*Conference Article*

# Locking Mechanisms and Breaker Pedal Locking System in Backhoe Loaders

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## Abstract

*Backhoe loader machines have various types of locking mechanisms including hood lock, hand breaker drum lock, boom lock and the breaker pedal locking system. All of those mechanisms have their own kinematic analysis in order to ensure that the locking mechanisms work as planned. This article focuses on the kinematic analysis of the breaker pedal locking system and the theory behind the system.*

**Keywords:**  Mechanism, Locking System, Kinematic Analysis

## 1.      Introduction

There are various locking mechanisms in backhoe loaders including the hood lock, hand breaker drum lock, boom lock and breaker pedal locking system. While most locking mechanisms are not complicated, some of them require detailed analysis before the application. The most important criteria being the collision between the parts. In order to understand the criteria, various lock types should be observed. The concept of lock

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systems will be fully understood. Therefore, the need to conduct detailed analysis will be understood.

## 2. Locking Mechanisms in the Machine

Locking roughly means holding two parts together. In backhoe loaders, there are many types of locking mechanisms varying from strong to weak according to their field of use. The hood lock mechanism, hand breaker drum lock mechanism, boom lock mechanism and braking pedal locking mechanism will be mentioned in this article. Out of all these mechanisms, the braking pedal locking mechanism will be focused on the most. Because the range of motion of the connecting parts cannot be designed properly without a kinematic analysis.

## 2.1. Hood Locking Mechanism

Hood locking mechanism is used to close the hood of the machine. Main system is connected to the hood and the hold bar is connected to the engine plate.
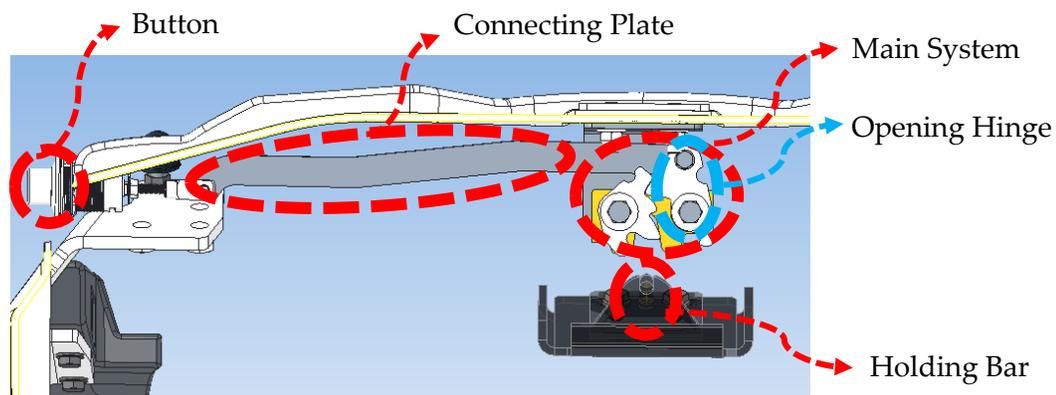


*Figure 1: Hood Locking System*

The working principle of Hood Lock Mechanism: Initially the lock mechanism is open. When the hood is pushed down, mechanism allows the holding bar to interlock with the system. When it is locked, it cannot be opened unless the opening hinge is pushed in a horizontal fashion. In order to push the opening hinge, button should be pressed, therefore pushing the connecting plate, therefore pushing the opening hinge.
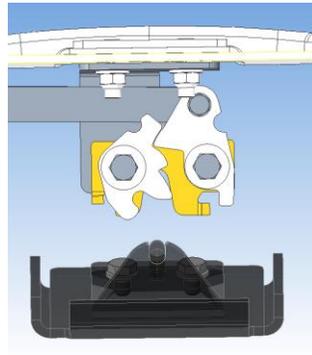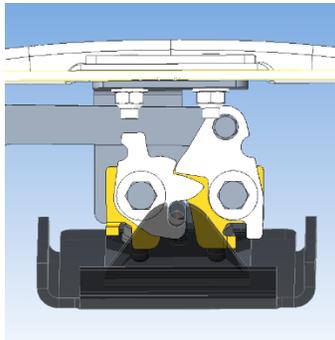
*Figure 2: Hood Lock Mechanism (Open State)*



