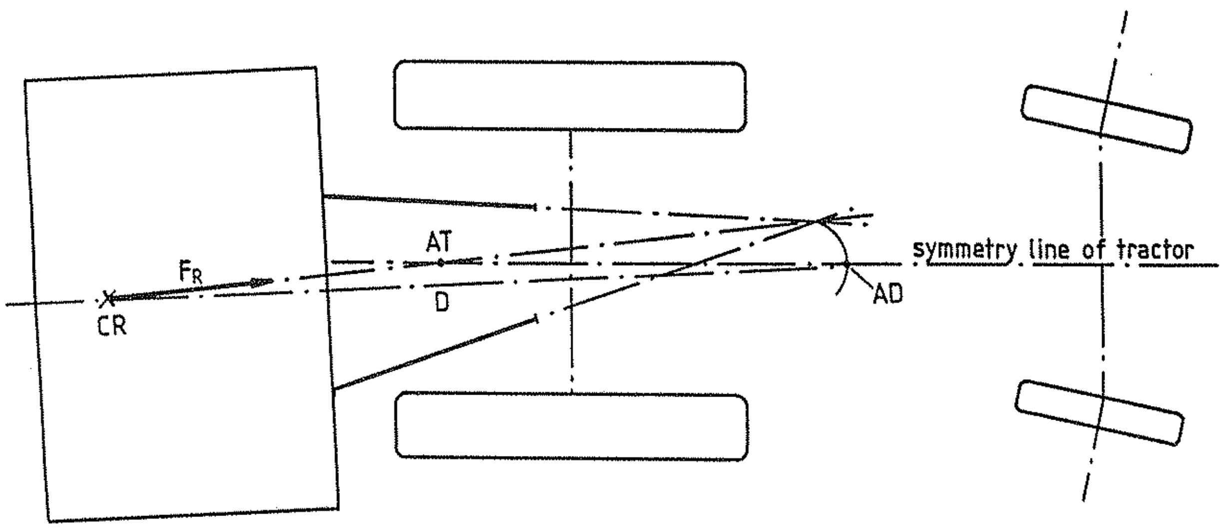
SVERIGES
LANTBRUKSUNIVERSITET

Three-point and One-point Hitches

Implement Behaviour, especially in the Horizontal Plane

Håkan Jönsson



Tryck: SLU/Repro, Uppsala 1987

Institutionen för lantbruksteknik

Swedish University of Agricultural Sciences
Department of Agricultural Engineering

Rapport 110
Report

Uppsala 1987
ISSN 0283-0086
ISBN 91-576-2945-5

Abstract

The influence of the geometry of the hitch on the behaviour of the tractor and of the implement is theoretically analysed. Three-point hitches are compared to one-point hitches.

In the vertical plane the possibility, when a three-point hitch is used, to position the virtual hitch point very low and very far ahead of the implement is found to be advantageous, together with its property to allow easy adjustment of the position of the virtual hitch point.

In the horizontal plane, the tractional hitch point of a three-point hitch normally does not coincide with its directional hitch point. When a one-point hitch is used the tractional and the directional hitch points coincide. This very fundamental difference gives the three-point hitch some unique properties. Equations describing the angle deflection and the lateral deflection of both directional and non-directional implements are presented. They show that a non-directional implement's lateral deflection as well as its angle deflection when used on a hillside or when asymmetrically loaded, normally are much smaller when a three-point hitch is used than when a one-point hitch is used. An equation is also presented describing the return of an implement after a lateral deflection.

The theory of a laterally mobile, but stable, front-mounted three-point hitch is presented.

THE ORIGINAL PUBLICATIONS

This thesis for the degree of *Agronomie Licentiat* consists of a summary and of the following three papers:

1. **Jönsson, H.** 1983. Trepunktskopplingens geometri och dess betydelse för traktorns och redskapets funktion. Paper presented at NJF seminar no 48 "Kobling og fjernbetjening af traktorredskaber", Horsens, Denmark. (In Swedish.) Abstract published in Nordisk Jordbrugsforskning 1984, no. 1, p. 16. (In Swedish.)

2. **Jönsson, H.** 1983. The three-point hitch. Influence on tractor and implement. (Swedish University of Agricultural Sciences, Department of Agricultural Engineering, Report no. 92). Uppsala. (In Swedish with English summary and abstract.)

3. **Jönsson, H.** 1986. Influence of the hitch on lateral performance of implements. Paper presented at international conference AG ENG 86, Noordwijkerhout, the Netherlands.

SUMMARY

Historical background

The invention of power engines, steam engines and internal combustion engines started a period of very rapid mechanization on the farms. In field operations the new engines were used for the heaviest task, plowing. In Europe, plowing was first mechanized by means of winching systems using one or two steam engines (Renius, 1985). In North America, the first mechanization was achieved with direct traction steam engines (tractors). The development in the early nineteen hundreds of fairly reliable internal combustion engines led to a growing popularity of tractors, also in Europe.

