ANTHROPOMETRY IN ENGINEERING DESIGN (A CASE STUDY OF CASSAVA GRATING MACHINES INSTALLED IN DOKO AND KUTIGI METROPOLIS OF LAVUN LOCAL GOVERNMENT AREAS OF NIGER STATE)

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Abstract:

The introduction of various types and sizes of machines in the market for processing food has drawn the attention of many engineers to the efficiency and safety of the operator during the operation of those machines. There is the need to specify the type of people to operate these machines based on ergonomic standard. The functional grating machines were number and ten selected from each village metropolis. The Anthropometric measurements were carried out on two operators in each station using measuring tape, ruler, office chair and weighing scale. The study reveals that operators are of various sizes and ages. The most important factor required in operation is training. The anthropometric data collected were treated statistically and the statistical result presented for use in engineering. The statistical results can be used for modification of existing machines for better performance, designing of new machines and sitting facilities (stools and chairs) during operation.

The history of mankind has of course always include the efforts to design tools and other devices to better serve human need and to provide protection from adverse environment. The profiles of man is filled with evidence of his efforts, both successful and unsuccessful to improve facilities. Through the use of a particular device for example an axe or a bow and arrow, it was possible to identify its deficiencies during use and to modify it accordingly so that the next generation to use these devices can effectively use them. (McComick and Sanders 1982). Evolutional process was important as a basis for improvement in terms of human consideration. It was found for example, that some items of military equipment such as high-speed aircraft, radar and fire control systems could not be managed effectively by their operators, that human errors were excessive and that many accidents occurred because of human mistakes which were attributed to design deficiencies (Brigham, 1972). Also, some of the accidents occurring in industries during operation are attributed to faulty engineering designs (Shiru, 2001). It is very important to consider anthropometry aspects early in the design process and in a systematic manner too.

Anthropometry is the measurement of the size and the proportions of the human body (McCormick & Sanders 1982). The human body in its structure and mechanical function occupies a central place in man machine systems design. Failure to provide a few centimeters increase in length, which might be critical to the operator, can jeopardize performance, operator's safety, and machine reliability. With proper food for thought, these critical measurements can be provided without compromising the design.

An equipment, no matter how well engineered, can be destroyed or abused by an uncomfortable efficient operator. By using reliable anthropometric data, it is possible to establish proper size of equipment involving human use. For design purposes, two types of anthropometric dimension are necessary; they are structural and functional dimensions. (Sule, 1983).

Static (structural) body dimensions are taken with the body of the subjects in fixed (static) standardized positions. Many different body features can be measured. The measurement would of course have specific applications, such as in designing helmets, earphones or frame of glasses. However, measurement of certain body features probably, have rather general utilities. In the use of anthropometric data, one needs to be aware of the fact that such data for different group of people vary considerably. Some indications of such differences must be shown. The range of variability is from the 5th to the 95th percentage of the sample from which the data were collected. Functional Body Dimensions are the body dimensions taken under conditions in which the body is involved in some physical movement. The central postulate of the emphasis on use of functional dimensions often relates to the fact that in performing physical functions, the individual body members normally operate not independently but rather in concert. The practical limit of arm reach for example, is not the sole consequence of arm length. It is also affected in part by shoulder movement, partial trunk rotation, possible bending of the back and the function that is to be performed by the hand. Example of dimension for working positions include prone, crawling, kneeling etc. while reaches for workspace layout include overhead reach, thumb reach, lip reach, grasping reach etc. For the collection of reliable anthropometric data, three conditions must be satisfied. (Adekoya, 1993) these are

1. The measuring technique must be specified and standard. This is the only way data from different groups can be compared and test subjects can be accurately located as percentiles of a user group.
2. The groups measured should be representative of equipment users neglecting age, sex, race, and occupation, geographic locations and socio economic status.
3. Samples should be large enough to yield required reliability. The term reliability is used here to denote the extent to which results are reproducible from sample to sample.

