Flexiseeder project engineered in steel, an inverse shape of an early Ojyord impellor, and direct coupled it to a new vehicle generator run as a motor, while up-grading an older system, with good results (Plate 3).

While successful, this "Farmall" conversion was not considered marketable as a standard Flexi-drive module. Better options were required for maintaining torque at lower speeds. Hence John Brooks Ltd was approached for an alternative solution which they offered, comprising a permanent magnet DC motor (12 or 28 V) coupled with a manual variator. Concurrently, a pattern was made of the original Oyjord (counter clockwise) impellor with a standard boss attached, so that replacement impellors could be cast, machined and sold at affordable prices, as part of the proposed new Flexiseeder drive module and/or spare parts. At the same time, preparations were made to set up for casting inverse impellors from the Farmall conversion.

[13] Common settings are: 600rpm for big beans, 750rpm for soya and peas, 900rpm for grain, oilseeds etc, and between 1000 and 1200 rpm for fertilizer.

Farmall conversion driven with 12 V dynamo

UDL0.18B5 63B5 Brooks drive Variator



M4-6363505 180W 1500RPM 12VDC 63B5 EMP Motor

Left: Flexiseeder Brooks-S&N mechanical vari-speed module including two impellor blocks, one cast in bronze and the other aluminium.

Because the unit is heavy (8.5 kg excluding impellor) and the centre of gravity is low, it is ideal to incorporate in self levelling devices, attached to mechanical distributors. It is also to be tested as an addition to the distributor head of air delivery systems, including self levelling devices to improve the CV between seed delivery to individual outlets (see Leuchovius et al.,2008).

Plate 3. Initial Farmall conversion shown as "project starting point" compared with the end result; a Flexiseeder Brooks – S&N mechanical variator coupled to a Permanent Magnet 12V DC Motor.

Mechanical Variator

The mechanical Variator Ratio is given as 8.2 to 1.6 which equates to an output range of approx. 185-930rpm, based on a 1500rpm input speed. The speed of a DC motor is proportional to the armature voltage, but this will drop as the load is increased . Refer to the load test results, following.

Electric Motor

The 180W [14](or ¼ HP) motor's output torque is multiplied by the variator ratio (less efficiency). Therefore at lower speeds there is more torque available. By reversing the input polarity, this motor may be rotated either clockwise or counter clockwise.

Model #	M4-6363505

[14] This size of motor is also available with a base speed of 2000rpm which equates to an output range of approx. 250 to 1250 rpm should you require a higher range.

Voltage	12 (24 Volt option available)
Speed	1500 rpm (2000 rpm option available)
Power	180 / 250 W
Enclosure	TENV
Configuration	SHT-463, FLG-46311mm Shaft with 4mm Key Slot (D63 Frame), 140mm Std. Flange (D63B5 Frame)

Load test results are provided below.

T(n.m)	N(rpm)	I(amps)	Pout(w)	Eff.(%)	Loss(w)	Pin(w)
0.00	1,750	1.96	0.00	0.0	23.56	23.56
0.10	1,697	3.47	17.77	42.6	23.91	41.69
0.20	1,683	4.98	35.24	58.9	24.57	59.81
0.30	1,668	6.49	52.40	67.2	25.53	77.94
0.40	1,653	8.01	69.26	72.1	26.80	96.06
0.50	1,639	9.52	85.81	75.1	28.38	114.18
0.60	1,624	11.03	102.05	77.1	30.26	132.31
0.70	1,610	12.54	117.99	78.4	32.44	150.43
0.80	1,595	14.05	133.62	79.3	34.94	168.56
0.90	1,580	15.56	148.95	79.8	37.73	186.68
1.00	1,566	17.07	163.97	80.1	40.84	204.81
1.10	1,551	18.58	178.68	80.2	44.25	222.93
1.20	1,537	20.09	193.09	80.1	47.96	241.06
1.30	1,522	21.60	207.20	79.9	51.98	259.18
1.40	1,507	23.11	221.00	79.7	56.31	277.31
1.50	1,493	24.62	234.49	79.4	60.94	295.43
1.60	1,478	26.13	247.67	79.0	65.88	313.56
1.70	1,464	27.64	260.56	78.6	71.12	331.68
1.80	1,449	29.15	273.13	78.1	76.67	349.80
1.90	1,434	30.66	285.40	77.6	82.53	367.93
2.00	1,420	32.17	297.36	77.0	88.69	386.05
2.10	1,405	33.68	309.02	76.5	95.16	404.18
2.20	1,391	35.19	320.37	75.9	101.93	422.30
2.30	1,376	36.70	331.42	75.2	109.01	440.43
2.40	1,361	38.21	342.16	74.6	116.39	458.55
2.50	1,347	39.72	352.59	74.0	124.08	476.68
2.60	1,332	41.23	362.72	73.3	132.08	494.80
2.70	1,318	42.74	372.54	72.6	140.38	512.93
2.80	1,303	44.25	382.06	71.9	148.99	531.05
2.90	1,288	45.76	391.27	71.2	157.90	549.17
3.00	1,274	47.27	400.18	70.5	167.12	567.30

