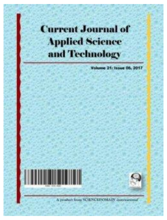


Current Journal of Applied Science and Technology

28(6): 1-12, 2018; Article no.CJAST.43491
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

A Visual Basic Programme for Performance Evaluation of Three-point Linkage Hitch System of Agricultural Tractors

L. K. Dhruw[1], C. M. Pareek[1*] and Naseeb Singh[1]

[1]Department of Agricultural and Food Engineering, IIT Kharagpur, India.

Authors' contributions

This work was carried out in collaboration between all authors. Author LKD developed software in visual basic for evaluating the performance of three-point linkage hitch system. Author CMP wrote the first draft of the manuscript. Author NS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2018/43491
Editor(s):
(1) Dr. Giovanni Bucci, Professor, Department of Industrial Engineering and Information and Economy, University of L'Aquila, Italy.
Reviewers:
(1) G. Jakasania Ronak, Junagadh Agricultural University, India.
(2) Jaime Cuauhtemoc Negrete, Agrarian Autonomous Antonio Narro University, Mexico.
(3) A. Ashok Kumar, College of Agricultural Engineering, Acharya N. G. Ranga Agricultural University, India.
(4) Subrata Kumar Mandal, CSIR-Central Mechanical Engineering Research Institute, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/26037

Original Research Article

Received 15th June 2018
Accepted 22nd August 2018
Published 30th August 2018

ABSTRACT

A visual basic programme that evaluates the performance of three-point linkage hitch system of agricultural tractor in vertical longitudinal plane was developed. The three-point linkage hitch performance parameters were determined by generating the locus of upper hitch point, lower hitch point and virtual hitch points throughout the power travel of lift arm by computer simulation. The effect of different dimensional parameters of three-point linkage hitch on its mechanical advantage was also analyzed. The results revealed that the mechanical advantage of the three-point linkage hitch system is most affected by the lift rod length. Developed programme has the potential to validate the three-point linkage hitch design according to the standard defined in ISO 730. The developed programme is simple and practically useful for design engineers and also meet the user requirements for educational and research purpose.

**Corresponding author: E-mail: chaitanyapareek@gmail.com;*

Keywords: Three-point linkage hitch; simulation; visual basic programme; mechanical advantage.

NOMENCLATURES

All dimension are in mm. All points denoted considering the real axle centre as the origin point. All the inclinations are measured from the vertical axis, positive in a counter-clockwise direction	
Sym.	**: Description**
(X_{LAP}, Y_{LAP})	*: x, y coordinates of lift arm pivot point (LAP),*
(X_{LLP}, Y_{LLP})	*: x, y coordinates of lower link point (LLP),*
(X_{ULP}, Y_{ULP})	*: x, y coordinates of upper link point (ULP),*
(X_{LHP}, Y_{LHP})	*: x, y coordinates of lower hitch point (LHP),*
(X_{UHP}, Y_{UHP})	*: x, y coordinates of upper hitch point (UHP),*
(X_{VHP}, Y_{VHP})	*: x, y coordinates of virtual hitch point (VHP),*
L_1	*: Distance between lower link point to the lift arm pivot point,*
L_2	*: Length of the lift arm,*
L_3	*: Length of the lift rod,*
L_4	*: Distance between lift rod connection point on lower link and lower link point,*
L_5	*: Length of the lower link,*
L_6	*: Distance between lower link point and the upper link point*
L_7	*: Length of the upper link,*
L_8	*: Mast height,*
ϕ	*: Lift arm inclination,*
ϕ_{LHP}	*: Lift arm inclination at a given height of lower hitch point,*
ϕ_{LR}	*: Lift rod inclination,*
ϕ_{LL}	*: Lower link inclination,*
ϕ_{UL}	*: Upper link inclination,*
ϕ_P	*: Pitch angle,*
α	*: Inclination of the line joining lower link point and lift arm pivot point,*
β	*: Inclination of the line joining lower link point upper link point,*
R_{Rear}	*: Rear wheel radius,*
H_{LHP}	*: Height of lower hitch point from the ground*

1. INTRODUCTION

From last decade, the increased use of agricultural tractors significantly contributes to enhancing the farm mechanization level, which leads to the higher agricultural productivity. The tractor drawbar is dominantly used power outlet where the implements are attached through three-point linkage hitch system. The three-point linkage hitch system is the articulation of two lower links and one upper link. Its main function is to enhance the tractive performance of two wheel drive tractors by increasing the dynamic load transfer on the rear wheel during the pulling of implements. It also helps in the maneuverability of tractor-implement combination in the field as well as during the transportation. The geometry of the hitch system plays an important role in its functioning. The design consideration of the three-point linkage hitch system is provided in ISO 730 [1] and ASAE Standard S217.12 [2]. These design standards define some geometric constraints for designing the three-point linkage hitch system to increase the safety, compatibility with implements, and implement stability [3]. The design of the three-point linkage hitch system involves the complexity with a high number of design variables and design constraints. Analysis of three-point linkage hitch geometry in a number of tractors shows that the geometry of the hitch system is not optimized [3]. Hence, there is a need to evaluate the design of three-point linkage hitch system as per the standard for its proper functioning. Considerable research has been conducted for developing the simulation models to analyse the design of three-point linkage hitch system. Ambike and Schiedeler [4] used geometric constraint programming to generate kinematic configurations of a three-point hitch of tractor which allow the designer to address the dynamic issues of the hitch design. Kumar [5] applied Newton Raphson solution to three-point linkage hitch system of tractor to determine the range of movement of the lift arm and generate the path of motion of lower and upper hitch points. Molari et al. [3] used a numerical optimization approach to optimize the three-point linkage hitch by maximizing the lifting capacity and satisfying the constraints fixed by the standards.

