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DESIGN, FABRICATION AND TEST OF A SMALL FOUR-WHEEL VEHICLE FOR USE IN AGRICULTURE

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ABSTRACT

The goals of this study are to design and test the performance of a small 4-wheel vehicle for agricultural use, such as determining the vehicle's maximum traction force. Driving at the maximum gradient angle, turning radius, and braking distance, the maximum drive force derived from the calculation and test results of the vehicle is 604.91 Newtons, and the maximum possible speed is 50.51 kilometers per hour. The traction force is 483.89 Newtons, the turning radius is 2.48 m, and the inclination of the road that can be driven up is 15 degrees. With a total resistance of 121.02 Newtons, the vehicle has traction of 483.89 Newtons, making it capable of dragging a load with an acceleration of 1.94 m/s2 or 6.98 km/h/s. The turning radius was 2.36 m, and the error of the turning radius calculated from the experiment was 2.83 percent. The braking distance to a standstill from the braking test at a distance of 50 meters with a speed of 20 kilometers per hour was 4.232 meters.

KEYWORDS: A small ***4***-wheel vehicle for agriculture use; Vehicle performance; Maximum drive force; The braking distance.

I. INTRODUCTION

Thailand is an agricultural country, small 4-wheel vehicles for agriculture. It is an agricultural machine that uses an internal combustion engine as a power source for propulsion. Towing and driving various agricultural equipment, allows farmers to perform many agricultural tasks more conveniently and quickly. The agricultural areas of Thailand have different environments, such as topography.[1] The types and properties of soil in each area are different. When selecting agricultural machinery, one of the most important factors to consider is the environment. And due to the nature of agricultural areas in Thailand, most of which are divided into small plots, it is appropriate to use small 4-wheel vehicles for agricultural use. In addition, the factors that help promote small 4-wheel vehicles for agriculture are highly popular. The versatility of this vehicle, for example, in pumping water into the farm area, is an advantage. This vehicle used to connect with other types of agricultural equipment and transport agricultural products. In addition, the cost of building is not high, so most farmers in Thailand tend to have small, 4-wheel vehicles for agriculture. It is an important tool in a career because it is a small, 4-wheel vehicle for agriculture used to pull agricultural tools. It will be found that efficiency increases when the car can pull more while having the same consumption rate. Because fuel is the same, if a small 4-wheel vehicle for agriculture can be used to exert better traction, it means that it is more efficient, resulting in work savings that can reduce costs and increase production income. However, factors related to increasing the traction of small 4-wheel vehicles for agriculture It consists of the characteristics of the wheels used to drive, the condition of the area, and the nature and type of soil. Considering soil moisture, most farmers will opt for small, four-wheel vehicles for agriculture. By considering the factors in terms of price, speed of work, durability, and convenience of purchasing .The traction test of the small 4-wheel vehicle for agriculture must suit the conditions of the area of use. This will allow farmers to reduce production costs and increase the value of their own agricultural products. This research aims to design, calculate, and test the performance of small 4-wheel vehicles for agriculture, such as the traction of the car, driving power, slope, turning radius, and braking distance. This work is the subject of numerous studies. Payungsak Julyusan, et al.[2] reported the results of their research on measuring the force on the three-point hitch of agricultural tractors. In the country, popular use, therefore, and has developed a three-point force measurement tool to measure the force acting between the cars. Tractors and other category II agricultural equipment force measuring instruments are built on extended octagonal ring (EOR) transducers mounted on a quick coupler capable of measuring 40 kN horizontal and vertical forces, and 10 kN, respectively. The EOR transducer was constructed from S45C steel. Analysis of the stress distribution on the transducer by finite element method revealed that the optimal locations to install the strain gauge to measure horizontal and vertical forces are angle ϕ 95°and angle ϕ32°respectively. Samart Boon-arj[3] has tested the traction force of a walking tractor using steel wheels and rubber wheels for working in cassava fields. It was found that the soil condition was loamy sand, soil moisture 4.83 % dry basis. The traction force suitable for the tractor used in cassava fields was 1,719 Newtons. The suitable wheel type and the working power were 1.16 horsepower at the working speed. 2.7 kilometers per hour has a working capacity of 0.92 rai per hour And the performance of 85.3% is the traction force derived from the research data on the traction test of tractors using steel wheels and rubber wheels for working in cassava fields. This device can be used to make a decision in choosing the correct wheel of the walk-behind tractor and suitable for the conditions of the area of use. Manasak Thippoochom[4] has designed and developed steel wheels of walking tractors according to the research findings that while plowing with a tillage plowing tool; the plowing angle will be at 15-25 degrees relative to the plow groove to stabilize the wheels. Diameter of the steel wheel Walking tractors suitable for operation in most countries are around 80 cm, and a narrow front wheel width is likely to provide a low rolling resistance force, and From testing the designed and developed steel wheels of the walk-behind tractor by plowing the soil with a disc plow, it was found that the steel wheel of the walk-behind tractor of type 4 was shaped like a W, pointed at an angle of 53 degrees, and a wheel diameter of 87 cm. The wheel area is 272 square centimeters, the total required force of the wheel is minimum 1,301 Newtons, the minimum wheel rolling resistance is 757 Newtons, and the lowest wheel dissipated power is 823W, traction performance. Highest drag force was at 33.87 percent. According to the test results, the steel wheels of type 4 walk-behind tractors are suitable wheels in working in farm conditions. Wuthiphon Chansrakoo, et al.[5] conducted research to develop a tractor-trailed pineapple planter at the farmer level. Designed and built a prototype of a medium-sized tractor-trailed pineapple planter (39-50 horsepower) planted in double rows 50 cm. apart, 35-45 cm. apart from the trees. 50 cm. and select the size of shoots with a similar weight in the range of 300-500 kilograms. There is a pickup truck that can contain about 200 shoots on each side. Conveyor feeder is made of 10 cm. diameter PVC pipe. The opening of the planting groove is a plow leg type. Feed the pineapple shoots through the discharge tube behind the slit opener. And two shooters were used to cover the soil with the sprout's root by scraping the soil. The experimental results showed that the prototype planter had the working capacity of 0.63 rai/hour at a moving speed of 0.28 m/s, fuel consumption rate of 2.15 liters/rai, and planting efficiency. 96.05% The shoot was inclined at 72 degrees from the plane. The average planting depth is 16 cm, the average distance between plants is 34 cm., and the average distance between rows is 105 cm. Farmers who will use the pineapple planting machine should have a usable area of not less than 58. 47 rai/year and used for a period of 7 years, so it will be more worthwhile than hiring labor to plant In the case of a farmer having an area of use of 150 rai/year, if the farmer chooses to use a pineapple planter There will be working costs of 730.83 baht/rai, which is cheaper than hiring labor to plant 149.17 baht/rai.

