# DESIGN ANALYSIS OF A LOCALLY CONSTRUCTED ANTHROPOMETRIC DATA MEASUREMENT CHAIR

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# CERTIFICATION

This is to certify that this project work was carried out and compiled by OGBEH JEDIDIAH CHUKWUYENUM with matriculation number ENG1805195 Department of Industrial Engineering, Faculty of Engineering, University of Benin, Benin City, Edo State, in accordance with the rules and regulations of the University of Benin for the award of B.ENG in Industrial Engineering.

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# DEDICATION

This project is dedicated to God who through His strength and wisdom has brought me this far, and to my parents for their unending support towards me. To my siblings for always looking out for me and supporting me. And finally to my Church family for their unwavering support in prayers and in substance.

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# ABSTRACT

We see so much advancement in the field of ergonomics in this time. However, there remains certain limitations in the extent of research when it comes to anthropometric data acquisition and its direct impact in the development and production stages of office chairs.

This work covers the relevant findings of the design analysis of an anthropometric chair using Computer Aided Modeling software such as SolidWorks for the design of the component parts of the chair and ANSYS for the Finite Element Analysis. The whole analysis of the anthropometric chair reveals the stress-life curve of the chair, its crack life, stress points, areas of the maximum deformation and other significant analytical results. The research eventually reveals structural integrity and shows the life of the chair. This research serves to benefit all works pertaining to design in ergonomics.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background to the study

A proper foundation to this work would come easier with a clear understanding of what anthropometry means. It is a word obtained from the Greek words ‘anthropos’, which means man,

and ‘motron’, which means measurement (Herron, R.E. 2006). It is simply put, a measurement system for the human body. This measurement system was designed and pioneered by Alphonse Bertillon. Its operational use and relevance in study began in 1890, and even though it was eventually overshadowed by more advanced forms of identification, such as the fingerprint and the face recognition technology, its use remains vital in modern engineering and the design of systems.

Anthropometry is a branch of science that employs the use of non-invasive methods for determining the body’s size and composition. Anthropometric measurement, however, engages methods such as Body Mass Index (BMI), Waist-to-Hip Ratio, Skin Fold Test, and Bioelectrical Impedance (Nigeria Journal of Engineering Science and Technology Research, 2018). As studies have progressed, some researchers have defined anthropometric data as that measure that can be used in ergonomics to clarify the physical dimensions of places, equipment, and furniture. A critical text on the work of ergonomics is aptly corroborated by McCormick and Saunders (1993) of the Application of Information on Human Behavior, Abilities, and Possible Limitations and the Attributes to the Design of Tools, Machines, Tasks, and Environments for Productive, Comfortable, Safe, and Optimal Use. Recent studies have shown that office workers spend a notably longer part of their working hours seated. It is essential to take into cognizance the fact that traditional jobs that primarily involved more forward-oriented tasks are now being substituted for much more new approaches to work on a much wider variety of task postures, and positions (Springer, 2010).

In his research, Mandal (1985) established that 60 percent of the office workers claimed pangs in their back, neck, and shoulder, for which they blamed the furniture they had been using for long hours. It has become a vital factor in the elements of office design to know what tasks are being performed in the office and the varying physical attributes of the individuals utilizing the office. Ergonomics refers to the design of a product, workplace, or service around man for increased productivity and comfort levels. At work, school, or at home, when the products fit the user, the result projects more comfort, higher productivity, and less stress (Openshaw and Taylor, 2006). For furniture like chairs, economic features needed are the anthropometric attributes of the user. (Jan Dul and Bernard Weerdmeester, 2001) clearly complemented this view by projecting ergonomic design as a branch that should study the interaction between everyday life and works with objects used. This constant developing study has greatly affected the dynamics of industrial design and development.

### 1.1.1 The Necessity of Ergonomic Seating

In the broad context of office furniture, ergonomic design principles are used to create chairs, desks, and other workplace elements that support good posture, reduce the risk of musculoskeletal disorders, and promote the overall well-being, eventually increasing the productivity and job satisfaction of the user. The most common form of seating is found with the chair, while auxiliary forms would include benches, stools, balls, swings, etc. (Lueder and Nero, 1994). The best commonly applied approach in seating economics is the ‘seat must fit the user’ concept. Therefore, it is necessary to incorporate economic measures at the design stage of the chair.

### 1.1.2 The Ideal Anthropometric Chair

The Occupational Safety and Health Administration (OSHA) states the following as the essential elements of a chair. They are;

(i) **Backrest**

This element ensures adequate lumbar support and helps to maintain the natural S-shaped curvature of the spine. Poor back support and postures may result from inadequate backrest size, position, or even use. It must be wide enough to support the breadth of the waist and high enough to reach the shoulder blades.

(ii) **Armrests**

This element must be large enough to support most of the person’s lower arm but small enough, so they do not affect the chair positioning. Armrests relieve neck, back, and shoulder stress.

(iii) **Seat**

The seat must be comfortable and allow the feet to rest flat on the floor. It must be wide enough for the user’s hips and clothing, deep enough that the popliteal area (region behind the knees) is not contacting the front of the seat.

(iv) **Base**

Chairs must have a strong base and one that is adequate for the type of floor at the workstation.

Using anthropometric chair enables user to acquire the following data;

- Body height measurement.

- Head height measurement.
- Eye to eye measurement.
- Measurement of eye chain height.
- Head length measurement.
- Measurement of sitting popliteal height.
- Head width measurement.
- Upper shoulder width measurement.
- Sitting shoulder width measurement.
- Hand length measurement.
- Measurement of elbow spans.
- Measurement of height of handheld sitting.

The data above comprises some of the anthropometric data we can get from an anthropometric data measurement chair. As Springer (2010) suggested, a chair should be able to support a person's body and the activities being performed while simultaneously promoting movement.

## 1.2 Statement of the problem

The design of the ideal ergonomical chair would require an accurate data set from the anthropometric data measurement chair. Therefore, while there must be dimensional variations in the sample group, there is also a need for data reliability during data collection. If the data set collected would be the framework of office chairs to be produced in mass, then there is the optimality and seamless reliability of the data gotten. This challenge of reliability and accuracy of the product design can be carried out through structural analysis of the data measurement chair to ensure complete functionality in strength and stability, and to ensure that all variations of body measurements in width and size are efficiently accounted for by the chair.

## 1.3 Aim and Objectives of Research

### 1.3.1 Aim

The aim of this research is to analyze a locally constructed Anthropometric data measurement chair for the design of office chairs.

### 1.3.2 Objectives of Research

The objectives of this research include;

(i) Design of the component parts of the digitalized anthropometric data measurement

chair for the lecturers of the University of Benin.

(ii) Computer Aided Modelling of the digitalized anthropometric chair using Solid Works.

