Conference Article

Mini Backhoe Loader Agriculture Attachment Integration

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Abstract

General use of mini backhoe loader construction machines; Loading is done with the bucket at the front and digging is done with the backhoe at the back. Since the machine is small in size, it can be used in orchards, greenhouses and narrow agricultural areas. However, in order for agricultural equipment to be used with this machine, radical changes were needed. In this study, an adapter design that can be easily mounted on the mini backhoe loader and connected to the agricultural equipment was made using the CREO Parametric package 3D design program. The adapter design has been made to be suitable for use with a single operator. In this context, stab cylinders were added on the adaptor and a quick coupler system was used. In addition, high flow rate application allows the use of different agricultural attachments both at the front and at the rear.

In this paper, structural design details, analysis and applications of the integrated attachment are shared. An adapter has been designed to work well with attachments requiring 65 HP and lower power, and its functional suitability has been ensured.

Keywords: Mini Backhoe Loader, Agriculture, Attachment integration

1.   Introduction

Backhoe loaders are widely used in areas requiring heavy work, especially in the construction field. There are two main areas in the backhoe loader machine: the backhoe side and the loader side. Digging, trenching and loading operations are carried out with

the backhoe side, and loading operations are carried out with the loader side. Although the mini backhoe loader machine is weaker in terms of work capacity, it has almost the same features as normal size backhoe loader machines in terms of functionality. Unlike the backhoe loader machine, the mini backhoe loader machine has a more compact structure compared to the backhoe loaders used today. Thanks to this compact structure, it is possible to work in narrow spaces. Thanks to their small structure, mini backhoe loader machines provide the opportunity to work in greenhouses, gardens or anywhere that is difficult to reach. The general usage area of backhoe loader machines is loading thanks to the front loader bucket and digging thanks to the backhoe bucket. However, since backhoe loader machines do not have a PTO shaft, it is impossible to use the attachments used on the tractor. This paper describes the structural design details, analysis and applications of agricultural attachment integration on mini backhoe loader machines.

2.   62T Backhoe Loader

The general usage area of mini backhoe loaders is loading with the loader side and digging with the backhoe side. Its more compact structure than normal backhoe loaders allow it to enter and work in areas that normal backhoe loaders cannot enter.

3.   Current Agriculture Applications

Nowadays, agricultural attachments are used in the agricultural field to collect crops, transport crops, spray, fertilize, etc.

3.1   PTO Outlet

PTO (Power Take Off) output is used to drive attachments in agricultural machines. The PTO output, which is on a shaft connected to the hydraulic motor, is connected to the attachment by extending it with a telescopic shell. Thanks to the U-joint structure located above the PTO outlet and on the side of the attachment, the attachment can be used in an offset position parallel to the axis of the PTO outlet.
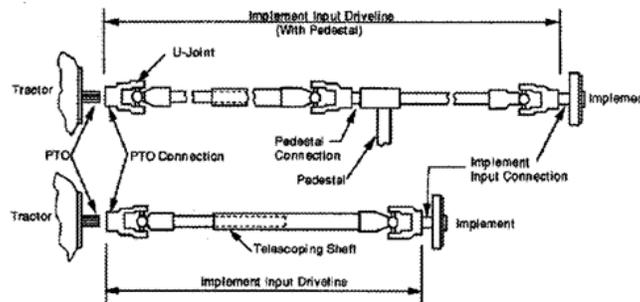

Figure 1: PTO Outlet

PTO output is generally driven at 540 RPM, but this value can go up to 1000 RPM.

3.2 Attachment Types

Agricultural attachments can be used in applications such as harvesting crops, loading and unloading, stacking bales, shovelling snow, breaking branches and digging soil.

3.2.1 Wood Chipper

Wood Chipper attachment is an attachment used to turn branches into sawdust. Branch parts that cannot be shredded by hand can be shredded thanks to the branch shredding attachment mounted on the back of agricultural machines.

Figure 2: Wood Chipper Attachment

3.2.2 Plough

The plough attachment digs the soil and prepares it for planting crops. The plough removes surface weeds.