The computer simulation is commonly used to visualize and to investigate a particular system without going through practical measurement. It provides the flexibility to the user for selecting and incorporating the various design parameters into the test system and analyze its consequence on the performance of that system. A computer simulation program for evaluating the design of three-point linkage hitch system helps the designer to analyze the geometrical characteristics of three-point linkage hitch system without conducting expensive as well as time consuming field tests. Moreover, it provides a cost-free approach to the researchers and tractor manufacturers to trace the path of three-point linkage hitch movement and evaluate that whether the existing design follows the design standards or not. The software development in Visual Basic.Net (VB.NET) program is very user-friendly and also provides the advantage of Dot NET framework. In past, various researchers used visual basic programming language for development of the simulation software. Wang [6] used visual basic programming for simulating the motion of six-bar linkage mechanism for optimization study. Christoloukas and Savaidis [7] developed a simulation software using Visual Basic Net programming package for the evaluation of the forces in a kinematic mechanism of a slider-crank system of V8 engine. Singh and Pandey [8] developed a Visual Basic Program for designing the front mounted three-point linkage hitch for high hp tractors. These programs have been proven to be highly flexible and user-friendly. Hence, in present study the Visual Basic .NET programming was chosen for development of computer program.

So, with the above views, the present study was undertaken with the objective of developing a user-friendly computer programme in Visual Basic for evaluating the performance of three-point linkage hitch system. Specifically, the program has to validate the given design of three-point linkage hitch system using computer simulation by accessing the database concerning tractor specification and input parameters of three-point linkage hitch system and also compare the simulation results with design standards. The programme also analyses the effect of different input parameters on mechanical advantage of three-point linkage hitch system. The purpose of this programme is to provide a research tool to the design engineers and scientists to analyse the effect of design input parameters of three-point linkage hitch system on its performance.

2. ALGORITHM FOR SIMULATION OF THREE-POINT LINKAGE HITCH SYSTEM

In a vertical longitudinal plane, the three-point linkage hitch system is a six-bar mechanism that can be modelled as two distinct four-bar linkages sharing two links. The basic components of the three-point linkage hitch system are shown in Fig. 1. The first four-bar linkage is called the driving mechanism, and it consists of a lift arm as a crank, lift rod as a coupler, lower link as follower and tractor chassis as a fixed link. The other four-bar linkage is called three-point linkage hitch, and it consists of the two lower links (which act as one in the vertical plane) as crank, implement frame as coupler, top link as follower and the tractor chassis as fixed link [4,5,9].

The representation of three-point linkage hitch system of an agricultural tractor in the vertical longitudinal plane is shown in Fig. 2. The following fundamental equations were used to develop a visual basic programme for simulation study of three-point linkage hitch system of agricultural tractors.

2.1 Determination of Power Travel of Lift Arm

The Power travel of lift arm is given by lift arm movement from minimum lift arm inclination $(\phi)_{min}$ to maximum lift arm inclination $(\phi)_{max}$. The minimum and maximum lift arm inclinations, i.e. $(\phi)_{min}$ and $(\phi)_{max}$ can be calculated by using the lowest and highest position of lower hitch points (as per test report) as:

$$\phi = \alpha + \cos^{-1}\left(\frac{L_1^2+L_{d1}^2-L_4^2}{2L_1L_{d1}}\right) + \cos^{-1}\left(\frac{L_1^2+L_{d1}^2-L_3^2}{2L_2L_{d1}}\right) \quad (1)$$

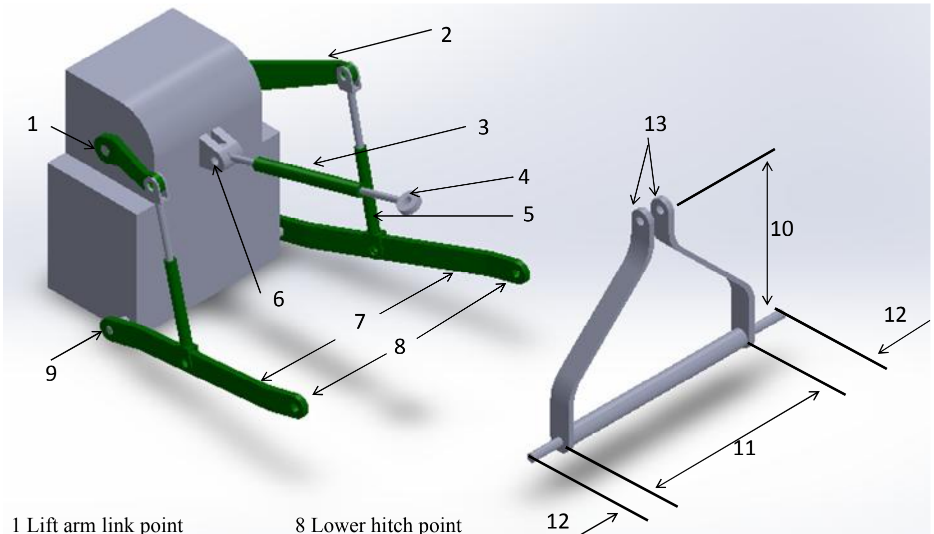
Where

$\alpha = \tan^{-1}\left(\frac{X_{LLP}-X_{LAP}}{Y_{LLP}-Y_{LAP}}\right)$ and

$L_{d1} = \sqrt{L_1^2 + L_4^2 - 2L_1L_4\cos(\pi - \phi_{LHP} + \alpha)}$

and ϕ_{LHP} can be calculated as

$$\phi_{LHP} = \frac{\pi}{2} + \sin^{-1}\left(\frac{H_{LHP}-H_{Rear}-Y_{LLP}}{L_5}\right) \quad (2)$$