(iii) Finite Element Analysis of the anthropometric chair using ANSYS 2022 for the

University of Benin lecturers

## 1.4 Scope of Research

This research will be limited to the analysis of an anthropometric measurement chair using ANSYS software to ensure optimal efficiency of the designed chair.

## 1.5 Significance of the Study

The study will primarily ensure that the anthropometric chair is able to meet its intended purpose and is safe for use by accounting for the possible variations in weight, height, and other significant measurements without structural failure. It will also help to provide more detailed results on the stability, strength, and rigidity of the anthropometric chair. This will further enhance the development and production stages of the chair for workers. On a broader scale, it will help fast-track studies and provide more efficient solutions in the field of ergonomics.

# CHAPTER TWO

## LITERATURE REVIEW

The subject of anthropometry and ergonomics as it relates to the design of chairs is relatively broad. Hence, the studies discussed in these literatures are the subjective thoughts and views of adept researchers and their works.

The Literature Review helps our project spot out past and possible limitations in current research. Identifying these limitations will enable our project to present precise solutions and upscale the comfort and general well-being of lecturers in the University of Benin. This review will gather past data, analyze, and project for future innovations.

All the relevant studies revealed in this study are based off the pillars of ergonomic chair design, anthropometric data collection methods, challenges, and considerations specific to locally constructed chairs, user comfort, precision in measurements, impact of cultural variations of design, effectiveness of different chair designs in accurately capturing anthropometric data and having an overall impact on the user experience.

Products or environments that are difficult to use provide a frequent cause of accidents when the physical and psychological capacities of users are ignored. The physical, cognitive, and anthropometric characteristics must be considered in product design (Rosner, et al. 2009).

Onawumi et al., (2016) actively developed an anthropometric model aimed at facilitating and ensuring the optimal design of the driver's workspace for the daily commercial bus drivers in Nigeria, using a sample size of 161 drivers who were randomly selected among a host of operators.

The prominent position often assumed by the driver for operations is sitting, and this validates the need for a well-appropriated and ergonomically suitable seat for the driver (Pachling and Chaitany, 2013). According to Qutubuddin et al. (2013), there were observed variations in the dimensions of the student furniture used in North Karnatuka. The disparity showed the furniture used in the engineering colleges more compatible with the anthropometric dimensions of the students than furniture in other facilities. Qutubuddin et al. (2013), in a complementary study, also showed the impact of incompatible furniture on the physical and mental health of the student. The students would, by default, take unnatural sitting postures (forward bend, lateral bend, etc.). This study suggested the need for an anthropometric database of the students in order to determine the suitable dimensions for the furniture in the future.

In the southeastern region of Nigeria, it was duly observed by Nnanna et al. (2019) that the design of the tables and chairs used in the sampled institution was not in any way compatible with the anthropometric dimensions of the staff. Recommendations were placed for similar studies to be carried out across the country. A study conducted by Akinyemi, D.O. (2013) to design tables and chairs for school students making use of the anthropometric data obtained from tertiary institutions of learning to design a chair that is economically safe to use in classrooms.

The outcome of this study proved that the design of tables and chairs can be done utilizing the method of 'one-size-fits-all' approach.

Another study carried out by Tunay, M and Melemez, K. (2008) analyzed bio-mechanical and anthropometric measurements collected from static anthropometric dimensions for both standing 8and sitting posture. The results showed that male students had a mean weight of 69.5 kg with a stature and popliteal height of 1,749 mm and 433 mm, with the female students having a mean height of 56.02 kg with a stature and popliteal height of 1,618 mm and 433 mm.

We see the relevance of anthropometric study again in a study conducted by Darkwa, N.A. (2014), examining the relationship between workers and anthropometric dimensions. Three chairs were evaluated in day-to-day use by workers and the outcome showed that there was no suitable furniture for the workers and inherently affected their sitting posture. The study duly recommended that institutions should promote correct active sitting habits and adopt the use of suitably designed work chairs. According to a study by Noshin et al. (2018), a revised approach of economic design based on anthropometric measurements was utilized in the design of an office chair. The study revealed the unique structural dimension of chairs in Bangladesh.

Fawzy and Almaz (2022), lay a strong emphasis on the essence of anthropometric data and ergonomics in the design of office chairs and portraying the key features of customization and user friendliness. The study suggested that user experience and health could be achieved without trading off comfort and performance in the design of office chairs when anthropometric principles and data set is utilized. Openshaw and Taylor (2006), examined the application of ergonomics to office furniture design, essentially establishing the relationship between product and user. The document stresses on a potential leap in comfort and productivity with the exploration of anthropometry in media workspace designs.

## 2.1 Historical Evolution of Office Chairs

The increasing prevalence of sedentary activities, such as office work and home-based tasks, has led to a decline in hard manual labor. Prolonged sitting can have detrimental effects on health and posture, causing back problems and muscle dysfunction. In response, engineers and scientists have developed ergonomic chairs to address these issues. These chairs are designed to support the body and promote healthy sitting postures by considering factors such as posture, comfort, and health. They feature adjustable components, pneumatic lifting and tilting mechanisms, and specific designs to reduce stress on the body. Some innovative solutions include ergonomic kneeling chairs, which distribute tension across the body and reduce pressure on the back and pelvis. These chairs are designed to be stable, functional, and to promote an active sitting position, reducing fatigue and the negative effects of prolonged sitting. The development of ergonomic chairs is based on the science of ergonomics, aiming to design products that best support the human body and promote health and comfort (Ansari et al. 2018).

**4750-4600BC European chair clay model**

**Ancient Egyptian princess Sitamuns' chair**

The chair has a long history, initially being a symbol of authority rather than a common item. Until the 16th century, chests, benches, and stools were more commonly used for seating.
Surviving examples of ancient chairs are limited, with most being of religious or noble origin. Our knowledge of chairs from antiquity comes from monuments, sculpture, and paintings, with a few actual examples found in museums. The design and materials of chairs have evolved over time, with distinctive designs emerging in different cultures. The chair remains a significant piece of furniture, with a rich and varied history.

**Egyptian chairs**

In ancient Egypt, chairs were crafted with great richness and splendor, often made of ebony, ivory, or gilded wood, and adorned with costly materials. They were supported by representations of natural forms, such as the legs of beasts or figures of captives, as the Egyptians believed that chairs needed to reflect natural forms to avoid creating chaos in the universe. Surviving examples of ancient Egyptian chairs are limited, with some well-preserved pieces recovered from tombs of pharaohs and wealthy individuals. The design and materials of these chairs were highly sophisticated for their time, and they varied based on the individual's status. The ancient Egyptians were highly skilled in woodworking, and their furniture, including chairs, was often more elaborate and richly decorated for royal tombs. The chair of Hetepheres I, the mother of Khufu, is an example of the luxurious and detailed ancient Egyptian chairs, reflecting the opulence and craftsmanship of the time

**Greek and Roman chairs**

Klismos chair, with curved backrest and tapering, out-curved legs,on the stele of Xanthippos, Athens, ca. 430-20 BCE A woman on a chair, side A of an Ancient Greek Attic red-figured loutrphoros, ca. 400 BC. From Benghazi, Cyrenaica, Louvre Museum, Paris. The earliest known form of Greek chair dates back to six or seven centuries BCE. On the frieze of the Parthenon Zeus occupies a square seat with a bar-back and thick turned legs; it is ornamented with winged sphinxes and the feet of beasts. The characteristic Roman chairs were of marble, also adorned with sphinxes.

