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Design Modification and Production of a Bicycle Powered By an Internal Combustion Engine

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ABSTRACT: The bicycle serves many purpose .Primarily it is used for transportation. It is also used for sports and leisure. As a means of transportation, there is need to provide more human comforts. This calls for the design modification with an internal combustion engine as a secondary driver, the research was conceived, designed and a prototype produced as shown in this research work. The minimum average speed of the bicycle over five testing speeds was 23.44km/h. The results of the test is promising.It suggests that the bicycle powered by an IC engine is a viable alternative to traditional bicycles being an innovative approach that priorities local resources. Further design should be carried out to incorporate multiple gears. Commercial production of this design is advocated for Nigerian government.

KEYWORDS: Bicycle, design, modification, internal combustion, engine.

1.0 INTRODUCTION

The bicycle is unique among human-powered machines in that it uses human muscles in a near-optimum way**.** A bicycle is a vehicle characterized by two wheels and propelled by pedals, which are connected to the wheels through a chain and gears. Steering is accomplished by handlebars. A bicycle is commonly referred to as a pedal cycle, bike, or cycle;a bicycle can be human-powered, engine or electric motor-assisted vehicle. A person who ridesa bicycle is known as a cyclist or bicyclist [1].

Bicycles made their debut in Europe during the 19th century, and by the early 21st century, their numbers had surpassed 1 billion worldwide. This figure not only exceeds the total numberof cars but also surpasses the number of individual car models produced. Bicycles serve as the primary mode of transportation in many regions and have become a widely embraced form of recreation. Moreover, they have found applications as children's toys, fitness equipment, tools for military and police, courier services, platforms for bicycle racing (sports), and even for showcasing impressive bicycle stunts. The invention of bicycles has had a profound impact on the society, both in terms of cultural influence and advancementsin modern industrial methods. Many components that played crucial roles in the developmentof automobiles were initially invented for bicycle use. This includes significant innovations such as ball bearings, pneumatic tires, chain sprockets, and tension-spoked wheels. These inventions not only revolutionized the world of cycling but also laid the groundwork for furtheradvancements in transportation and engineering.

The term "motorized bicycle" typically refers to a bicycle that combines both pedal power andinternal combustion (IC) engine power. However, it can also serve as an umbrella category encompassing bicycles that utilize alternative power sources. For instance, electric bicycles rely on electric motors powered by batteries instead of IC engine. It is important to differentiateIC engine powered bicycles from motorcycles, as the former combines pedal power with engine power, while motorcycles are exclusively powered by either IC engine or electric motors. The earliest attempts to construct IC engine powered bicycles date back to the 1860s.Pioneering engineers like Sylvester Howard of Roxbury and Philadelphia Copeland were among the first to build such bicycles, utilizing steam engines. However, these early designs were hindered by their weight and size. In contrast, Gottlieb Daimler developed a compact single engine design, significantly reducing both the size and weight of IC engine powered bicycles. This innovation marked a noteworthy advancement in the development of such bicycles.

In recent times, there continues to be an ongoing development of IC engine powered bicycles,both as complete designs and as add-on motor kits suitable for standard bicycles. These advancements are pursued by both hobbyists and commercial manufacturers. Several companies are currently engaged in the production of aftermath conversion kits, enabling conventional bicycles to be transformed into IC engine powered vehicles. Electrically poweredbicycles rely on batteries as their power source. However, these batteries have limited capacity,resulting in restricted range, especially when higher power output is required. Consequently, the design of electric bicycles must carefully consider these constraints while ensuring efficientperformance, safety under extreme operating conditions, and an economically viable use of materials and manufacturing processes. The reasons for the success to date of IC engine

Vehicles are easily understood when one compares the specific energy of petroleum fuel to thatof batteries. The specific energy of fuels for IC engines varies but is around 9000WhKg^{-1}, whereas the specific energy of a lead acid battery is around 30 WhKg^{-1}. Once the efficiency ofthe IC engine, gearbox and transmission (typically around 20%) for a petrol engine isaccounted for, this means that 1800 WhKg^{-1} of useful energy (at the gearbox shaft) can be obtained from petrol. With an electric motor efficiency of 90% only 27 WhKg^{-1} of useful energy (at the motor shaft) can be obtained from a lead acid battery**.** Tostore the same amount of useful electric energy when compared to IC engines requires a largesize of lead acid battery. Another problem that arises with batteries is the time it takes to recharge them. Electric vehicles batteries are expensive. Additionally, aesthetic appeal is an important aspect to consider, ensuring that the design of these bicycle is visually appealing tousers.

The issue of transportation efficiency and congestion in urban areas is a major reasonnecessitating this concept. As cities continue to experience growing populations and increasingtraffic congestion, finding efficient and sustainable transportation solutions becomes crucial. Motorized bicycles offer an alternative mode of transportation that can help alleviate traffic congestion, reduce commute times, and provide a more efficient way to navigate through crowded city streets. By integrating an IC engine into bicycles, riders can enjoy the benefits ofassisted propulsion, allowing them to cover greater distances with less physical effort. This solution provides a means of transportation that is faster than traditional bicycles while still being compact, maneuverable and environmentally friendly when compared to conventional motor vehicles. The production of bicycles powered by an Internal Combustion Engine can play a significant role in addressing transportation inefficiencies and improving the overall mobility experience in urban environments.

The need to develop a bicycle equipped with an internal combustion engine to enhance bicycle transportation by reducing human effort and achieving higher speeds when compared to conventional bicycles is very significant.

This bicycle powered by an IC engine when designed and produced will result inaccelerated transportation, alleviated traffic congestion, decreased commuting time, and improved efficiency.

Transportation being integral to all human activities holds a central position in the history of human civilization. It is widely acknowledged that a society’s progress is inherently linked to itstransportation system. Therefore, a society lacking an efficient and advanced transport infrastructure remains at primitive stage. Historical records demonstrate that the rise of imperial empires and great kingdoms was consistently preceded by establishment of an effective and well-developed transport system, emphasizing its crucial role in societal achievements. It is therefore no exaggeration that transport is the tonic of human existence. The earliest mode of transportation,undoubtedly was by human foot. Since the beginning, humans have been characterized by their movement from one place to the another driven by the pursuit of better opportunities. However, this form of transport was inherently slow, as humans could not travel more than three miles per hour. Around 7000 B.C., the use of wooden sledges became prevalent among communities engaged in hunting, fishing, and residing in regions such as Egypt, northern Europe, and the fringesof Arctic. These sledges were pulled behind either humans or animals, although their mode of propulsion may seem rudimentary, it represented a significant technological advancement. Duringthe ancient period, a major breakthrough in the realm of transportation occurred with the introduction of wheeled transport and the first wagons featured wheels were constructed from threeplanks of wood which were joined together in a rough circular form. It is important to note that speed was not the primary characteristics of these early vehicles.

1.1 Brief History of Bicycle

The origin of the bicycle can be traced back to the late 18th century, marking the beginning of itscaptivating history. Over the years, the development of this transformative mode of transportation

Involved numerous inventors and significant advancements. The bicycle, a seemingly straightforward mechanical marvel that we are familiar with today, is, in fact, the result of a prolonged and persistent pursuit for a human-powered vehicle [1]. One of thesignificant milestones in bicycle history occurred in 1817 when Baron Karl Drais, a German forestmaster, created the “draisine”. This invention stemmed from Drais’s desire to have a practical human-powered vehicle that would facilitate his regular inspection tours of the land under his supervision. The draisine being the first human-powered land vehicle to make a serious attempt atpublic acceptance, left a lasting impact. The draisine was constructed primarily of wood, with exception of iron tires, the draisine featured two mini-carriage wheels aligned in a straight line anda single cushioned seat. The rider assumed an upright position and propelled the draisine by pushing off the ground with one foot, followed by the other, mimicking the motion of walking orrunning.

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The term “bicycle” was introduced in the 1860’s in France to describe a new kind of two-wheelerwith a mechanical drive **.** It was adopted by both English and French for two-wheelvehicle. The introduction of pedals to two-wheeler vehicle called “Michaux Velocipede” or “boneshaker” by a French blacksmith, Pierre Michaux in 1861 marked a major breakthrough. Thetwo-wheeler was propelled by pedals attached directly to the front hub. The front was slightly larger than the rear wheel for improved gearing. The frame has extension for riders to keep their legs during descents, so that the rider would not have to follow rapidly spinning pedals because the front hub has no free wheel mechanism. Some of the pedals were slotted so that the pedals could be slid up or down to suit the rider. The seat can be adjusted forward or backward so as to accommodate different statures. The rider can stop the bicycle by pedaling backward or by pullinga cord that applies a metal spoon to the iron wheel of the rear tire.

James Starley patented the Aerial bicycle on August 11, 1870. It featured a larger-than-normal driving wheel**.** Starley acknowledged the benefits of incorporating a geared step-up transmission, although early testers discovered that the existing chain mechanism often became immobilized by the grit and gravel present on roads at that time. The 1870s markedthe era of high-wheelers, when they reigned supreme. Between 1884 and 1885, a direct connectionbetween the front wheel and the handlebars was established. This new arrangement proved to be simpler and more dependable compared to the previously employed rack-and-pinion and other indirect systems.