These early tractors were often equipped with an integral plow. This motor-plow concept was however relatively soon replaced by the concept of a "naked" tractor and a pulled plow. The farmer could use the "naked" tractor in many more tasks than just plowing. He got a universal tractor.

Compared to the integral plow, the pulled plow was far more difficult to use. The motor-plow could often lift the plow mechanically. The driver's seat on a motor-plow was placed in such a position that the driver easily could see and control the work done by the plow. One hundred percent of the integral plow's surplus weight was transferred to the tractor, thus improving traction. It was much easier to back with a motor-plow than with a tractor-pulled plow combination.

The disadvantages of the pulled plow led to the idea of a mounted plow. This plow would have most of the advantages of the integral plow. Many different hitches were invented to connect the tractor to mounted implements. In operation the three-point hitch, invented and patented by Harry Ferguson, proved to fulfil most agricultural requirements. The introduction of the three-point hitch led to a major break-through in the use of mounted implements. Today, the three-point hitch is standard equipment on universal tractors all over the world.

The three-point hitch has however one major drawback in that the hitching operation itself is both difficult and dangerous (Aas et al., 1985). The present study was initiated by the need to make the hitching operation safe and simple. One way to reach this goal is to use a quick-attaching coupler. However quick-couplers influence the geometry of the three-point hitch. To be able to evaluate different quick-couplers it is neccessary to understand how the operational characteristics of the hitch are influenced by its geometry. The goal of the present study has been to improve this understanding.

Previous research

In the middle fifties and early sixties much research was done on the geometry of the three-point hitch, probably inspired by the expiry of different three-point hitch patents. Examples of this research are; Flerlage (1956), Bjerninger (1960; 1961), Hain (1953), Skalweit (1953)

and Thaer (1956). The German research was used to set down a standard for the geometrical design of the three-point hitch. Since this standard was successful, the three-point hitch research in the sixties and seventies concentrated on the hydraulic lift rather than on the geometry. In spite of the popularity of the three-point hitch very little research on its geometry has been published in the last twenty years.

Skalweit (1953) investigated the geometry of the three-point hitch in the horizontal plane. He showed how the width of cut of the first plow bottom varied if the driver made minor diversions from the intended track. He could also, using a geometrical technique from Hain (1953), show how the convergence of the lower links influences the distance it takes for a plow to return to its correct lateral position after a disturbance.

Flerlage (1956) reported numerous experimental results that indicated the importance of the convergence of the lower links on the behaviour of the plow in the horizontal plane. In Germany his results were used to standardize the lower link convergence. Bjerninger (1961) also notes the influence of the lower link convergence on the variation of the width of the first furrow.

The influence of the hitch geometry in the horizontal plane on the behaviour of implements was quantitatively analysed at the University of Newcastle upon Tyne by Reece et al. (1966), Cowell & Makanjuola (1966) and Makanjuola & Cowell (1970). They developed a second order dynamic model of the return of the implement after a lateral disturbance. In this model they treated the directional properties of the implement quantitatively but neglected the influence of a force in the upper link. In their validation the test implement proved to be heavily overdamped except when very extreme linkage parameters were used (Cowell & Makanjuola, 1966). In most cases the forces due to acceleration could be neglected, thus in reality reducing the model to a first order dynamic model. Makanjuola & Cowell (1970) also published equations describing the lateral deflection and the angle deflection of an implement that is operated on a hillside or around a curve. The equations are, because of the geometry involved, fairly complicated.

Kepner et al. (1978) stated that three-point mounted implements are pulled towards one small area in the tractor (in the present study approximated by a point called the tractional hitch point). The implements are pointed towards another small area in the tractor (approximated by a point called the directional hitch point).

In the present study the existence of one tractional and one directional hitch point is used to develop a simple first order dynamic model of the return of the implement after a lateral disturbance. In this model acceleration forces are neglected. Simple equations are also developed describing the lateral deflection and the angle deflection of the implement when operated on a hillside or around a curve and when operated with asymmetrical load.

Present study

One-point hitches are used world-wide to pull implements. When a one-point hitch is used the tractor and the implement by definition ideally make contact in just one point. Since this point cannot convey any torque the resulting hitch force passes through this one point, also called the real hitch point. Since the tractional force between the tractor and the implement always passes through this point it is the tractional hitch point. Since the implement, when it moves relative to the tractor, turns around the real hitch point, it also is the directional hitch point. Thus, for a one-point hitch, the tractional and the directional hitch points coincide. This applies in all planes through the hitch.