**Mexican chairs**

One type of chair in ancient Mexico is called the icpalli and is mentioned by Jacques Soustelle. The Dail Life of the Aztecs.p.122. The icpalli can be seen in Diego Rivera's mural of the Aztec market of Tlatelolco, Palacio Nacional, Mexico City. The icpalli is also featured in the Codex Telleriano-Remensis; dignitaries and emperors are depicted sitting in them.

**Medieval chairs**

Seigniorial chairs at a table with tin cutlery, pottery, medieval glass and earthenware in majolica, c. 1465 The chair of Maximian in the cathedral of Ravenna is believed to date from the middle of the 6th century. It is of marble,round,with a high back, and is carved in high relief with figures of saints and scenes from the Gospels-the Annunciation, the Adoration of the Magi,the flight into Egypt and the baptism of Christ. The smaller spaces are filled with carvings of animals, birds, flowers and defoliate ornament. The Chair of St. Augustine, dating from at least the early thirteenth century is one of the oldest cathedral still in use.

**English chairs**

An English side chair (c. 1850) of unknown maker. The chair s made of papier-maché with inlaid mother of pearl, gilded and painted decoration. Part of the Baltimore Museum of Art collection.

**19th century chairs**

The art nouveau school produced chairs of simplicity. The Arts and Crafts movement produced heavy, straight lined, minimally ornamented chairs. The most famous being the Michael Thonet Bendwood chair or the 'bistro chair' created in 1859 which has revolutionized the industry and is still being produced today.

**20th century and modern chairs**

The 20th century saw an increasing use of technology in chair construction with such things as all metal folding chairs, metal-legged chairs, the Slumber Chair, moulded plastic chairs and ergonomic chairs,recliner chairs (easy chair),butterfly chair,beanbag chairs,the egg or pod chair, plywood and laminate wood chairs, and massage chairs.

Additional Guidelines For Designing Office Furniture;

1. **Seat Height**: Office chairs should have adjustable seat height to accommodate users of different heights. The seat height should be set at a level that allows the user's feet to rest flat on the floor or a footrest, with the thighs parallel to the floor.
2. **Lumbar Support**: Lumbar support is crucial for maintaining proper posture and reducing lower back pain. Office chairs should have adjustable lumbar support to accommodate the natural curve of the spine.
3. **Armrests**: Armrests should be adjustable and not restrict arm movement. They should be positioned at a height that allows the user's arms to rest comfortably on the desk.
4. **Backrest**: The backrest should be firm, supportive, and adjustable. It should provide adequate support to the user's back and allow for proper posture alignment.
5. **Swivel Function**: Office chairs should have a swivel function to allow users to easily move around their workspace.
6. **Adjustable Work Surface**: An adjustable work surface, such as an electric adjustable sit down do work surface, can accommodate different users and support postural changes during work session.
7. **Footrest**: A footrest can help users maintain proper posture by providing support for their feet.
8. **Keyboard and Mouse Placement**: Keyboards and mice should be placed at a comfortable distance from the user's body, with the keyboard at a height that allows the user's forearms to rest parallel to the floor.

9. **Monitor Placement**: Monitors should be placed at a comfortable distance from the user's face, with the top of the screen at or slightly below eye level.

10. **Workstation Design**: Workstations should be designed to accommodate a variety of body sizes, weight capacities, and seated postures. Adjustability is essential for supporting postural changes and different users.

## 2.2 Ergonomic Guidelines for Office Furniture Design

The Business and Institutional Furniture Manufacturer's Association (BIFMA)'s guidelines for seating are very general and allow for different design interpretations. These guidelines are based on the Natick military studies using 5th to 95th percentile females and males (Openshaw and Tailor, 2006). WCSU (2008) further posits that an ergonomic chair should have the features described below.

### 1. Seat Height

The seat height should allow the user's feet to be comfortably supported by the floor or a proper footrest. It is expected that an ergonomic chair have adjustable seat height in order to guarantee the comfort of the user.

### 2. Seat Depth

Seat depth should be deep enough so that the region behind the knees (also referred to as the popliteal area) is not hitting the front of the seat. Two ways to prevent popliteal contact are fixing the overall depth of the chair and creating a depth adjustment. Adjusting the seat depth on a chair should be a natural motion that does not strain the user. Separating the armrests from the moveable seat can allow the armrests to be used as an advantage for easily charging the seat depth while seated. The controls for seat depth movement should be intuitive and easy to use, and not require excessive bending to reach. For example, a seat adjustment control like those found in automobiles could help achieve this simplicity.

### 3. Seat Width

The seat should be wide enough to accommodate a user's hips and clothing, and comfortably allow use of the armrests.

### 4. Backrest

The seat back should conform to the contour of the person's spine and give support to the back to alleviate stress on back muscles while seated. Generally, it should be high enough to reach the shoulder blades, wide enough to support the waist breadth, and. have a lumbar support to maintain the natural lordotic curvature of the lumbar spine.

### 5. Chair Range of Motion

The seat and backrest should allow for varied seated postures which can be achieved by allowing a rearward tilt of the back. A minimum of 100° rearward tilt (between 90° and 115°) is preferable. Some chairs also allow the seat to tilt at the same time. The only guidelines for seat tilt measurement is to ensure the torso-to-thigh angle is not less than 90°, and that the seat angle is between 0°-40° forward tilt.

## 6. Armrests

Armrests help relieve neck, shoulder, and back stress. Armrests can provide good surface area for the arm to contact so that the pressure between an arm and armrest is minimized. The armrests should be adjustable up and down, as well as in and out. This allows for more customization and better control of comfort.

## Chair controls

The controls are important, but the fewer and more intuitive they are, the better it can be for the user. A round knob usually means that it should be turned. A flat lever usually means it should be pulled or pushed. Some controls are also easier for individuals with disabilities to use than others. Graphic icons could be placed on the controls to show the user how to operate each lever or device. Images, rather than text, for instructions can prevent the need to translate instructions when selling products in different countries. In addition, it can be a quicker and easier way to communicate. The tension in the controls should allow minimal user effort to activate them. Controls should also be easy to reach and visible to the user. The design of ergonomic office furniture, particularly chairs, is significantly influenced by anthropometric data and the principles of ergonomics. Anthropometric data, which pertains to the measurements and proportions of the human body, plays a pivotal role in creating office chairs that cater to the diverse morphological characteristics of individuals. This data is essential for informing the spatial requirements and ergonomic needs of users, guiding the precise calibration of office chairs to promote optimal comfort and posture alignment (Fawzy, A and Almaz, H. 2022)
and (Noshin et al 2018).

