

Applied Ergonomic Design Of E-Bike With Antropometric Approach

M. Nushron Ali Mukhtar¹, Neysa Ivah Umma², and Ayu Dwi Candra Kartika³,
Arief Multi Prawira Diharja⁴

¹nusron@unipasby.ac.id

^{1,2,3,4}Departemen Industrial Engineering Universitas PGRI Adi Buana Surabaya

Abstract—Transportation is a tool that can be easiness for mobilities a thing or people from the place one to the othe place. Along with the times, transportation also develops. The one of transportation that developing is electric bike (e-bike). The development of electric bike is to improve the previous product, so that the electric bicycle that will produced is better than before as models, colors etc. when we make the electric bike design, the first thing that we do is ergonomic analytical so the product that will produced didn't give long term effect as muscle injury and joint pain for the user. We use analitycal RULA for analytical ergonomi to our design electric bike. We take 31 samples use the database from Student of Industrial Engineering AdiBuana Surabaya College. The result of the RULA value which shows the most ergonomics is at a headtube angle of 15 ° with a RULA value of 3. This shows that the design of this electric bicycle is quite ergonomic and the design is acceptable, although to be ideal in its body posture, further analysis is needed in order to obtain a better RULA value.

Keywords: Electric Bike; Ergonomic; Anthropometry; Design.

I. INTRODUCTION

The development of transportation in this modern times is currently growing rapidly. A good transportation system is by considering at conditions that facilitate mobility and environmentally friendly [1]. One of the efforts to creating this environment is the development of transportation that uses electrical energy. One of the forms of transportation that uses electrical energy is an electric bicycle (E-bike). Electric bicycles

are a type of transportation like other bicycles but, have an electric machine as the driving tools. Electric bicycles have been popular in the Indonesian market with various attractive designs. Electric bicycle products that commonly use in Indonesia are imported products from China such as the Yahonta and Tiger brands, but there are also some domestic products such as Xelimo and Betrix[2].

In terms of the use of electric bicycles as the transportation is significantly increased than before. In addition, the use of electric bicycles must be in accordance with their needs both in terms of shape and accessible features. [3]Electric bicycles can also be used for teenagers to the elderly so that, there are various types of electric bicycle (E-Bike) designs nowadays. However, the development of electric bicycle design must be adjusted to the body as well, and anthropometric measurements of the dimensions of the human body becomes one form to obtain an ergonomic condition. In addition, the design of an electric bicycle must have a tool size compatibility with the dimensions of the human who wears it, which is very important to reduce the occurrence of danger due to work errors and design errors [4].

In the elements of bicycle design, it cannot be separated from ergonomics [[4]. This is because ergonomics or Ergonomics (in English) comes from the Greek, namely Ergo which means work and Nomos means rules or laws. In Indonesia, the meaning of ergonomics is a science and application that needs to harmonize work with the environment on people or vice versa with the aim of achieving maximum productivity and efficiency through optimal human utilization [5]. Ergonomics is closely related to

designing electric bicycles so that the resulting output can provide an effective, safe, comfortable, healthy and efficient for its users.

To analyze ergonomics, anthropometric measurements are needed. Because humans have several body sizes that are different from each other, so that anthropometric data measurements are needed for various purposes, one of the design of an electric bicycle design is to fit the dimensions of the user's body. Anthropometry is a part of ergonomics which studies body size including linear dimensions, as well as content and also includes areas of size, strength, speed and other aspects of body movement [6].

The use of anthropometry in the design of electric bicycles is worked well so that, users do not feel tired when using them over long distances[7]. In addition, if the size of the bicycle does not suit the user, it can have long-term effects such as muscle injury or joint pain. Therefore, bicycle design must be based on data so that, the resulting product is also on target. In the manufacture of electric bicycles based on anthropometric data. The application of anthropometric data has been widely applied to all aspects of life [2]. one of which is applied to the design of bicycle designs. Also when we use a bicycle that does not fit our body dimensions, we will feel tired and uncomfortable.

Anthropometry is the science of the relationship between the structure and function of the body (including body shape and size) with the design of the tools used by humans[5]. Anthropometric data can be used for various purposes such as the design of work stations, work facilities, and also product design in order to obtain appropriate and appropriate sizes with the dimensions of the human body members who will use them[6]. Then the application of anthropometric data in the design process of electric bicycle designs for students is to determine the sizes of some bicycle parts so that the resulting product can be balanced and also ergonomic. In addition, also so that users or users of bicycles do not experience

health problems in the long term such as joint pain, and other health problems.