From searching for relevant research, the design and construction of small 4-wheel vehicles for agriculture are used to replace tractors at a minimum cost of 200,000 baht or more, increasing costs for farmers. The researcher therefore designed Build and test small 4-wheel vehicles for use in agriculture. Comes to help facilitate the work by being able to replace a small tractor, for example, use it to push the soil and the rear has a hook to tow a trailer for carrying agricultural products and can be used to drag a set of plows can.

TRACTOR

Types of tractors can be classified by driving method. This type of tractor has equipment and components that make the car drive. This can be divided according to the method of propulsion as follows:

Wheel tractors, the most common type of tractor in agriculture, are classified into three types: 1) A single-axle tractor with both rubber and steel wheels It can be used well for plowing, harrowing, and preparing the planting area for a small area.

Figure 1: Wheel tractor.[6]

Source: https://www.gbs.com.mm/en/products/tractors/four-wheel-tractor/tcr-4wt-kbt-l5018/

2. A track-type tractor is a tractor that is suitable for very soft soil conditions or in areas where wheeled tractors have problems and cannot work. condition of large agricultural areas and new reclamation areas as well.

Figure 2: Track-type tractor.[7]

Source: http://www.pcat.ac.th/_files_school/00000831/data/00000831_1_20141104-103803.pdf

3. Lawn and garden tractors are compact and lightweight tractors. For use in small gardens, the tractor has only two wheels and an engine of 1.5 to 5.2 kW. It is suitable for tillage and weeding between plots. As for the use in the lawn, it will be a tractor with 4 wheels used for mowing the lawn only.

