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THE INFLUENCE OF MODERN DAY TRACTOR CAB ERGONOMICS ON PRODUCTIVITY

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Abstract

This paper critically examines agricultural tractor operation and the effect ergonomics have on performance and productivity in modern cabs. Manufacturers of tractors, globally, are continually developing cab and operator control systems to increase productivity AGCO (2012). This research project specifically investigates the claimed increase in productivity from active control arms fitted to modern day tractors. Through practical testing and theoretical research, conclusions have been drawn, on how effective these systems are, how much productivity is increased by the use of them and the cost effectiveness in today's economic environment. This project critically evaluated five agricultural tractors with differing cab layouts, three of the tractors having a conventional cab layout, with manually operated controls, the other two tractors fitted with active control armrests. Methodology adopted four strategies using a time and motion exercise, calculating efficiency rates, calculating cost effectiveness and finally operator movement through functional anthropometrics. Results showed a minimal increase in productivity, however, a major reduction in operator movement indicates the possibility of potential health problems in the long term.

Key words: *tractor cab ergonomics, active control armrest, operator control systems, functional anthropometrics.*

INTRODUCTION

The present research work has the following aims:

- To prove if the use of an active control arm increases productivity. This will be tested in the form of a time and motion study.
- If productivity is increased, and by how much? By using the data collected from the time and motion study, efficiency rates can be calculated.
- How much work has to be done before the additional cost of the unit is recuperated. By carrying out fuel efficiency tests on the tractors chosen and collecting price data, a cost analysis can be formulated.
- To what degree is operator movement within the cab reduced by using an active control armrest. By recording and measuring operator movement during the time and motion study, statistical data on functional anthropometrics can be formulated.

High tech farming that has brought the innovation of the active control armrest. The concept of controlling tractor functions and associated implements has been under development for many years (Hoyningen-Huene et al., 2009). The International Harvester company first patented a design for a 'vehicle control armrest in a vibration isolated control module' on the 10th December 1975 (Kestian et al., 1975). He describes in detail the reasons for such armrests 'The consequence of tractor vehicle development is the increase in equipment that is remotely controlled from the operator's work station. Not only does the tractor operator have to attend to vehicle speed and direction as usual, but he is now concerned with operating ancillary equipment. This combination of increased speed and the broadening of operators responsibility for equipment control, imposes a significant work load on the vehicle operator if he is to work the tractor at its optimum efficiency.

These statements clearly paved the way for development within this specific area of cab design. Engineers and designers had looked into areas of single lever control. A large area at the time was powered wheelchairs for invalids (Kestian et al., 1975).

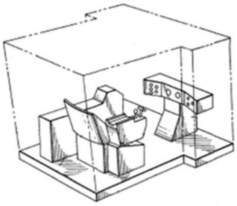

Figure 1. Perspective arrangement of the modular control cab

However, in the early years of armrest development, the main limitation factor came from the control linkages from the armrests (Whisler et al., 1984). 'The armrests were large and cumbersome' due to the cables and hydraulics used in their construction. Machines with such multiple control mechanisms required operators who were highly skilled (Proud et al., 2010). After a period of operating hours, the operators became fatigued, with no place to rest the hand or arm while operating the machine (Proud et al., 2010). Only in the early 1990's, with the development of electronics, did control armrests start to become more advanced. It wasn't just the agricultural sector that was trying to develop these armrests (Attebrant et al., 1997). In October 1992 Caterpillar had a patent passed for a 'Vehicle Control Console Having Finger Tip Controls' (Mackoway, 1992). This console, fitted to bulldozers, being the first to use electric switches linked to a micro-processer.

Manufacturers also began to establish that there was an element of operator fatigue as a result of using such armrests. Garberg et al. (1998) states 'The operator of a working vehicle is required to manipulate control mechanisms, often over long periods of time, as well as drive the vehicle. It is important that the mechanisms be positioned for comfortable operation.'

Figure 2. View of the console shown in connection with a seat

It had also been recognised that the operators forearm and hand, if left in an un-natural position, would soon lead to fatigue (Epple, 1997).

