Workload constraints: the measurement and interpretation of mechanical factors

by

D. C. Kemp

Overseas Division, AFRC Institute of Engineering Research, Silsoe, Bedford, UK *

Abstract

A brief description is provided of techniques developed by AFRC Engineering for measuring and logging factors that define the work done by draft animals and indicate some of its physiological effects. From the data already acquired by the use of the new instrument package in several projects, a relationship is emerging between the variability of the draft force and the heart rate of the working oxen. There is also tentative evidence of some animals' ability to recover sufficiently rapidly to be able to make use of brief respites during periods of continuous work. Both of these effects may be capable of exploitation to improve overall performance. There remains a need to identify a single indicator within acquired data patterns that would facilitate comparisons of the overall efficacy of animal-powered tasks.

Background

For many decades those attempting to improve the performance of working animals have had to rely on simple means to measure and record the mechanical factors associated with field tasks. Typically the methods used have involved measuring tape, stop watch and spring balance or other force indicating equipment. In proper hands such devices were, and still are, entirely accurate, but the quality and resolution of the data they reveal fall short of that needed to obtain a complete indication of the interactions between the animals and the implements they draw.

* Position at the time of the 1988 workshop.
A subsequent address may be found in the workshop participant address list.

In order to facilitate the more precise study of the efforts applied by draft oxen and their effects, the Overseas Division of AFRC Engineering has developed an instrument package to sense and record the parameters defining the work done and those indicative of the associated physiological responses. The package and the structure of the analytical methods with which it is associated are illustrated diagrammatically in Fig. 1.

Measurement techniques

Essentially the instrumentation consists of a set of sensors, an electronic signal condition-

Fig. 1: Schematic arrangements of the AFRC-Engineering animal power measuring system.

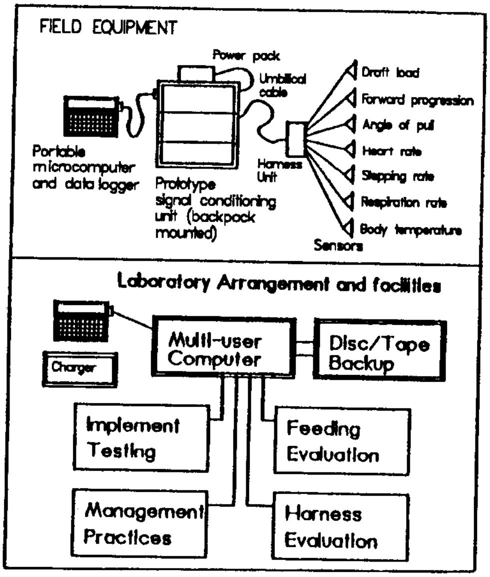


Table 1: Comparable performance data for "Ox No.2" (working as one member of a yoked pair).

Implement	Trial code	Mean horizontal force (N)	Mean vertical force (N)	Mean speed ($m\ s^{-1}$)	Mean pair power (W)	Mean heart rate (beats/min)
Bakhar*	BL	1227	768	0.49	559	121
Bakhar*	JL	671	271	0.72	529	117
Seed drill	JQ	945	325	0.91	855	126
Toolcarrier	JB	984	301	1.06	1008	125
Loadcar	BK	1212	247	0.93	1112	129
Loadcar	JO	610	246	1.00	609	113

* *Traditional wide cultivator or "blade harrow"*

ing unit and a micro-computer into which the data are logged. The signal conditioning and the computer are carried by an operator walking alongside the animals and implement under study. Sensor outputs are transmitted to a junction box, mounted at a convenient point on the harness or the implement, and from there they pass along a multi-core cable to the signal conditioner and data logger.

Mechanical measurements are taken from a strain gauge load-cell indicating the draft force, an inclinometer indicating the angle to the horizontal at which the force is applied, and a radar sensor from which the forward progression of the implement is obtained. Processing the data from these sensors enables both direct and some derived values, such as speed and power, to be logged.

The measurement of physiological factors has been restricted deliberately to those accessible by non-invasive means to enable farm animals to be studied. The factors sensed are:

- heart rate, measured by a detector responsive to blood flow in the ear;
- respiration rate, determined from the air flow in a direction-sensitive tube attached to a nose clip;
- stepping rate, measured by a unit responding to accelerations of a front leg to which it is attached;
- temperature change, measured by a thermistor bead.