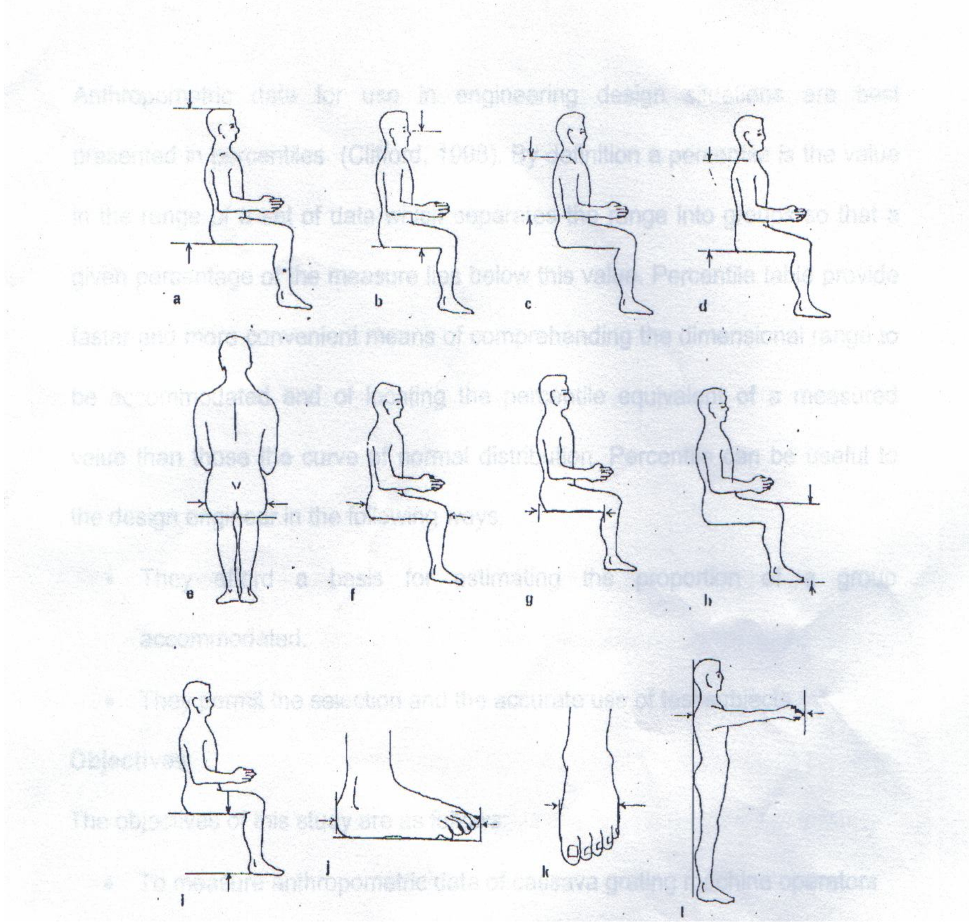
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Fig. 1: Some Anthropometric data required in Engineering design: (a) Sitting height; (b) Eye height (sitting); (c) shoulder-elbow; (d) should height (sitting); (e) hip breadth (sitting); (f) buttock-knee length; (g) buttock-popliteal length; (h) knee height (sitting); (i) popliteal height (sitting); (j) foot length; (k) foot breadth; (I) arm reach (m) standing height (n) weight.

Source: Shiru, 2001

Anthropometric data for use in engineering design situations are best presented in percentiles (Clifford, 1998). By definition a percentile is the value in the range of a set of data which separates the range into groups so that a given percentage of the measure lies below this value. Percentile table provide faster and more convenient means of comprehending the dimensional range to be accommodated and of locating the percentile equivalent of a measured value than those the curve of normal distribution. Percentile can be useful to the design engineer in the following ways.

- They afford a basis for estimating the proportion of a group accommodated.
- They permit the selection and the accurate use of test subjects.