Ergonomics, the science of designing products and environments to optimize human well-being and performance, is fundamental to the creation of comfortable and efficient office environments. In the context of office chair design, ergonomics involves a multifaceted approach aimed at enhancing user comfort, reducing musculoskeletal strain, and increasing productivity. By integrating ergonomic principles into the design process, office chairs can be tailored to support the natural contours of the body, thereby minimizing the risk of discomfort and fatigue during prolonged sitting (Openshaw and Taylor 2006). The combination of anthropometric data and ergonomics in office chair design prioritizes user comfort, health, and performance. By leveraging anthropometric insights and ergonomic principles, designers can craft office chairs that not only accommodate the diverse physiological characteristics of users but also foster environments conducive to productivity and well-being in the university setting (Ivelic et al 2002). Ergonomic guidelines for office furniture design play a crucial role in creating comfortable and supportive seating solutions. These guidelines are based on established ergonomic principles and aim to minimize the risk of discomfort and fatigue for users. Karl and Robinette (1969) highlights the importance of ergonomic design in minimizing the risk of musculoskeletal disorders. The study emphasizes the need to consider anthropometric data, posture, and workspace design to eliminate job-to-worker mismatches and enhance user comfort. Openshaw and Taylor (2006) discussed the application of ergonomics to office furniture design, which requires considering how the products fit the people using them. The document suggests that ergonomics can contribute to more comfort, higher productivity, and less stress by addressing factors such as anthropometry, posture, repetitive motion, and workspace design. (Ivelic et al 2002) discusses the importance of anthropometric data in the design of office furniture, particularly chairs and seating equipment. The study underscores the need to consider anthropometric data, such as eye height and elbow height, in the design process to create furniture that minimizes back pain and repetitive strain injuries.

## 2.3 Challenges in Existing Literature

The existing literature on anthropometric data in office chair design has some limitations and gaps that need to be addressed. One limitation is that research is often narrowly targeted, focusing on the viewpoints of only one demographic or community. This limitation underscores the need for more comprehensive studies that consider the diverse anthropometric characteristics of different demographic groups, including University of Benin lecturers.

Another gap in the literature is the lack of research on the quality of educational research output in higher education. This gap highlights the need for more research on the effectiveness of educational research conducted by university lecturers in Nigeria, including the use of anthropometric data in the design of office chairs. Moreover, there is a need for more research on the factors associated with research wrongdoing in Nigeria. This research gap underscores the importance of ethical considerations in research, including the use of accurate and reliable anthropometric data in the design of office chairs.

# CHAPTER THREE

# METHODOLOGY

This chapter defines the methods and procedures which include the design of the individual components of the amthropometric chair through Computer Aided Design using SolidWorks and the analysis of the chair using ANSYS .

## 3.1 Description of Important Anthropometric In The Design of Chairs

The precise application of anthropometry and ergonomics in chairs design greatly improves human efficiency in performance, minimize hazards, and reduce the scales of musculoskeletal disorders. Improper use of the data can also result to chronic back pains , injuries and illnesses due to occupational health related problems. The anthropometric data acquisition chair was developed to be able to acquire important anthropometric dimensions needed for designing an ergonomic office chair.

(i) **Sitting Height**

The subject sits erect in the Frankfurt Plane with arms hanging at the sides and hands resting on the thighs. Vertical distance from the seat surface to vertex of the head with hair pressed down measured with a standiometer.

(ii) **Head Breadth**

This can be described as the maximum horizontal head width above the ears. This dimension varies significantly from person to person and it is important in design of the headrest of an ergonomic chair.

**(iii) Sitting Elbow Height**

This is the vertical distance from the bottom of the tip of elbow to the sitting surface, measured with the elbow in 90° of flexion. The subject wears light clothing and sits fully erect with thighs fully supported and the lower legs resting on the adjustable footrests. The upper arms hang freely downwards and forearms are horizontally placed on the adjustable armrests. The sitting elbow height is required to determine the height of the armrests.

(iv) **Sitting Shoulder Height**

The subject sits erect with his/her upper arms at the sides and hands on the thighs. Then, the vertical distance from the top of the shoulder at the acromion process to the sitting surface of the developed anthropometric data acquisition chair is measured. This dimension is important in the determination of height of the backrest height.

(v) **Shoulder Breadth**

This anthropometric parameter is the maximum horizontal distance across the deltoid muscles. The subject sits erect with his upper arms touching his sides and his forearms extended horizontally. This anthropometric parameter is used to determine the minimum width of the top of the backrest.

(vi) **Elbow-Hand Length**

The subject sits erect with the upper and lower arms at right angles to one another and the hand stretched out on the calibrated armrest. The distance from the posterior end of the elbow to the longest finger of the hand, while the upper arm is at an angle of 90° with the lower arm is measured. The forearm-hand length is the relevant measurement that is necessary to specify the length of the armrest of the chair.

(vii) **Sitting Hip Breadth**

This is the maximum horizontal distance across the hips in the sitting position. The sitting hip breadth is important in determining the seat width of a chair.

(viii) **Popliteal Height**

The subject sits fully erect on the sitting surface with both feet supported by the footrest adjustment. Then, the vertical distance from the footresting support to the seat surface of the chair is measured. The measurement is necessary in the determination of seat height.

(ix) **Buttock-Popliteal Length**

This is the horizontal distance measured with 90° knee flexion from the posterior surface of the buttock to the interior surface of the knee or popliteal space. The subject sits fully erect with thighs fully supported and sitting surface extended as far as possible into the hollow of the knee, the lower legs hanging freely. The distance from the backrest to the back of the knee by the forward edge of the sitting surface is measured. The buttock to popliteal length is used to determine the seat depth of a chair.

(x) **Buttock-Knee Length**

This is the horizontal distance from the posterior point on the buttocks to the anterior point on the knee, measured with the provided adjustments on the sitting surface of the developed anthropometric data acquisition chair. The subject sits erect with the feet on the footrest at 90° knee flexion, arms at the sides, and hands resting on thighs.

(xi) **Buttock (Lumbar) Height**

This is the maximum height from sitting surface to the posterior part of the buttock. This anthropometric parameter is important in the design of the lumbar support of an ergonomic chair.

(xii) **Height/Stature**

This is the vertical distance from the floor to vortex of the head with hair pressed down. The subject stands fully erect with both feet together and the head is oriented in the Frankfurt Plane. This parameter was measured using the in-built standiometer attached to the developed anthropometric data acquisition chair.

