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Design and Fabrication of a Pvcelectric Go-Kart

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Abstract This work which was carried out by a team of three final year students of Industrial/Production Engineering, is aimed at the design and fabrication of an electric-powered PVC go kart that was designed to carry the maximum weight of 55kg. Using up to sixty percent of locally-sourced materials, which is in line with the "Green Initiative" in a world currently over-run with combustible fuel powered automobiles and machines that further depreciates the ozone layer, the design of the project is achieved with the application of Computer-Aided Design tools. The shaped base houses the DC motor, the steering mechanism, and wheels that were mounted upon a plywood that serves as the chassis. The chassis which houses the battery and controller is made of 1inch diameter PVC pressure pipes cut to different shapes in order to meet the design requirements. The selected battery is a 45Ah, 12V DC, while the controller which is connected to the DC battery is PWM DC motor speed controller with amperage of 40A, and having the voltage rate of 10V- 55V. The DC motor which served as the engine of the go-kart motor is a 24V, with the torque of 92kg.cm (9.2Nm) and power of 450W running at a no load speed of 300rpm. While the DC motor is controlled with the motor speed controller, the steering mechanism was constructed and fabricated using a 200mm length of plywood and the turning mechanism is achieved using a 360^{O} door hinges. The objective of the project such as cost effectiveness, use of locally source materials and creating a go-kart whose speed limit can be varied was achieved.

Keywords go-kart, design, fabrication, machine, electric, chassis, PVC, vehicle, automobile

1. Introduction

Based on the harmful effects of gasoline and other petroleum production to the ozone layer, researchers are these days searching for alternative and reliable source of energy for automobilesthat will not emit harmful fumes to the environment. Some of these better sources of energy include bio-diesel, electricity, ethanol, natural gas, as well as hydrogen.

The benefits of some of these other sources of energy include reduction of different forms of air pollution because of the generation of energy that is devoid of greenhouse gas emissions, reduction of over-dependence on fossil fuel and energy supply diversification, enhancement of economic development, and well as the much needed job creation in manufacturing and installations for the teeming youths.

An electric powered vehicle which can be described as a recent innovation in the world of automobile industry is an automobile that is moved by a single or more electric motors using stored energy in rechargeable batteries. Apart from non-emission of toxic hydrocarbons, electric powered automobiles are very easy to operate as the rotor is the only single moving part it consists of, hence they are very simple, efficient, and more reliable. Other benefits of electric cars include: easy to maintain, eco-friendly, low maintenance, cost effective, less pollution, renewable energy, and enhanced safety. A good example of an electric powered automobiles a go-kart, it is a small four-wheeled vehicle that are manufactured in diverse forms and shapes, ranging from unpowered models to super-powered racing vehicles.

Go-kart by definition has no suspension and no differential. They were initially created in the 1950s. Post war period by airmen, as a way to pass spare time. Art Ingels is generally accepted to be the father of karting, as he built the first kart in Southern California in 1956. From then, it became very popular all over America and Europe. According to Ravikanth *et al* [1], go-kart is a simple four-wheeled, small engine, single Seated racing car used mainly in United States, which was initially created in the 1950s. However, Kiral, and Abhishak [2], observed that a go kart has no suspension and no differential, usually raced on scaled down tracks, but are sometimes driven as entertainment or as a hobby by non-professionals.

They are usually raced on scaled down tracks, but are sometimes driven as entertainment or as a hobby by non-professionals. Carting is commonly perceived as the stepping stone to the higher and more expensive ranks of motor sports. Kart racing is generally accepted as the most economic form of motor sport available. As a free-time activity, it can be performed by almost anybody and permitting licensed racing for anyone from the age of 8 onwards.

Kart racing is usually used as a low-cost and relatively safe way to introduce drivers to motor racing. Many people associate it with young drivers, but adults are also very active in karting. Karting is considered as the first step in any serious racer's career. It can prepare the driver for highs-speed wheel-to-wheel racing by helping to develop guide reflexes, precision car control and decision-making skills. In addition, it brings an awareness of the various parameters that can be altered in order to improve the competitiveness of the kart that also exist in other forms of motor racing.