Objectives

The objectives of this study are as follows:

- To measure anthropometric data of cassava grating machine operators
- To treat the data statistically to bring about the statistical values for each measurement
- To use the statistical values to compute the percentiles for the range of group accommodated.
- To use the statistical values for the modification of existing cassava grating machines for improved performance and operators comfort.

Materials and Methods

Anthropometric parameters for sample population were obtained in Lavun Local Government, Niger State of Nigeria using measuring instruments.Two *machine* operators were selected from each of the twenty stations bringing the sample population n = 40.

The instruments used are as follows:

1. Weighing scale: To measure the weight
2. Measuring tape: for measuring various dimensions
3. Office Chair: For supporting operator during measurement
4. Ruler:Tomarktheelevel.

Results and Discussions

The measurements taken (fig. 1) were treated and using table 1 the results obtained are shown on table 2 and 3. The result obtained compares favourably with McCormick and Sanders, 1982 hence the percentiles computed at 5% and 95% in table 3 indicates the category of operators that the installations properly fit. It invariably means that these operators, even though they are not formally educated, are quite informed about some of these principles. In fact, most of the operators train on the job for between six months and two years.

Table 1: Factors for Computing Percentiles from Standard Deviation

Percentiles	Factors (F)
0.5-99.5	2.258
1.0-99.0	2.326
2.5-97.5	1.960
5.0-95.0	1.645

20.0 - 80.0	0.842
25.0-75.5	0.674
30.0-70.0	0.524

Source: Adekoya, 1993

Table 2: Anthropometric Data of Operators in Lavun Local Government

	Measurements	Doko Metropolis		Kutigi Metropolis	
		X	+ S.D.	X	+ S.D.
a.	Sitting height (cm)	76.51	5.66	74.11	6.21
b.	Eye height sitting (cm)	53.15	5.46	52.20	6.10
c.	Shoulder elbow length (cm)	33.20	1.40	31.10	3.80
d.	Shoulder height sitting (cm)	45.52	6.33	42.35	5.61
e.	Hip breath sitting (cm)	31.15	1.11	30.90	1.21
f.	Buttock knee length (cm)	60.17	4.12	59.22	5.11
g.	Buttock popliteal length (cm)	50.10	3.81	49.61	4.22
h.	Knee height sitting (cm)	54.80	3.11	53.45	4.62
i.	Popliteal height sitting (cm)	43.95	3.36	44.50	6.10
j-	Foot length (cm)	24.22	1.21	24.90	1.92
k.	Foot breath (cm)	9.10	0.76	8.82	0.82
1.	Arm reach (cm)	67.19	6.81	65.72	9.21
m.	Standing height (cm)	164.15	3.92	150.44	6.14
n.	Weight (kg)	65.12	4.81	60.17	8.75

Table 3: Computer Percentiles of Anthropometric Data at 5% and 95% Values

	Measurements			Percentiles	
		%	+ S.D.	5%	95%
a.	Sitting height (cm)	75.31	5.94	65.54	85.08
b.	Eye height sitting (cm)	52.68	5.78	43.17	62.19
c.	Shoulder elbow length (cm)	32.15	2.60	36.43	27.87
d.	Shoulder height sitting (cm)	43.94	5.97	34.12	53.76
e.	Hip breath sitting (cm)	31.03	1.16	29.12	32.94
f.	Buttock knee length (cm)	59.70	4.62	52.10	67.30
g.	Buttock popliteal length (cm)	49.86	4.02	43.25	56.47
h.	Knee height sitting (cm)	54.13	3.87	47.71	60.52
i.	Popliteal height sitting (cm)	44.23	4.73	36.45	52.01
j-	Foot length (cm)	24.56	1.57	21.98	27.14
k.	Foot breath (cm)	8.96	0.79	7.66	10.26
I.	Arm reach (cm)	66.46	8.01	53.28	79.64

m.	Standing height (cm)	157.44	3.53	151.63	163.2
n.	Weight (kg)	62.65	6.78	51.50	73.80