Figure 3: Plough Attachment

3.2.3 Soil Rotavator

The soil rotavator is used to cultivate, spread and aerate the soil. In this way, it contributes to the growing of crops. The blades on the rotavator cut the soil and distribute the soil.

Figure 4: Rotovator Attachment

4.   Adaptor Design

62T mini backhoe loader machine can dig/load with its rear side and load with its front side. However, an adapter is required to attach agricultural attachments to the 62T. This adapter must be suitable for attachment mounting and must have a PTO output. A three-point hitch mechanism was used to mount the agricultural attachment on the 62T machine. The three-point hitch mechanism allows the operator to mount the attachment to the machine alone. A hydraulic motor with a PTO shaft is used to provide PTO output from the machine. The hydraulic motor is controlled from the machine's hydraulic line.

4.1 Three Point Hitch Mechanism

The three-point hitch mechanism has similar structural elements for the front and rear. The functions of the elements are stated below:
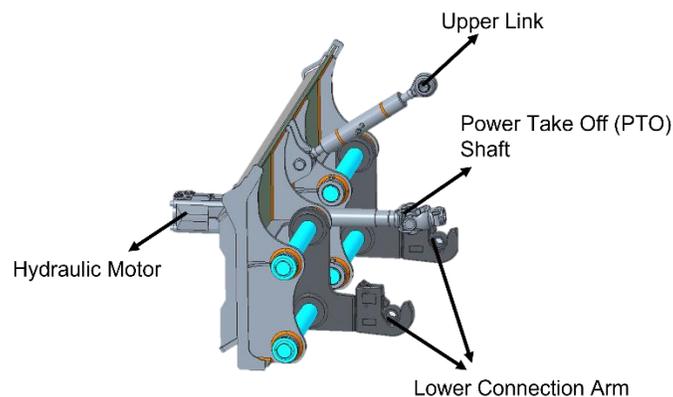
Figure 5: Three Point Hitch Mechanism

Upper Link: It is mounted on the upper connection point of the attachment. It creates a reaction moment in the opposite direction to prevent the attached attachment from tipping outwards.

Lower Connection Arm: Connects to the lower attachment points of the attachment. The lower arms bear the weight of the attachment.

Hydraulic Motor: The hydraulic motor is connected to the hydraulic line of the machine and enables the PTO output to be driven.

Power Take Off Shaft: PTO output is connected to the agricultural attachment.

4.2 Structural Calculations

When making the structural calculation of the adapter, it must be able to carry the weight of the attachment to be mounted on the adapter within the safety coefficient value. The weight of an average agricultural attachment is taken as 385 kg. The center of gravity of the attachment is assumed to be 0.7 meters far of the lower and upper attachment point. Below are the calculations:

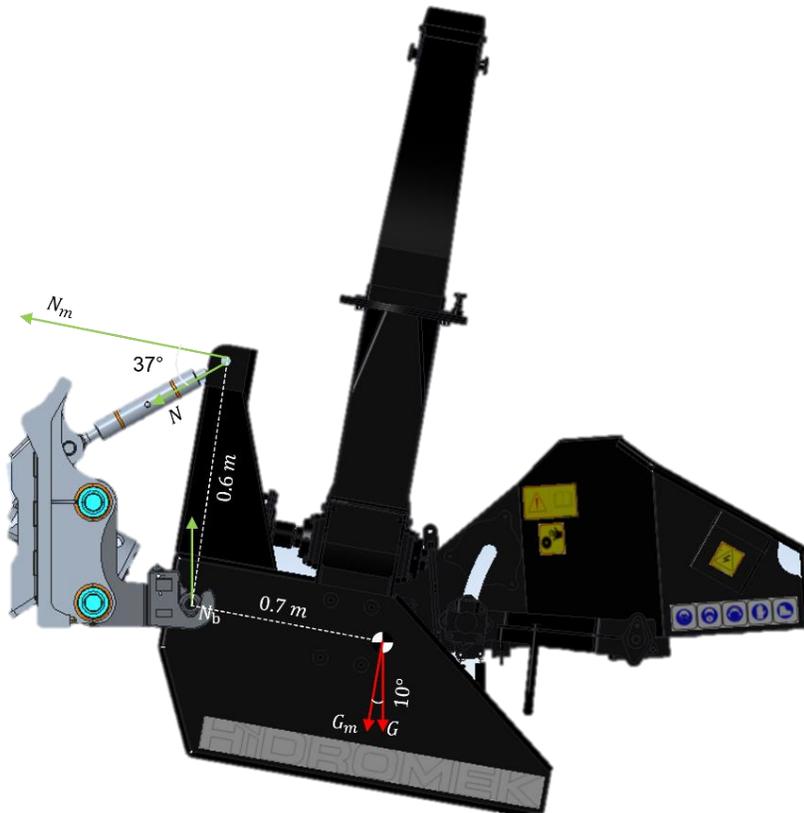Upper Link and Lower Link Arms Load Calculation:

Figure 6: Adaptor with Wood Chipper Attachment

The average attachment weight is taken as 385 kg:

$$G = 385 \ kg = 3776 \ N$$

The moment created by the weight is calculated:
Since the attachment is stationary, the total moment at point b must be zero.

$$\sum M_b = 0$$

The relationship between all moments acting on point b:

$$\sum M_b = 0 = (N_m * 0.6 \ m) - (G_m * 0.7 \ m)$$

$$N_m * 0.6 \ m = G_m * 0.7 \ m$$

$$G_m = G * \cos(10)$$

$$G_m = 3718 \, N$$

$$3718 \, N * 0.7 \, m = 2603 \, N.m$$

The force to resist this moment from the upper connection is calculated:

$$N_m * 0.6 \, m = 2603 \, N.m$$

$$N_m = 4338 \, N.m$$

$$N = \frac{N_m}{\cos(37)} = \frac{4338}{\cos(37)} = 5432 \, N$$

According to the calculations, the upper connection element should not undergo plastic deformation within the safety factor when a force of 5432 Newtons is applied. To check this, the weakest part of the upper link is measured:
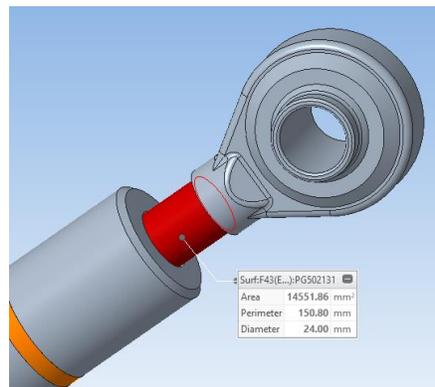

Surf:F43(E...):PG502131	
Area	14551.86 mm²
Perimeter	150.80 mm
Diameter	24.00 mm

Figure 7: Upper Link Diameter

In order for a shaft with a diameter of 24 mm and material S355jr to be considered safe, the stress on it must be less than 235 MPa. The stress value is calculated below:

$$\sigma = \frac{F}{A} = \frac{5432N}{\pi(12 * 10^{-3})^2 m^2}$$

$$\sigma = 12 \, MPa$$

The tension value on the shaft was found to be a safe value. This stress will not cause any deformation; the same stress calculation must be made for the lower arms:

To calculate the stress on the lower link arms, it is necessary to calculate the weight of the attachment as well as the force exerted on the lower arms resulting from the moment response of the upper link element. The reaction force reflected from the upper link to the lower arms is as follows:

$$N_t = N * \sin(37) = 5432 * \sin(37)$$

$$N_t = 3269 \, N$$

The reaction force is parallel to the attachment but not parallel to the lower arms. If the 10-degree inclination of the attachment is taken into account, the calculation of the force acting vertically on the lower arms is as follows:

$$N_t = 3269 * \cos(10) = 3219 \, N$$

The calculation of the total vertical force acting on the lower arms is as follows:

$$F_y = G + N_t$$

$$F_y = 3776 \, N + 3219 \, N = 6995 \, N$$

Based on the weakest point of the lower arm, the point where the stress calculation will be made is shown below:
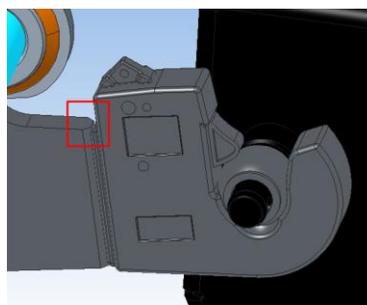