1 Lift arm link point
2 Lift arm
3 Upper link
4 Upper hitch point
5 Lift rod
6 Upper link point
7 Lower link
8 Lower hitch point
9 Lower link point
10 Mast height
11 Lower hitch point span
12 Linch pin hole distance
13 Mast

Fig. 1. Components of the three-point linkage hitch system

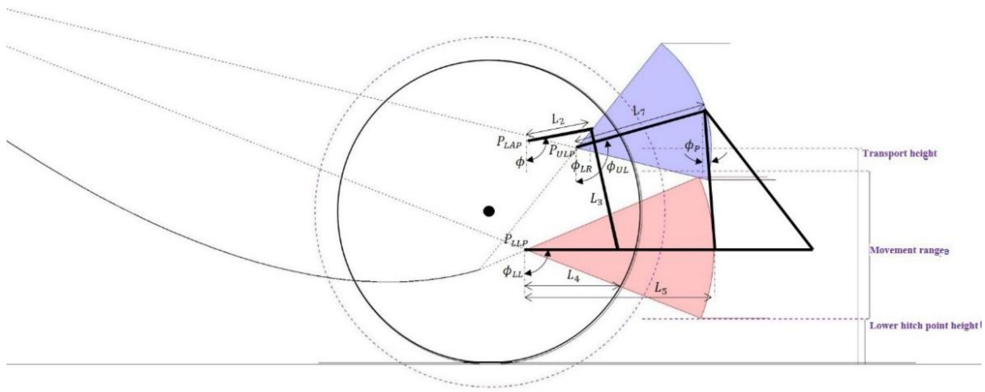


Fig. 2. Three-point linkage hitch system of a tractor

2.2 Lift Rod Inclination (ϕ_{LR})

The lift rod inclination (ϕ_{LR}) can be calculated as:

$$\phi_{LR} = \cos^{-1}\left(\frac{L_2^2+L_{d1}^2-L_1^2}{2\,L_2\,L_{d1}}\right) + \cos^{-1}\left(\frac{L_3^2+L_{d1}^2-L_4^2}{2\,L_3\,L_{d1}}\right) + \phi - \pi \quad (3)$$

Where L_{d1} is the distance between lower link point and the connection point (P_1) between lift arm and lift rod. P_1 (X_{P1}, Y_{P1}) can be calculated as

$$P_1 = (X_{LAP} + L_2\sin(\phi), Y_{LAP} - L_2\cos(\phi))$$

And L_{d1} can be calculated as

$$L_{d1} = \sqrt{(X_{LLP} - X_{P1})^2 + (Y_{LLP} - Y_{P1})^2}$$

2.3 Inclination of Lower Link (ϕ_{LL})

The inclination of the lower link (ϕ_{LL}) can be calculated as:

$$\phi_{LL} = \frac{\pi}{2} + \tan^{-1}\left(\frac{Y_{P2}-Y_{LLP}}{X_{P2}-X_{LLP}}\right) \quad (4)$$

Where P_2 (X_{P2}, Y_{P2}) is the lift rod connection point on lower link and it can be calculated as:

$$P_2 = (X_{LAP} + L_2\sin(\phi) - L_3\sin(\phi_{LR}), Y_{LAP} - L2\cos\phi + L3\cos\phi LR$$

2.4 Inclination of Upper Link (ϕ_{UL})

The inclination of upper link (ϕ_{UL}) can be calculated as:

$$\phi_{UL} = \beta + \cos^{-1}\left(\frac{L_6^2+L_{d2}^2-L_5^2}{2L_6L_{d2}}\right) + \cos^{-1}\left(\frac{L_7^2+L_{d2}^2-L_8^2}{2L_7L_{d2}}\right) \quad (5)$$

Where

$$\beta = \tan^{-1}\left(\frac{X_{ULP}-X_{LLP}}{Y_{ULP}-Y_{LLP}}\right)$$

2.5 Inclination of Mast (ϕ_P)

The inclination of mast (ϕ_P) can be calculated as:

$$\phi_P = \phi_{LL} - \cos^{-1}\left(\frac{L_5^2+L_{d2}^2-L_6^2}{2L_5L_{d2}}\right) - \cos^{-1}\left(\frac{L_8^2+L_{d2}^2-L_7^2}{2L_8L_{d2}}\right) \quad (6)$$

Where L_{d2} is the distance between the lower link point and upper hitch point.

$$L_{d2} = \sqrt{L_5^2 + L_6^2 - 2L_5L_6\cos(\pi + \beta - \phi_{LL})}$$

2.6 Lower Hitch Point (X_{LHP}, Y_{LHP})

By knowing the lower link inclination (ϕ_{LL}), the co-ordinate of lower hitch point can be estimated as:

$$(X_{LHP}, Y_{LHP}) = (X_{LLP} + L_5\,sin(\phi_{LL}), Y_{LLP} - L_5\cos(\phi_{LL})) \quad (7)$$

2.7 Upper Hitch Point (X_{UHP}, Y_{UHP})

By knowing the upper link inclination (ϕ_{UL}), the coordinate point of upper hitch point can be calculated as:

$$(X_{UHP}, Y_{UHP}) = (X_{ULP} + L_7\sin(\phi_{UL}), Y_{ULP} - L_7\cos(\phi_{UL})) \quad (8)$$

