DESIGN AND PROTOTYPING OF ELECTRIC CARRYING TRACTORS

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ABSTRACT

Locations with hard-to-reach access make people living in 3T (Terluar/Front, Terpencil/Remote, Terbelakang/Backward) areas unable to enjoy quality fuel oil (BBM) at affordable prices. This research provides solutions for people in remote areas and communities in the 3T area to utilize agricultural equipment without dependence on fuel. The agricultural equipment in question is a Multifunctional Portable Tractor driven by an electric motor, using a battery. Batteries are recharged from solar sources through solar panels, water turbines and wind turbines. The research method used adopts the "Walter Franco" method (Franco et al., 2020). Product design and development involved 3 farmer groups from 3 different regions in West Java and six small machinery component industries in West Java, Indonesia. Research methodology involves the use of observations and field-testing prototypes as instruments. This research resulted in innovative equipment that can be used for sloping land farming. This equipment is the only mechanical agricultural equipment that can be folded and carried by one person, so its contribution to research in inclined land farming is very large. This equipment is proven to cultivate land on sloping land profitably, so its contribution to farmers in Indonesia and other countries will be very significant.

Keywords: Carrying tractor, Electric drive, 3T, Sloping land, Agricultural mechanization

INTRODUCTION

Indonesia is an agricultural country with vast agricultural land potential, but until now it is still difficult to achieve food self-sufficiency [1]. Various efforts have been made, one of which is to convert forest land into agricultural land [2]. Indonesia develops social forestry to use forest land for agriculture in surrounding communities [3].

The sloping land in Indonesia is vast. 45% of Indonesia's agricultural land is located on slopes and hills with an altitude of 350-1000 m above sea level [4]. Sloping land agriculture in Indonesia faces a variety of problems including soil erosion, soil quality degradation and land fragmentation [5].

Sloping land is used for agriculture because it supports food security. Agriculture is essential to support the Sustainable Development Goals [6]. Agriculture on sloping land is a land resource that can be utilized for food security and sustainable agricultural development [7]. Agricultural land on this type of land is very important for smallholder farmers' land to maintain their food security and livelihood [8]. Economic and social growth can be achieved through effective land management, which can help reduce poverty [9].

Indonesia's total land area is around 191 million ha. More than 85% of Indonesia's surface is covered by tropical rainforest vegetation, hamlets, mangroves, agricultural products, and grasslands. Indonesia's land use features show that about 5% of the country's land is residential and residential areas, while nearly 54% of the country's land (102.3 million ha) is forested and forested land—fixed forests and plantation forests. There are 56.5 million hectares of agricultural land, of which 22.4 million hectares are plantations, 17.2 hectares are dry land (dry land and gardens), and 8 hectares are rice fields, with 4.4 hectares (or 55% of rice fields) irrigated [10].

On the other hand, locations with hard-to-reach access make people living in 3T (Frontier, Remote, Backward) areas unable to enjoy quality fuel oil (BBM) at affordable prices. The challenge is very heavy, especially in the mechanism of transportation modes used in fuel delivery, it is not uncommon to combine 2 to 3 modes of transportation with very long travel times, and geographical, weather, and security challenges.

This research provides solutions for remote communities and communities in the 3T area in utilizing agricultural equipment without dependence on fuel. The agricultural equipment in question is a Multifunctional Carrying Tractor driven by an electric motor, using a battery.

The specific objectives of this study are:

1) Produce Carrying Tractors driven by electric motors that can be utilized by people in remote areas and remote islands.
2) Produce products whose production does not depend on imports. Electric Motors, Batteries and Controllers can already be produced domestically.

RESEARCH METHODOLOGY

This research was developed using the method "Walter Franco" [11]. The purpose of this study is to establish a methodology for making devices and machines to help cultivate agricultural land on sloping land, limited land and land that is difficult to reach by farmers. According to (Franco et al., 2020), the methodology consists of two main phases: (1) studying scenarios; and (2) machine design.

This methodology applies various methods in its design development, namely co-design methods, meta-design approach and technological hybridization. The results obtained from this study are the development of innovative agricultural equipment for highland areas in a sustainable manner.

