Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 11, Special Issue 8, 2023
DOI (Journal): 10.37591/JoPC

http://engineeringjournals.stmjournals.in/index.php/JoPC/index

Research article JoPC

Incorporating Sensors and Algorithms for Enhanced Go-Kart Driver Awareness and Navigation

Karimulla Syed[1,*], B. Nageswara Rao[2], Yadavalli Revanth Sri Sai[3],
Mohammed Aousaf Ur Rahman[3], Gedala Durga Raj[3], K. Prasanth Kumar Reddy[4]

Abstract

This study is motivated by the Go Kart Design Challenge (GKDC), wherein dedicated teams from the University collaboratively endeavored to bring to life a competitive go-kart. Serving as an invaluable learning platform for mechanical engineers, the project involved comprehensive engagement in go-kart design calculations, budget estimations, fabrication, qualification testing, and dynamic participation in competitions. This paper succinctly outlines the key phases of the project, encompassing the design process, fabrication intricacies, rigorous testing procedures, and the team's active involvement in competitive events. Notably, the research introduces a pioneering dimension by incorporating sensors and advanced algorithms into the go-kart system, contributing to enhanced safety measures and heightened driver alertness. The integration of these innovative elements marks a progressive step forward in the evolution of go-kart design, reflecting the team's commitment to pushing boundaries and embracing cutting-edge technologies in pursuit of excellence.

Keywords: AISI 4130 steel; Arduino NANO; Brake system; Ultrasonic sensor; Water level sensor.

INTRODUCTION

Go-kart is a small four wheeled automobile designed specifically for recreation and racing. It is introduced in 1956 by Art Ingels of California (see Figure 1). Later, the activity spread to Europe and other parts of the world. Go-karts have no suspension and no differential. Different parts of the go-kart are the chassis; the brakes; the steering; tire; engine; and transmission. Learning driving techniques is useful. Chassis design plays an important role in driver safety. The go-kart chassis design should specify the safety factor, so that its bearing capacity exceeds its working load, and the deformation is within the allowable range.

Literature Survey

Jafri et al. [1] modelled Go-Kart Challenges 2017 (GKC-17) using SolidWorks and FEA (Finite Element Analysis) was performed to obtain the deformation of chassis parts under static loads. Raghunandan et al. [2] performed a dynamic analysis of the AISI 4108 kart chassis. Shrehari and Srinivasan [3] used ANSYS 16.0 software and performed FEA of the go-kart specifying boundary conditions including manufacturing aspects. Suresh Kumar [4] used CATIA software to model the car chassis and used ANSYS to perform the crash analysis on car chassis. Pamungkas et al. [5] modelled a tubular space-frame chassis using SolidWorks and examined the chassis behavior with impact absorbers using

***Author for Correspondence**
Karimulla Syed

1Assistant Professor, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Green Fields, Vaddeswaram, Guntur, Andhra Pradesh, India
2Professor, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Green Fields, Vaddeswaram, Guntur, Andhra Pradesh, India
3Under Graduate Students, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Green Fields, Vaddeswaram, Guntur, Andhra Pradesh, India
4Research Scholar, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Green Fields, Vaddeswaram, Guntur, Andhra Pradesh, India

Received Date: December 28, 2023
Accepted Date: January 10, 2024
Published Date: March 15, 2024

Citation: Karimulla Syed, B. Nageswara Rao, Yadavalli Revanth Sri Sai, Mohammed Aousaf Ur Rahman, Gedala Durga Raj, K. Prasanth Kumar Reddy. Incorporating Sensors and Algorithms for Enhanced Go-Kart Driver Awareness and Navigation. Journal of Polymer & Composites. 2023; 11(Special Issue 8): S362–S373.

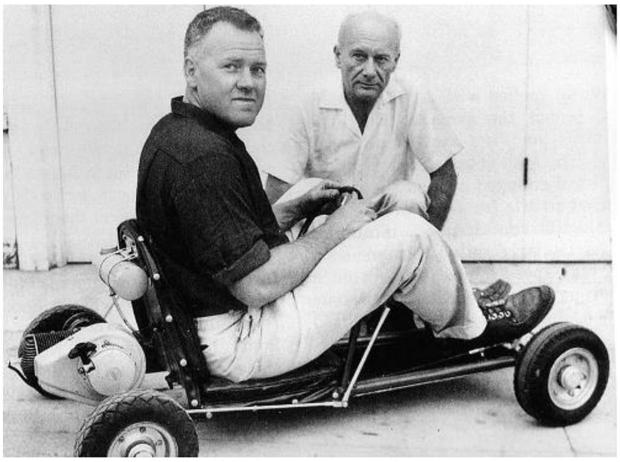


Figure 1. Art ingels (left) and lou borelli drive the first go-kart outside ingels' garage in echo park (https://sfcriga.com/art-ingels-the-inventor-of-the-go-kart).