Figure 8: Lower Arm Weak Point

The weakest point on the lower arm is the welded area. The calculation of the force on the weld was found to be 6995 N in the calculations made above. Two different methods should be used to calculate the tension on the source. Separate calculations must be made for shear force and moment force. The calculation made using the cutting force is given below:
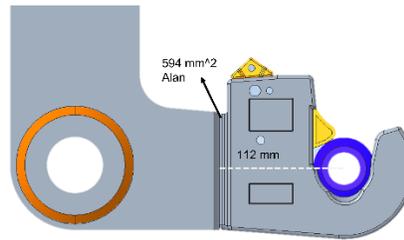
Figure 9: Lower Arm Dimensions

$$\tau = \frac{Q}{F_k}$$

$$Q = 6995 \ N$$

$$F_k = 594 \ mm^2$$

$$\tau = \frac{6995}{594} = 11.8 \ MPa$$

As a result of the calculations, the shear stress was found to be 11.8 MPa.

No.	Structural detail	Description	Requirements	FAT Steel	FAT Alu.
6		Cruciform joints with load-carrying fillet welds	Fillet welds, as welded	90	36

Figure 10: Force Illustration in IIW Welding Book [9]

The brittle yield value of the weld zone in the relevant region is safe at 90 MPa according to the IIW booklet. Since the found value of 11.8 MPa is within the safe value, the lower arms are suitable for attachment carrying function.

The lower arms and upper link were found to be secure enough for a 385kg attachment. Since the design criterion was chosen to be able to handle all attachments suitable for the power of the machine, the safety coefficient was found to be high.

4.3 Hydraulic Motor Calculations

PTO outputs generally operate at 540 rpm, but can go up to 1000 rpm as needed. The hydraulic motor to be selected must have the capacity to provide this speed. If we take the speed of 540 rpm as basis, it is expected that a machine that can reach a flow rate of 120 L/min can reach at least 540 rpm at maximum flow rate. Calculations are as follows.

$$Max_{rpm} = \frac{Flow\ Rate\ \left[\frac{L}{dk}\right]}{Displacement\left[\frac{cm^3}{rev}\right]}$$

$$Max_{rpm} = 540\ rpm$$

$$Displacement = 200\frac{cm^3}{rev} = 0.2\frac{L}{rev}$$

$$Flow\ Rate = Max_{rpm} * Displacement$$

$$Flow\ Rate = 540\ rpm * 0.2\frac{L}{rev} = \mathbf{108\frac{L}{min}}$$

Flow rate calculation was made according to the displacement value of the selected hydraulic motor and it was found that sending 108 L/min to the hydraulic motor lines was sufficient to provide 540 rpm.

4.4 Integration and Assembly

In order to mount the adapter on the machine, the bucket must be removed from the front and the backhoe assembly from the rear.
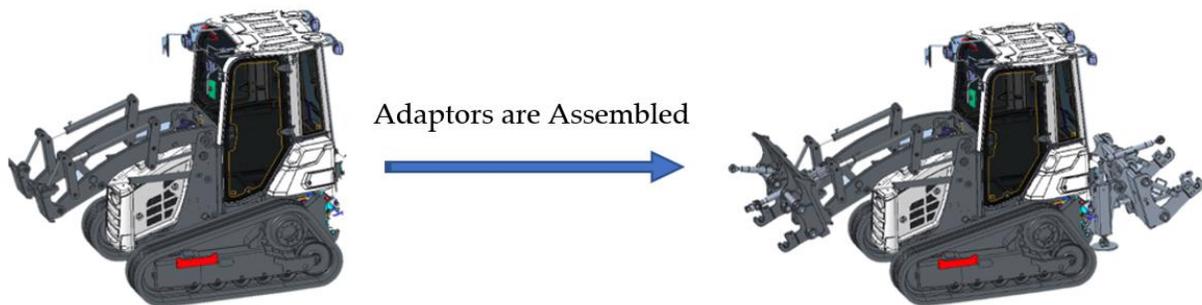

Figure 11: 62T Adaptor Assembly

After these operations are completed, a front attachment can be installed instead of the bucket at the front, and a rear attachment can be installed instead of the backhoe at the back.