Figure 3: Lawn and garden tractors.[8]

Source: http://www.pcat.ac.th/_files_school/00000831/data/00000831_1_20141104-103803.pdf

Vehicle Performance Calculation[9]

1. **Maximum Velocity**

The maximum possible speed of the vehicle is the position that produces high power in top gear while the engine produces maximum power.

$$V = \frac{3.6(2\pi r)N}{i_o} \quad (1)$$

Where,

V = Velocity, km/h

R = Tire Radius, m

N = Engine Speed, rps

i_o = Overall Gear Ratio

2. **Find the maximum driving force**

The maximum thrust of the car will occur at engine speed.

$$F = \frac{\eta_t i_g i_f T_e}{100r} \quad (2)$$

Where,

F = The maximum Driving Force

η_t = Transmission Efficiency, %

ig = Gear Ratio

if = Final Ratio

Te= Engine Torque, N.m

3. **Find maximum gradiant**

The vehicle can climb the steepest slope must use the maximum driving force.

Wheel Rolling Resistance Coefficient;

$$Kr = 0.015+0.00016V \quad (3)$$

Where,

Kr = Wheel Rolling Resistance Coefficient

V = Vehicle Speed, km/h

Wheel Rolling Resistance

$$Rr = Kr.W \quad (4)$$

Where,

Rr = Wheel Rolling Resistance

Kr = Wheel Rolling Resistance Coefficient

W = Vehicle Weight

Area of Vehicle

$$A = 0.8\ W.H \quad (5)$$

Where,

A = Area of Vehicle

W = Width of Vehicle

H = Height of Vehicle

Air Resistance

$$Ra = K_a A V^2 \quad (6)$$

Where,

Ra = Air Resistance

Ka = Air Resistance Coefficient

A = Area of Vehicle

V = Vehicle Speed

Gradient Resistance

$$R_g = \frac{WG}{100} \quad (7)$$

Where,

Rg = Gradient Resistance

W = Vehicle Weight

G = Gradient

4. **Calculation of drag force**

$$\mathbf{Fdrag = Fdriving\ force - Rt} \quad \mathbf{(8)}$$

Where,

F_{drag} = Drag Force

$F_{driving\ force}$ = Driving Force

R_t = Total Resistance

Design and Fabrication

The steps in designing a small 4-wheel vehicle for agriculture are: 1. studying data from research related to small 4-wheel vehicles for agriculture; and 2. designing the structure of a small 4-wheel vehicle for agriculture by using the SolidWorks program to sketch the structure to hold various equipment as shown in Figure 9. Figure 10 depicts the finished small four-wheel vehicle for agricultural use. Figure 11 reveals the transmission system of the vehicle.

Figure 9: Model of a small 4-wheel vehicle for agriculture designed with Solid work program.

Figure 10: a fabricated small 4-wheel vehicle for agriculture use.

Figure 11: Transmission System.

II.EXPERIMENTAL SET-UP

Experimental equipment, namely a small, 4-wheel prototype vehicle with a capacity of 13 horsepower, was tested. The experiment was conducted on April 20–23, 2022, choosing a day with a clear sky for the most accurate experimental results. Equipment and tools consisted of

1) A prototype of a small, 4-wheel vehicle with a capacity of 13 horsepower
2) A tape measure
3) A protractor for measuring angles
4) An application to capture speed on a smart phone.

The procedure for determining the braking distance is as follows:

1. Determine the point where the braking test will be performed. 50 meters away from the starting point.
2. Take a small, 4-wheeled vehicle for agriculture to the starting point.
3. Start the engine.
4. Leave the starting point at a speed of 20 kilometers per hour.
5. At the point where the brakes are to be lifted, lift the accelerator and immediately apply the brakes.
6. Measure the distance from the point where the brake pedal is applied to the distance of the front wheel when the car is stationary.
7. Record the experimental results.

The studies are shown in Figures 12–13.

Figure 12: Testing to catch the braking distance.

The turning radius experimental procedure is: 1. Set a straight line using talcum powder in a line. 2. Bring small 4-wheel vehicles for agriculture to the starting point 3. Begin driving from the starting point.4. Make a leftmost turn at 35 degrees with the wheels on both sides of the car overlapping in a circle. 5. Measure the diameter of the wheel track that covers the powder by measuring at the outermost wheel distance. 6. Record the experimental results.

Figure 13: Turning radius experimental procedure.

The experimental procedure for determining the maximum slope is as follows: 1. Bring small 4-wheel vehicles for agriculture to the test point to find the highest slope. 2. Experiment at a slope of 15 degrees, a distance of 3.5 meters. 3. Drive up the slope to the test.

