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Computer simulation of three-point linkage parameters for virtual hitch point and optimum depth of operation

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ABSTRACT

A computer program is developed in Visual Basic 6.0 to locate the virtual hitch point of tractor with respect to depth of operation and to optimize the three-point linkage parameters for matching the virtual hitch point with the line of pull. The concept of Cartesian coordinate geometry was used in the program development. The virtual hitch point was calculated by solving the straight line equations of lower and upper link of three-point hitching system at particular depth of operation. For determining the line of pull, draft was calculated from ASAE equation and coordinate of centre of resistance was assumed to the 2/3 of depth of operation in the line of centre of gravity of implement. The optimum depth of operation is the depth for which line of pull passes above and near to VHP which was calculated in the program through the iteration process. The locus of virtual hitch point with respect to depth of operation was observed as parabolic. The distance of virtual hitch point from the rear axle centre increases with increase in depth of operation in all cases. The optimum depth of operation for a test tractor was observed as 269 mm using the developed program. This depth depends substantially on lower link (length and link position) and implements parameters (weight and height of hitch point). Therefore, this program may be very useful in simulating the three-point linkage and implement parameters as per the requirement of depth of operation.

1. Introduction

Tractor is well-accepted power source for the Indian agriculture especially when the availability of human and animal power in farm is diminishing day-by-day (Singh et al., 2014). The tractor with mounted implement has well proven advantages such as better weight transfer, easy implement transportation, hydraulically depth control, automatic depth and draft control, etc. In mounted implement case, drawbar performance depends significantly on three-point linkage parameters. The most important performance affecting parameter is virtual hitch point (VHP), which is a virtual intersecting point of extended line of top and lower link. The virtual hitch point depends upon the linkage geometry along with the depth of operation. The VHP should lie just below the line of pull for better tractor performance and the depth at which this condition achieve is known as optimum depth of operation (Macmillan, 2003). A virtual line passing through the centre of resistance of the implement along with the direction of pull is known as line of pull. It mainly depends on depth of operation, implement pull (draft and vertical force) and weight of the implement. It is clear from the above facts that VHP and line of pull both depend on depth of operation and therefore, it plays important role in matching the VHP with line of pull. The matching of VHP with line of pull requires complex and series of calculations, which leads to the ignorance of its effect in drawbar performance prediction.

Computer program is very useful tool for solving the complex and series of calculations in short span of time. The development of tractor related computer program is of great interest for scientists and researchers in recent pasts (Al-Hamed and Al-Janobi, 2001; Sahay and Tewari, 2004; Sahu and Raheman, 2008; Pranav and Pandey, 2008; Kumar and Pandey, 2009; Ishola et al., 2010; Pranav et al., 2012, 2015). Prasanna Kumar (2012, 2015) has analysed the three-point linkage parameters by Newton-Raphson method to generate the path of motion of lower, upper and virtual hitch points in the movement range of the hitch. None of the research has attempted to match the VHP with line of pull which is one of the important performance parameters. Keeping this importance in mind, a computer program is developed to calculate the optimum depth of operation by matching the VHP with line of pull considering three-point linkage geometry.

2. Theoretical considerations

This section deals with the theories and concept adopted for

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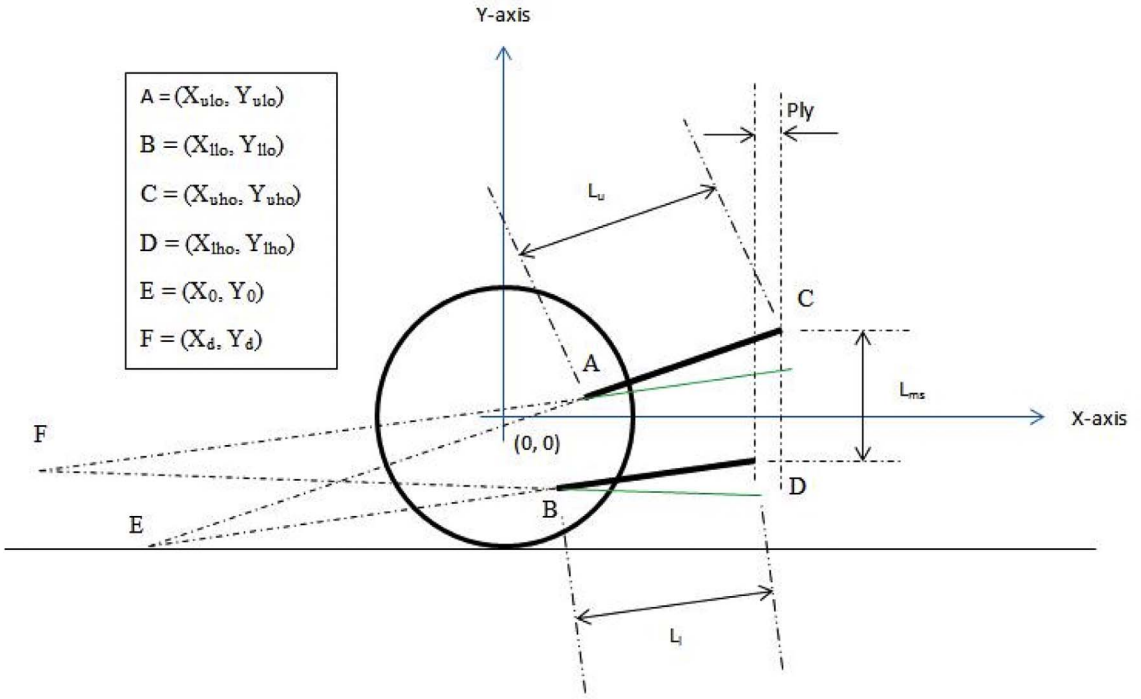