In 1885, James Starley’s nephew, John Kemp Starley built a bicycle called “Rover” (safety bicycle)that was propelled by chain and sprocket connected to the rear hub **[**1]. The Rover received so many criticisms that it was undignified as at that time but the Rover stood out becauseof its improved level of comfort, because the seat is adjustable to accommodate different physique,the handlebars is adjustable also but most especially was that the Rover conforms more with aerodynamics and as such faster. It was said that reducing the air resistance does not appear to have been one of Starley’s primary objectives. In 1886, Starley further modified the Rover by making the two wheels of equal size. 0ne major development in the mainstream flowing to modernbicycle remained: the pneumatic tire. This was patented in 1888 by John Boyd Dunlop, a Scottishveterinarian in Belfast**.** John Dunlop discovered that a tire with an inner-tube filledwith compressed air will not only cushion the ride, it also increases the bicycle speed by about a third. This innovation was incorporated in the Rover which increased the demand.

Following 1900, numerous advancements were achieved in terms of materials, frame design, andcomponents, yet the fundamental design of the bicycle remained largely unchanged. One particularly notable technological improvement was the introduction of multiple-speed gearing. In1896, William Reilly received a patent for a two-speed internal hub gear, which subsequently became a feature of high-end bicycles in Britain. By 1913, the Sturmey-Archer Company was producing 100,000 three-speed hub gears annually. Meanwhile, French cyclists conductedexperiments with various multiple-speed mechanisms, leading to the establishment of derailleur gears in France by the 1920s. These gears allowed the chain to move from one sprocket to another,providing cyclists with increased versatility. During World War II, American soldiers came acrosslightweight geared bicycles in Europe, sparking the emergence of a small adult market in the 1950sand 1960s. In the 1960s, a new design gained popularity among teenagers, exemplified by the Schwinn Stingray. These bicycles featured high-rise frames, small wheels, banana-shaped saddles,and long handlebars. By 1968, they accounted for approximately 75 percent of bicycle sales in theUnited States, with an estimated 20 million teenagers owning high-rise bicycles. However, as theyoutgrew these bikes, young consumers transitioned to 10-speed bicycles, named so due to their two chainwheels and five freewheel sprockets, offering a total of 10 different gear ratios. This shiftin preference triggered a second boom in the industry, with annual U.S. sales doubling from 7 million to 14 million between 1972 and 1974. Roughly half of the bicycles sold during this periodwere 10-speeds.

The resurgence of cycling came with the advent of the mountain bike, initially referred to as "clunkers" by its creators. These bikes were developed in northern California during the 1970s. Bythe 1980s, mountain bikes had replaced 10-speed bicycles to an extent that the mountain bike wenton to become the standard bicycle in the developed world, with a staggering 95 percent share of bicycle sales in the United States in 1993. As a result, touring and racing bicycles came to be known as road bikes.

A motorized bicycle refers to a bicycle that incorporates an attached motor or engine and a transmission mechanism. This setup serves two purposes: it can power the bicycle independentlywithout human effort, or it can provide assistance to the rider while pedaling. According to [2], walking and cycling represent sustainable modes of transportation that contribute to reducing traffic congestion while promoting livable, inclusive, healthy, and affordable cities. A distinct differentiation can be observed between a motorized bicycle and a motorcycle based on the presence of pedals. A motorized bicycle retains its pedals allowing the rider the option to utilize either the engine or motor for propulsion while also being

Table to cycle independently of motorized assistance. The earliest motorized bicycles were essentially regular utility bicycles that were enhanced by the addition of a motor and transmissionmechanism. These modifications aimed to provide assistance to rider’s normal pedal propulsion. During a time when gasoline engine and transmission technologies were still at an early stage of development and power-to-weight ratios were relatively low, a dual-purpose system appeared especially advantageous. Over time pedal propulsion was gradually substituted by continuous reliance on two or four stroke engines, however, the idea of utilizing engine assistance for ordinarybicycles has persisted. This concept has resurfaced periodically throughout the years, especially during periods of austerity or fuel shortages. In countries where the cost of automobiles or fuels isexcessively high, motorized bicycles have maintained enduring popularity as a primary mode of transportation.

In the late 18th century, investors began experimenting with attaching steam engines to bicycles, tricycles, and quadracycles, laying the foundation for motorized bicycles or motorcycle. The French Michaux Perraux steam velocipede of 1868 is widely regarded as the first true motorized bicycle, followed by the American Roper steam velocipede of 1869, created by Sylvester Roper from Roxbury, Massachusetts**.** Roper showcased his machine at fairs and circusesin Eastern United States in 1869 and end up building 10 samples. Despite these earlyattempts to propel bicycles by means other than human power by Michaux and Roper, they were not successful from both practical and commercial perspectives because of its complexity [3].

The emergence of the gasoline-powered IC engine in the 1890’s made the production of motorizedbicycle viable and marketable. This innovation set the milestone for the further development of motorized bicycle and motorcycle. In 1892, a Frenchman Flix

Millet built the millet motorcycle which incorporated a fixed-crankshaft radial engine within the rear wheel, along with the pedals for cycling. Due to the breakthrough made on the area of motorized bicycle, Thomas of Buffalo New York in 1896 began selling gasoline engine kits for propelling ordinary bicycles. In 1897, Minerva Company in Belgium began the manufacture of standard bicycles beforediving into motorcycles and cars. A lightweight lip-on engines was manufactured, designed to bemounted beneath the front down tube of bicycles primarily intended for Minerva bicycles. However, these engines were also offered in form of kit, making it adaptable to nearly any bicyclemodel. These engines operated by driving a belt connected to a large gear wheel on opposite sideof the rear wheel from the chain, enabling the bicycle to be motorized. With the progression of engine power, the occurrence of frame ruptures became more frequent. In response to that, Minerva

Introduced a new in-frame design in 1903, positioning the engine at the bottom of the bracket**.**

The California motor company in 1901 built and sold a single cylinder, 1.5 horsepower, four-strokeengine that was incorporated in a standard bicycle in the United States of America. The motorizedbicycle was linked to the four-stroke engine with the use of a belt. Motorized bicycle underwent significant changes in 1903 to accommodate larger and more powerful engines, leading to the adoption of larger and heavier loop bicycle frames. These new frames were designed to accommodate higher displacement engines, which enabled increased speeds. Alongside the framemodifications, a new riding position emerged, shifting the rider’s feet forward, where they could rest on platforms. This enhanced the rider’s comfort and control utilizing the motor propulsion. To further enhance control at higher speeds, manufacturers began incorporating front and rearsuspension to maintain stability.

The year 1939 marked the induction of the Whizzer gas-engine bicycle in the United States of America. This innovative kit featured a four-stroke engine. The initial whizzer model utilized a friction drive mechanism which was later replaced by a more efficient belt drive system. Whizzerfaced challenges initially with engine reliability. It later gained moderate popularity during WorldWar II. The scarcity of fuel and automobiles during the war led to increased demand for alternativetransportation options, making the whizzer a sought-after choice for war plant workers and individuals with priority transportation needs. Following the war, the whizzer gained further popularity among young people who sought greater speed and performance. This enthusiasm for faster speeds propelled the whizzer into the spotlight, capturing the attention of the youth demographic. Within the same period the United Kingdom experienced a resurgence in the popularity of motorized bicycles, leading to the emergence of cyclaid and the cyclemaster motor wheel. The cyclemaster is a hub motor designed to be easily attached to a regular bicycle. Cyclemaster’s versatility and convenience made it a favored choice among riders looking to add motorized power to their bicycles. In 1946, the French velosolex motorized bicycle went into production and remained in manufacturing until 1988 when it was widely produced. This motorized bicycle employed a friction drive mechanism connected to the front wheel. Thevelosolex got more acceptance in China and Hungary.

In recent times, motorized bicycles continue to be developed both as complete designs and as add-on motor kits for standard bicycles, catering to both part-time hobbyists and commercial manufacturers. The advent of new, lighter and more powerful IC engines has led to another reawakening for motorized bicycle. This conversion of a regular bicycle to a motorized bicycle has proven beneficial as an alternative mode of transportation especially in regions facingchallenges such as growing traffic congestion, fuel hike and fuel shortage.

Motorized bicycles come in different types. There are basically to major types of motorized basedon their power sources:

Gas-powered motorized bicycles: These types of motorized bicycles use a sizeable, lightweight IC engine to produce mechanical power from the chemical energy contained in the fuel. The fuel-air mixture before combustion and the burned products after combustion are the actual working fluids. The work transfers which provide the desired power output occur directly

Between these working fluids and the mechanical components of the engine**.** They have a clutch and a gear system. Gas-powered motorized bicycles can offer higher speeds and longer range when compared to their electric counterparts and they are very easy to refuel.

Electric bicycles: These bicycles are propelled by an electric motor powered by a battery.

The electric bicycle consists of an electric battery for energy storage, an electric motor, and a controller. The battery is normally recharged from mains electricity via plug and a battery chargingunit that can either be carried onboard or fitted at the charging point. The controller will normallycontrol the power supplied to the motor, and the speed.

A bicycle powered by an IC engine comprises of these components:

Frame: The bicycle frame serves as the primary structure onto which various components, including wheels, are attached. It provides essential strength, stability, and support while determining the overall geometry and characteristics of the bicycle. In contemporary bicycles, thediamond frame has become the most prevalent design for upright bicycles. The diamond frame consists of two distinct triangles: the main triangle and the rear triangle. The main triangle comprises four tubes—the head tube, top tube, down tube, and seat tube. The rear triangle consistsof the seat tube joined by paired chain stays and seat stays. The head tube accommodates the headset, which serves as the connection point for the fork. The top tube connects the head tube tothe top of the seat tube. It may either be positioned horizontally or slope downwards towards the seat tube, providing additional clearance for standing over the bicycle. The down tube links the head tube to the bottom bracket shell. The rear triangle connects to the rear fork ends, where the rear wheel is attached. It consists of the seat tube along with paired chain stays and seat stays. The chain stays connect the bottom bracket to the rear fork ends, while the seat stays connect the top of the seat tube to the rear fork ends. This arrangement of tubes and triangles in the diamond framedesign ensures a robust and balanced structure, enabling efficient power transfer, stability, and easeof handling **[**4]**.**

Wheels: The bicycle wheel consists of spokes that are extended between a hub and rim, heldtogether by threaded nipples. The rim, located on the outer circumference of the wheel, securely holds the tire in position. It is constructed using lightweight, strong, and corrosion-resistant aluminum alloy. The spokes play a crucial role in providing support and stability to the wheel andare made of durable steel wires. Meanwhile, the hub serves as the central component of the wheel,housing the bearings. The wheel's strength and durability are closely tied to the number of spokesit possesses, as a greater quantity can better distribute the load. A large, hollow cross-sectional design of the rim ensures both bending and torsional rigidity, while also offering high resistance against buckling when subjected to compression. This compression strength enables the rim to

Handle the force exerted by multiple tightly tensioned spokes, resulting in a high load-carrying capacity.

