Prototype Design of Transmission Trainer as Learning Media to Support Student's Learning Interest

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ABSTRACT

Based on observations, there were some students who felt sleepy or were not interested in the materials being taught, even though the presenter had prepared good presentation and explained it coherently, especially in engineering subjects. Therefore, tools in the form of learning media are needed. This research specifically had a purpose to build a 5-speed manual transmission trainer that could be used as a lecture learning facility based on Toyota Kijang's car transmission. The method used in this study was prototype design method. Starting from the plan, design, and manufacture. The results showed that this trainer was driven by a motor with 100 watts of power with a torque of 335 Nmm which drove the belt with maximum tensile stress of 14.76 N. Motor rotating in 2850 rpm would rotate the transmission shaft with speed of 570 rpm and torque on the shaft of 1668 Nm.

Keywords: *Prototype Design, Transmission, Learning Media*

1. INTRODUCTION

The education world is one of platforms to create superior generations becoming moral and knowledgeable human. Through education too, children can learn to observe, imitate, apply and even create. This is consistent with what is stated in the 1945 Constitution, that one of the goals of the Indonesian people is to educate the nation's life. Based on those goals, we need a method, strategy and learning media that can help students foster learning interest. However, based on observations made by researchers, there were some students who feel sleepy or less interested in the material being taught, even though the presenter had prepared good presentation and explained them coherently, especially in the courses with calculations, one of which was Machine Elements II. Therefore, tools were needed in the form of learning media .

Inside in the Machine Elements II there were belt, pulley, and gear. This material tended to be less understood by students if they did not used teaching aids. Belt, pulley, and gears are parts of the power train. These components were created by researchers as learning media in the form of trainer transmission because transmission gearbox system was assembled from three kinds of subsystem with Bond graph Causality Definition: PGT (Planetary Gear Trains), Clutch and Inertial Rotator [1]. The gearbox supplied a few gear ratios from its input shaft to its output shaft for the engine torque-speed profile to match the requirements of the load [2].

Lectures are designed to deliver new information to a large group of students.[3]. But lectures need some media to deliver subject matter, that is learning media. Learning process based on the curriculum need to be supported by learning media [4]. In line with that thing, Mechanical Engineering laboratory conditions of Universitas Hasyim Asy'ari still has minimal facilities considering the age of the institution that is still young, including learning facilities to support lectures. In Mechanical Engineering laboratory, there is only one unit of the engine stand intact, which is not ideal for lecturing the Engine Element II, especially in the material of the gears where the transmission system is not visible in the gears components so that students can't perform real analysis of the gears in accordance with material on Engine Element II.

Therefore, it was necessary to present a learning tool in the form of a transmission trainer that would provide students the opportunity to prove the theory and formulas obtained in the gear material in the Engine Element II subject. This research specifically had a purpose to build Toyota Kijang's 5-speed manual transmission trainer that could be used as lecture learning facility.

1.1. Manual Transmission

A manual transmission is a type of transmission used in motor vehicle applications. It uses a driver opera-ted clutch, usually engaged and disengaged by a foot pedal or hand lever [5]. The transmission includes three major types of components: input and output shafts, speed gears and synchronizers [6]. The type of manual transmission in this research used was 5 speed transmission Toyota Kijang Innova. This type was selected because Toyota cars commonly used in Indonesia and many trainers used Toyota's components for learning media.

1.2. Belt

Belt are used to transmit power from one rotational drive to another. A belt is a flexible power transmission element that runs tightly on a set of pulleys [7]. A belt drive transmits power between shafts by using a belt to connect pulleys on the shafts by means of frictional contact or mechanical interference [2]. One type of belts is V-belts. They have V-cross section. V-belts are utilized to transfer energy from a driver to the driven and usually transfer one speed ratio to another through the use of different sheave sizes [8].

1.3. Power Train

In a motor vehicle, the powertrain or powerplant comprises the main components that generate power and deliver it to the road surface [9]. But in this trainer power train was only used to drive the gearbox, consisted of a driving pulley, v-belt, and driven pulley.

1.4. Power Train

Communication media in the learning process are often referred as learning media. The main function of learning media is as a means to achieve learning goals [10]. In general, learning media is divided into 6 (six) types, namely: (1) Text; (2) Audio; (3) Visual; (4) Motion; (5) Real objects and models; and (6) People [11].