2.8 Virtual Hitch Point

Virtual hitch point is the point of intersection between lower link and top link. The lower link, lower hitch, upper link and upper hitch points has the coordinates of $LLP\ (X_{LLP}, Y_{LLP})$, $LHP\ (X_{LHP}, Y_{LHP})$, $ULP\ (X_{ULP}, Y_{ULP})$, and $UHP\ (X_{UHP}, Y_{UHP})$ respectively. The virtual hitch point $VHP\ (X_{VHP}, Y_{VHP})$ can be calculated as

$$X_{VHP} = \frac{m_{UL}X_{ULP}-Y_{ULP}-m_{LL}X_{LLP}+Y_{LLP}}{(m_{UL}-m_{LL})} \quad (9)$$

$$Y_{VHP} = \frac{m_{UL}Y_{LLP}-m_{LL}Y_{ULP}+m_{LL}m_{UL}(X_{ULP}-X_{LLP})}{(m_{UL}-m_{LL})} \quad (10)$$

Where slope of lower link, $m_{LL} = \frac{Y_{LHP}-Y_{LLP}}{X_{LHP}-X_{LLP}}$ and slope of upper link, $m_{UL} = \frac{Y_{UHP}-Y_{ULP}}{X_{UHP}-X_{ULP}}$

2.9 Mechanical Advantage

The mechanical advantage of the three-point linkage hitch system defined as the ratio of the amount of vertical load on lower hitch point to the force on the lift rod.

Mathematically, the mechanical advantage can be given as:

$$MA = \frac{L_2\ \sin(\phi_{LL}-\phi_{LR})}{L_5\ \sin(\phi-\phi_{LR})} \quad (11)$$

2.10 Validation of Three-point Linkage Hitch Standard

The three-point linkage hitch constraint parameters such as lower hitch point height (S_1), movement range (S_2), transport height (S_3), lower hitch point clearance (S_4), minimum distance between PTO to lower hitch point (S_5), maximum distance between PTO to lower hitch point (S_6) and minimum pitch angle at highest position of lower link (S_7) is defined in standard for different hitch category of the tractors as given in Table 1.

Table 1. Three-point linkage hitch parameter constraints (ASABE S217.12)

Definition	Category				
	1	2	3	4	4H
Lower hitch point height	200 max	200 max	230 max	230 max	230 max
Levelling adjustment	100 min	100 min	125 min	150 min	150 min
Movement range	610 min	650 max[1)]	735 min	760 min	900 min
Transport height point (lower point axis to be horizontal throughout)	820 min	950 min	1065 min	1200 min	1200 min
Lower hitch point clearance	100 min	100 min	100 min	100 min	100 min
Mast adjustment height					
highest position	580 min	610 min	660 min	710 min	710 min
lowest position	200 max	200 max	230 max	255 max	255 max
Torsional free float	60 min	60 min	75 min	75 min	75 min

[1)] *For tractors with PTO power above 65 kW, this dimension shall be 700 mm minimum.*

Table 2. Three-point linkage hitch design validation conditions

Conditions	Lift arm position	Lower link position
C1	Maximum	Maximum
C2	Minimum	Minimum
C3	-	Horizontal

In the constraint validation programme, mainly three conditions [3] were considered as given in Table 2. The condition C1 is defined as when the lift arm at its maximum position (lifting condition). The condition C2 is defined as when the lift arm is at its lowest position (lowering condition). The condition C3 is defined as when the lower link is at a horizontal position.

The three-point linkage hitch parameters were validated according to the standard defined in ISO 730 (Table 1) using Eqs. (12) – (18). The subscript $C1$, $C2$ and $C3$ denote the conditions as given in Table 2. For example, the $(H_{LHP})_{C1}$ represents the height of lower hitch point from the ground when the lift arm position is at maximum (Condition *C1*).

$$(H_{LHP})_{C2} - S_1 \leq 0 \quad (12)$$

$$S_3 - (H_{LHP})_{C1} \leq 0 \quad (13)$$

$$S_2 - \{(H_{LHP})_{C1} - (H_{LHP})_{C2}\} \leq 0 \quad (14)$$

$$S_5 - \{X_{LL} + (H_{LHP})_{C3}\} \leq 0 \quad (15)$$

$$\{X_{LL} + (H_{LHP})_{C3}\} - S_6 \leq 0 \quad (16)$$

$$S_4 - \left\{\sqrt{(X_{LHP}^2)_{C1} + (Y_{LHP}^2)_{C1}}\right) - R_{Rear} \leq 0 \quad (17)$$

$$S_7 - (\phi_{\mathrm{P}})_{C1} \leq 0 \quad (18)$$

3. DEVELOPMENT OF VISUAL BASIC PROGRAMME

A programme for evaluating the performance of the three-point linkage hitch system was developed using Visual Studio 2017 Integrated Development Environment (IDE). The program was written in Microsoft Visual Basic .NET (VB.NET) programming language. It mainly consists of four sections, User input section, three-point linkage hitch design validation section, computer simulation of three-point linkage hitch, and performance analysis of three-point linkage hitch. These sections are described below:

3.1 User Input Section

This section includes the opening screen of the developed programme which comprises two frames, i.e. tractor specifications and three-point linkage hitch parameters as shown in Fig. 3. The first frame requires the information about hitch category and rear wheel radius. The second frame needs the value of three-point linkage hitch parameters according to ISO 730 [1] such as lower link length, lower link point position, lift rod length, distance of lift rod connection point on a lower link from lower link point and lift arm point position. The next button is provided for moving to the second screen of the developed programme. The values of three-point linkage hitch dimensions are taken from the tractor test report in user input screen. The user input data used in this study are given in Table 3.