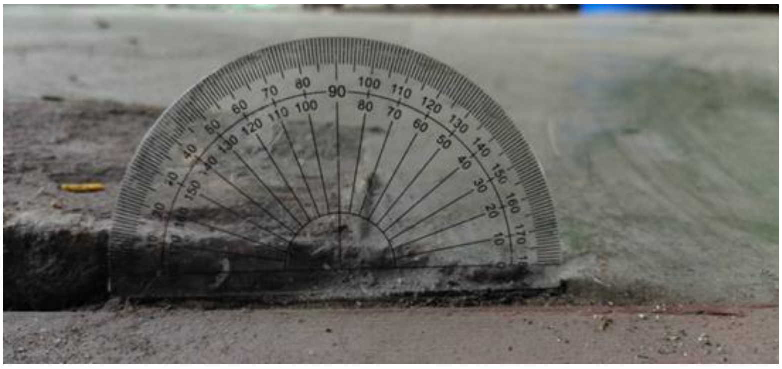

Figure 14: Experiment at a slope of 15 degrees.

Analysis of the load on the vehicle frame in 3 conditions is as follows:

1. The driver's weight is 70 kg at a distance of 1.42 meters.
2. Engine weight: 25 kg at a distance of 1.42 meters
3. Frontal weight of 30 kg, distance of 0.025 meters

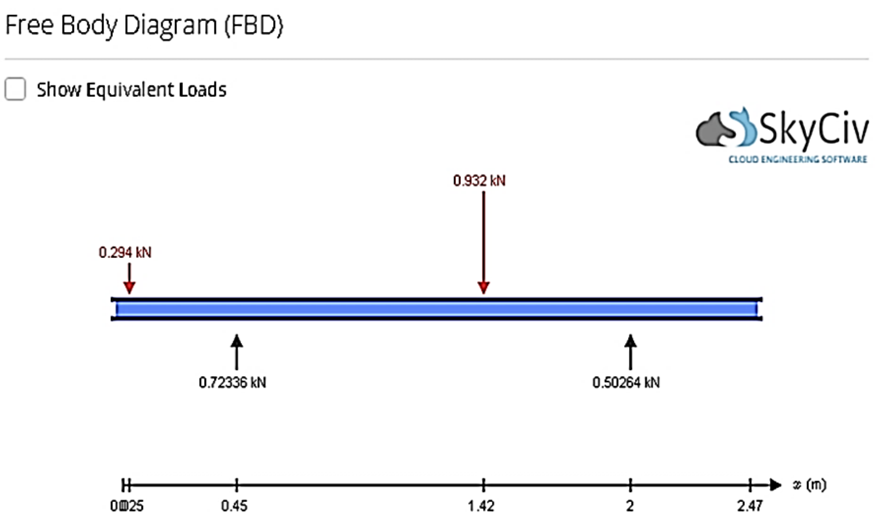

Figure 14: Free Body Diagram (FBD).[10]