IC Engine: The motorized bicycle is equipped with a compact and lightweight spark ignitionfour-stroke internal combustion engine, which serves as the primary power source. This engine offers several advantages, including its manageable size, ease of maintenance, and maneuverability. One notable benefit of using a gasoline engine is its ability to generate significantpower output from a relatively small amount of fuel, which can be conveniently refilled when needed [5].

Rear drive mechanism: The rear drive mechanism comprises of the cassette, derailleur and drive chain. The cassette is the set of multiple sprockets that attaches to the hub on the rear wheelwith the aid of a lock ring. The cassette work together with the derailleur to provide multiple gearratios to the rider. The chain transfers power either from the pedal or an engine to propel the bicycleforward.

Tires: The bicycle tires interact with the road surface to provide the needed traction and stability. Bicycles tires come in different patterns; it can be tube or tubeless depending on the intended use.

Throttle: The throttle is used to control the fluid flow (fuel-air mixture) thereby controlling the engine’s power and speed.

Brakes: The bicycle brakes are mechanism used to retard the speed of the moving bicycle orto bring it to rest in a shortest possible distance whenever required. The rim brakes are the most common type of bicycle brakes. Rim brakes operate by applying friction to the side of the bicyclewheel rims. When the lever is squeezed, the brake shoes which are positioned on the either side ofthe rim, come in contact with the rim surface, generating friction that slows down the bicycle.

The saddle is composed of three parts, namely a hard inner shell at the bottom, a middle layer of foam on the inner shell, and a cloth or leather surface covering the middle layer. The saddles height can be adjusted to ensure proper support andcomfort during the ride. To enhance rider comfort, some saddles are equipped with suspension components that absorb vibrations and shocks transmitted through the frame and seat post. Gel- foam or multi-density foam padding is often incorporated into the saddle design to cushion the impacts from the road. Additionally, certain saddles feature integrated saddle rails that have extended length, allowing them to flex vertically and provide a limited amount of shock and bumpabsorption.

Engineering design software helps to model, validate andcommunicate ideas before production. In embedded systems, the use of software facilitates the

Ease of manufacture, ease of assembly, a great reduction in cost and lead time. Simulation softwareserves as a design tool for the manufacturer to predicate the performance of a new system. Simulation helps in understanding how the system operates without committing resources for theiracquisition. The following software’s was majorly used for the design of thisproject work;

Solid works is a solid modelling, industry-leading Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE) that runs primarily on Microsoft Windows. Solidworks uses parametric design modular, meaning you can easily edit the design at any stage in thedesign process and the designer can see how the changes will affect its neighboring components. Solid works is used for 3D mechanical design, design communication, tooling creation and product simulation. This software was used in the design ofthe various components of the bicycle powered by an internal combustion engine.

The main objective of this research is design modification and production of a bicycle powered by an internal combustion engine.

2.0 MATERIALS AND METHOD

2.1 Theory of Operation of the Machine

The bicycle powered by an internal combustion engine is a fascinating hybrid of traditional cycling and internal combustion engine technology. It combines the efficiency and simplicity ofa bicycle with the power and speed of an internal combustion engine. Understanding the theoryof operation behind a bicycle powered by an IC engine is essential for designing and building areliable and efficient system. Typically, a two- stroke engine is chosen for this machine becauseof its compact size, lightweight and power-to-weight ratio.

The machine consists of an IC engine transferring power (rotational motion) to the rear wheel with the aid of a sprocket, chain drive system and a clutch mechanism. Figure 1 showsthe orthographic drawing of the project design

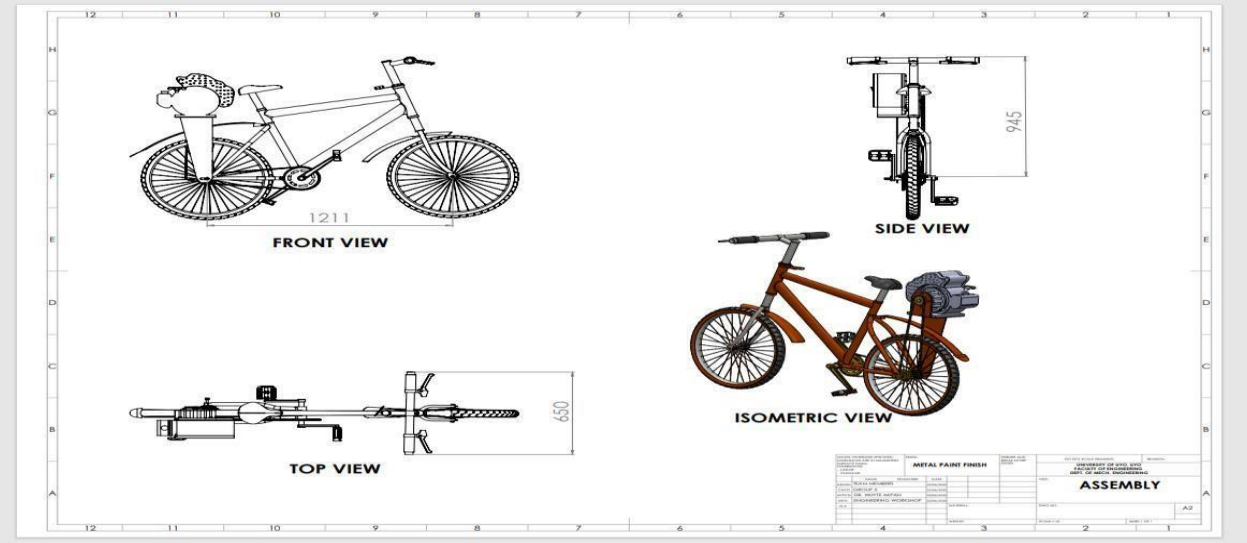

Figure 1: Orthographic drawing of the design

2.1.1Design Criteria

In the course of this project some basic design criteria were considered to get an overall idea aboutthe whole design of the bicycle powered by IC engine to suit its intended usage. This machine is designed to carry one person per time. The operation of the machine is intended to be made simpleand easy to operate. Some of the factors which were taken into account while designing this bicycle powered by an IC engine are as follows;

(i) Load carrying ability: A sizeable engine with the desired power output that can carry the total load on the bicycle.

(ii) Speed: The speed of IC engine powered bicycle will be between 10km/h- 15km/h.

(iii) Availability of materials for easy production and replacement when necessary.

(iv) Factors like durability, reliability, wear, noise especially from chain influenced the choiceof material used in the design.

The overall cost of the machine was analyzed critically in the design phase and productionstage so as to make it affordable.

2.1.2 Design Analysis

The major design was the determination of the power needed to overcome the load on the IC engine powered bicycle that will deliver a speed between 10km/h to 15km/h and a proper gear alignment. Figure 2 is a schematic drawing of the forces acting on the bicycle.

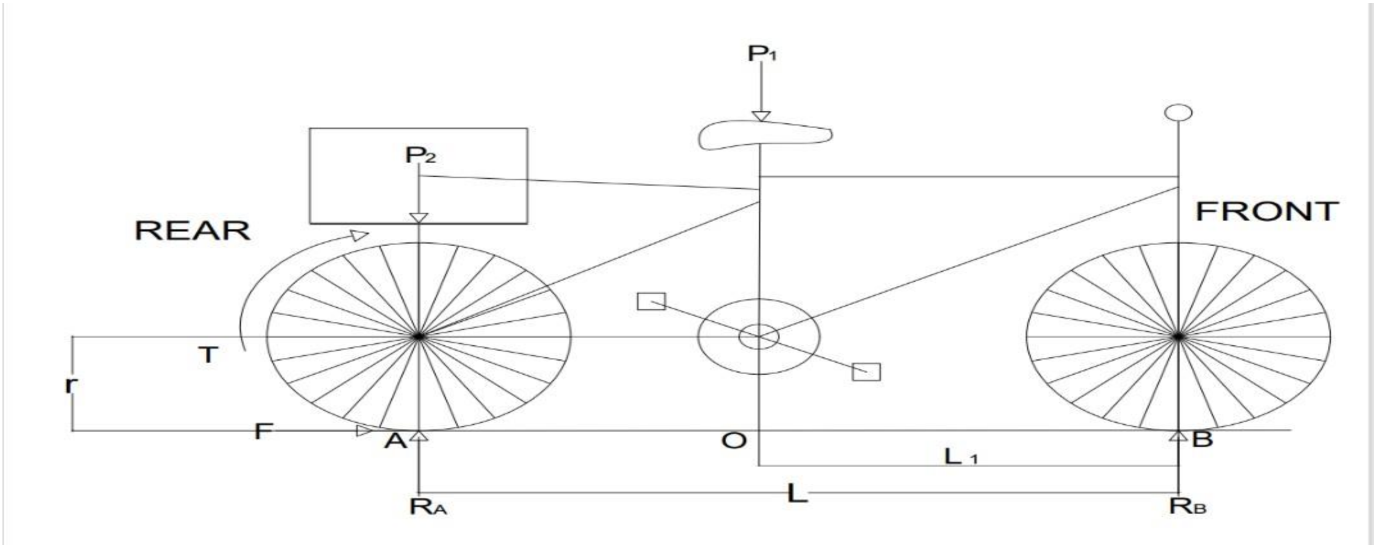

Figure 2: Schematic diagram of forces acting on the bicycl

For the design of the IC engine powered bicycle, a decided mass of W_r kg is to be used as the allowable load for the design of the machine with a factor of safety of C, as given in the Equation1.
Weight of rider is W_r^*