Therefore, it is necessary to analyze an ergonomic design by applying anthropometric data. For this reason, it is necessary to have CATIA VR5 software in analyzing ergonomic body posture using the RULA method. Based on the description above, this article carries the title "Ergonomic Analysis on E-Bike Product Design with Anthropometric Approach"[8]. This article is considered important, considering that the use of anthropometric data for the manufacture of electric bicycle designs is very necessary so that the products produced are on target and do not cause long-term effects if there is an error in size.

II. RESEARCHMETHOD

In making this electric bicycle design, we measured anthropometric data using several tools such as a meter tape, weight scales, segmometer, elbow ruler and also a chair as a backrest. The sample used is by using data from students of Industrial Engineering, Universitas PGRI Adi Buana Surabaya with a total of 31 students.

The use of anthropometric data in designing electric bicycles for students uses body dimensions, namely arm length, buttock height to floor, popliteal height, ankles to floor, leg width, palm width, hip width, shoulder width and arm length [7].

Then this research uses a quantitative approach, the RULA method with the help of CATIA VR5 software, and anthropometric data measurement is one of the important tools for data collection, the authors use several techniques in data collection, namely observation (observation through pre-existing designs), and measurement anthropometric data[9]. The data that has been obtained will be processed and used to design electric bicycles to be more ergonomic. Anthropometric data collection was carried out in the Ergonomics Laboratory of Industrial Engineering, Universitas PGRI Adi Buana Surabaya in November 2021. This research was carried out systematically and gradually according to Figure 1 as follows:

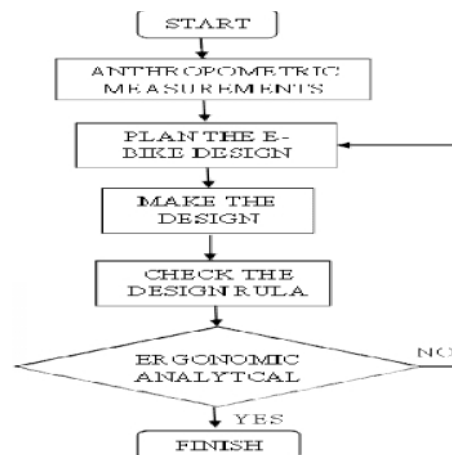


Figure 1. Flowchart Diagram of Planning The Design

III. Results and Discussion

In designing this E-Bike there are several things that need to be considered:

1. The length of the arm used to measure the distance from the saddle to the handlebar.
2. Height of the butt to the floor to measure the distance from the saddle to the floor.
3. Popliteal height is used to measure the distance from the saddle to the footrest.
4. The ankle to the floor is used to measure the height of the footrest
5. Foot width is used to measure the width of the footrest.
6. The width of the palm is used to measure the width of the hand grip on the handlebar.
7. Hip width is used to measure the width of the saddle to be used.
8. Shoulder width is used to measure the width of the handlebar.
9. The length of the hand is used to measure the width of the handlebar grip

Then, in order to develop an electric bicycle (E-Bike), some genuine data is required to identify the most ergonomic size. As a result, we used a sample of 31 Industrial Engineering students from PGRI Adi Buana University Surabaya. We process the data after knowing the sample data to determine the ergonomic size using the existing sample. Several sizes are known based on the measurements taken, as shown in table 1 below.