However, when a three-point hitch is used this is not the case. As a three-point mounted implement moves laterally in the horizontal plane the directional line of the implement intersects the symmetry line of the tractor within a short line segment (AD in figure 1). Since this line segment is very short, it can normally be approximated by a point. The line segment AD can be considered the directional hitch point. A small area AT can be considered the tractional hitch point since the implement's line of pull intersects this small area, irrespective of the lateral position of the implement relative to the tractor. Thus, when a three-point hitch is used the tractional hitch point, AT, does not normally coincide with the directional hitch point, AD.

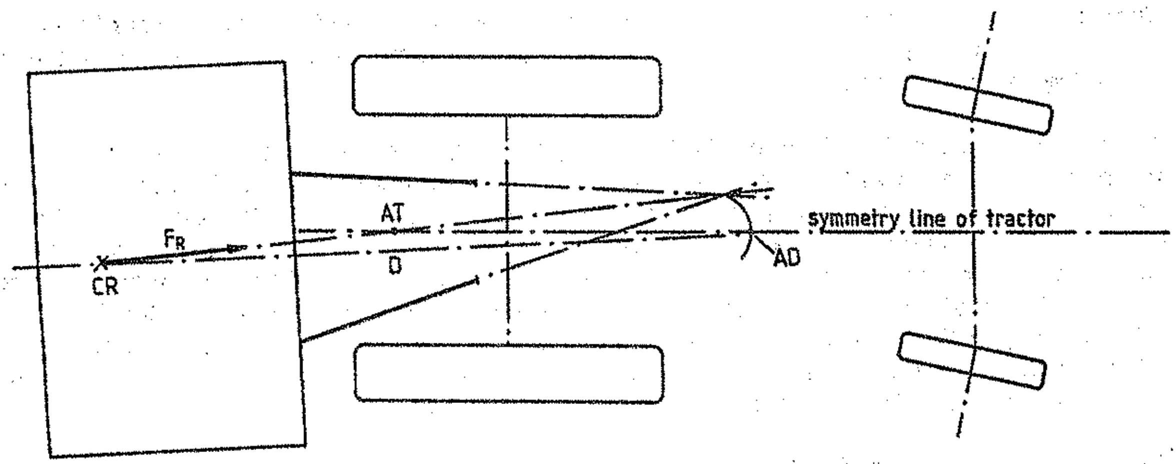


Figure 1. When a three-point hitch is used the tractional hitch point, AT, normally does not coincide with the directional hitch point, AD. The directional line of the implement is denoted by D, the resulting hitch force by F_R and the center of resistance by CR.

The differences between a three-point and a one-point hitch are analysed in papers 1 and 2. Both papers deal with the evaluation of an experimental quick-attaching hitch for mounted implements. The experimental hitch had real hitch points in the horizontal, the vertical longitudinal and the vertical lateral planes.

In the vertical longitudinal plane the analysis of the three-point hitch is done using the concept of a virtual hitch point. The possibility of the three-point hitch to place the virtual hitch point very low (even below the ground is possible) and very far in front of the implement (even in front of the tractor is possible) is found important when plowing hard ground. It is also easy to change the location of the virtual hitch point, thus adjusting the weight transfer when a free floating hydraulic lift is used as well as adjusting the angle the implement is tilted forward as it is lifted. The correct adjustment of this tilting angle is important since it influences the quality of the work produced by some implements, for example centrifugal broadcasters, sprayers and some soil-engaging implements (Jönsson & Svensson, 1986). This angle also influences the clearance of the rear part of long implements in transport position as well as the energy needed to lift the implement.

In the horizontal plane the analysis of the three-point hitch is done using the earlier mentioned concepts of one tractional and one directional hitch point. In the analysis in papers 1 and 2 only perfect directional implements, i.e. implements that move in the direction they are pointing, and perfect non-directional implements, i.e. implements that move in the direction they are pulled, are treated. The analysis shows that when a non-directional implement is used on a hillside or when it has an asymmetric center of resistance its lateral deflection as well as its angle deflection are normally much smaller if a three-point hitch is used than if a one-point hitch is used.

When the three-point hitch is used it is easy to adjust the direction of the line of pull of a directional implement. This is a necessary adjustment when plowing.

In a field experiment reported in paper 2 the directional property of a mounted plow as well as the location of its directional hitch point were verified. In paper 2 the theoretical possibility of a laterally mobile but stable front-mounted three-point hitch is discussed. A hitch according to this theory was later built. This hitch proved to be laterally stable with directional as well as non-directional implements (Svensson, 1987). The model of the lateral behaviour of implements has also been successfully used to interpret some experimental results reported by Flerlage (1956) (Jönsson & Svensson, 1986).

In paper 3 the model describing the behaviour of implements in the horizontal plane is developed to quantitatively treat the directional property of the implement in two situations. These situations are hillside use of the implement and asymmetrical loading of the implement.