DISCUSSION AND CONCLUSIONS

The global scope and application for modules presented in this technical note exceed the immediate uses outlined. These products will bring new opportunities in design, operator safety and comfort into the market for research; more so than where hydraulic systems have been used, without compromising equipment efficiency and affordability. At the same time, the opportunity remains for very heavy work, to use these digital drive lines to actuate hydraulic systems. The Olympic skeet launcher referenced in this article provides an example of the parallel use and cross-over of these technologies.

The use of electrically controlled and driven components facilitate, in general, the use of standard modules for plot machines. Stepper motor drivelines (or any electriacally controlled driveline) offer a flexible solution for plot machines because one can:

- Easily adopt the system for different situtations without replacing machine components
- Easily move and locate the driveline for use in different machines (seed drills, fertilizer applicators, spray equipment, etc.)
- Extend it to be controlled by GPS systems instead of a land-wheel with encoder/pulse donor
- Extend the driveline to control parts of the process, like releasing seed, lifting coulters etc. Electrically operated functions on plot machines have additional advantages over manual systems including:
    - Providing a more uniform function from time to time compared to manual operation
    - Relieving an operator for monitoring the work operation (it is easy to push a button)
    - Allowing an operator to sit in various positions and still be able to control the function
    - Being able to coordinate and control a range of linked functions from automatic GPS / driveline systems

Where next?

Future work with the step motor drive module is projected to include:

- A choice to set fixed step motor speeds regardless of machine travel speed
- Added support for linear change of dose as a function of traveled distance, with or without compensation for vehicle speed variations
- Enhancing the system with start/stop functions and possible other on/of functions
- Adding a setup/communication protocols for external control of the driveline from a computer, for example
- Development of computer control software also supporting GPS information

REFERENCES

Leuchovius, T., E.J. Stevens, D.S. Fraser, C.D. Roberts, T. Gaardlos, M. Bakkegard. 2008. Plot machine modules: More flexibility and lower costs. The Flexiseeder Approach. Proceedings of IAMFE Congress 2008, AgroTech, Århus, Denmark.

Small, G.T., N.B. Baker, E.J. Stevens, T. Leuchovius, T. Gaardlos, M. Bakkegard. 2008. Flexiseeder air assisted delivery and distribution module: An overview including technical specifications. *Flexi Technical Note - 003*. Proceedings of IAMFE Denmark 2008. AgroTech, Århus, Denmark.

Stevens, E.J., T. Leuchovius, T. Gaardlos, I. Close, N.D. Collins, G. Gray. 2008. Flexiseeder seed and fertilizer coulter module: An overview including technical specifications. *Flexi Technical Note - 004.* Proceedings of IAMFE Denmark 2008. AgroTech, Århus, Denmark.

Stevens, E.J., T. Leuchovius, T. Gaardlos, N.D. Collins, I. J. Close, G.M. Gray. 2008. Flexiseeder cell wheel and distributor module: An overview including technical specifications. *Flexi Technical Note - 005*. Proceedings of IAMFE Denmark 2008. AgroTech, Århus, Denmark.

Stevens, E.J., T. Leuchovius, T. Gaardlos, C.D. Roberts, G. M. Gray, L.P Thian. 2008. Flexiseeder frame module: An overview including technical specifications. *Flexi Technical Note - 006*. Proceedings of IAMFE Denmark 2008. AgroTech, Århus, Denmark.

Stevens, E.J., T. Leuchovius, T. Gaardlos, A. Russell, R. Zuerrer, M. Bakkegard. 2008. "Flexiseeder": A new modular approach to help improve correlation / cross-over of results between plot and field research and commercial agriculture, horticulture and viticulture. Proceedings of IAMFE Denmark 2008. AgroTech, Århus, Denmark.

Thian, L.P., E.J. Stevens, T. Leuchovius, T. Gaardlos, K.I. Thian, M. Bakkegard. 2008. Flexiseeder ”continuous-run” seed and fertilizer modules for small-scale users: An overview including technical specifications. *Flexi Technical Note - 002.* Proceedings of IAMFE Denmark 2008. AgroTech, Århus, Denmark.