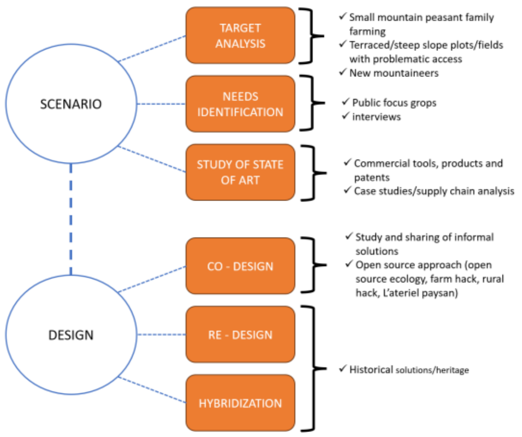

Figure 1. Walter Franco's design methods [11]

3D modelling aims to visualize and analyze objects or structures in more detail before the production process or physical implementation is carried out. This helps save time, cost, and resources required for hands-on physical experiments and provides an opportunity to identify and fix potential problems before they happen in the real world.

Figure 2. Model Frame when in assembly

The resulting 3D design is listed in the cudgel image below. The design concept developed accommodates the design of the carrying tractor frame with a conventional engine so that production costs are expected to be reduced.

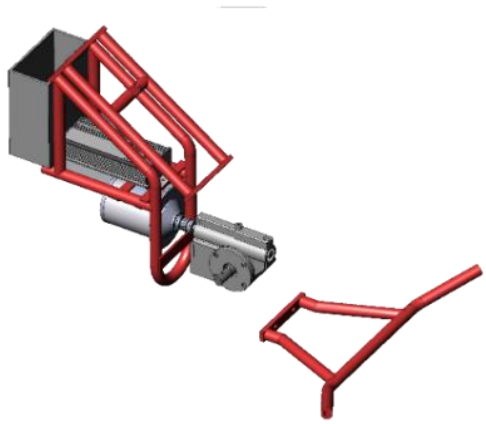

Figure 3. Model Frame when folded.

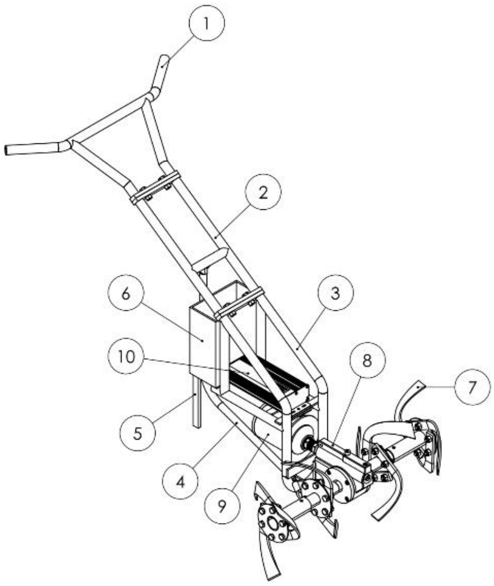

Figure 4. The main components of an electric-carrying tractor

Table 1. Tractor components

No	Part Name	Weight
1	Upper Frame	1.2 kg
2	Middle Frame	2.6 kg
3	Lower Frame	6.2 kg
4	Back Blade	0.9 kg
5	Support	0.6 kg
6	Battery pack	0.8 kg
7	Blade	3.5 kg
8	Gearbox	3 kg
9	Electric Motor	1.3 kg
10	Controller	1.1 kg

The tractor component consists of 10 main components with the weight of each listed in Table 1. The total weight of the tractor is 21.2 kg or 17.7 kg without blades, light enough for farmers to carry. Figure 6 shows a prototype of an agricultural tool that can be folded so that its dimensions become compact.

The prototype frame can be folded so that the dimensions become more compact, initially 72x100x40 cm after being folded to 72x83x40 cm. The knife part can be removed easily so that when the knife is removed and the frame is folded, its dimensions become 62x63x40 cm.

RESULTS AND DISCUSSION

Gearbox Design

The design of the gearbox must be compact considering that this cultivator must be small enough to be carried. The gearbox consists of a Gear Housing and a Worm Gear with a ratio of 1:42. This type of gear can deliver the perpendicular power required to rotate the blade. The following is the design (Figure 5) and prototype of this electric cultivator gearbox (Figure 6).