The aim of this project is to design and fabricate an electric go-kart vehicle. This is geared towards reducing the usage of organic fuel powered vehicles and to design a vehicle which works efficiently in the emerging electric vehicle sector. Each and every day the prices of petrol and diesel keep on fluctuating, and also increase with higher rate but rarely fall down. This is tremendously depleting the fuel reserves. So basically it is important to design such a vehicle that will be electric-powered in order to reduce overdependence on petroleum products.

This project mainly focuses on designing of cheaper electric system compared to other electric go-karts vehicle. The project includes design of ideas, imaginary concept, designing, analysis, teamwork, project management and development, costing and budgeting. The concept is to design and fabricate a durable and cost-effective cart with mainly locally-sourced materials.

2. Literature Review

According to Abdullah *et al* [3], by the definition of International Karting Commission, a kart is a land vehicle with or without a bodywork, with 4 non-aligned wheels in contact with the ground, two of which control the steering while the other two transmit the power. Its main parts are the chassis (which consists of a body frame work that is made up of a set of bent steel pipes that are welded together) with an engine, four wheels and tires attached on it.

Go-kart technology has been widely developed since the introduction of wheels. But, it was not fully implemented in racing activity until the past three hundred years in America. The first go-kart was simply a cart consisting of wheels and handles jointed together as children pushed from behind when learning to walk or a four-wheeler platform where children where children can sit on it while another push the kart around.

Rong [4], while quoting Smith (2002), explained that Art Ingels who was a veteran hot rod and race car builder at Kurtis Kraft in California, America invented the first ever go-kart in 1956. Initially, karting is a leisure motorsport enjoyed by airmen during the post-war period. Although go-kart originated from United States, it has also gained interest in countries all over the worlds especially in Europe.

Main Components of Go-Kart

Chassis

The chassis of a go-kart, also known as the go-kart frame is like a foundation that is attached to the axles and also holds the engine. Chow [5], pointed out that the chassis of a go kart does not have much difference from a normal car chassis, as it is less complicated and much easier to design and fabricate. It is crucial to have a good design of chassis that will it give a better traction for the driver to maneuver especially when driving in corners at high speeds.

Manigandan *et al* [6], while quoting Walker (2005), noted that the absence of conventional suspension in go-kart compare to a normal vehicle requires the chassis itself to be flexible as a replacement of the suspensions. However, the go-kart chassis has to be rigid enough to withstand the strains it might experience such as weight of the drivers. In addition, a good traction from a proper design will also have less vibration which will result to a longer chassis life span.

Engine

A typical go-kart has a two-stroke and four-stroke engines to choose from. According to Mehta [7], by referring to Vortex's engine specifications, a two-stroke engine usually produces power at range of 8hp single-cylinder unit to 90hp with a twin cylinder unit.

Transmission system

Similar to any other transmission systems, by using gear ratios, it is important in order the conversion of power from engine to prop shaft. It consists of drive train, prop shaft, final drive shafts and whit or without gearbox and clutch, depending on the type of go-kart. However, there is no differential in a go-kart's transmission system compare to conventional transmission especially in Karting World Championship which it is prohibited (CIK-FIA, 2010).

Tyres

Prajapati *et al* [8], explained that wheels and tyres are in go karts are much smaller than those used on a normal car, as the tyres must be hard with increased grip. Unlike vehicle tyres that are used on normal road to cater for different road conditions, go-kart has specific tyres for dry or wet track so that drivers can have maximum performances and grips from the tyres. Slick and wet tyres are two main types tyres used in karting. A slick tyre does not have grooves on the tyre. Slick tyre is used when the track is dry. On the other hand, wet tyres which are grooved are used in order to have more grips when the track is slippery. Hence, for track conditions that are in wet conditions, wet tyre will be employed.

Chassis Materials

Most of the automotive components and parts are made of cast iron, such as brake drums and rotors, spindles, engine blocks, and many other components including fasteners. There are different types of steel for each component, which requires different strengths and characteristic from the material. The amount of carbon in steel is the most important point in determining the strength, hardness, and machining characteristics.

Polyvinyl Chloride

Polyvinyl Chloride (PVC) is one of the most commonly used thermoplastic polymers in the world, it is a naturally white and very brittle (prior to the additions of plasticizers) plastic. It is used most commonly in the construction industry but is also used for signs, healthcare applications, and as a fiber for clothing.