(xiii) **Weight**

The weight of each subject is measured using a personal mechanical scale attached to the standiometer unit of the developed chair. The subject stands upon the personal mechanical scale at the standiometer unit, and their weight is read on the scale of the measuring device. This parameter helps in determining the force that will be impressed on the seat pan of an office chair when in use. Hence, proper design and material selection is carried out in order to override impending failure of the chair when in service.

### 3.2 Anthropometry and Ergonomic Design of Office Chairs

Anthropometry is an aspect of ergonomics that deals with the measurement of size and the proportion of the human body. Engineering anthropometry is the application of anthropometric data to equipment, workplace, and clothing design to enhance the efficiency, safety, and comfort of the user (Abdu and Olaboye, (2002), and Hertzberg, (1972)). This is sequel to the fact that people come in many sizes and shapes (Openshaw and Taylor, 2006). Besides, it has been reported that chairs designed based on the anthropometric data of the end-user is a way of maintaining user welfare and safety (Mahmoudi and Baz-Rafshan, 2013).

There are two types of anthropometric data that can be utilized for the purpose of design, as reported in Abdu and Olaboye, (2002). They are structural dimensions which are taken when the body of the subject is in a fixed position, (e.g. sitting, height, weight, etc.) and functional dimensions taken from the body position that result from motion of the subject, (e.g. overhead reach, thumb-tip reach, etc.).

In a study conducted by Ismaila et al., (2013), titled, An Anthropometric Design of Furniture for Use in Tertiary Institutions in Abeokuta, southwestern Nigeria, it was reported that the anthropometric data of the Nigerian students were not considered in the design of the tables and chairs they use. Similarly, in an anthropometric survey and appraisal of furniture for Nigerian primary school pupils, Ismaila et al., (2010), observed that there is a mismatch between the anthropometric dimensions of the pupils and the furniture they are using currently. The aforementioned corroborates the submission that chair design based on anthropometric data analysis is highly recommended as there is a link between seat type and the occurrence of musculoskeletal disorders (MSDs) with neck, shoulder, upper back, lower back, thigh, and knee symptoms (Mahmoudi and Bazrafshan, 2013), and Ivelic et al., 2002.)

**Criteria for Reliability of Anthropometric Data**

Abdul and Olaboei, (2002) and Adekoya (1999), posit that for an anthropometric data to be reliable, it must satisfy the following criteria:

(i) The measuring technique must be specified and standard, so that data from different groups can be compared and test subjects can be accurately located at the center of a user group.

(ii) The group measured should be representative of the equipment or facility users, irrespective of age, sex, race, occupation, and such factors like geography or socioeconomic status.

(iii) The sample should be large enough to yield required statistical reliability or reproducibility from sample to sample.

### 3.2.1 Postural Influences on Sitting

A good seated posture is one that is comfortable, does not put a lot of stress on the user's buttocks, back, or arm muscles, and allows the user's feet to be on the floor. In addition, Iverik et al. (2002) reported that inappropriate sitting caused by poorly designed chairs accounts for headaches (14%), pain in the neck and shoulders (24%), back pain (57%), backside (16%), lower leg (19%), and pain in knees and feet (2%). These are common postures found in the office environment that can be considered when designing an office chair. Openshaw and Taylor (2006) gave these postures as standing, sitting, reaching, and moving. Hence, a good lumbar support is necessary for the protection against spinal injuries resulting from prolonged sitting on an office chair.

Furthermore, static sitting posture while sitting on a poorly designed working chair that have no support for the lumbar region and small depth of seat, can cause neck and backache because of increased pressure on the inter-vertebral disc. Besides, small depths of the seat have harmful effects on muscles and on the circulation of blood and lymphatic fluid in the legs. Static sitting can thus induce stress on the cardiovascular system and can have detrimental effects on the digestive organs (Jaworski and Karpinski, 2017, and Ivelic et al., 2002).

### 3.2.2 Seating and the Human Spine

The human spine is composed of 26 individual bony masses. 24 of those are bones called vertebrae. The vertebrae are stacked one on top of the other and form the main part of the spine, running from the base of the skull to the pelvis. At the base of the spine is a bony plate called the sacrum, which is made up of five fused vertebrae. The sacrum forms the back part of the pelvis. At the bottom of the sacrum is a small set of four partly fused vertebrae, the coccyx or tailbone. Adding the fused and partly fused bones of the sacrum and coccyx to the 24 vertebrae, the spine has 33 bones altogether (Ogle, 2010, and Case et al., 1999).

The vertebral column, from a prior mechanical viewpoint, can be seen as a double S-shaped spring structure. This natural architecture combination of bone and muscles is a perfect design to maintain its stability in posture and still be flexible while maneuvering. When an external load is applied to this spring setup, it produces mechanical stress, which manifests itself by realignment of the vertebrae construction, depressing the discs, changing and foreshortening the vertebral column, (Jaworski and Karpinski, 2017, Gilad and Tichauer, (1999). The architectural structure of the human spine is shown in the figure below.

In the figure above, the spine is labelled in 3 sections; the cervical spine, the thoracic spine, and the lumbar spine. Starting from the top, there are 7 cervical vertebrae, 12 thoracic vertebrae, and 5 lumbar vertebrae. The human spine is the main structure that supports the human body weight and external loads to allow the torso to reach a variety of positions and to protect the spinal nervous system (Case et al., 1999).

### 3.2.3 Curvature of the Spine (Kyphosis and Lordosis)

According to Ogle (2010), two common excessive curvatures of the spine are kyphosis and lordosis. Spinal kyphosis is when the upper back and shoulders are overly rounded forward. Similarly, spinal lordosis is when the bones of the spine appear to be forward when seen from the side. This is most commonly seen in lumbar lordosis, where the concave part of the low back has too much curve. These spinal curvatures can result from prolonged use of un-ergonomic chairs. Kyphosis and lordosis have a variety of causes, but in today's world, many of us sit too much and exercise too little, so muscular weakness and the resulting physical imbalances contribute greatly to these problems. Besides, many people do not consider the design characteristics of the chair they sit on (Ivelic et al., 2002).

A seat that is properly designed helps in maintaining the lumbar spine curvature through the seat back, taking the body load, thereby composing the muscles. Contrarily, a seat that is badly designed causes lordosis loss by the leveling of the lumbar curvature. This leads to intensifying disc tension, resulting in the gluteal muscles and spinal ligaments being hurt, and a kyphosis rise by the expansion in the curvature of the thoracic C-shaped in the upper spine (Muhammad, et al., 2018).

A bricklayer's hunchback is an example of a kyphosis-like problem that reflects a weakness in the back muscles, especially the extensor muscles that hold the upper back upright. Furthermore, Ogle (2010), posited that swayback is a layperson's term for lumbar lordosis. It is often associated with weak abdominal muscles that are not able to hold the low back and pelvis in their neutral position, where the pelvis is like a level bowl. Instead, weak abdominals allow the pelvic bowl to tip forward, creating excessive curve at the back. The kyphosis and lordosis of the spine are shown in the figure below.