This change of thought by leading manufacturers has yet again led to new designs and patents being introduced. John Deere in 2001 designed an 'Ergonomic Tractor Seat Armrest and Hand Control.' The design of this armrest allowed the operator's right elbow to be supported on an armrest. This supporting point then becomes the fulcrum point for forearm movement to the control levers and switches (Arthur et al., 2001). This design also accommodated different operator sizes, as an operator with a larger torso would not have his elbow in the same lateral location as an operator with a slender torso (Arthur et al., 2001). Manufacturers have also recognised that if an operators hand has to move from one element to another, there may be a delay between work tool manipulations. This therefore resulted in poor quality work or low production. This analogy directly links into ineffectively placed controls or non ergonomical locations to suit all machine operators (Proud et al., 2010).

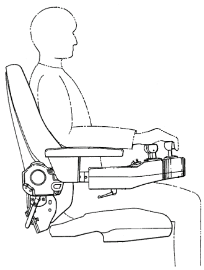

Figure 3. Typical operator position while using an active control armrest

Figure 4. Operator's right arm position when using a John Deere CommandARM

MATERIALS AND METHODS

Five tractors were selected for the programme: 1986 Ford 5610, 72bhp; 2009 Kubota M7040, 71bhp; 2009 John Deere 6230, 100bhp; 2009 Fendt 415, 150bhp; John Deere 7280R, 280bhp
A range of specific tests were carried out in order to form a comprehensive conclusion which comprised of the following:

- Fuel consumption test: to establish fuel used per horsepower hour using a Froment Sigma 5 dynamometer and physically measuring the fuel used during each test.

Figure 5. Collecting power/fuel consumption data

- Time and motion test: to establish the time taken to complete the exercise using a Tag Heuer timer for accuracy.

Figure 6. Tag-Heur timer

- Functional Anthropometrics: to establish the amount of body movement during the exercise.

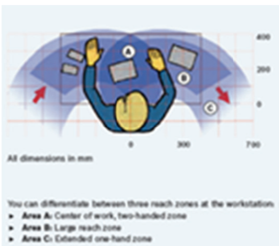

Figure 7. Anthropometric body movement

Whilst carrying out a standard three point headland turn, a typical manoeuvre for a tractor while carrying out field operations such as power harrowing. This turn sequence was replicated under test conditions in a prescribed test environment. The task being broken down into four prescribed phases:
1. Start of sequence: implement lift;
2. Directional change into reverse;
3. Directional change into forwards;
4. End of sequence: implement lower.

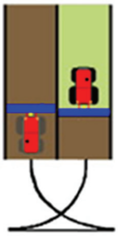

Figure 8. Planned manoeuvre

From carrying out the time and motion study it was found that the expected outcomes for this test were correct. From the range of tractors tested, there was a total difference of 16.84 seconds. Therefore operation time from an old conventional tractor to one with an active armrest fitted is halved. However, what became unexpected were the tractors fitted with active control armrests had significant differences in the time taken to complete the manoeuvre.
The three tractors tested with a conventional cab layout had similar average times having only a difference of 2.46 seconds between them. This is quite significant, as the cab layouts and control positions differ enormously between the Ford 5610 and the John Deere 6230. Again it was expected that as the tractors age decreased so the efficiency of the turn would increase, due to advancements in technology, such as shuttle control.
The most surprising differences occurred when testing the tractors fitted with active control armrests. An average difference of 10.55 seconds between the manufacturers being recorded. When comparing the Fendt 415 and the John Deere 7280R in a standard sequence there was a difference of 5.02 seconds. However, when a recorded operation sequence was added to the Fendt 415 the time doubled to 10.55 seconds. On further analysis of these

manoeuvres, it was found that the time delay came from the direction changes within the sequence. Both tractors were fitted with a constantly variable transmission, but used different principles to achieve this. The John Deere uses a clutch pack system whereas the Fendt uses a hydrostatic system. There was a greater time delay in the John Deere's transmission when a direction change was being carried out, and the operator being unable to accelerate when doing this, as the power take up became too harsh. Whereas in the Fendt, the direction change is smooth and acceleration in reverse could be achieved.