$W_r = W^*C_r$ Equation 1

where W_r is the maximum load and C is the factor of safety.The force P, applied is shown in Equation 2
$P = W_r\ a$ Equation 2

where W_r is the maximum load and a is the acceleration due to gravity, gThe force therefore reduces to the expression in Equation 3.
$P = W_r g$ Equation 3

Weight of bicycle is W_b
From literature review (Richard, 1984) the actual percentage distribution of the total weight of the bicycle plus rider that is shared by each wheel for a “good handling bicycle”, ideal distribution is generally considered to be 45% of the total weight on the front wheel and 55% onthe rear wheel.
$P_1 = P + W_b$ Equation 4

Weight of engine is P_2

Reaction force on point A (rear wheel) is R_A Reaction force on point B (front wheel) is R_B Torque on rear wheel is T
Radius of rear wheel is r
Frictional force acting on rear wheel is F

Upward forces = Downward forces (for balance and stability)

$\sum Fy = 0$ ( )

$P_1 + P_2 - R_A - R_B = 0$ Equation 5

$R_B = P_1 + P_2 - R_A$ Equation 6

$R_A = P_2(L/L) + P_1(L_1/L) = (P_2L)/L + (P_1L_1)/L$ Equation 7

$R_A = \frac{(P_2L) + (P_1L_1)}{L}$ Equation 8

Substituting equation 3.8 into Equation 3.6
$R_B = (P_1 + P_2) - \frac{(P_2L + P_1L_1)}{L}$ Equation 9

Taking the sum of moment about A (clockwise +ve)

$\sum M_A = 0$

$T - F(r) + R_A(0) + P_2(0) + P_1 (L - L_1) - R_B(L) = 0$ Equation 10

$T = F(r) - R_A(0) - P_2(0) - P_1 (L - L_1) + R_B(L)$ Equation 11

$T = rF - P_1 (L - L_1) + R_B(L)$ Equation 12

Recall that frictional force is;

$F = \mu R = \mu R_A$ [6] Equation 13

Substituting equation 3.8 into Equation 3.13

$F = \mu \frac{(P_2L + P_1L_1)}{L}$ Equation 14

Substituting Equation 14 and 9 into Equation 12 to get the final expression for torque onthe rear wheel

$T = \mu r \frac{(P_2L + P_1L_1)}{L} - P_1 (L - L_1) + \left\{ (P_1 + P_2) - \frac{(P_2L + P_1L_1)}{L} \right\} L$ Equation 15

Recall that;

Power, $P = Tw$ (kW) Equation 16

where; T is torque (Nm)

w is angular velocity (rad/s)

But $w = v/r$ Equation 17

where; v is linear velocity (m/s)

r is radius of rear wheel (m)

Substituting Equation 17 into Equation 16,We have that,

$P = \frac{Tv}{r}$ Equation 18

Substituting Equation 3.15 into Equation 3.18 we have the equation for the power required tomove the IC engine powered bicycle;

$P = \mu r \frac{(P_2L + P_1L_1)}{L} - P_1 (L - L_1) + \frac{(P_1 + P_2) - (P_2L + P_1L_1) L}{L} \times v/r$ Equation 19

$P^* = P \times C$ Equation 20

For distance L_1

Taking moment about point O

$\sum M_O$;

$R_A(L - L_1) - P_2(L - L_1) - R_B L_1 = 0$ Equation 21

$R_A L - R_A L_1 - P_2 L + P_2 L_1 - R_B L_1 = 0$

Rearranging the Equation above

$P_2 L_1 - R_A L_1 - R_B L_1 = P_2 L - R_A L$ Equation 22

$L_1(P_2 - R_A - R_B) = L(P_2 - R_A)$ Equation 23

From Equation 5, summation of vertical forces $\sum F_y$;Upward forces =

downward forces

$P_1 + P_2 = R_A + R_B$ Equation 24

Rearranging the equation

$-P_1 = P_2 - R_A - R_B$ Equation 25

Substituting Equation 3.25 into Equation 3.23 we have,

$L_1(-P_1) = L(P_2 - R_A)$ Equation 26

$L_1 = \frac{L(P_2 - R_A)}{-P_1}$ Equation 27

$L_1 = \frac{-L(P_2 - R_A)}{P_1}$ Equation 28

$L_1 = \frac{L(R_A - P_2)}{P_1}$ Equation 29

$R_A = P_2 + 55\% P_1$ Equation .30

$R_A = P_2 + 0.55P_1$ Equation 31

$L_1 = \frac{L(R_A - P_2)}{P_1}$ Equation 32

Substituting Equation 30 into Equation 32

$$L_1 = L \frac{\{(P_2 + 0.55P_1) - P_2\}}{P_1} \quad \text{Equation 33}$$

$$L_1 = L \frac{(P_2 + 0.55P_1 - P_2)}{P_1} \quad \text{Equation 34}$$

$$L_1 = \frac{L (0.55P_1)}{P_1} \quad \text{Equation 35}$$

$$L_1 = 0.55L \quad \text{Equation 36}$$

For the bending stress,

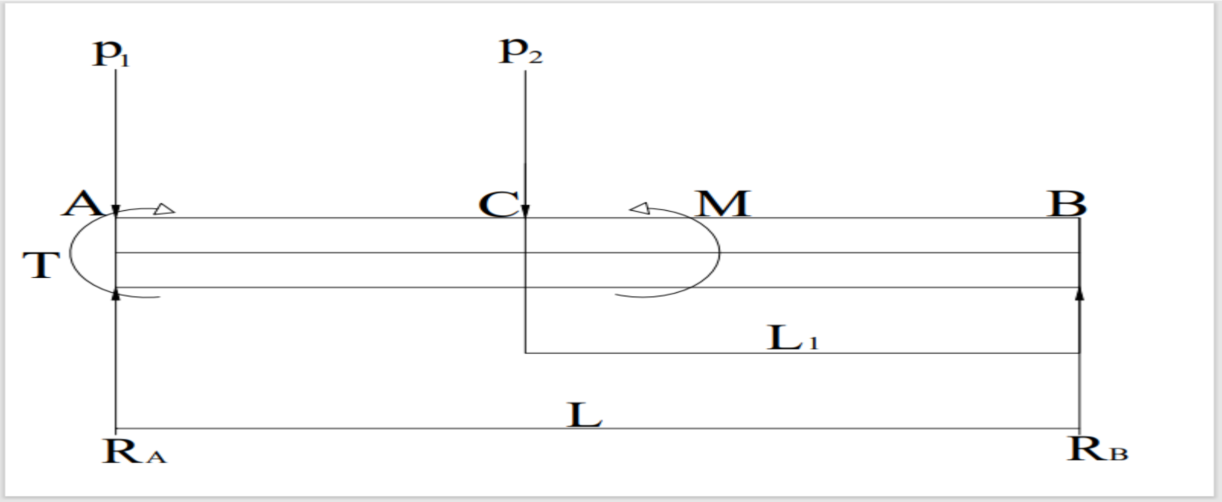

Figure 3: Schematic diagram of forces and moments acting on the bicycle

Taking sum of moment about C to be M;

$$M = T + R_A(L-L_1) - P_2(L-L_1) - R_B(L_1) \quad \text{Equation 37}$$

Figure 4 shows the schematics of the bicycle frame

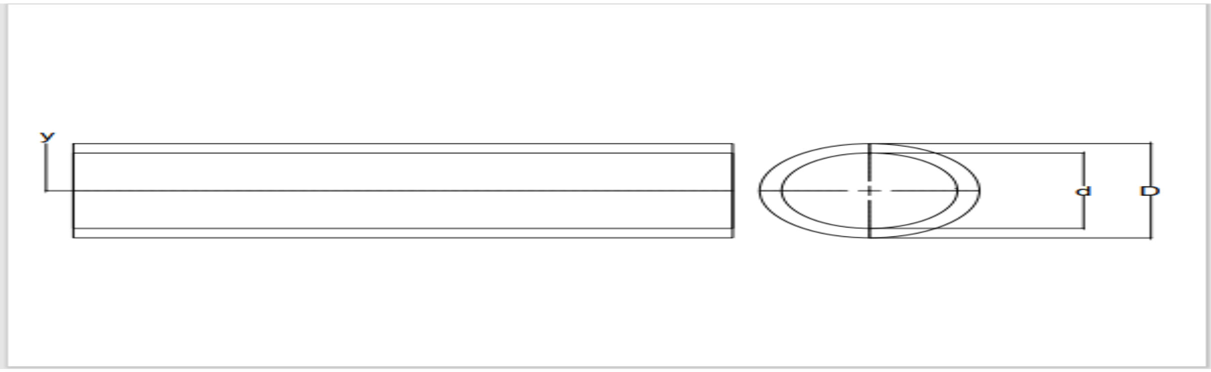

Figure 4: Schematic diagram of the bicycle frame pipe

The outer diameter of the hollow pipe is D, The internal

diameter of the hollow pipe is d,

From literature **[8]** bending stress, Ϭ is given as

$$Ϭ = \frac{My}{I}$$ Equation 38

where,

M is the sum of moments about the mid-point C

y is the centroid of the section when the x-axis is taken as the neutral axis,

$$y = \frac{D}{2}$$ Equation 39

I is the moment of inertia of the hollow pipe and is given as,

$$I = \frac{\pi (D^4 - d^4)}{64}$$ **[7]** Equation 40

Substituting equation into equation bending stress σ becomes,

$$\sigma = \frac{64 \left[T + R_A(L-L_1) - P_2(L-L_1) - R_B(L_1) \quad y \right]}{\pi (D^4 - d^4)}$$ Equation 41