3.2 Three-point Linkage Hitch Design Validation Section

This section consists of second screen of the developed programme which displays the standard dimensional parameters of three-point linkage hitch based on the hitch category selected in previous screen along with the user input data of existing three-point linkage hitch dimensions.

In this section, the programme determines the various standard dimensional parameters of existing three-point linkage hitch design and also cross-validate these parameters according to the standard defined in ISO 730 (Table 2) using Eqs. (12) - (18). If any parameter of three-point linkage hitch is not satisfied with the standards then the programme shows a message as “Standard not satisfied” on the screen as shown in Fig. 4. In addition, it highlights the standard parameter which does not meet the criteria of standard, essential for easier attachment of tractor to the different implement.

3.3 Computer Simulation of Three-Point Linkage Hitch

In this section, the three-point linkage hitch system is simulated in vertical longitudinal plane using the Eqs. (1) - (10). The simulation process is carried out by clicking the simulate button provided on second screen of the developed programme. At the beginning of the simulation, initial values of tractor specification, and the dimensions of three-point linkage hitch system which user want to simulate were assigned. After collecting the user input data required for execution, the programme simulates the three-point linkage hitch system in the vertical longitudinal plane. The simulation process flowchart is shown in Fig. 5.

Table 3. User input data for developed programme

Parameters (Data taken from the test report)	Values (mm)
Rear wheel radius	670
Location of the lift arm pivot point (X_{LAP}, Y_{LAP})	(173, 310)
Location of the lower link point (X_{LLP}, Y_{LLP})	(160, -166)
Location of the upper link point (X_{ULP}, Y_{ULP})	(384, 282)
Lift arm length	280
Lift rod length	540
Lower link length	825
The distance between lower link point and lift rod connection point on the lower link	409
Upper link length	590
PTO end from the rear axle centre	426