Compared to the equations published by Makanjuola & Cowell (1970) the equations given in papers 1, 2 and 3 are very simple. In spite of this, they ought to work also when there is a force in the upper link. The equations are based on the existence of one tractional and one directional hitch point and on the directional properties of the implement as described by Cowell & Makanjuola (1966). Neither the directional hitch point nor the directional properties of the implement are influenced by a force in the upper link. According to Kepner et al. (1978) only the position, not the existence, of the tractional hitch point is influenced by a force in the upper link.

Future research

In the future the developed model of the lateral behaviour of implements must be further verified. This is especially important in load situations when there is a force in the upper link. Verification is an urgent research task since the model has implications on the use of three-point hitch quick-couplers as well as on the three-point hitch standard.

In addition the model ought to be further developed. An equation for the return of an implement, with a quantified lateral stiffness, after a lateral disturbance has already been developed but not yet published. Many questions also remain concerning the behaviour of laterally mobile front-mounted three-point hitches.

Acknowledgements

I want to express my sincere gratitude to Professor Nils Möller for the freedom I have had in pursuing my work and to Professor Bruno Nilsson for always having a couple of spare minutes whenever I have a question.

I am grateful to the skilful workshop staff at the Department of Agricultural Engineering.

I am very grateful to Sylvia Andersson, Eva Pålholm and Örjan Bergwall for their excellent work in making the different manuscripts legible and to Nigel Rollison for revision of my English manuscripts. I am much indebted to Anders Wesslén for solicitous printing of this report.

I want to thank my wife Ingrid for her encouragement and support and for the initial correction of many mistakes in the English manuscripts.

Part of the work has been sponsored by the Swedish Council for Forestry and Agricultural Research through the Scandinavian Contact Agency for Agricultural Research, which is gratefully acknowledged.

Any correspondence concerning the subject of this thesis will be most gratefully received.

The address is: Dept. of Agricultural Engineering
Att: Håkan Jönsson
Box 7033
S-750 07 UPPSALA
Sweden

Phone: int. 46-18-17 10 00, -17 18 86 (direct); nat. 018-17 10 00, -17 18 86 (direkt)

References

Aas, M., Bergström, J. & Norén, O. 1985. Lift quick-couplings for tractor and implements (Swedish Institute of Agricultural Engineering, Report no. 406). Uppsala, Sweden. (In Swedish with English summary.)

Bjerninger, S. 1960. The effect of the tractor on the working depth of the mounted plow and the effect of the plow on the slippage of the tractor (Swedish Institute of Agricultural Engineering, Report no. 266). Uppsala, Sweden. (In Swedish with English summary.)

Bjerninger, S. 1961. Directional stability of mounted plough and steering of tractor (Swedish Institute of Agricultural Engineering, Report no. 294). Uppsala, Sweden. (In Swedish with English summary.)

Cowell, P.A. & Makanjuola, G.A. 1966. The lateral dynamic behaviour of tractor-mounted implements, with particular reference to the three-point linkage. J. agric. Engng Res. 11(3), 152-169.

Flerlage, B. 1956. Normung der Dreipunktaufhängung am Schlepper. Grundlagen der Landtechnik, Heft 7, 89-106.

Hain, K. 1953. Die Form der Furchensohle auf unebenem Acker bei verschiedenen Anbausystemen. Grundlagen der Landtechnik, Heft 4, 72-76.

Jönsson, H. & Svensson, J. 1986. Utredning rörande vissa förändringar i den internationella standarden för trepunktskopplingen. Unpublished.

Kepner, R.A., Bainer, R. & Barger, E.L. 1978. Principles of farm machinery. 3rd edition. USA.

Makanjuola, G.A. & Cowell, P.A. 1970. Optimization of the lateral dynamic behaviour of tractor mounted implements. J. agric. Engng Res. 15(3), 201-220.

Reece, A.R., Gupta, R. & Tayal, S.S. 1966. The lateral stability of tractor implements. J. agric. Engng Res. 11(2), 80-88.

Renius, K. Th. 1985. Traktoren - Technik und ihre Anwendung. München.

Skalweit, H. 1953. Die Führungskräfte von Schlepper-Arbeitsgeräten bei den genormten Anbausystemen. Grundlagen der Landtechnik, Heft 4, 54-64.

Svensson, J. 1987. Self-centering front-mounted three-point hitch. Principles and function (Swedish University of Agricultural Sciences, Department of Agricultural Engineering, Report). Uppsala, Sweden. (In Swedish with English summary, to appear.)

Thaer, R. 1956. Untersuchungen über die Dreipunktaufhängung der Geräte am Schlepper. Grundlagen der Landtechnik, Heft 7, 72-88.