*Figure 3: Hood Lock Mechanism (closed)*

## 2.2.    Hand Breaker Drum Locking Mechanism

There is a hand breaker option in backhoe loaders. However, the hand breaker hose drum does not come with a built-in locking system in order to save space. Therefore, a custom-made locking system was designed.
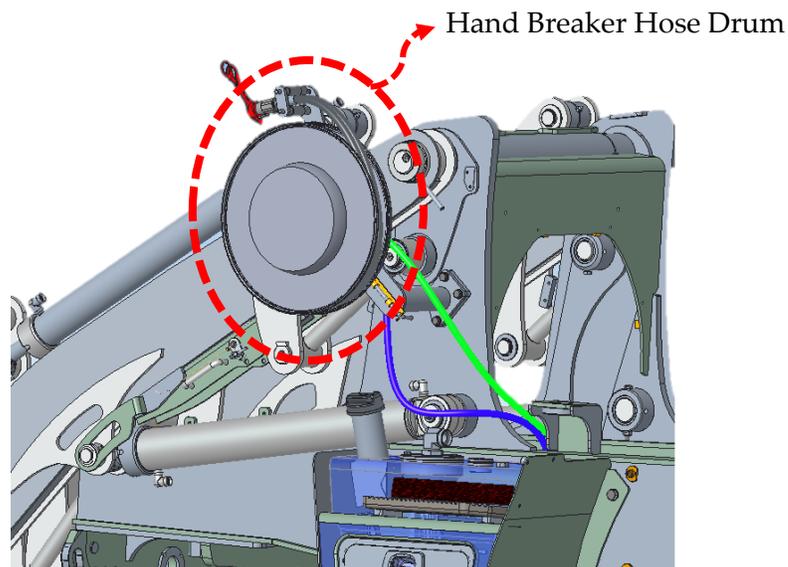


*Figure 4: Hand Breaker Hose Drum Assembly*

Since the hose drum doesn't have a built-in locking system, an external locking system was mounted at the back of the hose drum.

The system consists of a fixed frame and a slider lock, which are shown below:

Fixed Frame
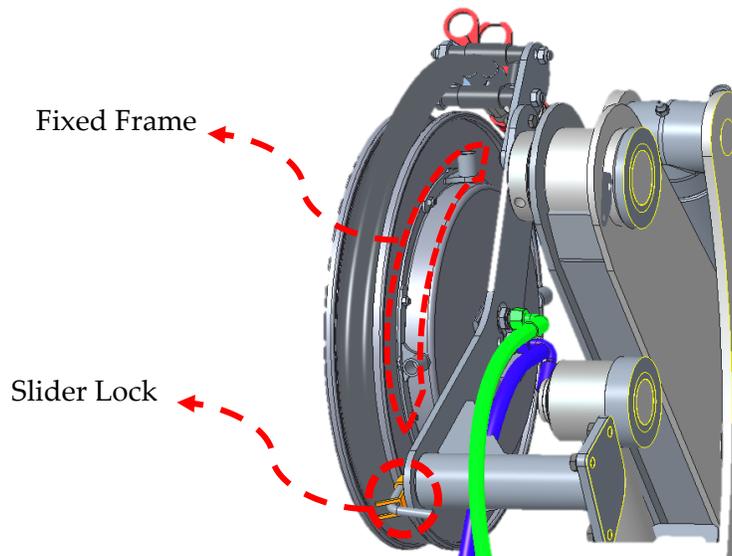
Slider Lock

*Figure 5: Hose Drum Locking Mechanism*

When the slider lock system aligns with the fixed frame locking tubes, operator can slide the lock into the tube, locking the whole hose drum in place. The locking motion can be seen below:
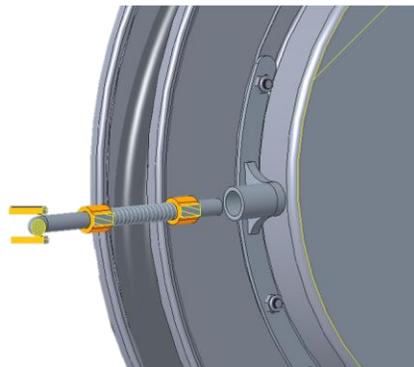
*Figure 6: Hose Drum Lock (Open)*