### 3.2.4 Service Requirement

Service requirement in material selection entails the properties a material should possess in order for it to be able to serve the purpose for which it was introduced in the design. Examples of such properties are hardness, strength, stiffness, toughness, corrosion resistance, thermal conductivity, etc.

## 3.3 Detail Design of Important Parts of the Anthropometric Data Acquisition Chair

A generally employed design specification is that the chair must suit the portion of the users that stretch among the 5th% female and the 95th% male figures using necessary Anthropometric dimensions. Since the anthropometric data acquisition chair is being designed for users in Nigeria, the design will be based on a careful comparison of relevant sitting anthropometric dimensions for Nigerian adults obtained by Muhammad et al. (2018) as shown below

**Relevant Nigerian Seating Anthropometric Data for Chair Design (mm)**

| Body Dimension | 1st | 5th | 95th | 99th | Mean/(SD) | 1st | 5th | 95th | 99th | Mean/(SD) |
|---|---|---|---|---|---|---|---|---|---|---|
| Hip Breadth | 245 | 282 | 449 | 474 | 340(480) | 270 | 295 | 475 | 558 | 370(600) |
| Buttock to Popliteal Length | 344 | 434 | 580 | 610 | 503(480) | 330 | 394 | 550 | 580 | 475(530) |
| Popliteal Height Sitting | 330 | 381 | 510 | 565 | 458(520) | 320 | 340 | 510 | 909 | 449(210) |
| Elbow-to-Elbow Breadth | 320 | 364 | 583 | 600 | 437(580) | 316 | 340 | 584 | 650 | 431(670) |
| Shoulder Height Sitting | 435 | 510 | 703 | 783 | 589(590) | 394 | 480 | 670 | 700 | 564(620) |
| Sitting Elbow Height | 130 | 145 | 246 | 434 | 197(530) | 125 | 149 | 246 | 519 | 203(610) |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Buttock-Knee Length | 432 | 530 | 690 | 704 | 607(520) | 400 | 490 | 654 | 699 | 586(308) |
| | | **MALE** | | | | | | **FEMALE** | | |

**Source : Muhammad *et al*. (2018)**

### 3.4 Computer Aided Design

This primarily involves the creation of 2D and 3D design simulations of real-world objects with the aim of optimizing designs before manufacturing. It is completely carried out with scale, precision, and physics properties in order to optimize and perfect the design before manufacturing. It is generally seen as the development of computer models with varying geometrical constraints. The models often provide a three-dimensional representation of a component or a whole system. In the process, the parameters (size, shape and geometry) are often controllable.

The resultant CAD output must give information such as materials, procedures, measurements and tolerances.

For this design analysis, we will be utilizing SolidWorks for the development of the anthropometric chair and its component parts and the ANSYS for the total structural analysis of the chair.

### 3.5 SolidWorks

This is a three-dimensional parametric design software used in the design of products of special and general purposes.

The following components of the anthropometric chair were designed using the relevant dimensions stated below;

**The Seat Pan**

The Seat Pan Area (Asp) and Seat Pan Perimeter (Ps) are given by the equations

Asp Length x Breadth (3.7)

$P_{SP}$(Length + Breadth) x 2 (3.8)

But

Length of seat Pan = Popliteal length

Breadth of Seat Pan = Hip Breadth

Since the chair is for data collection, a value greater that what is presented in Table 3.2 as hip breadth was used to design the chair so that it can accommodate a very wide range of subjects.

Hence,

Length = 600 mm

Breadth = 550 mm (from Table 3.2)

Therefore

$A_{sp}$=600 x 550-330,000 mm²

Similarly,

$P_{SP}$ = (600+550) x 2 = 2,300 mm

The seat pan height is gotten from the 95th percentile of the popliteal height of the user group. The seat pan height is given as 510 mm from Table 3.2.

### 3.5.1 Lumbar Support

This is an important feature of an ergonomic chair that was included in the design of the anthropometric data acquisition chair in order to enhance the comfort of subjects during anthropometric measurements. The lumbar support helps to protect the lower region of the spine from sitting related injuries.

The 95th percentile of the lumbar height of the user group is used to determine the height of the lumbar support. The hip breadth is taken as the breadth of the lumbar support area.

Thus,

$Area_{LS}$= Lumbar Height x Hip Breadth

Where,

Lumbar Height = 300mm (Chosen based on Lumbar Height in Mahmoudi and Bazrafshan, 2013)

Hip Breadth = 600mm

Hence;

$\text{Area}_{(LS)} = 300 \times 600 = 180{,}000\text{mm}^2$

Hence, $180{,}000\text{mm}^2$ represents the portion of the backrest constructed to be open so that it can provide support for the spine of subjects when chair is in use.

### 3.5.2 The Back Rest

The backrest height of a chair is designed based on the sitting shoulder height of the user group. Since this is a data acquisition chair, the backrest was designed to be able to accommodate adjustments for measuring anthropometric dimensions like sitting height, shoulder height, head breadth and shoulder breadth. Hence, the available sitting height was used as a guide in designing the chair height against the same breadth used for the seat pan.

Hence, the chair was designed to be 1010mm, which is an exaggeration of the sitting height presented in Onawumi et al., (2016) in order for it to be able to accommodate a wider range of users within Nigerians.

Using,

Backrest Area($A_{BR}$) = Sitting Height x Seat Breadth

However, Chair Height includes Lumbar Height

Chair Height – Lumbar Height = 1010 – 300 = 710mm²

Area ($A_{BR}$) = 710 x 600 = 426,000mm²

### 3.5.3 Arm Rest

The sitting elbow height is a determinant in the design of armrest height. Since the chair is designed for the purpose of anthropometric data collection, care was taken to choose a value that can accommodate the highest and lowest expected anthropometric value. Hence, the armrest was designed to be adjustable within the range within the range of 80mm and 400mm.

Similarly, the length of the armrest was designed to 680mm which is an exaggeration of the forearm to hand length presented in Ismaila et al., 2013. The Adjustable Arm Rest Designed for the Anthropometric Data Acquisition Chair is shown below.

FIG 3.1 **Adjustable Arm Rest**

### 3.6 Adjustments for Anthropometric Measurements

Sequel to the fact that this chair being designed is solely for the purpose of anthropometric data collection, adjustable arms were constructed to be able to measure relevant anthropometric dimensions needed for designing an ergonomic office chair. The adjustments were fabricated in the faculty of engineering central workshop using various workshop operations such as bench fitting, sheet metal, grinding and welding operations.