Table 1. Anthropometric Data Measurement Results

No.	Nama	Ukuran Tubuh (dalam satuan mm)								
		Lebar Pinggul	Tinggi Pantat ke Lantai	Lebar Tangan	Panjang Tangan	Mata Kaki ke Lantai	Lebar Kaki	Lebar Bahu	Tinggi Popliteal	Panjang Lengan
1	Arief Multi P. D.	390	885	110	190	75	112	430	425	780
2	Ayu Dwi C. K.	340	810	90	160	75	95	380	425	680
3	Putri Nia Luki P.	360	735	90	160	70	90	390	400	650
4	Rama Maulana K.	360	860	110	190	90	100	420	43	770
5	Yunnanta Adi Putra	400	860	90	170	90	100	430	470	760
6	Dida Kristian Adi W.	335	770	95	175	65	110	420	395	690
7	Fani Ardiansyah	380	860	140	180	100	100	400	490	760
8	Sindi Berliyani	350	730	90	175	60	90	380	420	640
9	Wahyu Illahi	370	790	90	170	100	100	430	470	750
10	Dhanny Ar-Royan	425	850	90	170	90	105	480	460	770
11	Alfi Rohmatil M.	400	830	90	180	90	110	460	490	730
12	Muhammad Nizar N.	380	860	115	180	90	120	500	420	770
13	Muhammad Irvan W.	390	860	105	180	70	120	450	420	780
14	Diva Nalurita S.	350	835	85	175	90	85	410	420	700
15	M. Ramadhan N.	360	740	110	160	80	100	380	470	700
16	Andre Puja Kusuma	400	810	100	190	80	110	480	390	700
17	M. Ahsanudin	350	860	110	185	75	100	400	430	750
18	Dimas Tio Pratama	440	860	115	200	100	120	510	480	810
19	Kelvin Fariez Al-Hikam	410	770	85	185	90	100	420	480	750
20	Neysa Ivah Umma	340	755	85	160	60	90	400	415	700
21	Erlita Rusdiana	410	800	90	165	65	100	400	420	675
22	Oki Lilian Purnama	380	810	120	180	90	110	440	420	710
23	Rifka Ayu Laiyyinah	400	760	95	170	100	90	400	420	670
24	Nabila Afni Ulul A.	320	760	90	155	70	95	360	430	660
25	Rivaldo Josua Getrin R.	340	930	100	190	90	100	400	470	800
26	Alif Dwi Prasetyo	400	870	115	195	70	95	460	480	750
27	Putri Amelia Divaio	320	790	90	160	70	90	370	490	680
28	Erika Zahra F.	320	760	95	160	100	95	390	495	660
29	Ahmad Hikam Nuril R.	300	740	90	170	80	85	430	470	700
30	Gerald Binta Syaifudin A.	450	870	125	200	70	120	450	470	720
31	Novia Alvi Andari	340	820	95	180	80	80	400	420	680

Before we analyze the anthropometric data as above, the data

adequacy test is carried out first. By using the following formula:

$$N' = \left[\frac{\frac{k}{s} \sqrt{N \sum X^2 - \sum X^2}}{\sum X} \right]^2 \quad (1)$$

By using the data adequacy formula above, a data adequacy test is calculated using the number of

observational data (N) of 31 for each data presented in table 1. If N' N then the data is considered sufficient [10]. So that the

results obtained as table 2 as follows:

Table 2. Results of the Data Sufficiency Test

No.	Body Size	Test for data adequacy (N')	N' N
1	Hip Width	3,91	Enough
2	Buttocks Height to the Floor	1,62	Enough
3	Hand Width	7,22	Enough
4	Hand Length	2,01	Enough
5	Ankle to the Floor	9,25	Enough
6	Feet Width	4,60	Enough
7	Shoulder Width	3,12	Enough
8	Popliteal Height	12,94	Enough
9	Arm Length	1,66	Enough

The results are acquired from the average in table 3 after acquiring the anthropometric

data above and looking for the average in each body size:

Table 3. Average of Body Size

No.	Body Size	Average (mm)
1	Hip Width	371,3
2	Buttocks Height to the Floor	814,2
3	Hand Width	100,0
4	Hand Length	176,1
5	Ankle to the floor	81,5
6	Feet Width	100,5
7	Shoulder Width	421,6
8	Popliteal Height	432,2
9	Arm Length	720,8

The standard deviation, as well as the 5th and 95th percentiles, are then calculated to determine which size is the most ergonomic. The 5th and 95th percentiles are calculated to determine the adequacy of the data results, which will subsequently be used to select

bicycle size. Calculate the sample standard deviation, which is the square root of the sample variance[8], before estimating the size of the 5th and 95th percentiles. The following is the formula:

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}} \quad (2)$$

Calculate the 5th percentile using the formula 3 after knowing the standard deviation

$$p \quad 5 = a - (1,645 \times s \quad d \quad)$$

of each body dimension:

The formula for calculate 95th percentile is change the minus to plus so the

$$p \quad 95 = a + (1,645 \times s \quad d \quad)$$

formula as the fourth bellow:

While the formula for the 95th percentile is to change the – sign to + so that it

uses the 4th formula as follows:

Table 4.
Measurement of 5th Percentile and 95 Percentile Deviation

No.	Body Size	Standard Deviation (mm)	Percentile 5 (m)	Percentile 95(mm)
1	Hip Width	37,3	309,9	432,7
	Buttocks			
2	Height to the Floor	52,7	727,5	900,9
3	Hand Width	13,7	77,5	122,5
4	Hand Length	12,7	155,2	197,0
5	Ankle to the Floor	12,6	60,7	102,2
6	Feet Width	11,0	82,5	118,6
7	Shoulder Width	37,9	359,3	483,9
8	Popliteal Height	79,0	302,2	562,2
9	Arm Length	47,2	643,1	798,5

The following findings are achieved after understanding the results of the 5th percentile and 95th percentile calculations, then deciding the size for the e-bike design using the 5th percentile or 95th percentile calculations:

1. The width of the saddle is taken from the size of the 95th percentile hip width, which is 21.5cm
2. The height of the bicycle is taken from the height of the buttocks to the 5th percentile floor, which is 72.7cm

3. The width of the handlebar grip is taken from the size of the 95th percentile hand width, which is 12.2cm
4. The width of the footrest is taken from the size of 2x the width of the 95th percentile foot, which is 23.6cm
5. The length of the handlebar is taken from the 5th percentile shoulder width, which is 35.9cm
6. The distance from the saddle to the footrest is taken from the 95th percentile popliteal height, which is 56.2cm

- The distance from the saddle to the handlebar is taken from the 5th percentile arm length, which is 64.3cm

After obtaining the anthropometric size

values above, a reference is made to the electric bicycle design that has been made in the CATIA VR5 software, making the E-Bike design as shown in Figure 2, as follows:

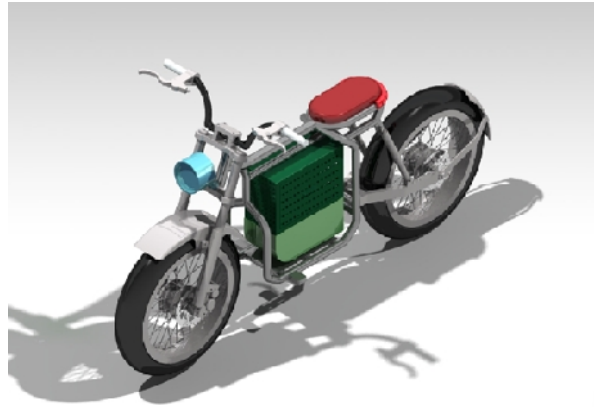


Figure 2. E-Bike Design

Then, using the RULA approach and the CATIA VR5 software, an analysis of the ergonomic elements of the electric bicycle design is performed. The goal of this ergonomics analysis is to estimate the value of the rider's risk of injury; the lower the RULA value on the bicycle, the more ergonomic the bicycle. The RULA analysis was performed

using a headtube angle of 15° and 17° for comparison, with the goal of determining which angle is the most ergonomic. We chose a 15° headtube angle based on the headtube angle comparison. Figure 3 shows the results of an RULA analysis with a 15° headtube angle:

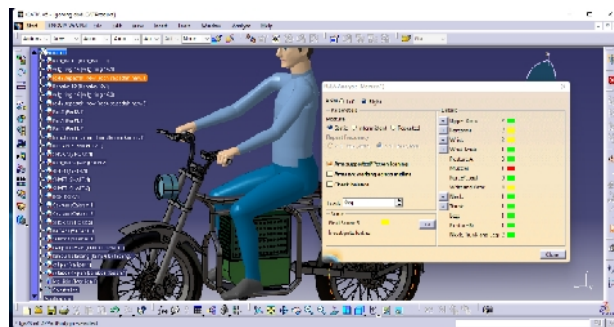


Figure 3. Posture at Headtube Position 15°

The result of the RULA value which shows the most ergonomics is at a headtube angle of 15 ° with a RULA value of 3. This shows that the design of this electric bicycle is quite ergonomic and the design is acceptable, although to be ideal in its body posture, further analysis is needed in order to obtain a better RULA value. Smaller

IV. Conclusion

The conclusion of the research is, before we make the design product we have to measurement the antropometri for determine

ergonomic of the product so the product that produced suitable with body posture so it's didn't give long term effect. The antropometri database we get from 31 student of Industrial Engineering Adi Buana Surabaya University with range 19-27 age.

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