*Figure 7: Hose Drum Lock (closed)*

## 2.3. Boom Locking System

Boom locking system is used to lock the backhoe side while the machine is travelling. If the boom was not locked in, then the boom would slowly tilt down until it is completely collapsed. In order to prevent this, boom lock is being used. Below, open and closed boom lock systems can be seen:



*Figure 8: Boom Lock (open)*



*Figure 9: Boom Lock (closed)*

### 3.    Breaker Pedal Locking System

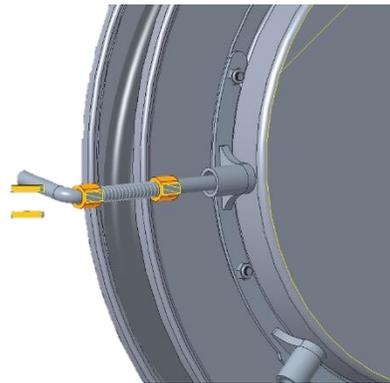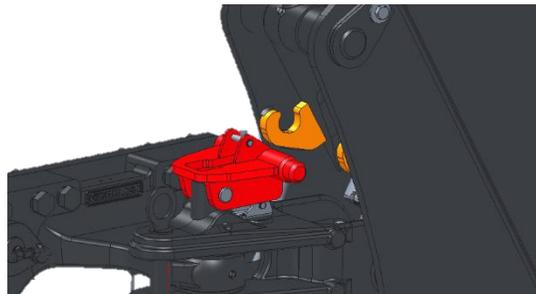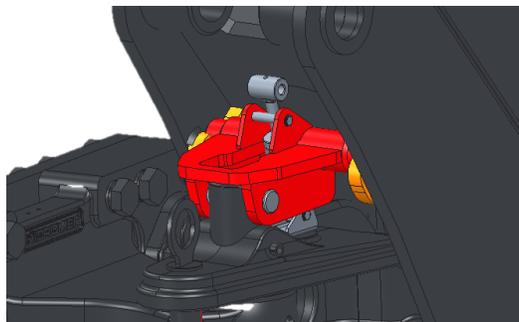### 3.1.    Problem Definition

Backhoe loaders have a breaker option that comes with the machine. In order to use the breaker, an actuator is required. In the current case, the actuator is a pedal mechanism. However, the mechanism does not have a locking system. Which means the pedal is free to move how much the operator presses. While this might seem like a good feature, field requirements are a little different. The operator wants to press the pedal as much as he/she can because it is hard to adjust the force that is applied by foot while working. Therefore, there should be a lock system on the pedal to limit the range of motion.

### 3.2.    Kinematic Analysis

In order to design a proper lock system, a kinematic analysis on the motion of the system should be conducted. Before the analysis, critical points should be determined and transferred into the analysis excel file. Critical points of the lock system can be seen below:
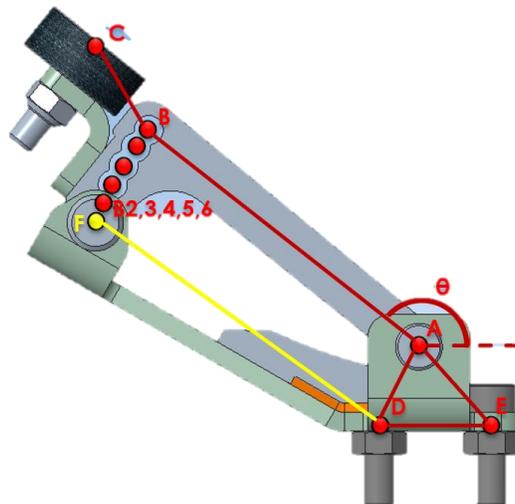


*Figure 10: Pedal Locking Mechanism and Critical Points*

According to the initial design, points D and E are used for mounting the lock system. Point A is the connecting point of the adjusting bar. Point B and the following B2,3,4,5,6 are the possible locking points. Point C represents the rubber chock. Point F is the secondary lock that stabilizes the adjusting bar.