Source: https://skyciv.com/free-beam-calculator

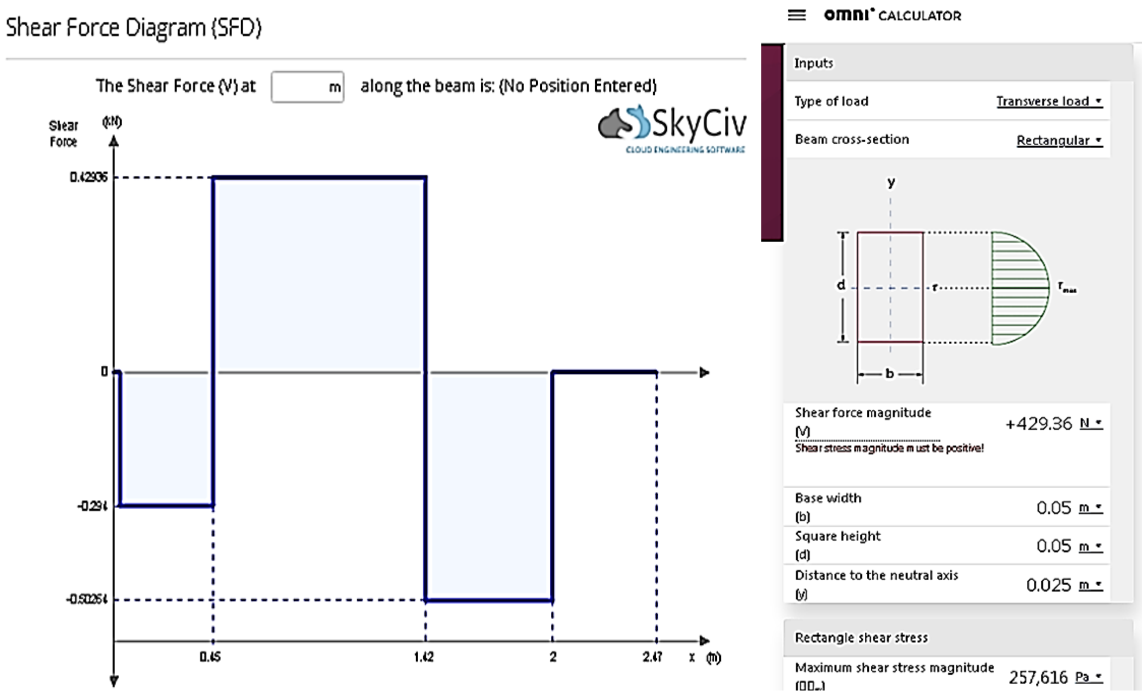

Figure 15: Shear Force Diagram (SFD)[10]

Source: https://skyciv.com/free-beam-calculator

From Figs. 14 and 15, the maximum shear strength will occur at a distance of 0.45 m to 1.42 m. The vehicle frame's steel has a cross section of 2"×2". Material St. 37 has a value of tensile strength (σt) = 360-510 MPa, and the calculation of the maximum shear strength at acting on the frame is 257.616 MPa, so this vehicle frame can be used safely.

III.RESULTS AND DISCUSSION

Turning radius measurement

The turning radius was measured from 3 trials of turning radius measurements; the average turning radius was 2.36 m. The relations between the temperatures and time are shown in Figure 5.

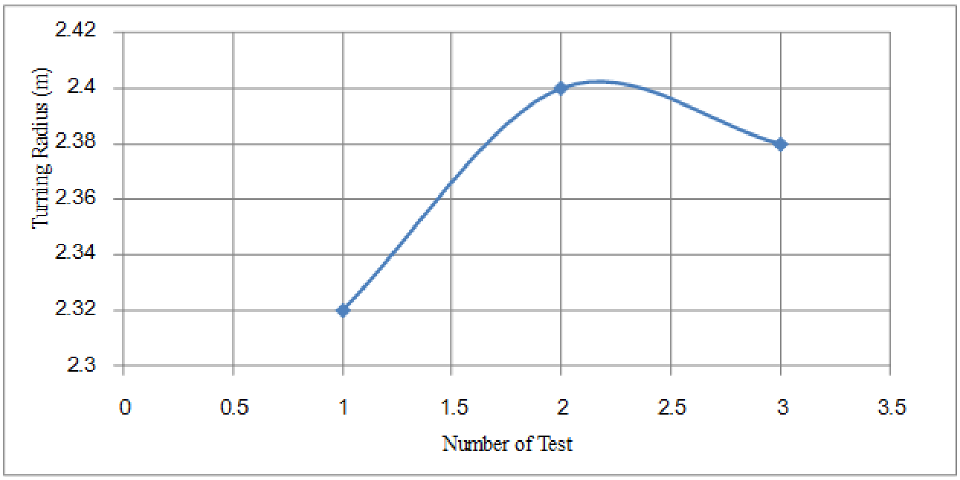

Figure 16: Turning Radius measurement at various tests.

Calculate the discrepancy compared to the calculation results.

$$= \left(\frac{2.48-2.36}{2.48}\right) \times 100$$

$$= 2.83\ \%$$

To find the braking distance, the braking distance was tested 5 times at a maximum speed of 20 km/h with an average braking distance of 4.232 m.