Thermoplastic materials become liquid at their melting point (a range for PVC between the very low 100 degrees Celsius and higher values like 260 degrees Celsius depending on the additives).

Rigid PVC has very high density for a plastic making, it is extremely hard and generally very strong. It is also readily available and very economical which combined with the long-lasting characteristics of most plastics made it an easy choice for many industrial applications like construction.

Body work

In order to achieve the set out goal of designing a go kart that looks appealing to the eyes, the body work has to be strong structurally, must be easily accessible and will have good quality finishing. To achieve these, the following procedures must be achieved: location of controls should be at convenient positions, body structure should be such that will prevent rusting or degradation of any kind, a light weight vehicle which permits easy assembly, comfort of the driver's seat, and attractive body styling.

3. Materials and Methods

Chassis Frame

The chassis of a frame serves the following purposes

- To support and various components like the controller and the geared DC motor.
- To withstand all loads without undergoing any form of deflection.
- To serve as a base for the electric vehicle.

A three dimensional schematic drawing of an electric go-kart is depicted in figure 1.

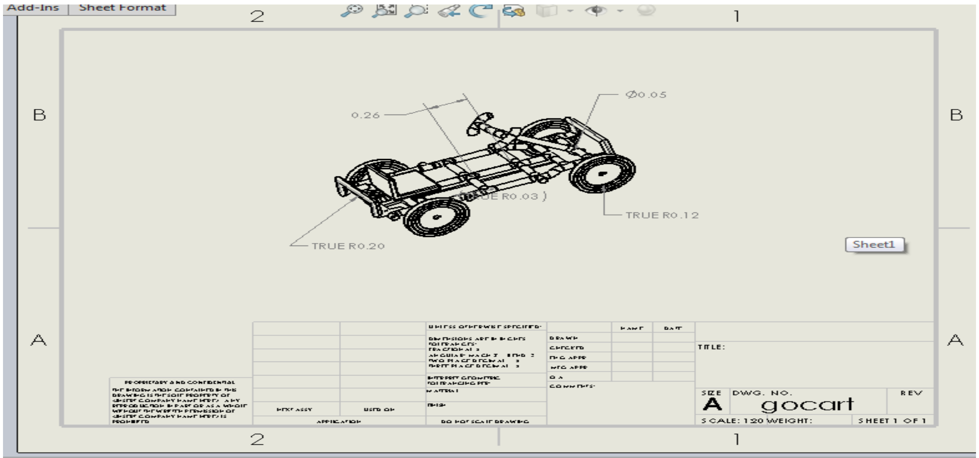

Figure 1: 3D schematic drawing of an electric go-kart

In the chassis frame design, the stability of the machine was considered, and to achieve this, the use of computer aided design software was employed. The software helped with the stress analysis tests, force analysis tests, and the deformation analysis, all were done using the finite element analysis software.

Solid works simulation is a computer aided design software that helps Engineers to determine the stresses, among other quantities, acting on a body based on the applied load. It provided a better alternative to the manual method of calculating the stresses acting on the different members of the body which will not only prove tedious, but will incur errors in the calculation due to the imperfections associated with humans.

Factor of Safety

There is obviously a need for a very high value of factor of safety because the project deals with human (driver), so life and property need to be protected. To this regard, a minimum FOS value of 3.2 was adopted. The material used for the chassis frame (pressured PVC pipe) has yield strength of 52Mpa. The point of maximum stress was found to be 16.25Mpa.

The major loads that are acting on the chassis frame considered here include: chassis frame made of PVC pipes (6.5kg), mass of electric motor (4kg) each, driver mass (average of 55kg), DC battery weights (26kg).

Geared Electric Motor

A gear motor is a specific type of electrical motor designed to produce high torque while maintaining a low horsepower, or low speed motor output. Geared motors can be found in many different applications. Common commercial applications of gear motor include in the design of cranes and a lift jack. The selected 24v D.C electric motor has a power rating of 450w (around 0.6 horsepower) with a synchronous speed of 1000rpm and a torque of 9.2Nm

Recall $$T=\frac{60p}{2\pi N} \quad (3.1)$$

And $$T=\frac{\tau\pi d^3}{1b} \quad (3.2)$$

Where T = Torque (0.0092Nmm)

P = power rating (450w)

N = synchronous speed (1000rpm)