For torsional shear strength of the pipe, τ

$$\tau = \frac{T \times r}{\ }$$ [8] Equation 42

where,

J is the polar moment of inertia for a pipe and is given as,

$$J = \frac{\pi (D^4 - d^4)}{32} \quad [8]$$ Equation 43

T is applied torque

r is the radial distance from the center of the pipe, that is

$$r = \frac{D}{2}$$ Equation.44

For the shear stress, Ʈ

$$Ʈ = \frac{V}{A}$$ Equation 45

where,

V is the shear force, but

$$V = (R_A + R_B)$$ Equation 46

A is the cross-sectional area of the pipe and is given as

$$A = \frac{\pi (D^2 - d^2)}{4}$$ Equation 47

Substituting equation and equation into equation, we have that

$$Ʈ = \frac{4(R_A + R_B)}{\pi (D^2 - d^2)}$$ Equation 48

Speed ratio:

$$S.R = \frac{\text{Number of driver teeth}}{\text{Number of driven teeth}} = \frac{N_A}{N_B}$$ Equation 49

2.2 Design Computation

For the design computation of the bicycle powered by IC engine, 70kg is taken as the decidedmass which serves as the allowable load for the design of the machine and applying a factor ofsafety of 1.1.

From Equation 1

Given,

$W^* = 70kg; C = 1.1$

Therefore,

W_r = 77kg From

Equation 3Given,

W_r = 77kg

$a=g=9.81m/s^2$

Therefore,

P = 755.37N

From Equation 4Given,

P = 755.37N; W_b = 117.72N

Therefore,

P_1 = 873.09N

From Equation 36Given,

L = 1.025m

Therefore,

L_1 = 0.56375m

From Equation 8Given,

P_2 = 43.164N; L = 1.025m; L_1 = 0.56375m; P_1 = 873.09N

Therefore,

R_A = 523.36N

From Equation .6Given,

P_1 = 873.09N; P_2 = 43.164N; R_A = 523.36N

Therefore,

R_B = 392.894N

From Equation 13Given,

μ = 0.7 [9] R_A = 523.36N

Therefore,

F = 366.352N

From Equation 12Given,

r = 0.305m; F = 366.352N; P_1 = 873.09N; R_B = 392.894N L =

1.025m; L_1 = 0.56375m

Therefore,

T = 111.74Nm

From Equation 18Given,

r = 0.305m; v = 2.778m/s; T = 111.74Nm

Therefore,

P =1018W = 1.018kW

Applying factor of safety to the power, From

Equation 20

Given,

P = 1018W; C = 1.1

Therefore,

P* = 1119.8kW

From Equation 37

Given,

T = 111.74Nm; R_A = 523.36N; L = 1.025m; L_1 = 0.56375mP_1 =

873.09N; R_B = 392.894N

Therefore,

M = 110.353Nm

From Equation 39Given,

D = 0.0286m

Therefore,

y = 0.0143m

From Equation 40Given,

Π = 3.142; D = 0.0286m; d = 0.0272m

Therefore,

I = 5973.71mm^4

From Equation 38Given,

$M = 110.353Nm$; $y = 0.0143m$; $I = 5973.71mm^4$

Therefore,

$\sigma = 264MPa$

From Equation 43Given,

$\Pi = 3.142$; $D = 0.0286m$; $d = 0.0272m$

Therefore,

$J = 11947.41mm^4$

From Equation 42Given,

$T = 111.74Nm$; $r = 0.0143m$; $J = 11947.41mm^4$

Therefore,

$\tau = 133.74MPa$

From Equation 46Given,

$R_A = 523.36N$; $R_B = 392.894N$

Therefore,

$V = 916.254N$

From Equation 47

Given,

$\Pi = 3.142$; $D = 0.0286m$; $d = 0.0272m$

Therefore,

$A = 0.0000614m^2$

From Equation 45Given,

$V = 916.254N$; $A = 0.0000614m^2$

Therefore,

$\tau = 15MPa$

From Equation 49Given,

$N_A = 30$; $N_B = 18$

Therefore,

S.R = 1.66

Figure 5 below is the shear force and bending moment diagram of the loads acting on the bicycle.

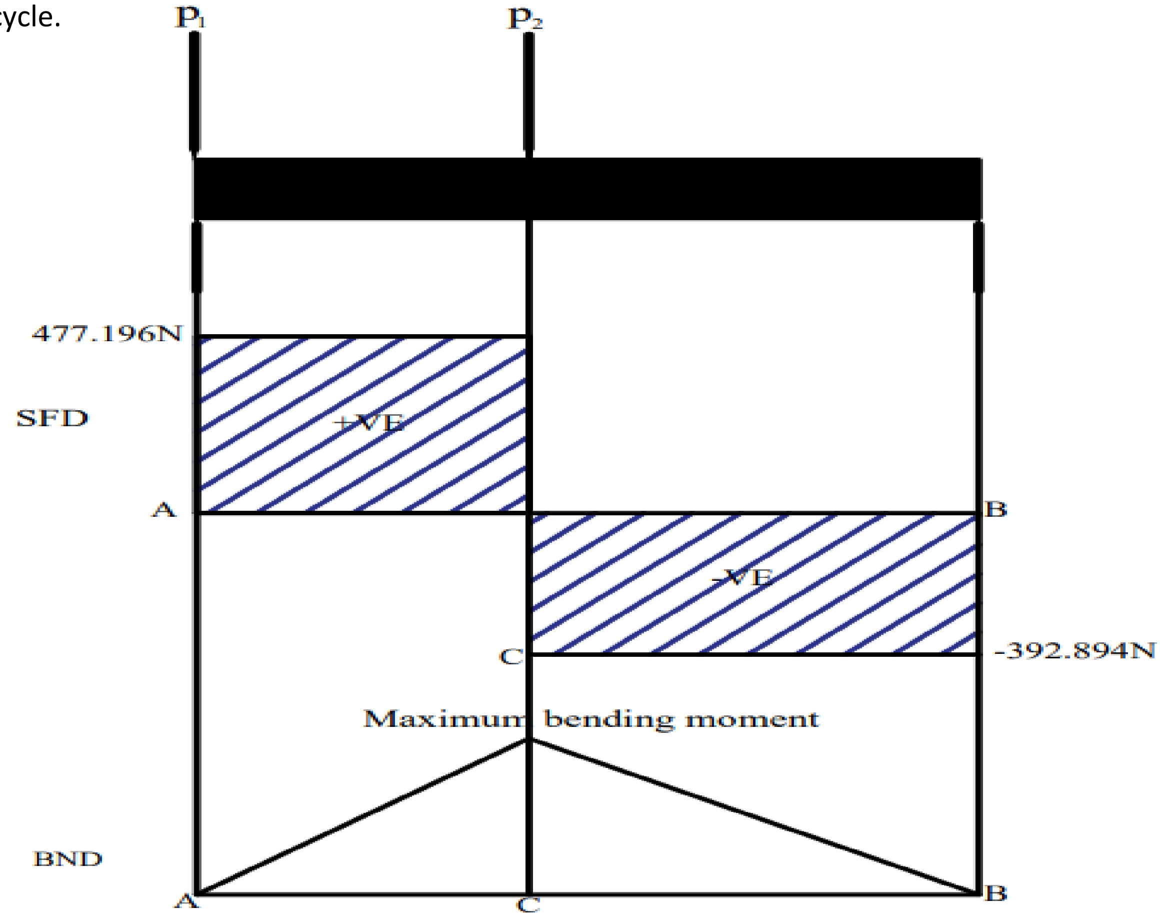

Figure 5: Bending moment and shear force diagram

2.3 Materials Selection Based on Computation

Following the results from the analysis based on computations, the appropriate materials for the bicycle powered by an IC engine components design were selected. Table 1 shows the calculatedvalues and properties of the materials.

Table 1: calculated vs. properties of materials

S/N	Component	Calculated value	Maximum value for the material	Remark
1	IC engine	Power rating 1119.8kW	1.2kW	
2	Frame	Strength of thematerial is 264MPa	350MPa	**Mild steel** has a suitable strength for this

3	Sprocket			**Medium carbon steel** has a suitable strength for this
4	Tire	Diameter; 610mm		Synthetic rubber
5	Engine bracket			**Mild steel** has a suitable strength for this
6	Chain			**Medium carbon steel** is suitable for this
7	Throttle			Rubber

Source: Field work, 2023

Table 2 below shows the general mechanical properties of mild steel,while Table 3 shows the general mechanical properties of medium carbon steel.