Finding the braking distance

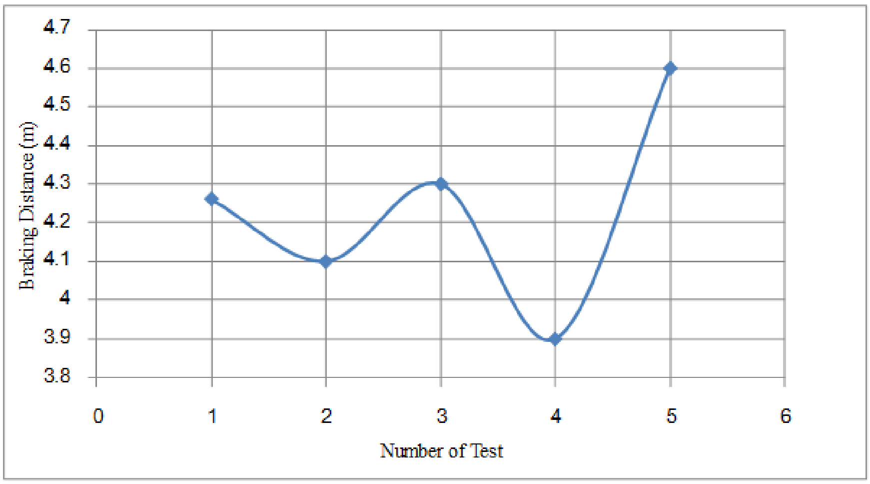

Figure 17: Braking distance measurement at various tests.

IV. CONCLUSION AND FUTURE SCOPE

In this research, the design, fabrication, and testing of a small four-wheel vehicle for use in agriculture were performed. Calculating various performance values of the vehicle, it was found that the maximum thrust of the engine was 604.91 Newtons and the maximum possible speed was 50.51 km/h. The traction force was 483.89 Newtons, the turning radius was 2.48 meters, and the slope of the road that could be driven up was 15 degrees when towing a 250 kg sugarcane leaf picker. With a total resistance of 121.02 Newtons, the engine has a traction force of 483.89 Newtons, capable of dragging the load at an acceleration of 1.94 m/s^2 or 6.98 kmph/s. The turning radius in a turn was 2.36 meters, and the deviation of the turning radius from the calculation with the experiment was 2.83 percent. The braking distance from the experimental braking distance of 50 meters at a speed of 20 kilometers per hour was 4.232 m. Future improvements should be made as follows:

1. Engine idle tuning must be tuned to suit actual operating conditions.
2. The use of a small 4-wheel vehicle for agriculture while in the gearshift position should have a letter indicating the gear position in detail for ease of use.
3. A signaling system should be installed for the safety of driving.
4. There may be further development of research by using electric motors to drive the vehicle into a hybrid car that can be used in two systems.

REFERENCES

1. Office of Agricultural Economics, “Agricultural Production Information,” https://www.oae.go.th. (March 1, 2022)
2. P. Julyusan, K. Watakij, and J. Sompong, "Determination of Three-Point Hitch Forceson an Agricultural Tractor," Research Report, Suranaree University of Technology, 2014.
3. S. Boon-arj ,"Traction Testing of Cage and Type Wheels Power Tiller for Working with Cassava Field ," Research Report, Suranaree University of Technology, 2014.
4. M. Thippoochom, S. Boon-arj, K. Manasook, and S. Soolprasert," A Study and Development of Cage Wheel for a Two-Wheel Tractor Using Upland Field," *Isan Rajamakala Journal of Science and Technology*, 2017; 2.
5. W. Chansrakoo, S. Arsawang, K. Wannaronk, T. Yothatoon, and P. Chantong-on, "Development of pineapple transplanter attached with medium size tractor," Thai Agricultural Research Journal, 2016; 2: 114-124.

6. “KUBOTA BRAND FOUR WHEEL TRACTOR,” L5018https://www,gbs.com.mm/en/products/tractors/four-wheel-tractor/tcr-4wt-kbt-l5018/Hydraulic article, https://www.pneu-hyd.co.th/ (March 5, 2022)
7. “Tractors used in agriculture,” http://www.pcat.ac.th/_files_school/00000831/data/00000831_1_20141104-103803.pdf. (March 5, 2022)
8. “Tractors used in agriculture,” http://www.pcat.ac.th/_files_school/00000831/data/00000831_1_20141104-103803.pdf. (March 5, 2022)
9. Terayoot Suwanaprateep, "Automotive engineering," Thai Wattana Panich Publishing, Bangkok, Thailand, 2000.
10. “Free Online Beam Calculator,” https://skyciv.com/free-beam-calculator/ (March 5, 2022)