Fig. 1. Linkage geometry of a tractor with VHP.

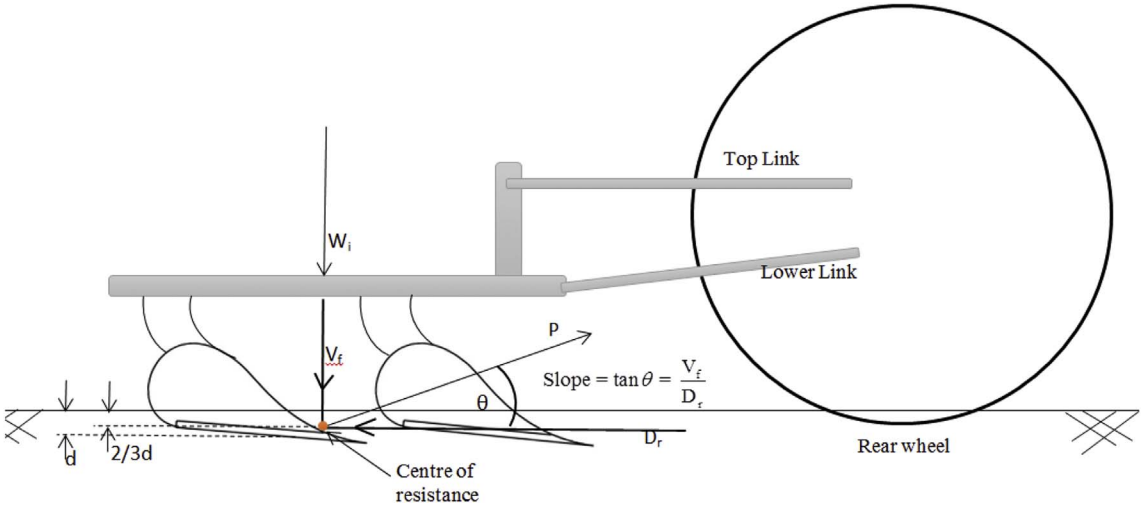

Fig. 2. Assumed location of centre of resistance.

calculating the VHP and line of pull along with the optimum depth analysis.

2.1. Calculation of VHP

The virtual hitch point was calculated using principle of Cartesian coordinate geometry. The analysis was performed in 2-dimentional plane which is shown in Fig. 1. The origin of the co-ordinate was assumed at rear wheel centre with rearward direction as X-axis and upward direction as Y-axis. Further, zero depth of operation is assumed when an implement kept on leveled surface at stationary condition. The coordinates of lower link point (X_{llo}, Y_{llo}) and top link point (X_{tlo}, Y_{tlo}) is calculated from three-point linkage parameters. The ordinates of lower hitch point (Y_{lho}) and top link hitch point (Y_{tho}) were estimated from the implement data i.e. height of lower hitch point and mast height at zero depth of operation. The abscissas of the lower hitch point (X_{lho}) and top hitch point (X_{tho}) were calculated using Eqs. (1) and (2), respectively.

$$X_{lh0} = \sqrt{L_l^2 - (Y_{lh0} - Y_{ll0})^2} + X_{ll0} \quad (1)$$

$$X_{th0} = X_{lh0} + ply \quad (2)$$

where,

L_l = length of lower link
Ply = horizontal distance between top and lower hitch point

Further, the straight-line equations were developed for top and lower links which are given in Eqs. (3) and (4), respectively.