**FIG 3.2 Wing Nut**

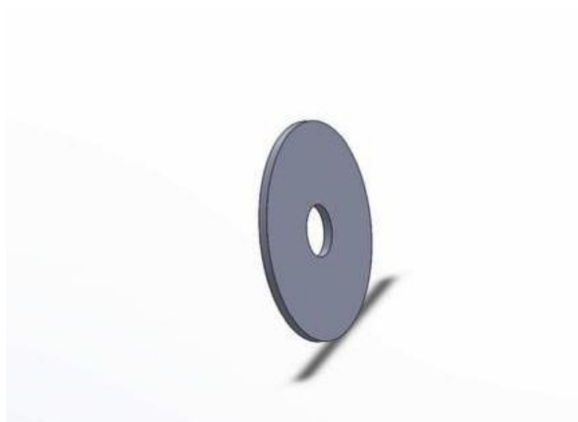
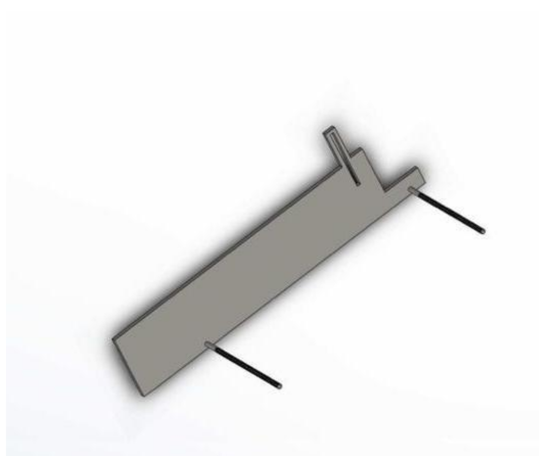


**FIG 3.3 Washer**

**FIG 3.4 Hexagonal Head Bolt**



**Hip Adjustment Plate**

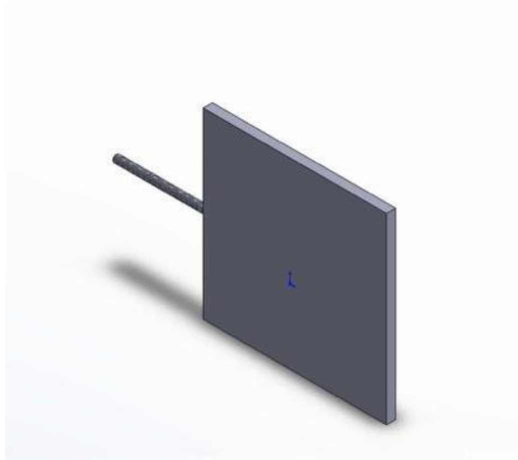


**FIG 3.5 Head Breadth Measurement Plate**

### 3.6.1 Standiometer Unit

The standiometer unit was incorporated in the developed chair in order to aid easy measurement of height and weight of subjects during data collection. A carrier was developed to house a personal mechanical scale purchased fo measuring the weight of subjects. Similarly, a calibrated flat wooden material replica to a wooden metre rule is attached to the top edge of the left side of the chair for measuring height. A moveable pointer navigates through the slot provided in the middle of the calibrated material . The height and weight of the subjects can be measured simultaneously at the standiometer unit. The design of the carrier made from a combination of sheet metal, flat steel bar and a piece of wood is presented below.

From;

Area of Carrie, $A_C = L_C \times B_C$

Perimeter of the Carrier, $P_C = (L_C + B_C) \times 2$

Where;

$L_C$ = Length of Carrier = Length of Weight Measuring Device + $A_A$

$B_C$ = Breadth of Carrier = Breadth of Weight Measuring Device

$H_C$ = Height of Carrier = Height of Weight Measuring Device

$A_A$ = Attachment Allowance = Thickness of Wooden Support

Where;

Length of Weight Measuring Device = 270mm

Breadth of Weight Measuring Device = 270mm

Height of Weight Measuring Device = 50mm

Thickness of Wooden Support = 30mm

Then;

$L_C = 270 + 30 = 300$

Area, $A_C = 300 \times 270 = 81000mm^2$

Perimeter of Carrier $= (300 + 270) \times 2$

Therefore, $P_C = 570 \times 2 = 1{,}140$ mm

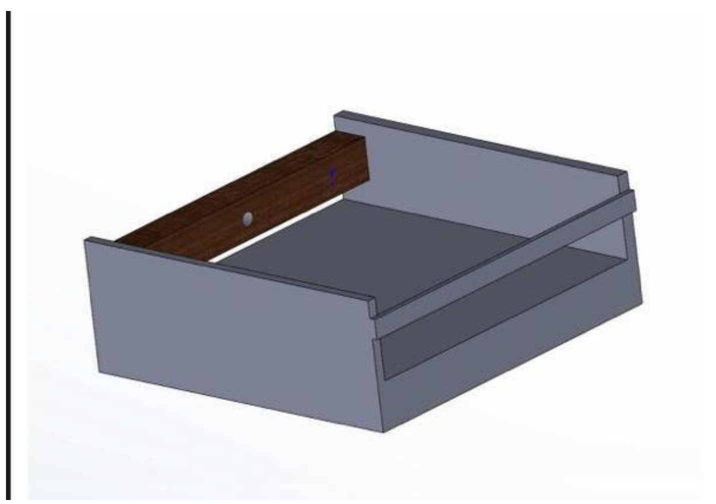


**FIG. 3.6 Weight Scale Carrier**

**FIG. 3.7. Wooden Frame of the Chair**

**FIG. 3.9. Attachment for Measuring Height**

The full assembly process involves the joining of the different of the chair together. Then, joining procedures were used to assemble the components in order to form the frame of the chair. The seat pan was joined to the backrest to form the first structural frame and then the adjustable armrest was attached using the required size of bolt and nut. The fasteners used here were designed to be moveable and removeable. The final part saw the inclusion of the various adjustment arms as well as the weight scale carrier. Various views are seen below :