Table 2: General Mechanical Properties of Mild Steel

S/N	MECHANICAL PROPERTIES	METRIC VALUES
1	Ultimate yield stress Ɣ	440 MPa
2	Yield Tensile Strength, α	370 MPa
3	Modulus of Elasticity, E	210 MPa
4	Bulk Modulus, β	140 MPa
5	Shear Modulus, ϒ	80 MPa

Table 3: General Mechanical Properties of Medium Carbon Steel

S/N	MECHANICAL PROPERTIES	METRIC VALUES
1	Ultimate tensile strength, Ɣ	620 MPa
2	Yield strength, α	420 MPa
3	Young's modulus of elasticity, E	200 GPa

2.4 Strength of the Material

The strength of material has to do with the behavior of solid objects subject to stresses and strains.The strength of a material is its ability to withstand an applied load without failure/rupture. A loadapplied to a mechanical system will induce internal forces within the components called stresses when those forces are expressed on a unit basis. The stresses acting on the material cause deformation of the material in various manner. Deformation of the material is called strain when those deformations too are placed on a unit basis. The applied loads may be axial (tensile or compressive), or shear. The stresses and strains that develop within a mechanical component mustbe calculated in order to assess the load capacity of that component. This requires a complete description of the geometry of the component, its constraints, the loads applied to the member andthe properties of the material of which the component is composed. With a complete description of the loading and the geometry of the component, the state of stress and of state of strain at any point within the component can be calculated. Once the state of stress and strain within the component is known, the strength (load carrying capacity) of that member, its deformations (stiffness qualities), and its stability (ability to maintain its original configuration) can be calculated. The calculated stresses may then be compared to some measure of the strength of the component such as its material yield or ultimate strength. Figure 6(a), Figure 6(b) and Figure6(c) show the graphical illustration of stress strain behaviours

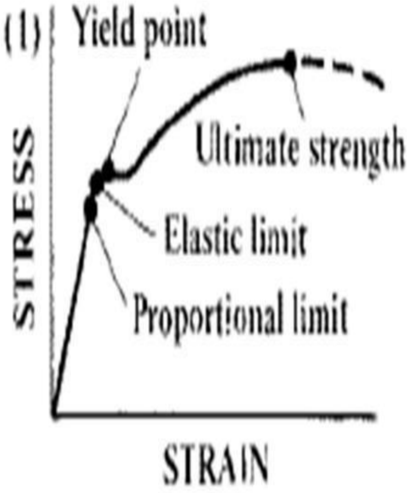

Figure 6(a): Yield point

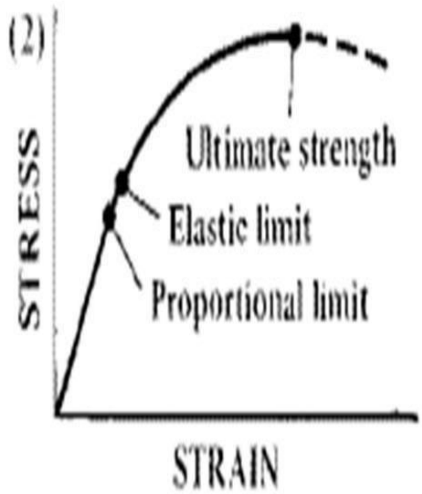

Figure 6(b): Ultimate strength

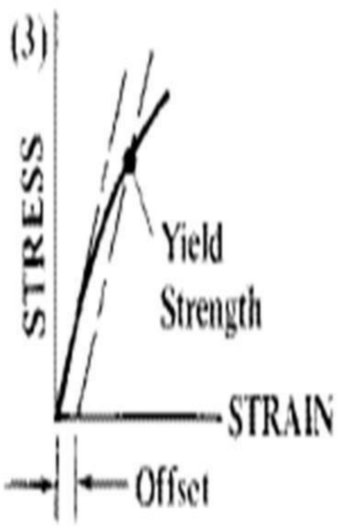

Figure 6(c) Yieldstrength

At the proportional limit on the graph the stress-strain curve begins to deviate from the linearrelationship between the stress and strain.

2.5 Bill of Engineering Measurement and Evaluation (BEME)

Table 4 is a table listing all the equipment/materials acquired for the project. The equipment type,quantities and cost for the equipment are shown in the Table 4.

Table 4: Bill of Engineering Measurement and Evaluation (BEME)

S/N	Item Description	Quantity	Unit Cost (#)	Amount (#)
1	Bicycle	1	34,000	34,000
2	Two-stroke engine	1	55,000	55,000

3	Chain	1	1500	1500
4	Accelerator	1	1500	1500
5	Sprockets	2	2300	2300
6	Mild steel sheet	1	8000	8000
7	Bolts, washer & nuts	10	150	1500
8	Solid works design			25000
9	Workmanship			5000
10	Total			133,800

2.6 Production Method

Custom Mounting Bracket

The custom mounting bracket was created by cutting a mild steel sheet into three sections: (40x10x3)mm, (18x10x3)mm, and (15x10x3)mm. These pieces were welded together to form a H-shaped structure. One side of the bracket was opened using a filing machine, as depicted in Figure 7. Additionally, four holes 10mm diameter each were drilled into the bracket to securely attach the engine. Subsequently, the filing machine was utilized to refine the rough welded surfaces.

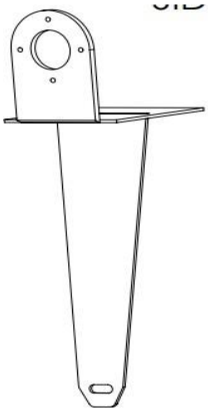

Figure 7: Custom mounting bracket

Engine Integration

The 2-stroke engine was affixed to the bracket using four diagonal 10mm bolts andaccompanying washers.

Cutting of Clutch Drum

The engine’s clutch drum was aligned, measured using the measuring tape and then cut using afiling machine.

Sprockets Integration

A pair of sprockets, one with 30 teeth on the clutch drum shaft and another with 18 teeth on therear wheel hub, were securely joined using a stainless-steel electrode. These sprockets were linked together by a chain.