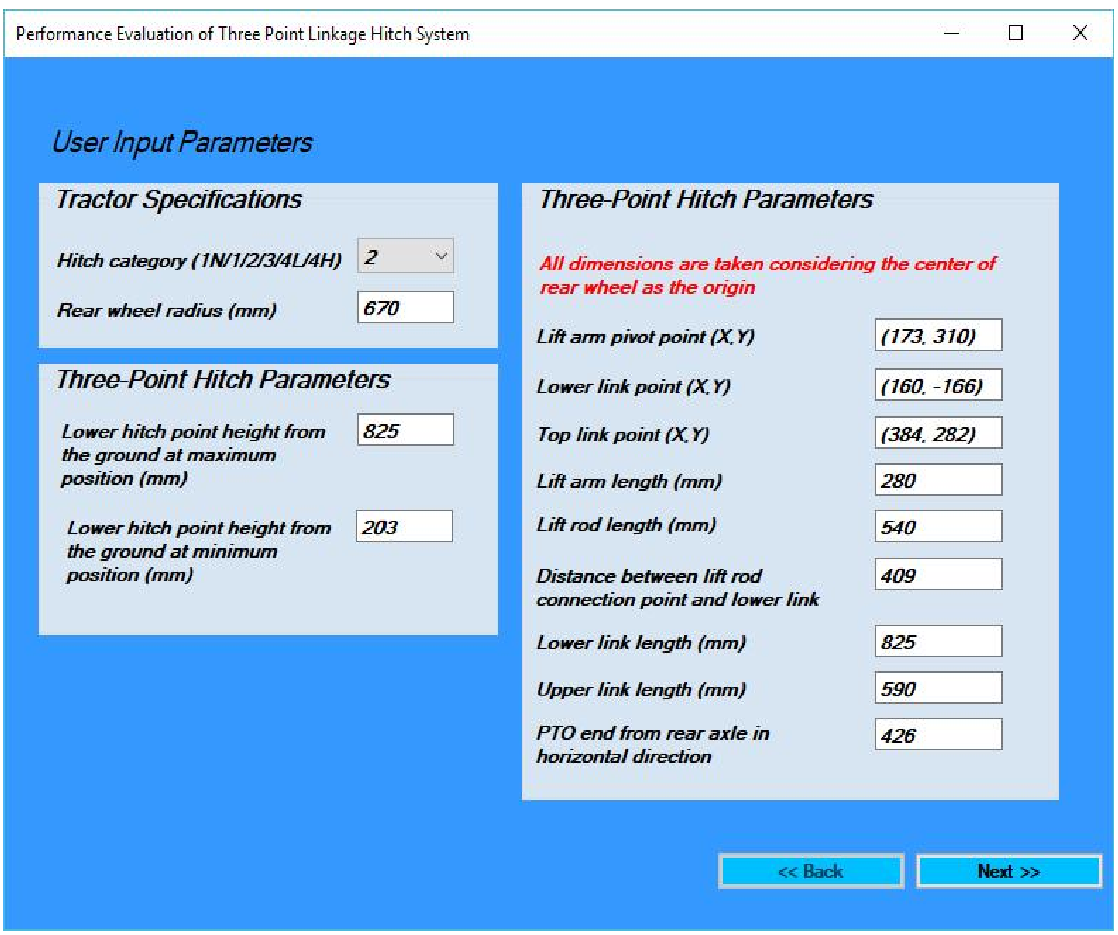


Fig. 3. User input parameter screen

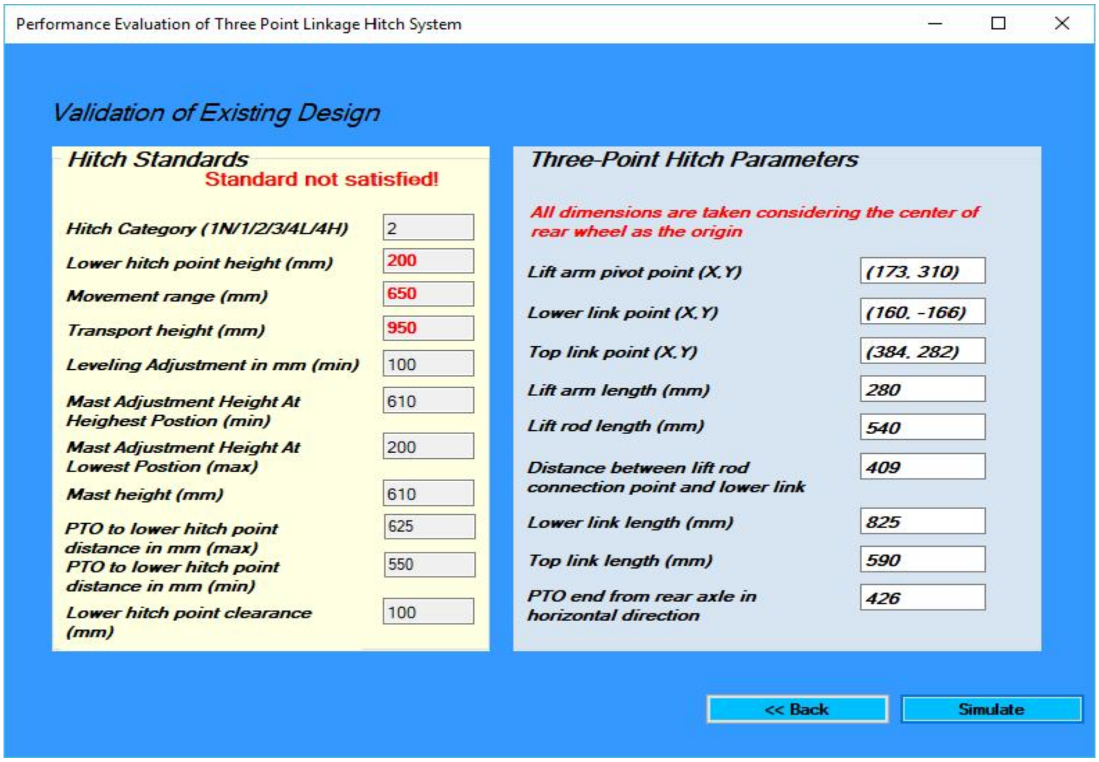


Fig. 4. Validation of three-point linkage hitch

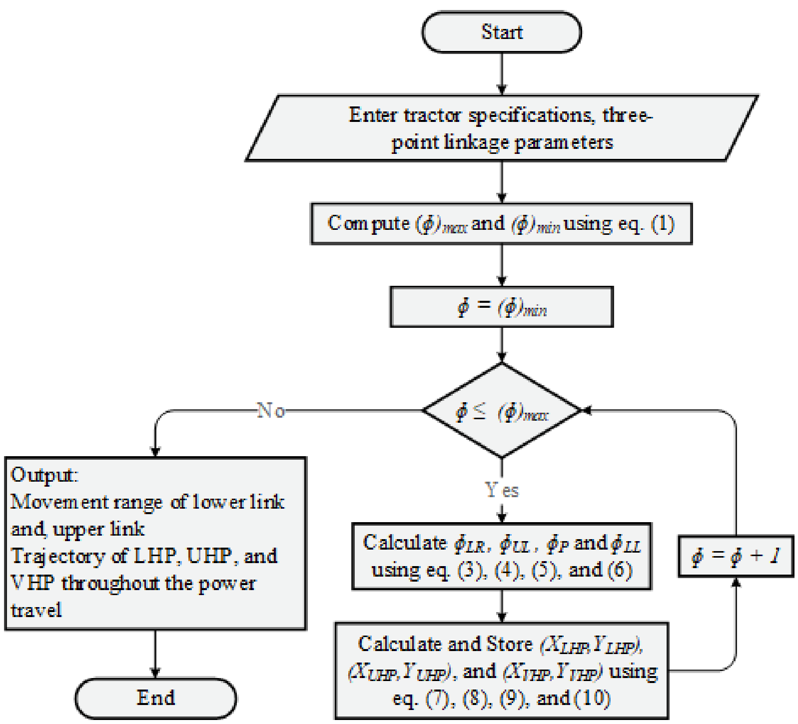


Fig. 5. Flowchart for simulation of three-point linkage hitch

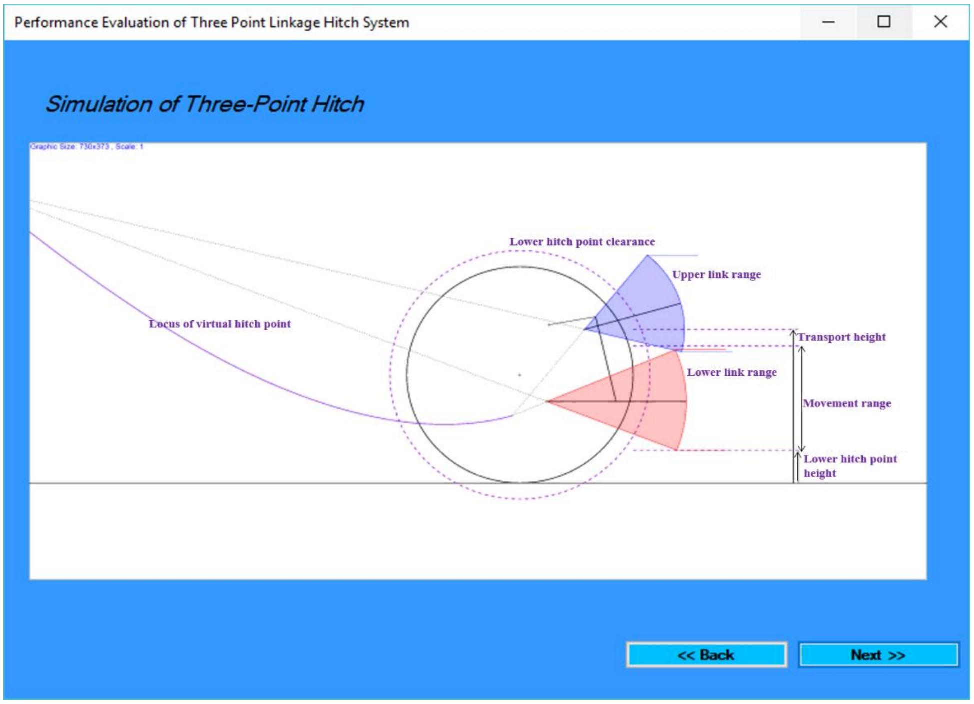


Fig. 6. Graphical representation of three-point linkage hitch

The various steps for simulation process is given as:

Step 1: Enter the tractor specifications and three-point linkage hitch parameters in opening window. These input data are taken from tractor test report.

Step 2: Compute the power travel of lift arm i.e. minimum lift arm inclination $(\phi)_{min}$ to maximum lift arm inclination $(\phi)_{max}$ using Eqs. (1) and (2).

Step 3: Set the three-point linkage hitch to lowest position i.e. $\phi = (\phi)_{min}$.

Step 4: Calculate the lift rod inclination (ϕ_{LR}), Inclination of lower link (ϕ_{LL}), Inclination of upper link (ϕ_{UL}), Inclination of mast (ϕ_P) using Eqs. (3)-(6).

Step 5: Calculate LHP, UHP and VHP using Eqs. (7), (8), (10) and (11).

Step 6: In simulation, the value of ϕ incremented by 1 and repeats from step 4. The simulation continued until the convergence criteria i.e. $\phi = (\phi)_{max}$ is achieved.

Step 7: the locus of LHP, UHP and VHP is generated by simulation for throughout the power travel of lift arm i.e. $(\phi)_{min}$ to $(\phi)_{max}$.

The above-mentioned simulation procedure was applied to a Category 2 three-point linkage hitch with the dimensions given in Table 3. The standard dimensional parameters given in ISO 730 for the selected three-point linkage hitch category is given in Table 1. The graphical