**FIG. 3.10. Anthropometric Chair Assembly (Rear View)**

**FIG. 3.11. Anthropometric Chair Assembly (Right View)**

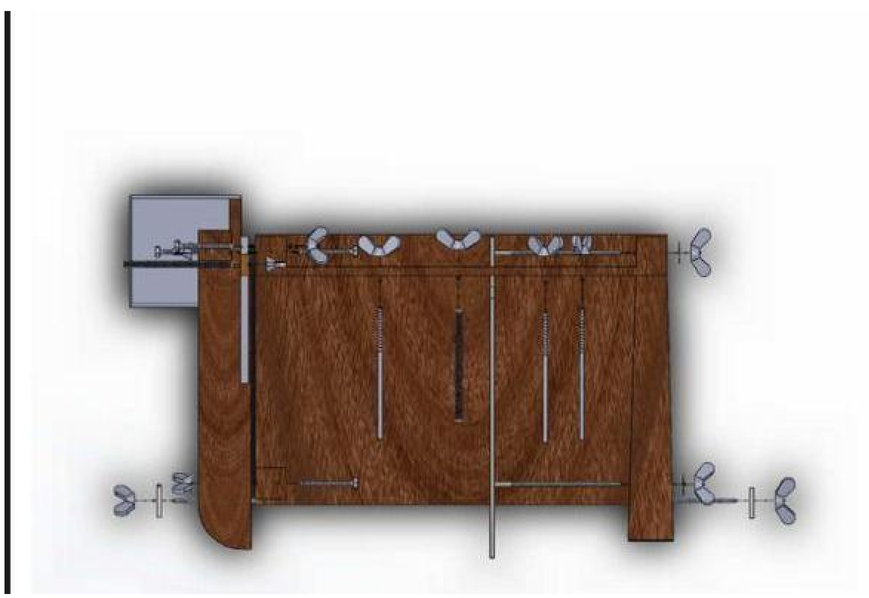


**FIG. 3.12. Anthropometric Chair Assembly (Top View)**

**FIG. 3.13. The Fully Assembled Anthropometric Chair**

## 3.7 Finite Element Analysis

FEA is the use of models and simulations in predicting and understanding the behavior of an object under various physical conditions. It is a developed computer-aided engineering tool used to analyze how a design behaves under real-world conditions. It is very instrumental in vibration, thermal and structural analysis.

Our software of preference for the FEA is ANSYS. In ANSYS, we would be carrying out static structural and dynamic structural analysis. This analysis will reduce the need for extensive prototyping. The steps in FEA is seen below;

(i) **Modeling**; In this phase, the sophisticated geometrical features of the chair are omitted in order to see the fundamental structure of the chair. Attention is given to the features that are structurally important in the chair.

(ii) **Material Definition**; Here the material properties of the chair which basically consists of the wood and sheet metal are defined. This helps to understand the nature of the chair's response during the analysis.

(iii) **Defining Loads**; Here, we define and identify the external forces acting on the chair and how those forces one component against another.

(iv) **Boundary Conditions**; Using mathematical equations, conditions are set for which the chair will exist to reduce the complexity of the problem.

(v) **Meshing**; Here, the geometry of the chair is divided into smaller shapes called the finite elements. Meshing brings together the computations from those finite elements to create a mesh structure. As nodal points increase, computations become more complex.

(vi) **Solution**; Here, Finite Element Method (FEM) computing software will have created a representation of the chair.

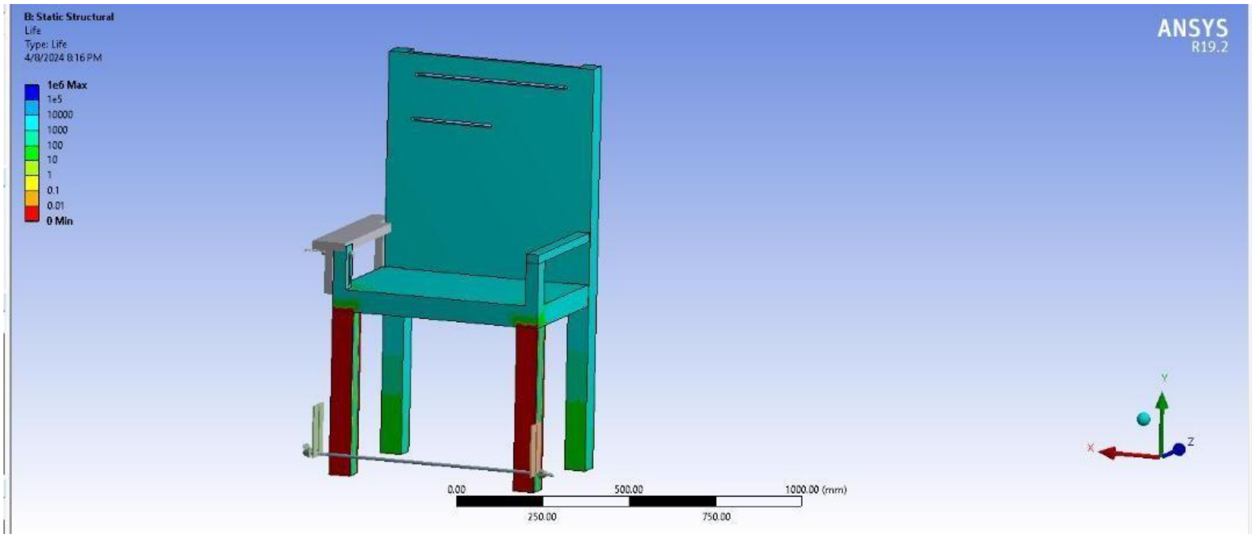



**FIG. 3.14. Stress Point Analysis View**

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1 RESULTS

The digitally constructed data acquisition chair went through Finite Element Analysis (FEA) using ANSYS (Product version 19.2).

## 4.2 Discussion of Results

The CAD model of the chair designed and extracted from SolidWorks is exported to ANSYS as an STEP file because of its cross-compatibility across many CAD programs.

In running the FEA analysis, the engineering data has to be set. This procedure accounts for the properties of the wood and the sheet metal. The overall properties of the chair such as the dimensions are also assigned. With the entry of all relevant dimensions and data, the geometry is imported into ANSYS space plane (Workbench) and then sent to Mechanical APDL for increased for increased control over the model and improved static structural interpretation.

Conclusively, the physics which would include the loading conditions, boundaries and regions are setup before the intended analysis is carried out.

# CHAPTER FIVE

## Conclusion and Recommendation

### 5.1 Conclusion

This work has successfully ended the design stage of an anthropometric data measurement chair. It was digitally constructed using SolidWorks and analyzed using ANSYS. Hence, the challenges associated with the reliability of the anthropometric chair have been duly addressed. In the broader context o occupational safety and health, this work holds the promise of greatly adding irrefutable knowledge without going through the labour of manual testing. It gives significant level of assurance to the development and production stages of office chairs in general.

### 5.2 Drawbacks

The major drawbacks experienced were;

(i) The time taken to learn how to operate and run the software. It was a tedious experience as there was no prior knowledge.

(ii) The use of a low-budget system in attempting to run the software was quite a frustrating experience.

### 5.3 Recommendations

The following recommendations are hereby made.

(i) The results of the design analysis presented in this study should used in the development and production of suitable ergonomic office chairs for lecturers of the University of Benin.

(ii) The result of this research will also greatly contribute to the existing literatures and works if occupational safety and health in the Nigerian educational setting.

(iii) This research work shares more insight into the relationship between strength of materials and failure. Therefore, it could be a practical reference in material science.

(iv) Finally, advanced studies should be conducted based on the analytic results obtained from this work in order to increase knowledge and credibility of this research line.

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