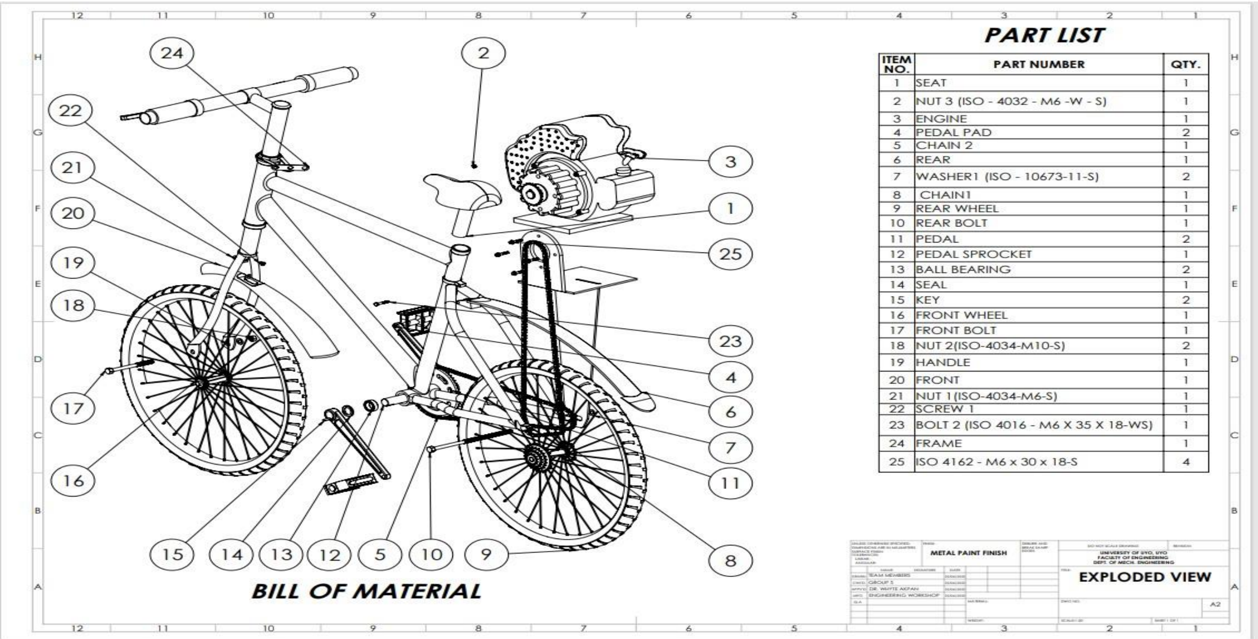

Figure 8. Exploded view of the Design

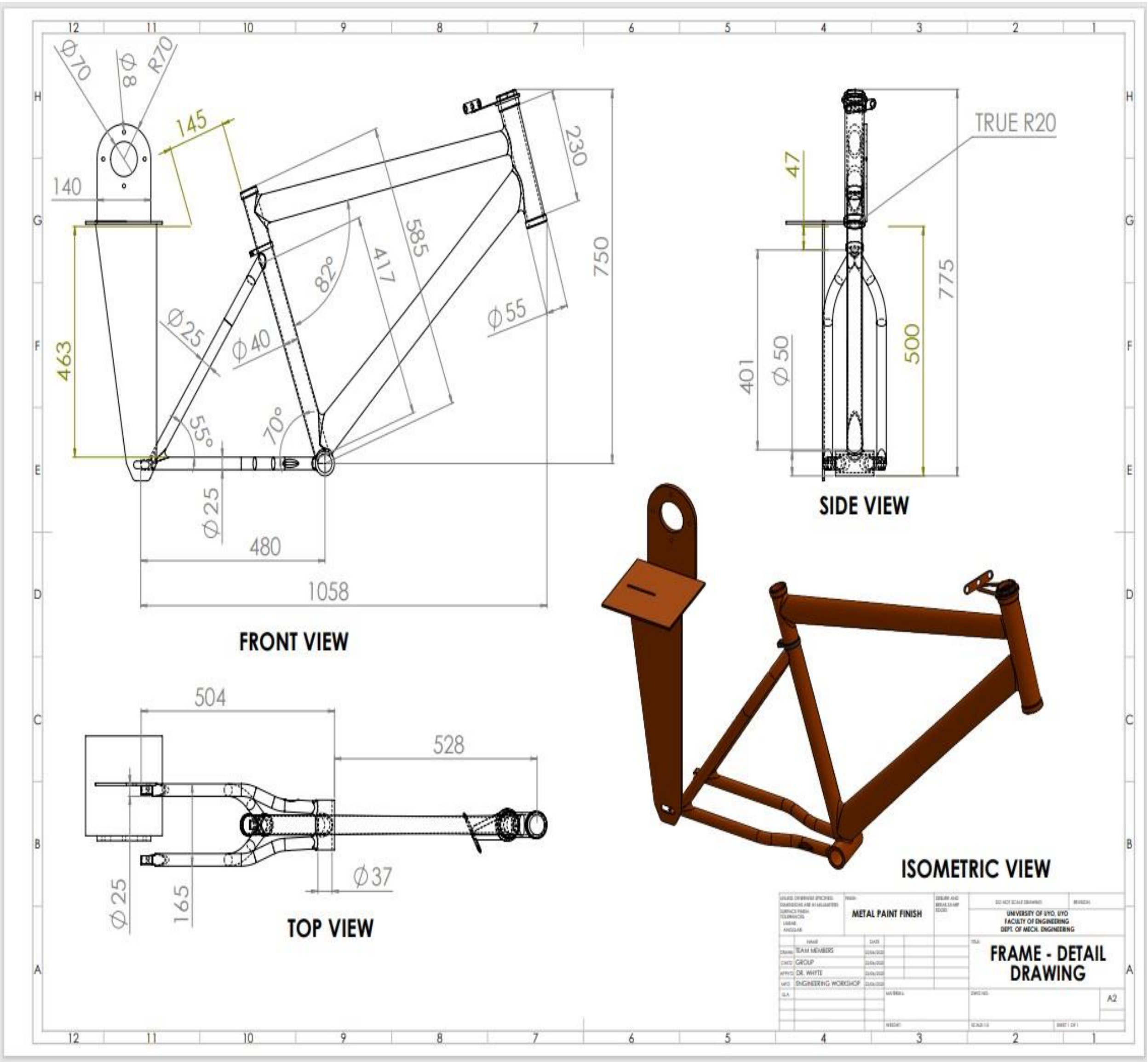

Figure 9: Modified bicycle frame

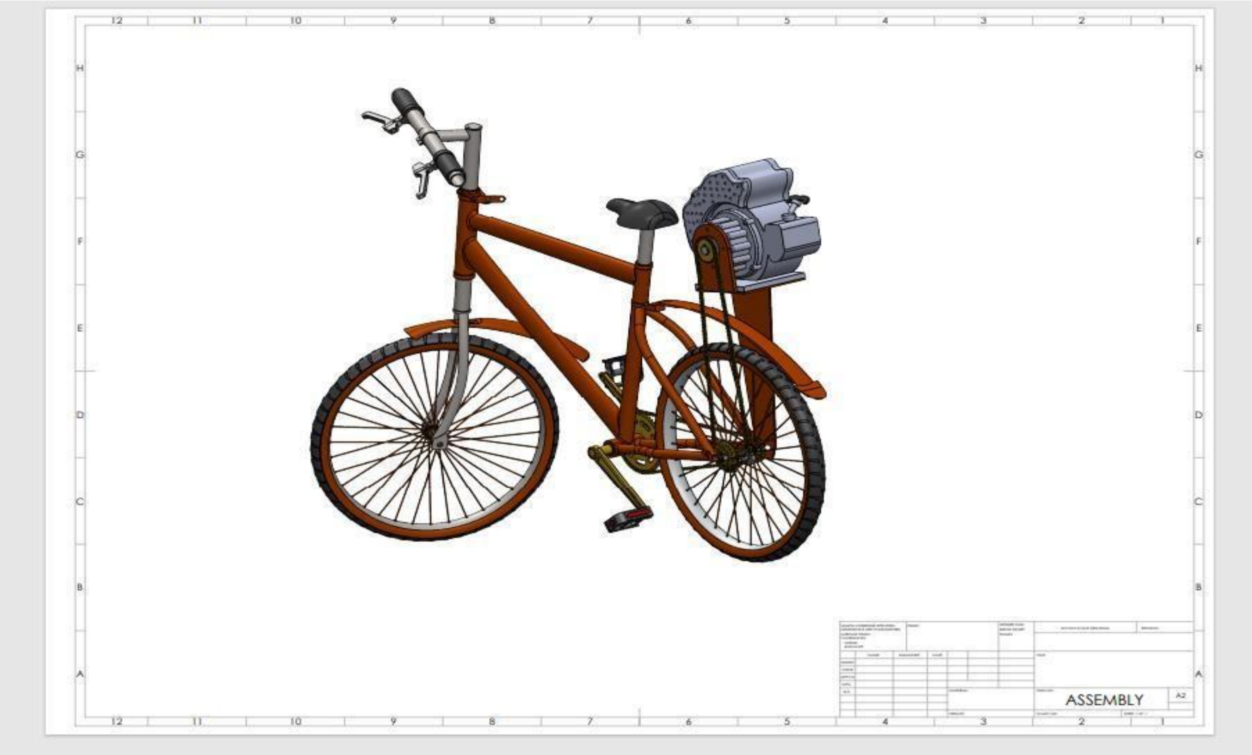

Figure 10: Isometric view of the design

3.0 RESULTS AND DISCUSSION

3.1 Results

The machine was tested and the following results were obtained

Table 5: Test Results

Distance(m)		Test 1(s)	Test 2(s)	Test 3(s)	Test 4(s)	Test 5(s)
100		16	15	16	14	16
	Speed (km/h)	22.5	24.01	22.5	25.70	22.5
200		21	20	21	20	21
	Speed (km/h)	34.27	36	34.27	36	34.27
300		28	27	24	22	23
	Speed (km/h)	38.56	40	45	49.1	46.94