The analysis is done with respect to the points above. Excel table can be seen below:
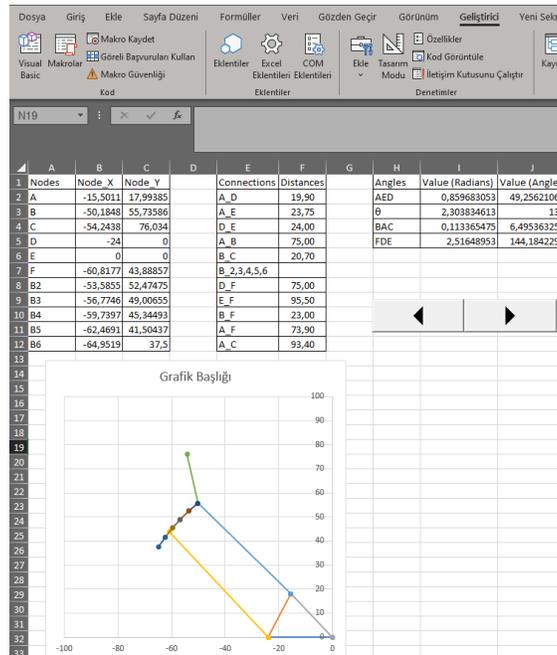
*Figure 11: Excel Kinematic Analysis of Locking Mechanism*

The analysis is based on nodes and the connection bars. Length of the connection bars are determined by the design and the nodes are a result of these bars. Therefore, if the values of the bar lengths were to change, the design would be different. An alternative design with the changed length values can be seen below:
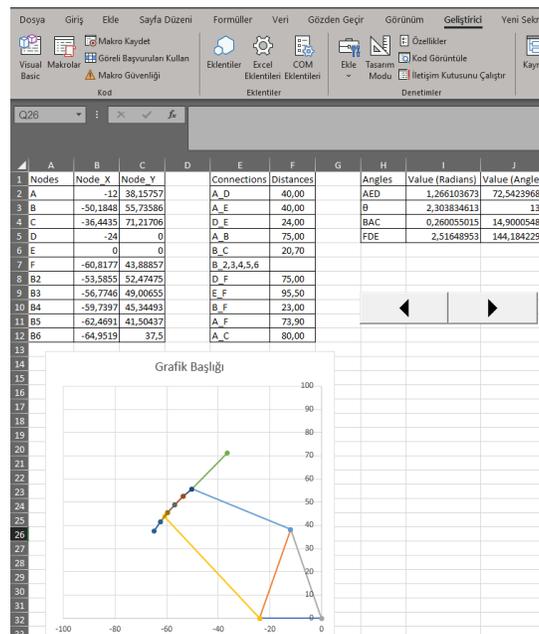


*Figure 12: Excel Kinematic Analysis of Alternative Design*

If the design criteria were to change, it would be easier to see the results of this change on the kinematic analysis table rather than modeling it on CAD program.

The way to conduct the kinematic analysis is as follows:

First three nodes are extracted from the design, the distance between the nodes are known but the angle in between should be known in order to write them down as nodes.

Cosign theorem is used in order to find the angle value.

`=ACOSB(F2;F4;F3)`

| | E | F | G | H | I | J |
|---|---|---|---|---|---|---|
| | Connections | Distances | | Angles | Value (Radians) | Value (Angle) |
| | A_D | 19,90 | | AED | 0,859683053 | 49,25621064 |
| | A_E | 23,75 | | θ | 2,303834613 | 132 |
| | D_E | 24,00 | | BAC | 0,113365475 | 6,495363254 |
| | A_B | 75,00 | | FDE | 2,51648953 | 144,1842292 |

Figure 13: Finding the Angle Value

In this analysis, some of the codes are written via the VBA (Visual Basic for Applications). Therefore functions such as "ACOSB()" cannot be found in the excel default functions. The function will be explained in detail on the next section. ACOSB function takes the edge values of the triangle and returns the angle value of a corner.

TOPLA  `=F5*COS(I3)`

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Nodes | Node_X | Node_Y | | Connections | Distances | | Angles | Value (Radians) | Value (Angle) |
| 2 | A | -15,5011 | 17,99385 | | A_D | 19,90 | | AED | 0,859683053 | 49,25621064 |
| 3 | B | =F5*COS( | 55,73586 | | A_E | 23,75 | | θ | 2,303834613 | 132 |
| 4 | C | -54,2438 | 76,034 | | D_E | 24,00 | | BAC | 0,113365475 | 6,495363254 |
| 5 | D | -24 | 0 | | A_B | 75,00 | | FDE | 2,51648953 | 144,1842292 |
| 6 | E | 0 | 0 | | B_C | 20,70 | | | | |
| 7 | F | -60,8177 | 43,88857 | | B_2,3,4,5,6 | | | | | |
| 8 | B2 | -53,5855 | 52,47475 | | D_F | 75,00 | | | | |
| 9 | B3 | -56,7746 | 49,00655 | | E_F | 95,50 | | | | |
| 10 | B4 | -59,7397 | 45,34493 | | B_F | 23,00 | | | | |
| 11 | B5 | -62,4691 | 41,50437 | | A_F | 73,90 | | ◄ | ► | |
| 12 | B6 | -64,9519 | 37,5 | | A_C | 93,40 | | | | |