τ = shear stress of material of shaft (220N/mm² for mild steel)

d = diameter of shaft

Combining equations (3.1) and (3.2) then making **d** the subject of formula.

$$d = \left(\frac{960p}{2\tau\pi^2 N}\right)^{1/3}\left(\frac{960 \times 450}{2 \times (3.142)^2 \times 220 \times 10^6 \times 1000}\right)^{1/3} = 0.008\text{m 0r 8mm}$$

Steering System Design

According to Nath *et al* [9], the basic aim of steering is to ensure that the wheels are pointing in the desired directions, which are achieved by a series of linkages, rods, pivots, and gears. A steering system must offer sufficient precision for the driver to actually sense what is happening at the front tires contact patch as well as well enough "feel" to sense the approach to covering limit of the front tires. It must be structurally stiff to avoid components deflections.

The steering must be fast enough for the vehicle's response to steering and steering correction to happen almost instantaneous, and it must also have some self-returning action. According to Heisler [10], the feel, feedback, and self-returning actions are function of the Kingpin inclination (steering axis), scrub radius, castor angle and self-aligning torque characteristics of the front tire. To maintain a particular direction of a vehicle, the steering handle must be constantly manipulated.

To achieve this, the driver will have to monitor some important factors which are beyond visual perception some of these factors would include for example, the roll inclination of the body, the feeling of being held steady in seat and the self-centering torque the driver will feel through the steering. The rotation is around the steering axis, pivot or steering rotation axis.

The steering mechanism used in a go-kart is a wagon-styled steering system. The steering is attached to the front axle so that when the wheel is turned, the kart's wheels will change the angle that they are facing.

Steer Angle (Δ)

This is the angle between the front of the vehicle and the steered wheel direction. The steer angle required to make a turn with no consideration for tire slip can be calculated from the equation below

$$\delta = \alpha \tan\frac{L}{R} \quad (3.3)$$

where α = wheel track

L = wheel base

R = wheel radius

The Required Acceleration of the Go-Kart

To obtain the acceleration of the go-kart, consideration is taken from a condition of rest (0km/hr) to the time (say 20 seconds) when the kart attains a velocity of 15km/h (for most go-kart)

Recall the Newton's equation for uniformly accelerated motion, α_M

$$\alpha_M = \frac{v_2 - v_1}{t} \quad (3.4)$$

where v_2, v_1 and t represent final velocity initial velocity and time respectively

$$\alpha_M = \frac{15-0}{20} \times \left(\frac{1000}{3600}\right) = 0.21\text{ms}^{-2}$$

This means that the electric vehicle increases in velocity by 0.21m/s every second for say a time of 15 seconds.

Body Design

The design process involves the following: concept development, body design, research, feasibility study and market survey, material selection and procurement, measuring and cutting out of dimensions, assembling and welding, and finishing and painting.

Body Frame

The frame material was selected based on flexibility, design versatility, resistance to flame and its ability to possess water tight joints. A total length of 554cm of pressurized PVC pipes was used as galvanized steel pipe was used to construct the 4-way. The latter was selected because it has low stress at the same magnitude of force applied compared to some other available materials. Steel has a young's modulus of 206.84Gpa and specific gravity of 7.8.

Body Exterior

The design intent is to build a body that not only looks appealing but also has better interactions with air flow, and reasonably strong and portable as well. In the material selection, we settled for plywood of dimensions 120cm*64cm, 20mm thickness. Plywood is prone to attack from insects and can easily get deteriorated but we sleeked to minimize this by painting.

The controller rating of 12V, 40A gives also an almost negligible resistance of 0.3Ω. This value of resistance is such to reduce opposition to flow of current. Its power rating of 480W can be considered relatively high too.

The D.C battery has specifications of 12V, 40Ah. Locally sourced 16 and 15 inches bicycle tires were also used.

Electric Motor

An engine or motor is a machine designed to convert one form of energy into mechanical energy. Power requirement of every vehicle is always provided by the engine. The choice to use the electric motor was because of its numerous advantages when compared to conventional internal combustion engines.

Seat Frame

In the seat frame construction, 30mm circular hollow pipe and 25mm square hollow pipes were employed. Both pipes have a thickness of 1 inch. These pipes offer light weight which enhances less aerodynamic drag.