representation of simulated system is shown in Fig. 6. The loci of the lower hitch point, top hitch point and virtual hitch point are graphically generated using Dot Net Frameworks' Graphics library. The movement range of the lower link and top link is also drawn. In Graphics, dotted lines shows the limits of standard value. Graphical representation helps to identify which parameter is close or far away from suggested standard values. Through the graphical representation, it is easier to visualize the reach of the linkages throughout the movement range of three-point linkage hitch system. It is easier to compare the parameters with the standard values.

3.4 Performance Analysis of Three Point Linkage Hitch System

In this section, the effect of different three-point linkage hitch dimensional parameters on its mechanical advantage is analysed. The mechanical advantage of three-point linkage hitch system is calculated using Eq. (11) and simulated throughout the power travel of lift arm. The mechanical advantage curve was plotted using Dot Net Frameworks' Chart library.

In order to analyse the relative impact of each three-point linkage hitch dimensional parameters on its mechanical advantage, a sensitivity analysis was carried out. For that purpose, each input parameter such as lower link length, lower link point position, lift rod length, distance of lift rod connection point on lower link from lower link point, lift arm point position was varied from -10 % to +10 % of its initial given value while keeping rest of input parameters as constant, and corresponding mechanical advantage of three-point linkage hitch throughout the power travel of lift arm was calculated.