The Procedure for Computing Percentiles

The steps involve in computing percentile after obtaining the anthropometric data is as follows:

1. Determine the sample mean.

$$\overline{X} = \sum_{i=1}^{n} x_i \ldots \quad (1) \quad \text{(Gomez and Gomez, 1984)}$$

Where: $\overline{x}$ = sample mean; n = sample size;
x_i = numerical value of the statistics and variables

2. Determine the standard deviation of the sample.

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

$$S = \sqrt{\frac{n \sum_{i=1}^{n} (x_1^2 - (\sum x - \overline{x})^2}{n-1}} \quad (3)$$

$$S = \sqrt{\frac{n \sum_{i=1}^{n} (x_1^2 - n\overline{x}^2(\sum x_1)^2}{n-1}} \quad (4)$$

3. Compute the percentiles.

$$Xp = \overline{x} + fs \text{ [for } p > 50^{th}] \quad (5)$$

$$Xp = \overline{x} - fs \text{ [for } p < 50th] \quad (6)$$

Where: xp = value of the percentile; p = percentile; $\overline{x}$ = sample mean;
f = factors corresponding to the percentile; s = standard deviation.

Sample Calculation

Example 1:

Given that $\overline{x}$ = 75.31 and s = 5.94. Determine 5th and 95th percentiles

From table 1 f = 1.645

From equation 6:

5th percentile = y = $\overline{x}$ – fs since (5th < 50th)

Therefore, 5th percentile = 75.31 - 1.645 x 5.94 = 65.54kg

From equation 5:

95th percentile = 75.31 + 1.645 x 5.94 = 85.08kg

Therefore, 95% of the sample has a weight less than 85.08kg

Application of Anthropometric Data in Design Situations

The correct procedure for design equipment using anthropometric data involves the following:

i. Determine the body dimensions important in the design (e.g. sitting height as a basic factor in seat to roof distance in automobiles, trucks, tractors cab designs.)

ii. Define the population to use the equipment. This establishes the dimensional range that needs to be considered (e.g. students, drivers, military personnel) in the design.

iii. Select the percentage of the population to be accommodated e.g. 90%, 98%, or whatever is relevant to the problem. It is pertinent to note that a minimum dimension, or aspects of a facility would usually be based on an upper percentile value of the relevant anthropometric features of the sample used. Such as the 90^{th} or 99^{th} percentile. The design of doors, escape hatches, passageways and the minimum weight carried by supporting devices such as chairs, ropes, ladders etc. Fall into this category. On the other hand, maximum dimension of facilities would be predicated on lower percentile (say 1^{st}, 5^{th}, or 10th) of the data. An example is the distance control devices from an operator. If those with short functional arm reach can reach a control, persons with longer arm reach generally could also do so.

iv. Certain features of equipment or facilities prepared should be adjustable in order to accommodate people of varying sizes. The forward backward adjustment of automobile seats and the vertical adjustments of typist chairs are examples. In the design of adjustable items such as these, it is fairly common practice to do so for the range of cases from 5^{th} to the 95^{th} percentiles v. Extract the values of the selected percentages from the appropriate anthropometric data tables.

vi. Determine the type of cloth and personnel equipment that will be worn (e.g. helmets, ear-protector, workshop overalls, civilian clothing, military clothing etc.) and add the relevant clothing increments to the values indicated in the dimension.

Conclusion

Anthropometric aspect must be considered for the proper design of physical equipment or facilities, it is of utmost importance to define the population of the intended users. This is because the human body occupies a central place in the design of man-machine systems. By following specified procedure, the relevant anthropometric data can be measured, collated and then analysed for a sample of the population. The analysed data can then be used in the design of equipment, facilities environments and installation of machines such that functional effectiveness and human comfort are enhanced.

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