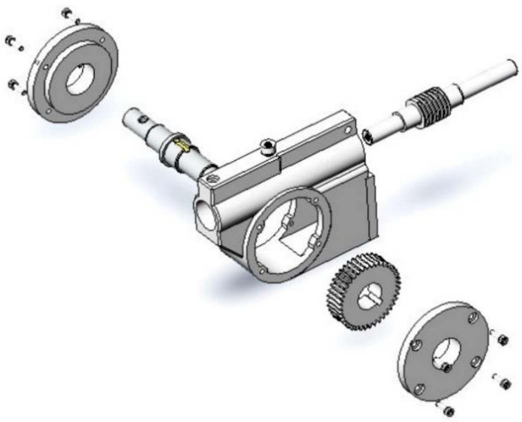

Figure 5. Gearbox design

Electric Motor Selection

Hoe Force (F_e) can be determined by the following equation:

$F_e = \pi g\ soil\ x\ A$

A = 2.704 cm^2 and

$\pi g\ soil$ = 1,59 kg/cm^2

$F_e = 42.14\ N$

Figure 6 Prototype of gearbox

The torque required to hoe the soil is determined based on the equation:

$$T = F_e . r = 7.670\ Nm$$

r is the blade radius = 0,182 m and T required torque in the output shaft of the gearbox.

Next, the power required by an electric motor can be determined by the equation:

$$P = \frac{2\pi . N . T}{60 . i} = 2,87\ KW$$

N is a blade rotation (143 rpm) while i is the gear ratio (1:42)

Figure 7. Electric Motor 3 KW

Battery Pack

Battery pack uses LifePO4 type with a capacity of 72v. This battery pack can be charged using a charger or using solar panels. This battery pack was developed so that it can be used in various tools such as Electric Motorcycles for the Village, Electric Ships, and others.

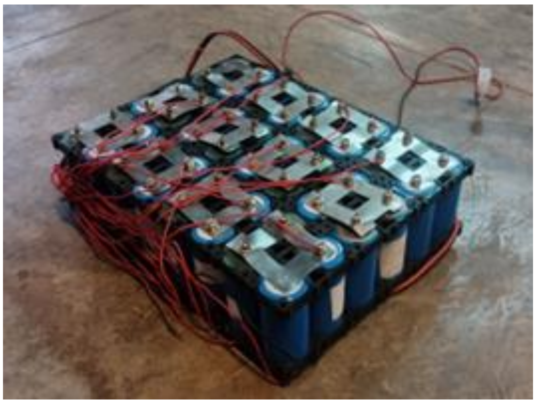

Figure 8. Battery Pack

Frame Design

The frame consists of 3 parts as shown in Figure 4, upper frame (no. 1), middle frame (no. 2) and lower frame (no. 3). This frame is made of 3 parts to facilitate folding and packaging (see figure 9).

The top frame can be removed through two pairs of nut bauds if needed. This is so that the packaging of this product can be more compact. As an illustration (Figure 5), the left image is the product packaging dimension with the top frame that is not removed, while the right image is the product packaging dimension with the top frame removed from the middle frame with dimensions reduced by 38%.

Figure 9. Comparison of product packaging dimensions

The frame material used is a pipe with a standard size of ASME B36.10 and a standard material type of ASTM A53 (Carbon Steel). The frame strength is simulated using the Finite Element Method and the results can be seen in Figure 10-12. The *Von misses* voltage for the upper frame is 38,387 N/m2, the middle frame is 3,634,697 N/m2 and the lower frame is 368,189 N/m2.