According to Jeong and park [11], the question of the correct design of seats with emphasis on comfort as regards to Nigerians arises due to the fact that required anthropometric measurements are not available and the local manufactures assume that manufacture of seats is an art rather than engineering. However, Bridger [12], observed that physical dimensions of furniture, equipment, clothing and workspaces are specified using anthropometric data to achieve proper ergonomic design.

During the course of the design and fabrication of the seat, some considerations were made on human factors (seat comfort), strength, weight of seat, and availability of materials. This has a major influence on material selection. The seat was designed to accommodate just the driver.

Thrust Force (Tractive Effort) Required for Motion

The trust force responds the force needed for the go-kart to be in motion. It is the sum of the force due to acceleration and the force due to road resistance. The road resistance to vehicle movement is given in tractive resistance. The tractive effort provides the propelling thrust at the tire to road boundary needed to overcome the vehicle is divided into;

- Air resistance/ drag: This results from the frontal area of the vehicle, vehicle speed and shape, streamline of body, wind speed and direction.
- This is due to the deformation of the tires, road surfaces, interaction of frictional scrub when tractive effort is applied and flattering distortion of the tires.
- Gradient resistance: This is as a result of the inclination of the road on which the vehicle is driven. The gradient resistance opposing motion, and therefore the tractive effort or power needed to drive the vehicle forward is directly proportional to the laden weight of the vehicle and the magnitude of the gradient.

Thrust force, F_T is given by the relation

$$F_T = F_{aero} + F_{roll} + F_{grad} + F_{acc}$$

$$F_T = C_d Av^2 + C_{rr}\, mg + \%\, slope.mg + ma$$

$$F_T = \frac{\mathcal{P}}{2} C_d Av^2 + mg\left(C_{rr} + \%\, slope + \frac{a}{g}\right)$$

Where $\mathcal{P}$ = air density = 1.2kg/m³

A = frontal area.m² = 1.97m² (calculated)

Cd = aerodynamic drag coefficient (0.45)

V = air velocity = 6.5m/s

Crr = rolling resistance co-efficient (approximately 0.015)

% slope in rise/run (tanθ, θ= 15°)

$$F_T = (\frac{1.2}{2} \text{ x } 0.45 \text{ x } 1.97 \text{ x } 6.5^2) + 85.95 \text{ x } 9.81\ (0.015 + \tan 15 + \frac{0.37}{9.81})$$

$$F_T = 292.8N$$

Electrical Connection

The main processing unit of the electrical system is the Electronic Speed Controller (ESC). It consists of different port right from the brake light up to accelerator. Battery is connected to battery port and throttle pedal is connected to derailleur in ESC unit. The battery need to be connected in series for getting complete power output. On pressing the throttle pedal, current is passed to motor through the battery pack as throttle pedal, current is passed to motor through the battery packs as throttle is the input which activates the MOSFET transistor and the system starts.

The powerhouse or driveline of the go-kart is a battery and a motor. Normal ICE (internal combustion engine) vehicles have transmissions (gear box) that provide speed fluctuations for different driving conditions; the same purpose in an electric vehicle is served by a controller. Generally go-karts don't have suspension system.

Technical Specification of the kart

- The stiffness of chassis enables better handling of the vehicle in different circumstances.
- Professional race karts weigh more than 50kg, without the driver seated in it.
- 4 stroke engines or electric motors are used.
- Wheels and tires are much smaller than those used in cars.

Designing the Frame

The frame was made out of 30mm square tubing and 25mm round tubing and 19mm round tubing for seat supports and the steering column just to make it easier to work with;

- The wheel base and track need to be approximately the same as a race kart, so 1040mm wheel base, and 680mm between the kingpins. This will provide the best handling kart as most race kart are pretty close to that size.
- The front wheels need space to move as they steer multiple bends are difficult to make so we kept the frame as simple as possible.

Battery Selection

a) Charging time of battery = $\frac{battery\ rating\ (Ah)}{charging\ current\ (A)}$

Charging current should be 10% of the Ah rating of battery.