Figure 14: Finding Node Coordinates

Here, in order to give motion to the adjusting bar, point B was written with respect to the angle of the bar. The angle value changes with the need and the angle of the adjusting bar changes accordingly.

Theta value is converted to the radians, then the B point is calculated

Now, lets move on to the pedal mechanism which the locking system will limit the motion of:
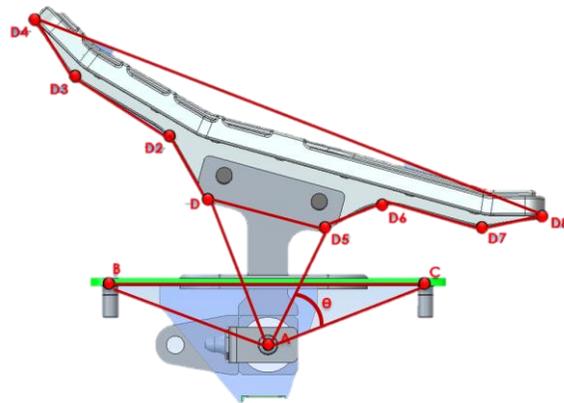
*Figure 15: Pedal Mechanism and Critical Points*

The locking system is used to lock the pedal above the kinematic analysis of the pedal is seen as below:



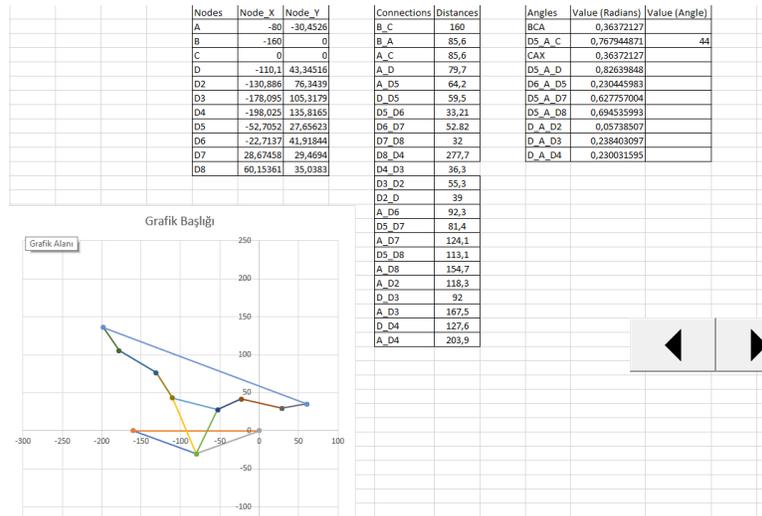| Nodes | Node_X | Node_Y | | Connections | Distances | | Angles | Value (Radians) | Value (Angle) |
|-------|--------|--------|--|-------------|-----------|--|--------|-----------------|---------------|
| A | -80 | -30,4526 | | B_C | 160 | | BCA | 0,36372127 | |
| B | -160 | 0 | | B_A | 85,6 | | D5_A_C | 0,767944871 | 44 |
| C | 0 | 0 | | A_C | 85,6 | | CAX | 0,36372127 | |
| D | -110,1 | 43,34516 | | A_D | 79,7 | | D5_A_D | 0,82639848 | |
| D2 | -130,886 | 76,3439 | | A_D5 | 64,2 | | D6_A_D5 | 0,230445983 | |
| D3 | -178,095 | 105,3179 | | D_D5 | 59,5 | | D5_A_D7 | 0,627757004 | |
| D4 | -198,025 | 135,8165 | | D5_D6 | 33,21 | | D5_A_D8 | 0,694535993 | |
| D5 | -52,7052 | 27,65623 | | D6_D7 | 52.82 | | D_A_D2 | 0,05738507 | |
| D6 | -22,7137 | 41,91844 | | D7_D8 | 32 | | D_A_D3 | 0,238403097 | |
| D7 | 28,67458 | 29,4694 | | D8_D4 | 277,7 | | D_A_D4 | 0,230031595 | |
| D8 | 60,15361 | 35,0383 | | D4_D3 | 36,3 | | | | |
| | | | | D3_D2 | 55,3 | | | | |
| | | | | D2_D | 39 | | | | |
| | | | | A_D6 | 92,3 | | | | |
| | | | | D5_D7 | 81,4 | | | | |
| | | | | A_D7 | 124,1 | | | | |
| | | | | D5_D8 | 113,1 | | | | |
| | | | | A_D8 | 154,7 | | | | |
| | | | | A_D2 | 118,3 | | | | |
| | | | | D_D3 | 92 | | | | |
| | | | | A_D3 | 167,5 | | | | |
| | | | | D_D4 | 127,6 | | | | |
| | | | | A_D4 | 203,9 | | | | |