ANSYS. Prasad et al. [6] used Pro E-software for modelling and ANSYS for static analysis to optimize the chassis and suspension of SAE Baja car. Following the Baja SAE India Rulebook, the parametric geometry of a roll cage created and imported to ANSYS for optimizing under impact loading [7]. LS-DYNA utilized for FE modelling of a truss chassis and performed the crashworthiness analysis [8]. Using CATIA V5, designed the chassis of a go-kart and performed impact analysis using PATRAN/NASTRAN for rider safety and the frame reliability [9].

Ramana Reddy and Revanth Kumar [10] considered high strength, low cost and lightweight AA6061 and Kevlar materials for improving the performance of go-kart. Chassis design and fabrication should be given the utmost attention. Mahatme et al. [11] modeled the go-kart chassis (made of AISI 4130 tubular beams) using CATIA V5 and performed analysis using ANSYS 19. Reddy et al. [12] hinted that the chassis must be the rigid and strong platform to support the suspension components. Krishnan et al. [13] performed modeling and analysis of a go-kart chassis in SOLIDWORKS 2016 and ANSYS 15.0. AISI 1018 grade steel tube (of 25.4 mm diameter and 1 mm wall thickness). Baburao et al. [14] and Joshi [15] hinted that chassis is made up of joining various small links by welding with limited number of joints and make the chassis strong enough to withstand high loads. Johnson et al. [16] designed, fabricated, and tested a go-kart as per the guidelines in rulebooks. They simulated the path travelled by go-kart for the specified steer angle and implemented sensors to the system for navigation and driver alertness. The design, analysis of chassis and realization of a typical go-kart with provision of rider comfort in case of sudden impacts, testing of the go-kart by racing organization, component failures and prevention, are described in [17]. SOLID WORKS and ANSYS-Explicit Dynamics tools utilized for designing the chassis and performing the static and dynamic analysis [18–23].

Most of the researchers performed the design and analysis of the go-kart using commercial software packages such as LS-DYNA, CATIA, PATRAN, NASTRAN, SolidWorks, and ANSYS. For safety and comfort of the rider, the design standards considered are: Federal motor vehicle safety (FMVSS No. 581), Insurance Institute for Highway Safety (IIHS), SAE (Society of Automotive Engineers) and ISIE (Imperial Society for Innovative Engineering) Rulebooks. Go-kart events conducted by popular organizations are: ISIE, ISNEE (Indian Society of New Era Engineers), Red Bull Go-Kart Race, IKC (Indian Karting Championship), FMSCI (T*he Federation of Motor Sports Clubs of India)*, JK Tyres (*Juggilal Kamlapat Ji Tyres & Industries Ltd*.), and NEKC (National Electric Kart Championship).

Purpose of the Article

Inspired by the work of the above researchers, teams formed from the University to realize a go-kart for competition and registered for the 9th GKDC event conducted in August 2022 by ISNEE [24]. Teams prepared the work flow chart (see Figure 2) basing the GKDC rulebook and started designing

Journal of Polymer & Composites
Volume 11, Special Issue 8
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

the chassis in fusion 360 as per the specifications and arrived the final design. The chassis fabricated from AISI 4130 steel pipes (having 2.54 mm thick and 25.4 mm diameter) using different tools (such as roller bending, welding, hand grinder, cutting tools, etc.). Steering and transmission teams took the responsibility of placing appropriately the steering system, engine and axel. Later on, attached the body parts like clutch, brake, accelerator, seat, aluminium sheets, fairings, etc. Another innovation team started brainstorming on the integration of sensors (brake fluid level warning and proximity warning systems) and algorithm into the system to improve navigation and driver awareness. Ultrasonic sensor for proximity warning and resistance-based water level indicator for brake fluid warning selected from the options like capacitance and resistance-based water level sensors for brake fluid warning system and IR blaster, Sharp IR, Ultrasonic sensors for proximity warning system. After testing & quality inspection by the scrutiny inspectors of ISNEE, participated in the 9th GKDC event in Bangalore.