The conditioned sensor outputs are scanned by the micro-computer at a rate of about 80 channels per second. The sequencing of the channels is set by the operator. Some channels are read more often than others: for example force, which may be very variable, is read more frequently than heart rate, which is only read as each pulse occurs. Several components of the equipment have been in use for some two to three years in various research projects. The present package and a more sophisticated derivative currently under development are described more fully in O'Neill, Howell, Paice and Kemp (1987) and in Howell and Paice (1988).

Results

Although the analyses of the data completed so far have been oriented mainly towards specific objectives, such as the comparison of implements, some more general relationships between work patterns and indicators of work stress have begun to emerge.

Draft force pattern

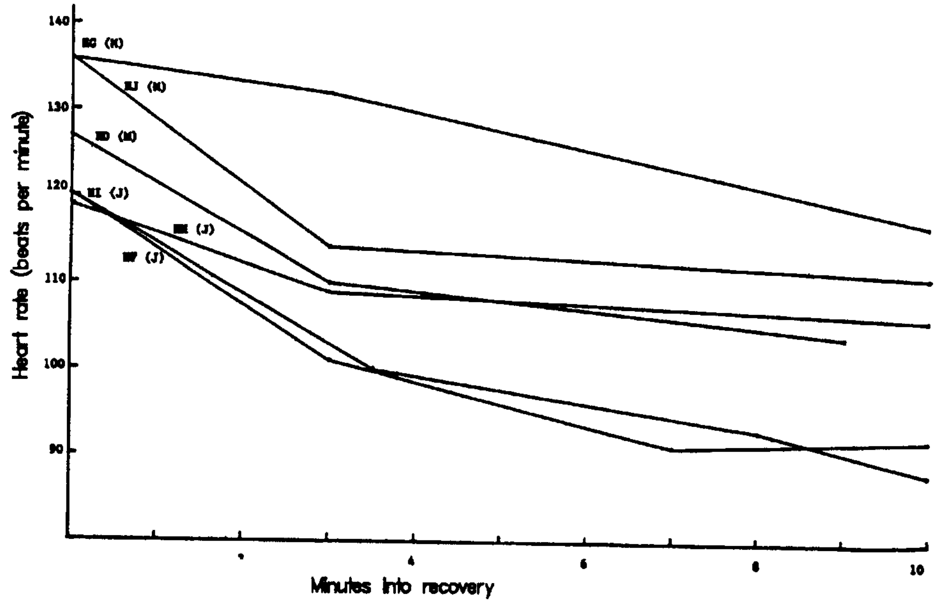
The precision of measurement is such that variations in draft force occurring in less than 0.1 second periods are revealed, together with the simultaneous responses of the animals to them. Typically, oxen appear to modify their movement in the face of wide force variations in order to achieve a more even power output. Furthermore this modification appears to be made at a physiological cost. Table 1 shows the heart rate of one ox from a group of 20 being surveyed in India and shows the effect on the heart rate of draft forces of differing variability at similar power outputs. The figures are tabulated in descending order of force variation. The *bakhar* (a wide blade cultivator or "blade harrow") has the most severe force irregularity of the series (although this would not always be so). The loadcar (a vehicle designed to apply a steady draft load) has least.

Further investigation of the data from which these results were derived, coupled with data from other animals in the same group and in different countries, has suggested that the smoothest force spectrum is not necessarily best tolerated. As yet it is unclear whether this is a true effect or whether it is engendered by the fact that the animals under investigation are not well practised in the task of pulling against smooth loads. However, it is very likely that there is an optimum draft force spectrum against which oxen will work with least distress and with the most profitable application of their effort. This optimum may well be achieved as a result of prolonged working with little difference in variability of force patterns, so that the animals become attuned to them. Thus the modification of implements, harnessing and hitching to achieve a degree of commonality in the patterns of force required could be a profitable area for research to improve draft ox performance. This concept follows closely the observation that "the disturbance of the integration between muscular functions hastens the onset of fatigue" (Brody, 1964).

Effects of resting

The benefits of rest after periods of sustained work are immediately apparent. They are well illustrated by the fall in heart rates at cessation of work, as shown in Fig. 2. Recovery, often indicated by reducing heart rates, commences as soon as work stops, with the greatest fall in rate occurring in the early stages of the process.