*Figure 16: Excel Kinematic Analysis of Pedal Mechanism*

However, kinematic analysis is not enough itself. The interactions of both the locking system and the pedal should be checked as well.

If the rubber piece of the pedal locking system is taken as the point of contact, when the covered space that it takes between the locking slots is observed, the below graph occurs:
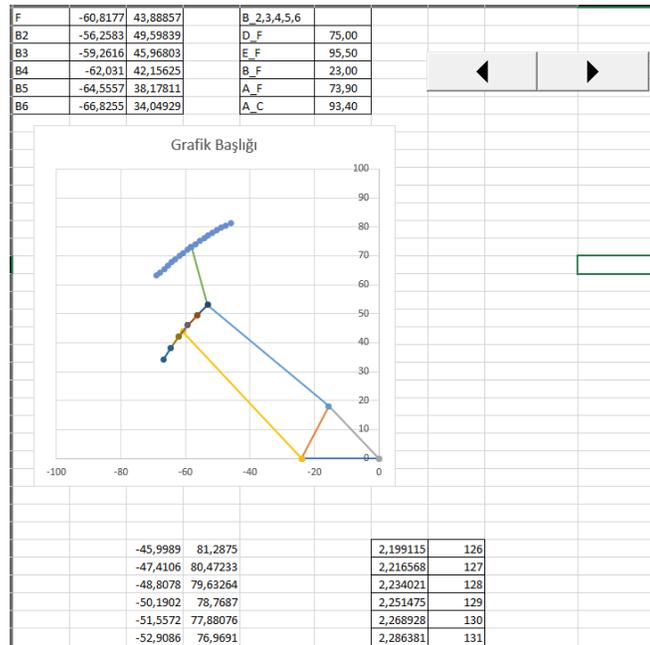
| F | -60,8177 | 43,88857 | B_2,3,4,5,6 | |
|----|----------|----------|-------------|-------|
| B2 | -56,2583 | 49,59839 | D_F | 75,00 |
| B3 | -59,2616 | 45,96803 | E_F | 95,50 |
| B4 | -62,031 | 42,15625 | B_F | 23,00 |
| B5 | -64,5557 | 38,17811 | A_F | 73,90 |
| B6 | -66,8255 | 34,04929 | A_C | 93,40 |

Grafik Başlığı

| -45,9989 | 81,2875 | | 2,199115 | 126 |
|----------|----------|---|----------|-----|
| -47,4106 | 80,47233 | | 2,216568 | 127 |
| -48,8078 | 79,63264 | | 2,234021 | 128 |
| -50,1902 | 78,7687 | | 2,251475 | 129 |
| -51,5572 | 77,88076 | | 2,268928 | 130 |
| -52,9086 | 76,9691 | | 2,286381 | 131 |