This paper briefly highlights the design, fabrication, testing, and participation in the competition. Also, provides the details on a new innovative approach of integrating sensors and algorithms into the system for safe driving and driver alertness.

Design

Design teams set goals on the strength, durability, safety, driver comfort, and pleasing look of the vehicle. To fulfill the set goals, sub-teams formed for chassis, steering system, brakes, transmission, body, and other components. Modeling and analysis of the systems was carried out using SolidWorks and Fusion 360. The design process is iterative depending on the material, cost, and parameters. Table 1 gives the design specifications of the kart as per the guidelines of GKDC. AISI 4130 steel tubes having 2.54 mm thickness and 25.4 mm tube diameter are selected for construction of the go-kart chassis. Figure 3 shows the 3D models of chassis. AISI 4130 tensile specimens tested in Annoor Test Labs, Gannavaram and reported the results in Table 2. The finalized chassis of go-kart is shown in Figure 4. Table 3 provides the specification of the go-kart engine. Table 4 gives the specifications of the braking system.

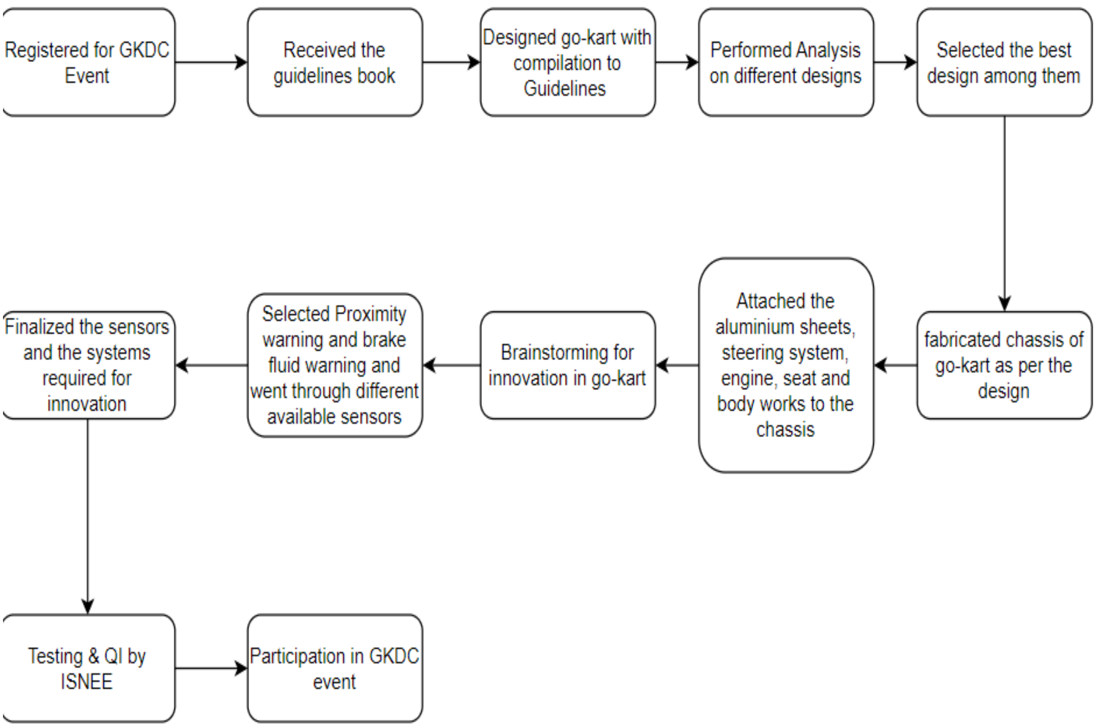


Figure 2. Workflow chart of the team for participation in GKDC event.

Table 1. Design specifications.