By taking these time and motion figures and placing them into the average field size for the UK of 5.8 Hectares (Ha) Britt *et al* (2000) while using an implement of 4m wide a total of 120 theoretical headland turns would be made. This data can be added to the time and motion times and 'non productive' times can be forecast.

RESULTS AND DISCUSSIONS

Fuel efficiencies in agricultural machinery have increased steadily since the 1980's (Grisso et al., 2010). This has been made possible by improved engine and transmission design and the improved ability to match tractors and implements to given field conditions (Grisso et al., 2010). The table below shows average tractor fuel efficiency rates over the past 30 years.

Table 1. Agricultural diesel engine fuel efficiency increases since 1980

Year	Average Kwh/L	% Increase efficiency
1980	2.3 Kwh/L	
2000	2.6 Kwh/L	11 %
2010	3.1 Kwh/L	16 %

It became clear from analysing the fuel data recorded, that the fuel efficiency data was inconclusive, and would make a minimal impact on productivity costs relating to tractors fitted with active control armrests.

From carrying out the time and motion study it was found that the expected outcomes for this test were correct. From the range of tractors tested, there was a total difference of 16.84 seconds. Therefore operation time from an old conventional tractor to one with an active armrest fitted is halved. However, it became apparent that tractors fitted with active control armrests had significant differences in the time taken to complete the manoeuvre.

Table 2. Average fuel cost per headland turn

Tractor	Fuel used ml/sec	Turn time average (Sec)	ml of fuel per headland turn	Fuel cost per turn.
Ford 5610	1.36	32.29	43.9	3.2 p
Kubota M7040	1.92	30.88	59.3	4.3 p
John Deere 6230	2.15	29.83	64.1	4.6 p
Fendt 415	3.30	20.98	69.2	5.0 p
(Teaching)		15.45	50.9	3.7 p
John Deere 7280R	9.80	26.00	255	18.6 p

The three tractors tested with a conventional cab layout had similar average times having only a difference of 2.46 seconds between them. This is quite significant, as the cab layouts and control positions differ enormously between the Ford 5610 and the John Deere 6230. Again it was expected that as the tractors age decreased so the efficiency of the turn would increase, due to advancements in technology, such as shuttle control.

The most surprising differences occurred when testing the tractors fitted with active control armrests. An average difference of 10.55 seconds between the manufacturers was recorded. When comparing the Fendt 415 and the John Deere 7280R in a standard sequence there was a difference of 5.02 seconds. However, when a recorded operation sequence was added to the Fendt 415 the time doubled to 10.55 seconds. On further analysis of these manoeuvres, it was found that the time delay came from the direction changes within the sequence. Both tractors were fitted with a constantly variable transmission, but used different principles to achieve this. The John Deere uses a clutch pack system whereas the Fendt uses a hydrostatic system. There was a

greater time delay in the John Deere's transmission when a direction change was being carried out, and the operator was unable to accelerate when doing this, as the power take up became too harsh. Whereas in the Fendt, the direction change is smooth and acceleration in reverse could be achieved.

Table 3. Non-productive time during headland turn

Tractor	Average turn time (seconds)	None productive time (Mins)
Ford 5610	32.29	64
Kubota 7040	30.88	61
John Deere 6230	29.83	59
Fendt 415	20.98	41
Fendt 415 (teaching)	15.45	30
John Deere 7280 R	26.00	52

Table 4. Comparison between none productive time and cost

Tractor	None Productive Time (Minutes)	Non Productive Cost
Ford 5610	64	£67.20
Kubota 7040	61	£64.05
John Deere 6230	59	£61.95
Fendt 415	41	£43.05
Fendt 415 (teaching)	30	£31.50
John Deere 7280 R	52	£54.60

Table 5. Extra tractor hours needed to work in order to re-co-operate extra capital outlay for tractors fitted with an active control armrest

Tractor Model	Difference between a model with and without an armrest	Hours worked to re-pay the difference
John Deere 6190	£860	819
New Holland T7.210	£6,333	6031
Massey Ferguson 7615	£6,551	6239
Case Maxxum EP140	£2,274	2165
Fendt 716	N/A	
Valtra N143	£7,706	7339

By taking these time and motion figures and placing them into the average field size for the UK of 5.8 Hectares (Ha) Britt et al. (2000) while using an implement of 4m wide a total of 120 theoretical headland turns would be made. This data can be added to the time and motion times and 'non-productive' times can be forecast.