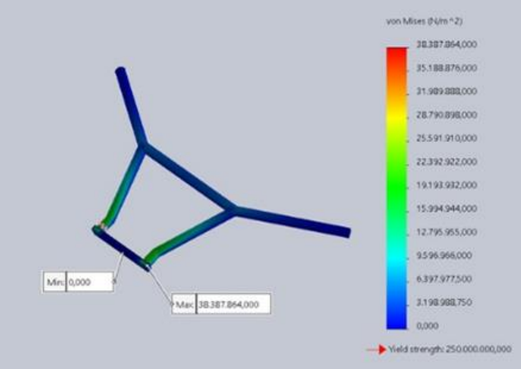

Figure 10. FEM simulation of Upper Frame

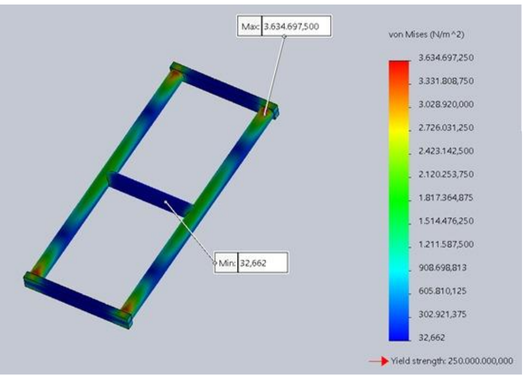

Figure 11. FEM simulation of Middle Frame

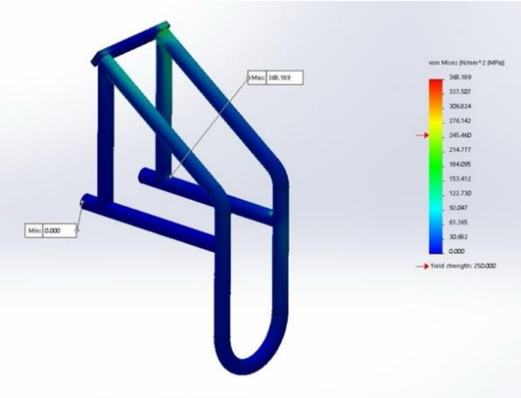

Figure 12. FEM simulation of Lower Frame

Manufacturing Cost Analysis

The cost of making a prototype can be described as follows:

Table 2. Cost of prototyping

No	Part Name	Biaya (Rp.)
1	Upper Frame	
2	Middle Frame	800.000
3	Lower Frame	
4	Back Blade	120.000
5	Support	220.000
6	Battery pack	3.850.000
7	Blade	900.000
8	Gearbox	1.890.000
9	Electric Motor	4.500.000
10	Controller	4.000.000
	Total	16.280.000

Operating Cost Analysis

The results of tests conducted on sloping land in West Bandung district, West Java as shown in Figures 14 and 15, it can be concluded that this equipment can be used to cultivate sloping land. Soil that has been treated using conventional equipment without mechanization (figure 14), is processed using a developed electric-carrying tractor (figure 15).

A comparison of the processing results of this two equipment can be seen in Table 3. The area that can be processed in 1 day (7 hours working) using conventional equipment is 181 m^2. For comparison, the area that can be processed using the developed equipment in 1 day is 1.736 m^2 (at ambient speed 5.5 m/min) In terms of land processing costs, conventional equipment costs Rp. 5,500,000 to process an area of 1 ha. While with the equipment developed, the cost needed is Rp. 985,000.

Table 3. Comparison of tillage results between conventional equipment vs electric carrying tractors

Parameter	Manual Equipment	Electric-carrying tractor
1-day work	181 m^2	1.680 m^2
Land size 1 Ha	Rp. 5.500.000	Rp. 985.000

Figure 13. Tractor prototype

Figure 14. The sloping land treated with conventional tools.

Figure 15. The sloping land is treated with an electric-carrying tractor.

CONCLUSION

The equipment developed has proven to be able to be used on sloping land practically, quickly, and profitably. Equipment can be brought to various conditions of good and minimal road infrastructure. This equipment can be carried by one person on foot or by motorcycle. An increase in tillage speed by 959% can have a significant impact on various aspects, including agriculture, the environment, and the economy. Farmers can prepare land more efficiently, allowing them to grow more crops in less time. This can result in increased agricultural production and food availability. Tillage costs dropped significantly by 79.9%. Lower tillage costs can lead to increased profitability for farmers. With less money spent on tillage, farmers can allocate their resources to other aspects of their operations, such as buying better seeds or investing in new technologies.

This research resulted in innovative equipment that can be used for sloping land farming. This equipment is proven to cultivate land on sloping land profitably, so its contribution to farmers in Indonesia and other countries will be very significant.

This equipment cannot be operated for "wetlands" such as rice fields because the weight of the equipment is too light.

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