2. METHOD

The method used in this research was design build method. Starting from the plan, design and manufacture. Furthermore, after the tool was finished, it would be presented on learning to find out the students' responses.

2.1. Research Phases

Research Phases were illustrated in the Figure 1 below:

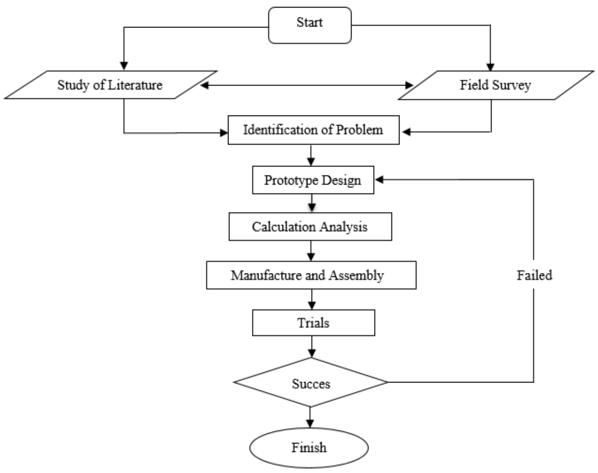

Figure 1 Diagram of Research Phases

2.2. Phase of Product Prototype Design

Phase of Prototype design involve:

- Literature Study

Literature study for calculation analysis based on Machine Element Design book [12].

- Prototype Design

Trainer design of Toyota Kijang 5-speed manual transmission system can be seen in the Figure 2 below:

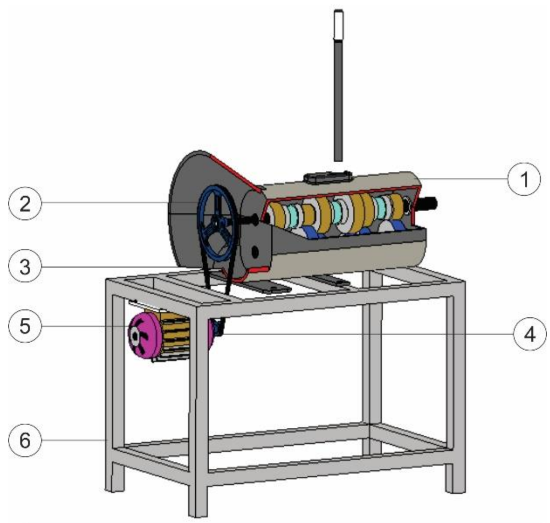

Figure 2 Trainer Design of Manual Transmission

Explanation:

1. Gearbox
2. Driven pulley
3. V-belt
4. Driving pulley
5. Motor cluth

6. Frame

- Tool Dimension

Frame dimension of Toyota Kijang 5-speed manual transmission system can be seen in the Figure 3 below:

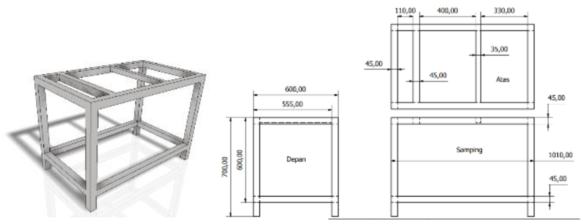

Figure 3 Frame Trainer of Manual Transmission

2.3. Calculation Analysis

Calculation of rotation ratio on each pulley. The ratio of driving pulley and driven pulley could be determined by the formula [12]:

$$\frac{n_1}{n_2} = \frac{D_1}{D_2} \tag{1}$$

Based on formula (1) above it is known: n_1 = driving pulley rotation; n_2 = driven pulley rotation; D_1 = diameter of driving pulley; D_2 = diameter of driving pulley. For calculation of motor torque, formula (2) below was used [12]:

$$P = \frac{2\pi n.T}{60} \tag{2}$$

Based on formula (2) above, it was known: P = motor power; n = motor rotation. Then the belt length (v-belt) was calculated according to formula (3) below[12]:

$$L_{12} = \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x} \tag{3}$$

Based on formula (3) above it is known: L = belt length; r_1 = radius of driving pulley; r_2 = radius of driven pulley; x = distance between pulley shafts. Calculation of belt contact angle (4) and pulley contact angle (5) use the formula below [12]:

$$\sin\alpha = \frac{(r_1 - r_2)}{x} \tag{4}$$

$$\theta_{12} = 180 - 2\alpha \tag{5}$$

Furthermore, the tension in the belt was determined by taking into the value, and the angle of the v belt flow. The calculation is as follows [12]:

$$2{,}3 \log\frac{T_1}{T_2} = \frac{\mu\,.\,\theta}{\sin\beta} \tag{6}$$

Based on formula (6) above it is known: T_1 = tension on the tight side of the belt; T_2 = tension on the loose side of the belt. Calculation of the tension on the v-belt (T_1, T_2), can be seen in the formula below [12]:

$$Motor\ Torque = (T_1 - T_2)\,.\,r_{pulley\ 1} \tag{7}$$

- Torque on Gearbox / Driven Pulley Shaft

After T_1 and T_2 are known then it can be counted the value of torque working on driven pulley that connected directly to the gearbox shaft that can be seen in formula (8) below [12]:

$$T = (T_1 - T_2)\,.\,r_{pulley\ 2} \tag{8}$$

2.4. Trials

The trainer was tested by turning it on using electrical energy. If the motor was running and able to turn the gearbox in the transmission, then the trainer was declared successful.

2.5. Time and Place of Research

The research was conducted within 6 months located at the Welding Laboratory of Engineering Faculty, Hasyim Asy'ari University, Tebuireng.

3. RESULT AND DISCUSSION

After trainer design determined then it was continued to process of making the frame, assembling the drive system, and assembling the transmission trainer. After all components were installed, the next step was trial and calculation of torque, power and maximum tensile tension.

3.1. Making of Trainer

- Making of Frame

The frame was made with hollow steel 5 x 5 and 4 x 4 with thickness 3 mm using Shielded Metal Arc Welding (SMAW) as seen in the Figure 4 below.

Figure 4 Frame of Transmission

- Constructing a Drive System

Drive system consisted of 100-watt cluth motor strung together with driving pulley with diameter 50 m connected by a v-belt to driven pulley with diameter 250 mm. Driven pulley was connected directly to the transmission gearbox shaft as shown in Figure 5 below:

Figure 5 Power Train

- Assembling a Trainer System

The transmission was mounted on a support frame holder using four bolts. The drive system then was installed, starting with installing driven pulley on the gearbox shaft, installing the v belt towards driving pulley which was already connected to the motor shaft. Then the motor was fastened to the frame using bolt nuts. Below is a trainer system that has been assembled.

Figure 6 Trainer

3.2. Calculation

- Calculation of Rotation Comparison for Each Pulley

The drive system in transmission trainer included motor, driving pulley, v-belt and driven pulley which were then connected to the transmission shaft. Further detail can be seen in the following picture:

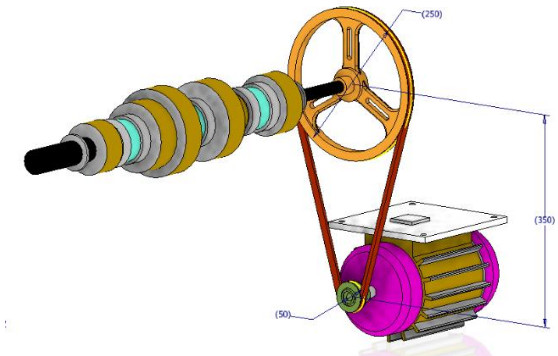

Figure 7 The Drive System in Transmission Trainer

The author determined the motor specifications first because the author wanted an electric motor with a cluth system. Motor with cluth system with 100 watts of power and 2850 rpm rotation was available on the market. These specifications were the basis of the author's calculations. Comparison of pulley rotation, ratio of driving pulley and driven pulley could be determined using formula (1):

$$\frac{n_1}{n_2} = \frac{D_1}{D_2} \quad (1)$$

$$\frac{2850}{n_2} = \frac{250}{50}$$

$$n_2 = \frac{2850}{5} = 570\ rpm$$

- Calculation of Motor Torque

It has been known before that the motor had output power specification of 100 watts and 2850 rpm. So motor torque that connected to driving pulley could be found using formula (2) as follows:

$$P = \frac{2\pi n.T}{60} \quad (2)$$

$$100\ watt = \frac{2\pi n.T}{60}$$

$$100\ watt = \frac{2.3,14.2850.T}{60}$$

$$T = \frac{100\ .\ 60}{2.3,14.2850}$$

$$T = \frac{6000}{17898} = 0,335\ Nm$$

- Calculation of V-Belt

Calculation of the v-belt length connecting driving pulley on the motor with driven pulley on the transmission shaft. Diameter of driving pulley was 50 mm and diameter of driven pulley was 250 mm. The distance between driving pulley and driven pulley (x) was 350 mm. So that the length of the belt could be known by using formula (3) as follows:

$$L_{12} = \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x} \quad (3)$$

$$= 3,14(25 + 125) + 2x + \frac{(25+125)^2}{350}$$

$$= 1171 + 28,6$$

$$= 1199,6\ mm$$

- Calculation of Belt Contact Angle

It was previously known that the diameter of driving pulley = 50 mm and driven pulley = 250 mm with a spacing of 350 mm. Using this data, we could find the contact angle of the belt and pulley according to the formulas (4) and (5).

$$\sin \alpha = \frac{(r_1 - r_2)}{x} \quad (4)$$

$sin\,\alpha = \frac{(25-125)}{350}$

$sin\,\alpha = \frac{-100}{350}$

$sin\,\alpha = 0{,}285$

$\alpha = 16{,}558^0$

- Contact angle of pulley (θ)

$$\theta_{12} = 180 - 2\alpha \quad (5)$$

$\theta_{12} = 180 - 2(16{,}558)$

$\theta_{12} = 146{,}884$

$\frac{\pi}{180}\ x\ 146{,}884 = 2{,}56\ rad$

- Comparison of belt tension

Furthermore, the tension in the belt was searched by looking at the value = 2.86, pulley friction coefficient (= 0.3 and the type A v belt groove angle was sin 190^0 [13]. Using the formula (6) the calculation was as follows:

$$2{,}3\ log\frac{T_1}{T_2} = \frac{\mu\ .\ \theta}{sin\,\beta} \quad (6)$$

$2{,}3\ log\frac{T_1}{T_2} = \frac{0{,}3\ .\ 2{,}56}{sin\,19^0}$

$log\frac{T_1}{T_2} = \frac{2{,}36}{2{,}3}$

$log\frac{T_1}{T_2} = 1{,}02$

$\frac{T_1}{T_2} = 10{,}4$

$$T_1 = 10{,}4\,T_2 \quad (7)$$

Where:

T_1 = Tension on the tight side of the belt

T_2 = Tension on the loose side of the belt

- Calculation of the tension on the v-belt (T_1, T_2)

To get T_1 and T_2 using torque formula (8) which was affected by the tight side and the slag side of the belt. The torque value is obtained from the motor torque that has been previously known.

$$Motor\ Torque = (T_1 - T_2)\,.\,r_{pulley\ 1} \quad (8)$$

$0{,}335\ Nm = (T_1 - T_2)\,.\,25\ mm$

$335\ Nmm = (T_1 - T_2)\,.\,25\ mm$

$(T_1 - T_2) = \frac{335}{25}$

$$(T_1 - T_2) = 13{,}4\ N \quad (9)$$

(7) and (8) are substituted

$10{,}4\,T_2 - T_2 = 13{,}4\ N$

$9{,}4\,T_2 = 13{,}4\ N$

$T_2 = 1{,}42\ N$

$T_1 = 10{,}4\,.\,1{,}42\ N$

$T_1 = 14{,}76\ N$

- Torque on The Gearbox / Driven Pulley

After T_1 and T_2 are known, amount of torque working on driven pulley directly connected to the gearbox shaft could be determined using formula (10), as follows:

$$T = (T_1 - T_2)\,.\,r_{pulley\ 2} \quad (10)$$

$T = (14{,}76 - 1{,}42)\,.\,125\ mm$

$T = 13{,}34\,.\,125\ mm = 1668\ Nmm$

4. CONCLUSION

Based on description above, prototype design of transmission trainer starting by trainer design, calculation of components in the form of motor power and torque, tension on the belt and torque on the gearbox shaft were obtained. Furthermore, making the frame components and assembling the drive components were also explained. This transmission trainer was driven by a motor with 100 watts of power with a torque of 335 Nmm which drove the belt with maximum tensile tension of 14.76 N. The motor rotated at 2850 rpm would rotate transmission shaft at 570 rpm with torque on the shaft at 1668 Nmm.

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