Fig. 2: Heart rates during animal recovery immediately after work. Results for six trials, with animals' initials (M or J) given in parentheses.



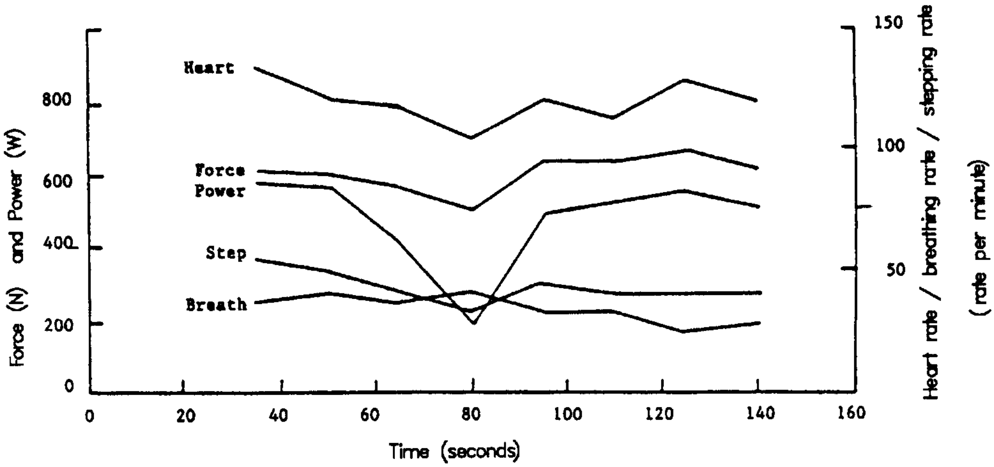


Fig. 3: Animal responses to a headland turn (readings averaged at 15 second intervals).

Heart rate may be used as an indicator of recovery towards the rested state. It has been observed from several of the data blocks acquired from tasks where there have been frequent reductions of power output, that these reductions are usually associated with a fall in heart rate. The fall occurs quickly and may persist for a short time after work has resumed. Furthermore the effect has appeared after respites of as little as 15 to 20 seconds. Fig. 3 shows a typical heart rate response to a headland turn when power output was reduced for some 25 seconds (although the animals did not actually stop).

These findings suggest that where tasks are particularly demanding, the introduction of a regime offering frequent regular short respites from work may be beneficial and may enhance the total amount of work that is done during a prolonged period.

Further work

Inspection of the data gathered shows that, of the various factors scanned, heart rate appears to be the best indicator of the animal's response to work. However, it can be elevated readily by events unrelated to work. Thus it is a reliable indicator only when falling from a level induced by sustained work. Other less direct factors are to be assessed in the future. One of the longer term aims of this research at AFRC Engineering is the identification of a reliable measure, or score, of the overall efficacy of a task being performed by a pair of animals and an implement. This would facilitate rapid comparisons of most aspects of draft animal power cultivation, including not only variations in implements and work routines but also harnessing, pair matching, pre-season conditioning, operator effects and other factors.

The investigations of the performance of ten pairs of oxen in India, referred to above, are continuing. Current trials aim to clarify the effects of varying draft force spectra, using research station animals for which predetermined work patterns can be set. In another aspect of the programme, the benefits of various resting regimes are being assessed.

Conclusion

The application of draft animal power has for long been an essential feature of tropical agriculture and in many ways the technology is well understood. Nevertheless opportunities remain for improving the use of draft animals.

Some possibilities for achieving greater benefits have been targeted already. It is likely that the application of the research techniques described here will allow others to be revealed.

Résumé

L'AFRC a développé des techniques de mesure et d'enregistrement des paramètres définissant le travail des animaux de trait et ses effets physiologiques. A partir des données acquises sur plusieurs projets par les nouveaux instruments de mesure, une relation directe peut être perçue entre le rythme cardiaque et les variations de la force de travail de l'animal. D'autre part, il semblerait que certains animaux soient capables de récupérer suffisamment rapidement pour pouvoir tirer profit de brèves périodes de repos. L'exploitation de ces deux aspects de la traction pourraient contribuer à l'amélioration des performances globales. Les études menées n'ont pas encore identifié un paramètre unique qui permettrait de comparer l'efficacité globale des différents travaux en culture attelée.

Acknowledgments

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Title photograph (opposite)
An ox cart carrying stover in Senegal
(Photo: Paul Starkey)