Roll cage/chassis	
Tube material	AISI 4130
Outer diameter	25.4 mm
Thickness	2.5 mm
Go-kart dimensions	
Ground Clearance	50.8 mm
Wheelbase	1371.16 mm
Back track width	1282.7 mm
Front track width	1117.6 mm
Overall Length	1930.4 mm
Overall Width	1524 mm

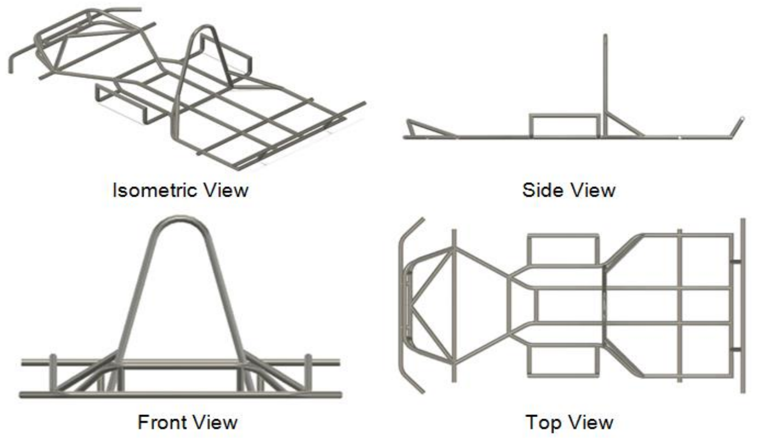


Figure 3. 3D models of the chassis.

Table 2. Achieved properties of AISI 4130.

Property	Specified Value	Achieved Result
Yield Strength, σ_{ys} (MPa)	> 460	653
Ultimate Tensile Strength, σ_{ult} (MPa)	> 560	705
% Elongation	21.5	29.4
Modulus of elasticity, E (GPa)	210	
Poisson's ratio, v	0.33	
Shear modulus, G (GPa)	80	
Density, **ρ** (g/cc)	7.85	
Bulk modulus, K (GPa)	140	

Table 3 Engine Specification (https://www.bikedekho.com/hero/cbz/specifications)

	Engine	Hero CBZ
	Max. Power	14.19 PS @ 8500 rpm
	Gross Torque	13 Nm @ 6500 rpm
	Bore diameter	57.3 mm
	Stroke length	63.1 mm
	Capacity	149.2 cc

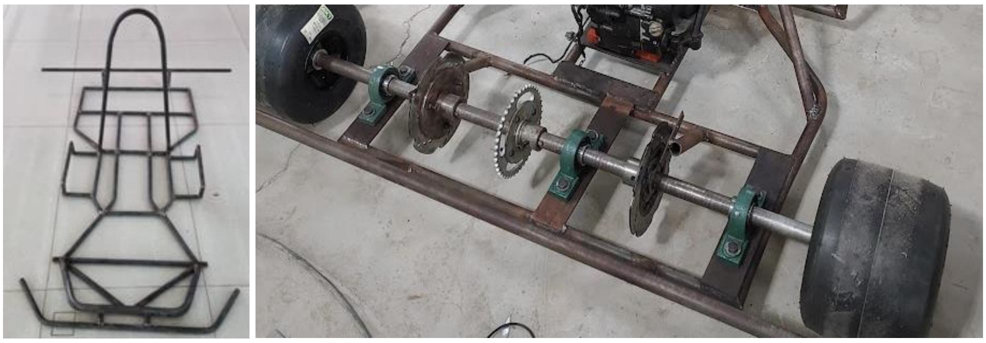


Figure 4. Chassis of the go-kart.

Table 4. Brake system specifications.

Property	**Value**
Mean effective radius, R_{mean}	0.085 m
Load Transfer	95 N
Static load at Front axle, R_f	706 N
Static load at Rear axle, R_r	863 N
Normal Force on Front Wheel, F_{NF}	611 N
Normal Force on rear wheel, F_{NR}	958 N
Deceleration	4.42 m/s^2
Force exerted by Caliper on Disc, F_{FCP}	732 N
Force offered by Caliper on Piston, $F_{Caliper}$	1832 N
Pressure on piston, P_R	18.65×10^6 N/m^2
Brake Torque	62.3 Nm
Force on Master Cylinder	1464 N
Force on Pedal	366 N

Braking Distance

Brake design calculations are made below to assess its adequacy and the braking distance. Heat produced during braking, induced forces, torque in braking system, and the area of contact for brake pads and brake discs. The following Table 4 data was achieved for the literature [25–26].