*Figure 17: Locking Mechanism Space Covered*

Now let's do the same process with the pedal, and the space between the main point of contacts of the pedal, which are D2 and D3 shown on the figure:

| D3 | -178,095 | 105,3179 | D_D5 | 59,5 | D5_A_D7 | 0,627757004 |
|----|----------|----------|-------|-------|---------|-------------|
| D4 | -198,025 | 135,8165 | D5_D6 | 33,21 | D5_A_D8 | 0,694535993 |
| D5 | -52,7052 | 27,65623 | D6_D7 | 52.82 | D_A_D2 | 0,05738507 |
| D6 | -22,7137 | 41,91844 | D7_D8 | 32 | D_A_D3 | 0,238403097 |
| D7 | 28,67458 | 29,4694 | D8_D4 | 277,7 | D_A_D4 | 0,230031595 |
| D8 | 60,15361 | 35,0383 | D4_D3 | 36,3 | | |
| | | | D3_D2 | 55,3 | | |
| | | | D2_D | 39 | | |
| | | | A_D6 | 92,3 | | |
| | | | D5_D7 | 81,4 | | |
| | | | A_D7 | 124,1 | | |
| | | | D5_D8 | 113,1 | | |
| | | | A_D8 | 154,7 | | |
| | | | A_D2 | 118,3 | | |
| | | | D_D3 | 92 | | |
| | | | A_D3 | 167,5 | | |
| | | | D_D4 | 127,6 | | |
| | | | A_D4 | 203,9 | | |

Grafik Başlığı

| -130,886151 | 76,3439 | | -178,095 | 105,317907 | | 0,767945 | 44 |
|-------------|----------|---|----------|-------------|---|----------|----|
| -132,742256 | 75,43955 | | -180,45 | 103,5852352 | | 0,785398 | 45 |
| -134,582296 | 74,50294 | | -182,774 | 101,8117341 | | 0,802851 | 46 |
| -136,405709 | 73,53436 | | -185,066 | 99,99794414 | | 0,820305 | 47 |
| -138,211941 | 72,53411 | | -187,327 | 98,14441763 | | 0,837758 | 48 |
| -140,000441 | 71,50249 | | -189,555 | 96,25171924 | | 0,855211 | 49 |
| -141,770664 | 70,43981 | | -191,749 | 94,32042548 | | 0,872665 | 50 |
| -143,522071 | 69,34639 | | -193,91 | 92,35112466 | | 0,890118 | 51 |
| -145,254129 | 68,22258 | | -196,036 | 90,34441663 | | 0,907571 | 52 |
| -146,966309 | 67,06871 | | -198,126 | 88,30091267 | | 0,925025 | 53 |

*Figure 18: Pedal Mechanism Space Covered*

In order to use these values in the machine, the results should be checked on the same graph in order to decide whether the design is suitable for the use:
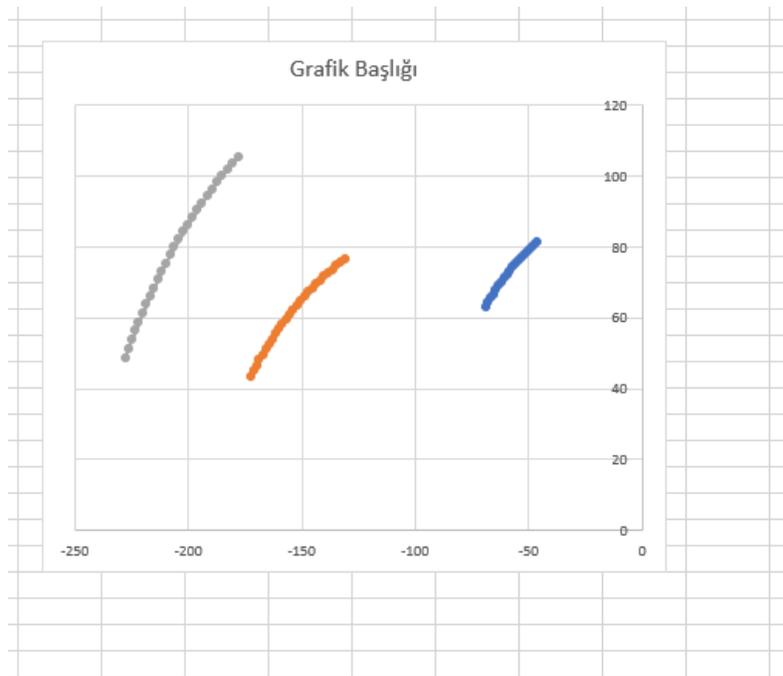
*Figure 19: Spaces Covered by Locking Mechanism and Pedal Mechanism on the Same Graph*