4.5 Utilizable Attachments

Attachments that can be used with the 62T agricultural machine must be able to operate at 65 HP or less. Attachments that can be used; Branch Grinder, broom, rotovator etc.

5.   Hydraulic System

5.1   High Flow Option

The high flow valve is fed by an additional pump next to the main pump, increasing the hydraulic flow from 60 L/min to 120 L/min. High flow line is used in lines that require high flow on the attachment. The representation of the high flow line on the hydraulic diagram is as follows:
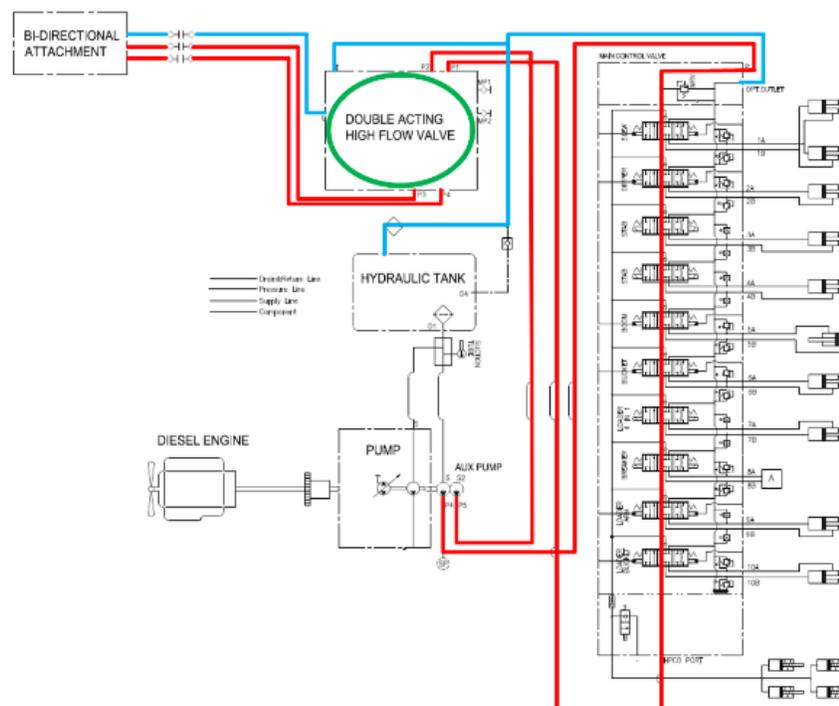

Figure 12: Hydraulic Diagram

5.2   Quick Coupler

The quick coupler system ensures fast attachment replacement. Normally, it takes approximately 3 hours to change all hoses concerning the attachment. However, thanks to the quick coupler system, this time is reduced to less than 15 minutes.

Figure 13: Quick Couplers

6.   Result

As a result of the design, analysis and tests, it has been observed that if suitable attachments are used for the engine and hydraulic system of the machine, the attachments work with the expected performance. In cases where an attachment higher than the capacity of the machine was installed, it was observed that the attachments worked at low performance as expected.

In order to expand the usage area of mini backhoe loader machines, it has been deemed appropriate to use them as a backhoe/loader or agricultural machine if desired by attaching appropriate adapters.

7.   Discussion and Conclusion

As a result of the design, analysis and tests, it has been seen that it is possible to use the machines used in the construction field in the agricultural field with the use of appropriate adapters. A sufficient level of functionality and efficiency has been reached. However, mounting an attachment on the adapter is not an easy process. Although it is possible, the process can be completed depending on operator skills. In this case, assembly should be made easier and should be made simple enough for every operator to do.

This research was conducted for mini backhoe loader machines, but the same process should be applied for normal backhoe loader machines. While the mini backhoe loader is limited to 65 HP, this number is higher for the normal backhoe loader, allowing the use of larger attachments.

In the next phase of the research, design analysis and tests can be carried out based on different machines from different sectors.

The 62T mini backhoe loader used in the construction industry can be used in the agricultural field if appropriate adapters are used.

8.   Acknowledge

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