Thermal Analysis (Energy distribution equation)

- KE = Heat loss + Friction loss + work done (1)
- Heat loss = Force exerted by caliper disc × Velocity × Time (2)
- Velocity = $(V_{wheel} \times R_{mean})/R_{wheel}$ = (16.67 × 0.085)/0.1334 = 10.62 m/s (3)
- Heat loss = = 732.852 × 10.62 × t = 7782.89 × t Joules
- Friction Loss = Weight × μ × V_{wheel}× time
  =1569.6 × 0.65 × 16.67 × t =17007.4 × t Joules (4)
- Work done = Force × Distance (s)
  = (m × a) × s (s = u × t–(1/2) a × t^2) = 160 × 4.4275 x (u × t–(1/2) a × t^2)
  = (11809.03t–1568.22t^2) Joules (5)
- Kinetic Energy = (1/2) × m × v^2 (20) = ((1/2) × 160 × 16.67^2)
  = 22231.11 Joules (6)

Here, m is the mass (kg), and v is the velocity (m/s) of the vehicle.

On substituting equation (14)

$22231.11 = 7782.89\ t + 17007.4t + 11809.03\ t – 1568.22\ t^2$

$\Rightarrow 22231.11 = 36599.32\ t – 1568.22\ t^2 \quad \Rightarrow\ t = 0.6241\ sec$

- Stopping distance, $S = ((u + v)/2) \times t) = [(16.67+0)/2] \times 0.6241$
  $= 5.2$ Meters (7)
- Rubbing Area on one side of disc $= \pi/4\ (D^2\text{-}d^2) = \pi/4\ (200^2\text{-}125^2)$
  $= 19{,}144.08023\ mm^2$ (8)
- Total Rubbing Area on Brake of disc = Rubbing Area on one side of disc × 2
  $= 19144.08023 \times 2\ mm^2 = 38{,}288.16\ mm^2$ (9)
- Brake Power = (Kinetic Energy ×Weight Distribution) /Brake Time
  $= 22231.11 \times 0.45/3.765 = 2657.1$ Watts (10)
  $(v = u + at \Rightarrow 0 = 16.67 + 4.4275\ t \Rightarrow t = 3.765\ sec)$
- Heat Flux, q = Brake Power/Total Rubbing Area on Brake of disc
  $= 2657.1/0.03 = 88570.15\ w/m^2$ (11)

Innovative Approach to Integrating Sensors into the System

For the innovation part of the kart, two systems are implemented. One is the collision Avoidance System, in which Ultrasonic Sensor is used for detection of other karts. Initially, some thoughts were given on the use of Sharp IR or Mini LiDAR and planned with Ultrasonic Sensor due to time and cost constraints, and unavailability of components. The whole system is placed on to a PCB. Details of the two implemented systems are as follows. Ultrasonic Sensor is used to detect the other karts moving close to the Kart and used an LED for indication to the driver. The whole system is controlled by a microcontroller running on a battery.

Ultrasonic Sensor

An ultrasonic sensor (Figure 5) is an electronic device that uses ultrasonic sound waves to determine the distance of a target object and then turns the reflected sound into an electrical signal. The speed of Ultrasonic waves is below the speed of audible audio waves. Ultrasonic sensors consist of the transmitter and the receiver.

The Arduino Nano (see Figure 6) has 30 male I/O headers that are arranged in a DIP-30-like format and can be programmed using the Arduino Software integrated development environment (IDE) available both online and offline and is shared by all Arduino boards. The board is powered by a 9V battery. And it can also be powered by connected with type-B mini-USB. LEDs use DC voltage and have power sources. LEDs pass current only in single direction(polarity). For indication, orange coloured light is employed. Printed circuit boards, which have lower manufacturing costs than conventional circuit boards, use conductive tracks to link components. Although the ultrasonic sensor advertised that it could measure a target's distance between 5 cm and 75 cm, tests showed that it could only accurately measure between 7 cm and 70 cm. Figure 7 shows the source code that was created.

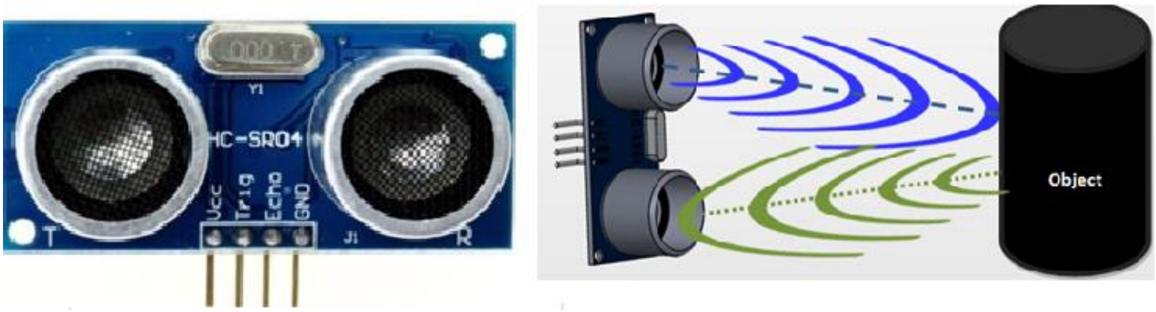


Figure 5. Ultrasonic sensor.