Figures 11, 12 ,13, 14 and 15 respectively show the test results

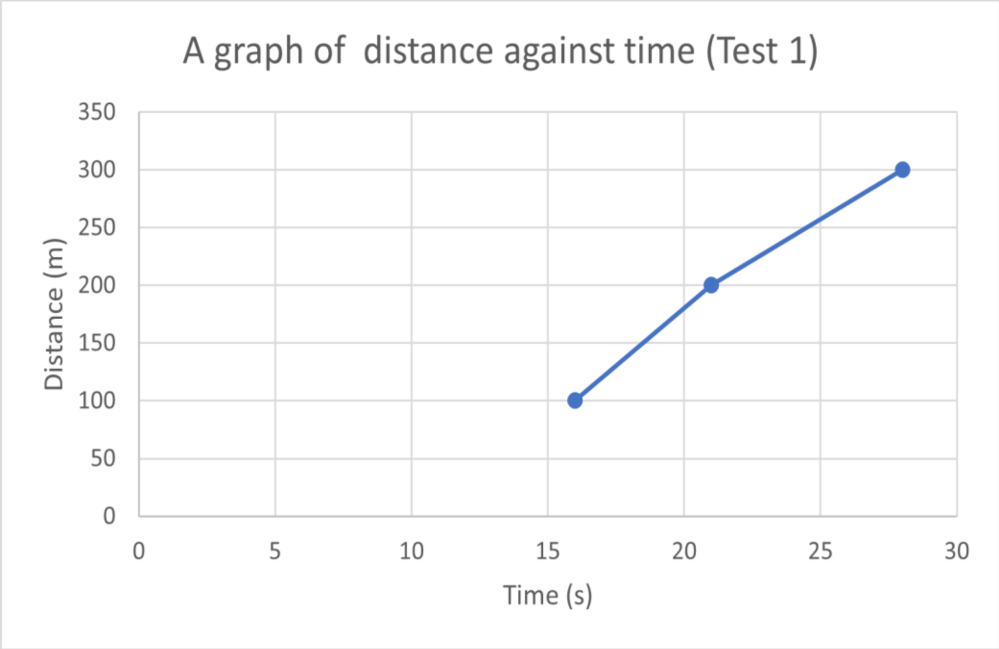

Figure 11: Test 1 graphical representationSource: Fieldwork, 2023

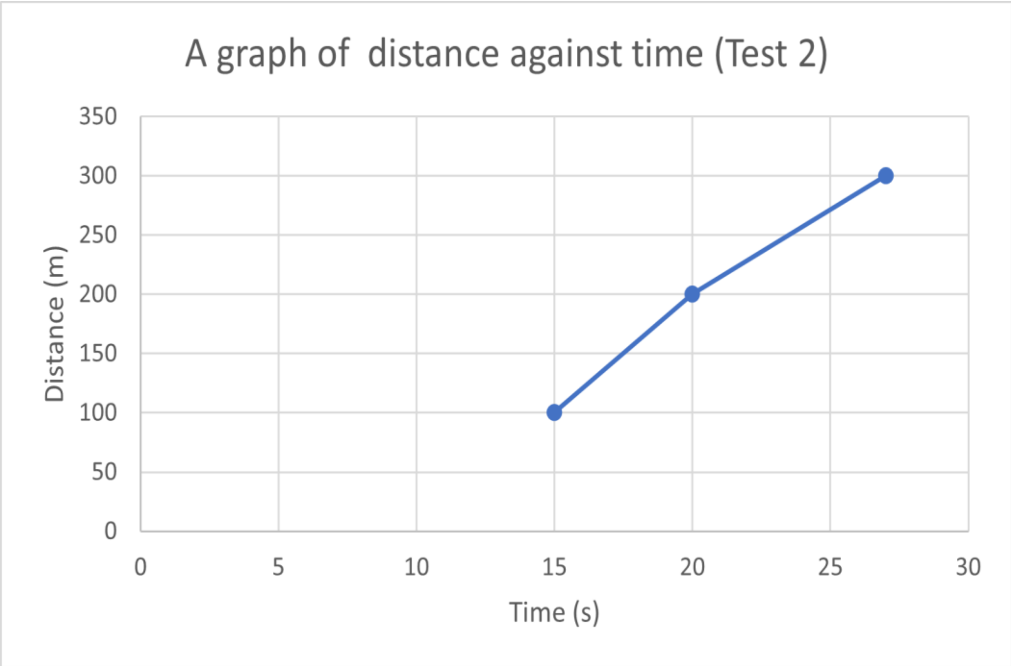

Figure 12: Test 2 graphical representationSource: Fieldwork, 2023

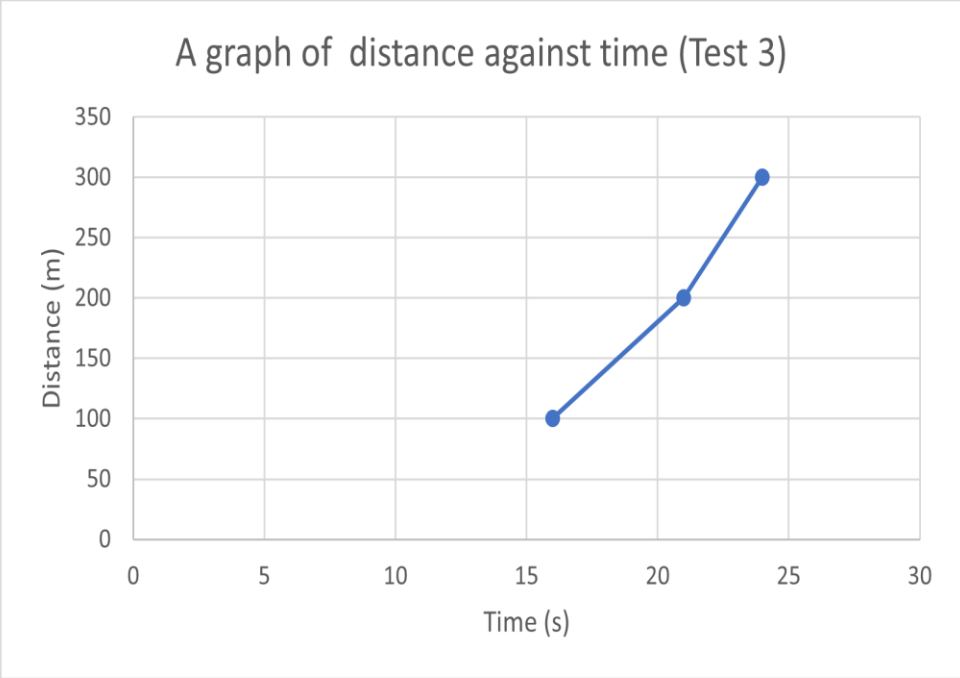

Figure 13: Test 3 graphical representationSource: Fieldwork, 2023

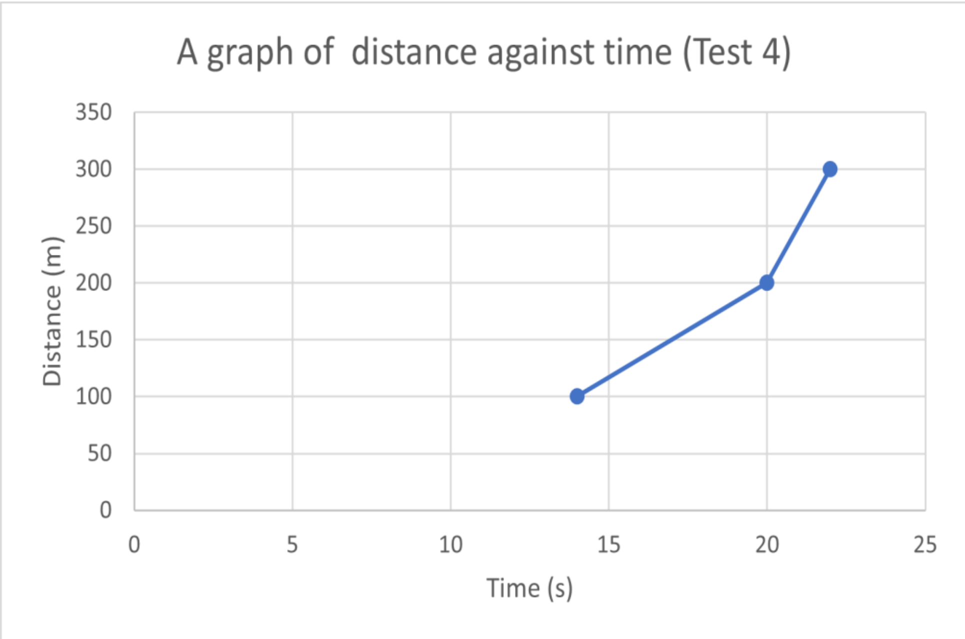

Figure 14: Test 4 graphical representationSource: Fieldwork, 2023

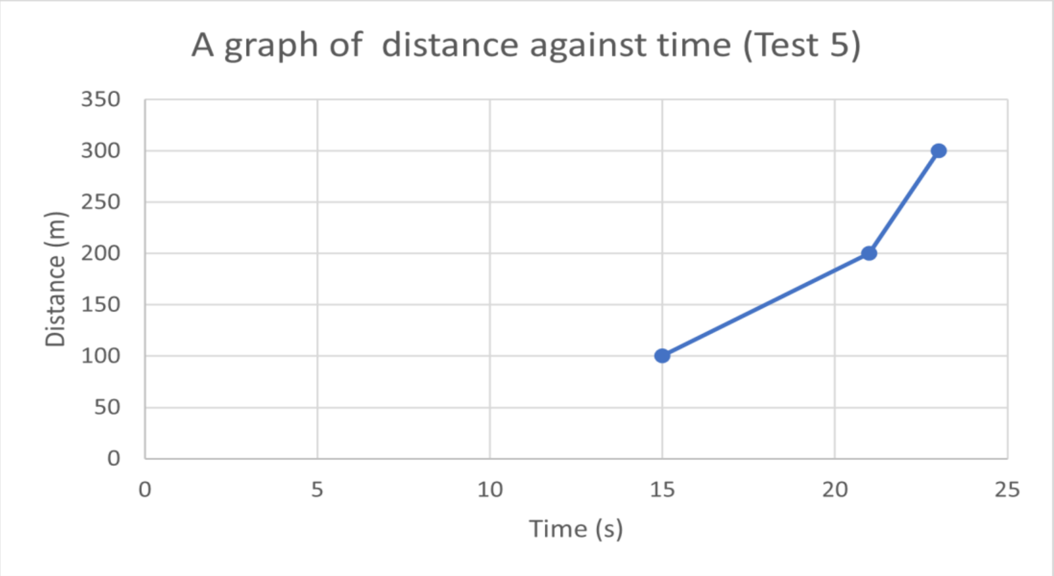

Figure 15: Test 5 graphical representationSource: Fieldwork, 2023

3.2 Discussion

The test was conducted in a controlled environment with the following conditions:

i. The bicycle was on a flat surface.
ii. It was within the allowable weight.
iii. The engine was in good condition.

Under these conditions, the minimum average speed of the bicycle over five testing was 23.44km/h. this means that the bicycle was able to travel 100m in an average of 15 seconds. The test also showed that the bicycle was able to accelerate from a standstill to 10km/h in 5 seconds. This is comparable to the acceleration of a traditional bicycle. The results of the test are promising,they suggest that the bicycle powered by an IC engine is a viable alternative to traditional bicycles.However, further research could be done to increase the load-carrying ability and integration of multiple gears.

4.0 CONCLUSION

The following conclusions are made;

1) The bicycle can carry a load of 70kg efficiently and up to the maximum load of 77kg asthe case may be.
2) The average speed of the bicycle for a distance of 100m is 23.44km/h.
3) The average speed of the bicycle for a distance of 200m is 34.96km/h.
4) The average speed of the bicycle for a distance of 300m is 43.92km/h.

The bicycle is equipped with an IC engine, represents an innovative approach that priorities local resources. Further design should be carried out to develop a bicycle powered by IC engine that uses multiple gears. Commercial production of this design is advocated for Nigerian government.

REFERENCES

1. Herlihy, D.V. (2004). Bicycle: The History. Yale University Press.
2. Brandt, J. (1981). The Bicycle Wheel: A Treatise on Wheelbuilding and Theory (2nd ed.). Avocet
3. Krensnak, B. (2008). *Motorcycling for Dummies. Hoboken, New Jersey: For Dummies, Wiley*Publishing.
4. Talbot, R. (1984). Designing and Building Your Own Frameset. Library of Congress
5. Giri, N.K. (2013). Automotive Technology (1st ed.). Khanna Publishers
6. Khurmi, R.S. (2008). A Textbook of Engineering Mechanics. S.Chand
7. Rajput, R.K. (2008). Strength of Materials (5th ed.). S.Chand
8. Khurmi, R.S., & Gupta, J.K. (2005). Theory of Machines (14th ed.). S.Chand
9. Kurtus, R. (2002). Determining the Coefficient of Friction. School for Champions