It has been found out that the range of motion of the pedal is enough for the locking system to work. However, the mechanism should have an offset from the position of the values accordingly. In the current case, the origin values are in different points. If the origin values and the necessary position of the locking system are considered, it can be said that the locking system should have a (-125mm, -20mm) offset with respect to the pedal system, which looks like below:
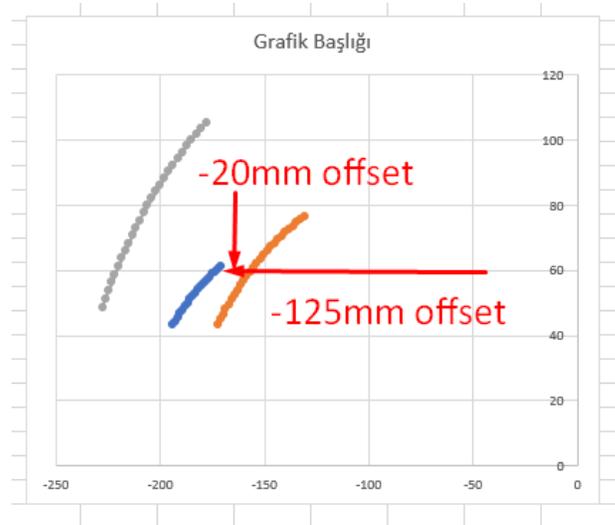


*Figure 20: Necessary Offset Values*

With these offset values, locking mechanism will interact with the pedal mechanism and it will limit the range of motion of the pedal mechanism.

### 3.2.1. Visual Basic Codes

Visual basic is used in excel to implement functions to use in the formulas that are written in the cells. In the kinematic analysis, formulas that are used repeatedly are written in visual basic and called into the cells. The visual basic code can be seen below:



*Figure 21: Visual Basic Functions*

AngCos(u1, u2, Opposite): This function uses the cosign theorem to calculate the angle of a specific corner with the known three edges of the triangle. U1 being the known side edge, u2 being the other and the opposite being the edge that is at the opposite side of the corner. Returns the angle.

MagCos(u1, u2, Angle): This function takes the side edges and the angle of the corner. Returns the opposite side edge length.

Acos(X)/Asin(X): These functions are used to easily get the Arccosine value of the given X.

D_R(): This function does not return a value. However, it is used to convert the angle value to radians.

### 3.3. Model Application

With the necessary design criteria met, finalized design can be seen below:
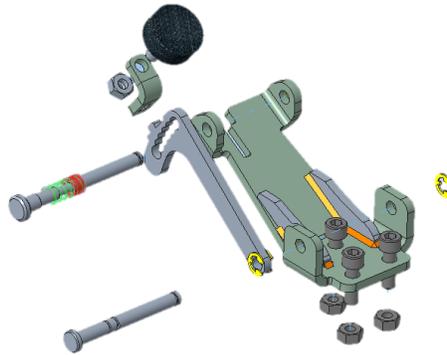


*Figure 22: Locking Mechanism Isometric View*
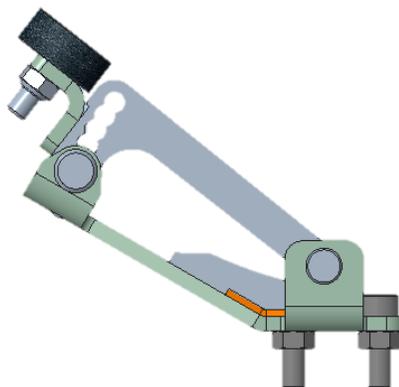


*Figure 23: Locking Mechanism Exploded View*



*Figure 24: Locking Mechanism Side View*

## 4.      Result

It has been found that the design of the locking mechanism is enough to restrict the movement of the pedal mechanism in the way that is necessary. If the design criteria were to change, the locking mechanism design will be easily changed with the help of the kinematic analysis done on the mechanism.

## 5.      Discussion and Conclusion

Locking mechanisms can vary from simple to complex according to their field of use. Not every locking mechanism require a detailed kinematic analysis but when it is needed, it can be done according to the methods that are given above.

After the kinematic analysis done on both of the mechanisms that are expected to interact, their interference can be observed throughout the kinematic analysis scheme.

It has been found that the locking mechanism used to limit the pedal mechanism meets the requirements of the design criteria.

## 6.      Acknowledge

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