Journal of Polymer & Composites
Volume 11, Special Issue 8
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

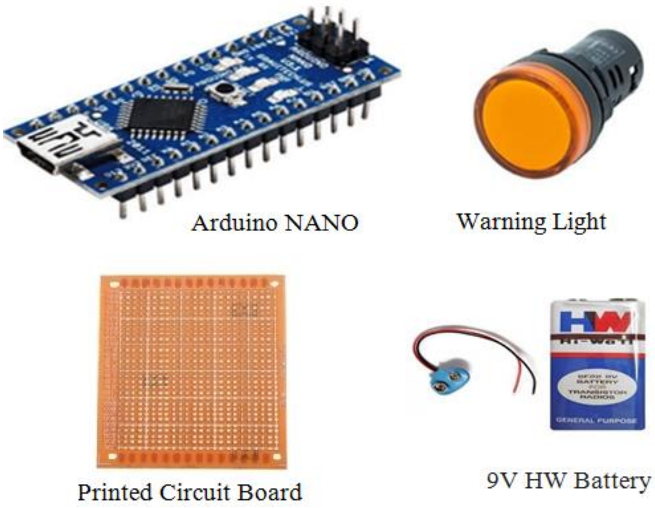


Figure 6. Arduino NANO.

```
const int TRIG_PIN = 3, ECHO_PIN = 2,LED_PIN  = 13;
const int DISTANCE_THRESHOLD = 70; // centimeters

// variables will change:
float duration_us, distance_cm;

void setup() {
Serial.begin (9600);
pinMode(TRIG_PIN, OUTPUT);
pinMode(ECHO_PIN, INPUT);
pinMode(LED_PIN, OUTPUT);
}

void loop() {
  // generate 10-microsecond pulse to TRIG pin
digitalWrite (TRIG_PIN, HIGH);
delayMicroseconds (10); digitalWrite(TRIG_PIN, LOW);
```

```
  // measure duration of pulse from ECHO pin
duration_us = pulseIn (ECHO_PIN, HIGH);
  // calculate the distance
distance_cm = 0.017 * duration_us;

if(distance_cm< DISTANCE_THRESHOLD)
digitalWrite(LED_PIN, HIGH);
  else
digitalWrite(LED_PIN, LOW);

  // print the value to Serial Monitor
Serial.print("distance: ");
Serial.print(distance_cm);
Serial.println (" cm");

delay(500);}
```

Figure 7. Source code for recording the measured distance of a target by an ultrasonic sensor.

Figure 8. Brake fluid measuring system [19].

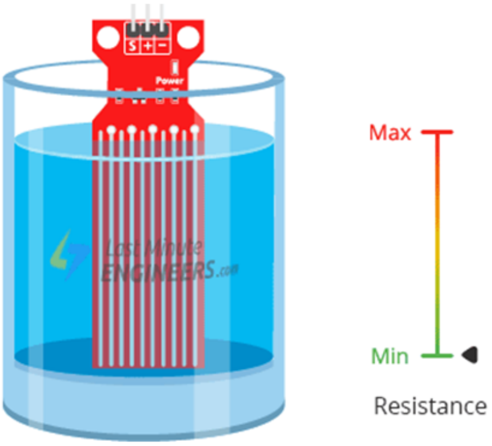
Brake Fluid Measuring System

A fluid detection sensor, namely the water level sensor (see Figure 8) was used for indicating the sudden drop of brake fluid level through an LED. Some thoughts were given on conductance base water level sensor. Opted for the Resistance based Water-Level Sensor due to time constraint, cost constraint and unavailability of the components,