Therefore Ah = 40Ah

Charging current for 40Ah battery = 40 x$\frac{10}{100}$ = 4A

Charging time of battery =$\frac{40}{4}$= 10 hrs (ideal case).

b) Practical case

20% of losses occurs,

40 x$\frac{20}{100}$ = 8

Therefore, 40 + 8 = 48Ah

Charging time of battery = $\frac{48}{4}$ = 12 hrs

c) Discharge time =$\frac{battery\ Ah \text{ x } battery\ volt}{Applied\ volt} = \frac{40 \text{ x } 12}{1000}$ = 0.48 hrs

Therefore, 0.48hrs = 28.8mins

4. Analysis of the Go-Kart Functionality

The integral construction produced a four wheeled machine that is made up of mainly of a chassis, steering assembly, an engine and a seat. It is vital to say that the most important part of a go- kart is the chassis. The chassis of our go-kart is an open design, where there is no roof and the driver's seat is positioned in the middle. The floor panel helps resist the sagging effect that might be caused by the weight of the driver.

The steering mechanism used is a wagon-styled system which is a simple mechanism that works well on a go-kart. Go-kart tires are made of a softer compound suitable for track usage. Although locally sourced, it provided us still with enough rigidity and stiffness. The kart is powered by a pair of electric motors obviating the need for a differential, and a DC battery running a motor controller.

The main focus of the frame design was on the stability of the kart and safety of the driver. The CAD model of the kart was done in CRED 2.0. Pressurized PVC pipes have been employed for the frame to reduce the overall weight. To check the feasibility of the frame design, finite element analysis has been done using ANSYS 14.5. The results obtained showed that the frame design was safe under maximal impact load conditions. Weight reduction was a major concern and hence the wagon-styled steering mechanism was selected for the kart.

The electric motor, the heart of the vehicle was selected and installed in such a way that it can perform well for an extended run time. PMDC motor was selected in this case. Speed control of the kart was done using a voltage controller. Design calculations were carried out and optimum results were obtained. An extensive market survey was also done on frame material, motor and transmission system for cost and availability international standards were followed throughout the design process.

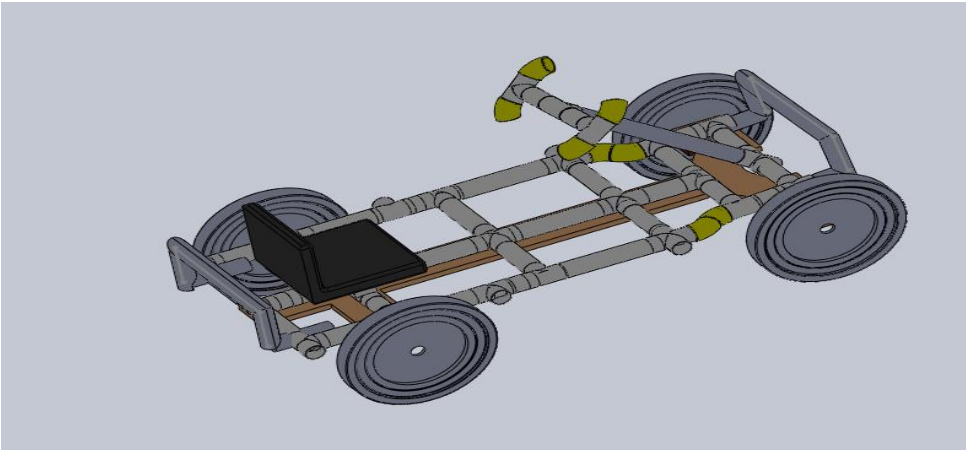

Figure 3: 3D View of the PVC electric go-kart

5. Conclusion

From the result obtained, the project is achieved and completed within the planned time-frame. A low cost PVC electric go-kart has been successfully designed and fabricated using locally sourced materials. The problem statements which are majorly over dependence on vehicles that runs with internal combustion engines, very low load carrying capacity using light-weight materials and high cost has been resolved as the electric vehicle developed compensate these deficiencies. The entire vehicle was designed and fabricated at the school workshop and it functions effectively.

The ergonomic suitability of the driver's seat was greatly enhanced due to the research carried out,as well as the adoption of SAE standard for seat design application of good aesthetic quality and good body finishing.

The aim of the study was achieved as a functional portable PVC electric vehicle with ease of assembly was designed and fabricated with sixty percent locally-sourced materials, with the innovative use of electric motors than the usual internal combustion engine, at a total cost of three hundred and eight Dollars.

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