Calculating the overall time consumed during the total number of headland turns for the prescribed area indicated a significant amount of non-productive time during the operation.

Calculating the costs created through the non-productive time associated with headland turning they showed little difference between each tractor, although adding a significant cost to the operation.

However, with operator movements decreasing by such a large amount are there new areas for operator concern by using active control armrests? Health problems directly linked to musculoskeletal fatigue are increased within the upper torso and neck. Lower limb, circulation problems could develop due to lack of leg movement and pressure points centred around the seat pan.

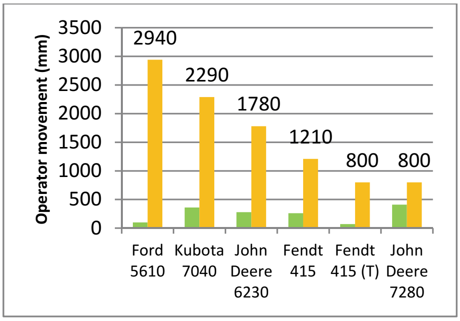

Figure 9. Anthropometric distance travelled

Intermediate work zone   Immediate work zone

This section of results shows the gradual downward trend of anthropometric distances travelled by the operator in the selected tractors. It is surprising the total distances travelled by the operator while carrying out the simulated manoeuvre. This can be related directly to operator fatigue and therefore the effect on overall productivity. Questions can also be raised concerning the lack of operator movement in the Fendt with the 'teaching' facility on, with the whole process being controlled from the function lever on the armrest.

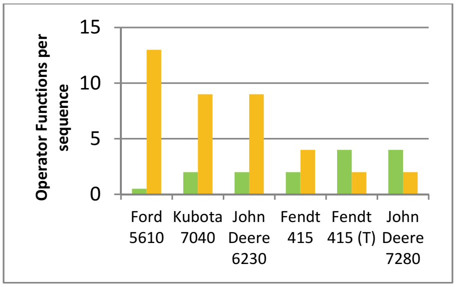

Figure 10. Number of anthropometric zones an operator enters when carrying out a simulated headland turn

The distances travelled in the two anthropometric zones show that even if the tractor is fitted with an active control armrest the amount of operator movement within the immediate work zone is minimal. This however doesn't reflect a true picture due to the immediate work area having smaller distances to travel.

As expected, the conventionally laid out tractors have more operations in the intermediate work zone, whereas the tractors with the active control armrests have a better immediate work zone ratio. The functions per turn are somewhat reduced with armrest control although using the Fendt in standard work mode creates more movement in the intermediate work zone as the hydraulic lift and lower function is located on the side console and not on the armrest.

CONCLUSIONS

After completing the study it is clear that active control armrests do increase productivity but not in the areas that were first predicted. Initial predictions in the area of time saving and the benefits to having one of these active control armrests fitted to a tractor is minimal. Manufacturers and their marketing departments lead the purchaser into thinking that the addition of one of these units will increase output from the machine and therefore lead to increased profit. This has been proven not to be the case. Commonly, the initial outlay for such a system far exceeds the increased profit the system brings.

After closer examination of the marketing statements one can interpret them in a different way, relating them to operator fatigue. It is clear that by using an active control armrest, operator movements are decreased, and therefore less physical fatigue occurs on the operator over the period of a working day. Fendt is the only manufacturer to refer to this operator fatigue directly in their sales literature. Meaning an operator might be able to work longer and therefore increase productivity.

However, with operator movements decreasing by such a large amount are there new areas for operator concern by using active control armrests? Health problems directly linked to musculoskeletal fatigue are increased within the upper torso and neck. Lower limb, circulation problems could develop due to lack of leg movement and pressure points centred around the seat pan.

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