Level sensor measures the level of brake fluid. LEDs use DC voltage for power source. LEDs pass current only in single direction (polarity). A red light is employed as a signal, and a 9V HW battery is used as the power source. Figure 9 shows the source code that was created. Figure 10 illustrates how the water level sensor operates.


```
// Values for storing water level & pin slots
int val = 0, sensorPower = 7, sensorPin=A0;
void setup() {
pinMode(sensorPower, OUTPUT); // Set D7 as an OUTPUT
digitalWrite(sensorPower, LOW); // Set to LOW so no power flows through the sensor
Serial.begin(9600);
}
void loop() {
  //get the reading from the function below and print it
  int level = readSensor();
Serial.print("Water level: ");
Serial.println(level);
delay(1000);
}
//This is a function used to get the reading
int readSensor() {
digitalWrite(sensorPower, HIGH);  // Turn the sensor ON
delay(10);              // wait 10 milliseconds
val = analogRead(sensorPin);    // Read the analog value form sensor
digitalWrite(sensorPower, LOW);  // Turn the sensor OFF
 return val;            // send current reading
}
```

Figure 9. Source code for recording the level of flowing substances.



Real Value (cm^3)	Sensor Value
50	412
100	536
150	658
200	786
250	874
300	943

Figure 10. Working of water level sensor [19].

The water level sensor requires three pins to connect.

- S (Signal) is an analog output pin connected to one of Arduino's analog inputs.
- + (VCC) pin provides power (3.3V to 5V) to the sensor.
- – (GND) is the ground pin.

Signal changes based on the water level (Resistance)

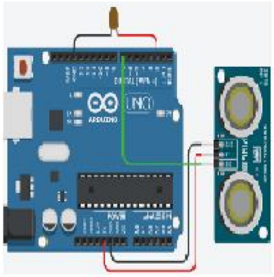
RESULTS AND DISCUSSION

The go-kart design challenge (GKDC) concept inspired teams from the University to realize a go-kart for competition. Mechanical engineering students gain knowledge and experience in the design calculations of a basic level vehicle (go-kart), budget estimations, fabrication and qualification testing and active participation in competitions.

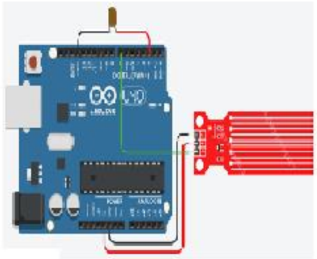
The design of the chassis played an important role for the safety of the driver and selected AISI 4130 steel tubes for the chassis construction. The steel tubes were bent appropriately. MIG welding is adopted for joint connections. Assembly operations initiated after the welding of chassis. Strength tests were performed by 4 members standing on Go-Kart. Ultrasonic sensor tested the working value with distance. As per the catalog, it can measure the distance accurately between 5 cm to 75 cm,

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

whereas accurate measurements were possible between 7 cm to 70 cm. The water level sensor calibrated the code as the resistance change for brake fluid. The container filled to the level of minimum required brake fluid and took sensor readings from sensor and calibrated the code. Figures 11 to 14 show the ultrasonic and water level sensors, printed circuit board connections, go-kart prior to and after alterations suggested by ISNEE.



Circuit for ultrasonic Sensor



Circuit for Water Level Sensor

Warning Lights for ultrasonic and water level sensors in go-kart

Figure 11. Circuit for ultrasonic and water level sensors, and warning lights in go-kart.

Ultrasonic sensor in go-kart

Water level sensor in go-kart

Figure 12. Ultrasonic and water level sensors in go-kart.

Printed circuit board connections in go-kart

Printed circuit board with Arduinos in go-kart

Figure 13. Printed circuit board connections in go-kart.

Go-kart prior to alterations suggested by ISNEE Go-kart after alterations suggested by ISNEE

Figure 14. Go-kart prior to and after alterations suggested by ISNEE.

ISNEE tested the go-kart with the driver for ground clearance in the range of 25.4 to 50.8 mm. Later, tested all fittings and members of the chassis, followed by all components of the go-kart. ISNEE members suggested isolating the circuit board for driver safety and keeping engine cover under the fuel tank to avoid accidents from leakage. After incorporating the necessary medications, the go-kart was qualified and permitted to participate in the event. Acceleration and deceleration tests were conducted to check the adequacy for radius of turning of go-kart. After completing 20 laps, the endurance test was conducted for mileage of the go-kart.

CONCLUSIONS

A typical go-kart is designed, fabricated, and assembled, which is tested and approved by ISNEE for the 9th GKDC event. The innovative sensors are made, tested, and integrated into the go-kart. The engine troubled with carburetor during the endurance round in the 6th lap and rectified. However, re-entering the round was not possible. Active participation in the event was made to deal with the real situation of mechanical problems.

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