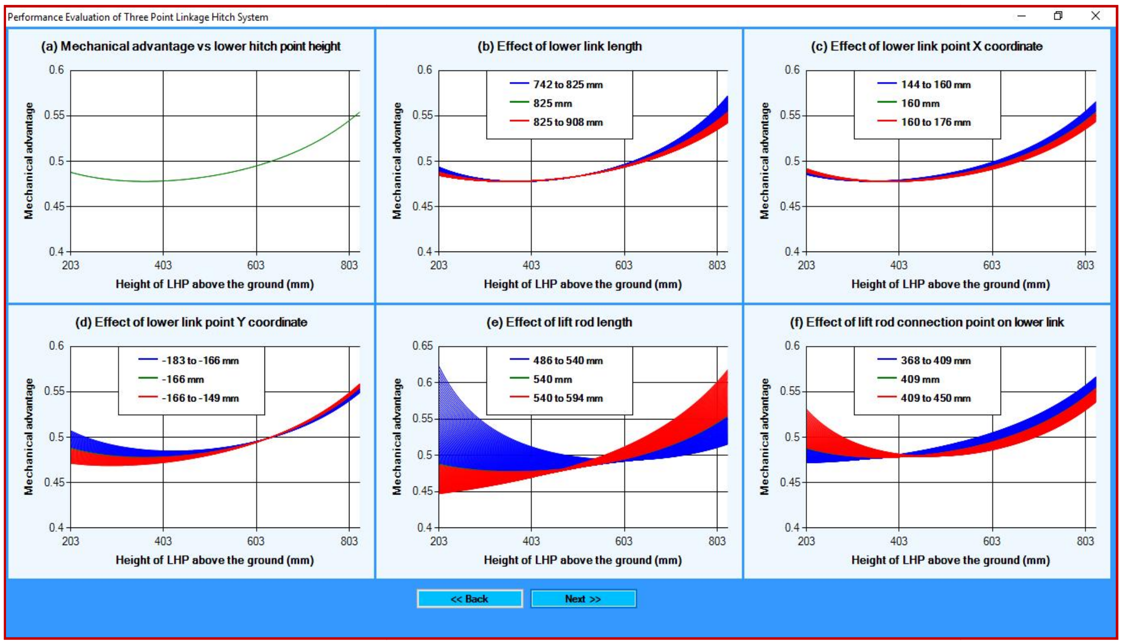


Fig. 7(A). Effects of different three-point linkage hitch parameters on mechanical advantage

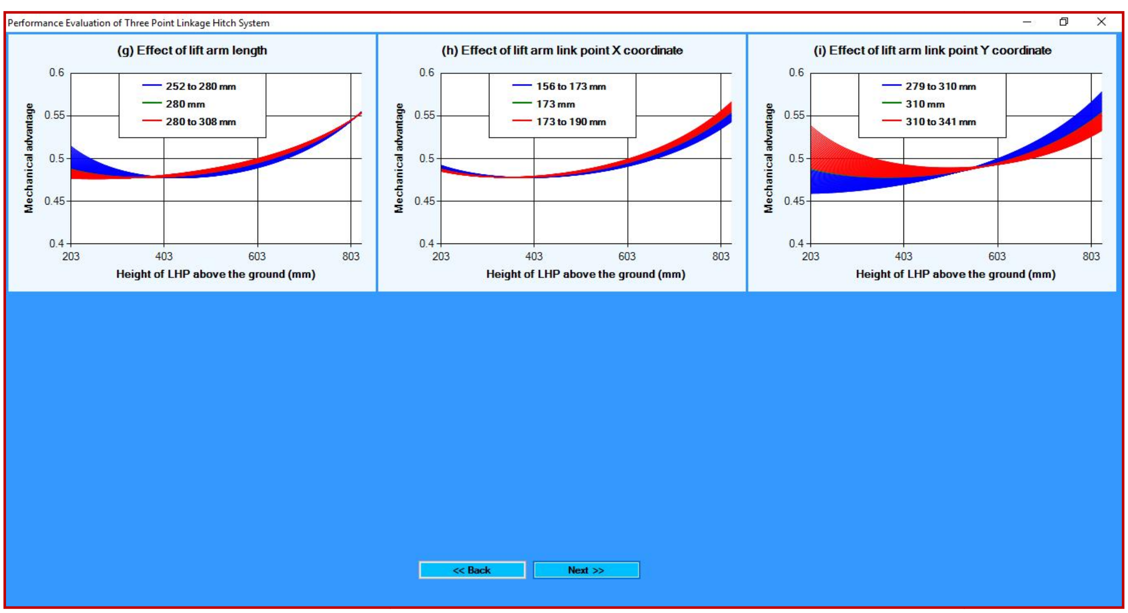


Fig. 7(B). Effects of different three-point linkage hitch parameters on mechanical advantage

Table 4. Sensitivity analysis of three-point linkage hitch parameters

Parameter	Sensitivity			
	Percentage change at lowest Position of LHP		Percentage change at highest Position of LHP	
	-10%	+10 %	-10%	+10 %
Lower Link length	0.119	-0.072	0.319	-0.218
Lower link position in X direction (X_{LLP})	-0.053	0.082	0.208	-0.191
Lower link point position in Y direction (Y_{LLP})	0.393	-0.340	-0.097	0.082
Lift rod length	2.762	-0.833	-0.701	1.143
Lift rod point on lower link	-0.330	0.875	0.221	-0.281
Lift arm length	0.544	-0.227	0.010	-0.022
Lift arm point in X direction (X_{LAP})	0.088	-0.056	-0.202	0.221
Lift arm point in Y direction (Y_{LAP})	-0.588	1.032	0.433	-0.387

The effect of different three-point linkage hitch parameters on its mechanical advantage throughout the power travel of lift arm is shown in Fig. 7(A) and 7(B). The blue curve indicates values of the parameter less than its initial value and red curves indicates values greater than the initial value.

After that the sensitivity i.e. Percentage change in mechanical advantage (output) corresponding to the percentage change in the input parameter was calculated by Eq. (19). The sensitivity of each parameter was calculated and tabulated in Table 4. The sensitivity analysis revealed that the lift rod length is the most affecting parameter (sensitivity 2.76) when it decreases at the lowest position of lower hitch point.

$$Sensitivity = \frac{\text{Percentage change in mechanical advantage}}{\text{Percent change in input parameter of three point linkage hitch}} \quad (19)$$

4. CONCLUSION

A computer based simulation programme in Visual Basic. Net programming language was developed for simulating the three-point linkage hitch system. The effect of different dimensions of three-point linkage hitch on its mechanical advantage was analyzed. The results revealed that the mechanical advantage of the three-point linkage hitch system is most affected by the lift rod length. The developed programme is highly flexible and user-friendly. The graphical user interface allows the user to choose various design parameters for three-point linkage hitch system. The developed program is simple, cheap and practically useful for design engineers and also serve the educational and research purpose.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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