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Sl. No	Name of Faculty	Page No
1.	Ms. Shelma George	1
2.	Dr. S. Christopher Ezhil Singh	27
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Grenze International Journal of Engineering and Technology, Jan Issue

An Adaptive Control Strategy for Performance Improvement of a Hybrid Vehicle with Fuel Cell and Supercapacitor

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***Abstract*—The automotive industry devotes significant research time and resources to developing hybrid energy storage systems for future vehicles. A hybrid energy storage system with complementary characteristics can improve the overall drive system efficiency. This paper presents an adaptive control strategy for a fuel cell and supercapacitor-powered hybrid vehicle topology. Mathematical modelling of the fuel cell supercapacitor hybrid electric vehicle topology is included in this paper. A practical drive cycle generally involves much uncertainty. Uncertainty in the drive cycle necessitates an adaptive control method for EV performance enhancement. In this context, A fuzzy logic-based control strategy is proposed for efficient energy storage unit utilization. The results reveal that the proposed fuzzy control works well in the city drive cycle, which involves frequent starting, stopping and acceleration. A case study employing a modified drive cycle and the driving pattern of the city of Trivandrum, Kerala, India, is used to validate the effectiveness of the proposed control approach. The data demonstrates that the fuzzy-based control method increases driving range by nearly 4%. Index Terms—Electric Vehicle, fuel cell, super capacitor, drive cycle, state of charge, fuzzy logic.**

***Index Terms*— Electric Vehicle, fuel cell, super capacitor, drive cycle, state of charge, fuzzy logic.**

I. Introduction

Electric vehicles that run on fuel cells have a bright future in transportation due to their high energy efficiency, extended range, and zero emissions. Heat and power can be generated using fuel cells as long as the fuel is available. It is not an energy-storing device but rather an energy supply. As a result, fuel cell vehicles always require additional storage, such as a battery or supercapacitor, to help them operate in poor conditions and store regenerative energy. Consequently, cars fueled by fuel cells are always hybrid. Utilizing fuel cells or hydrogen-powered vehicles reduces reliance on fossil fuels and advances the transition to green energy. Electric and hybrid vehicles are becoming a need of present-day life to solve environmental issues and a lack of fossil fuels. Using a fuel cell (FC) as the primary energy source for a car allows for emission-free operation. This ecologically beneficial technology has been developing for decades, reducing air pollution, oil dependency, and greenhouse gas emissions. Several governments encourage the use of green energy for transportation. The Indian

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government has also made many efforts to promote the production of hydrogen-powered automobiles. The Indian Ministry of Power released the green hydrogen and ammonia policy on February 17, 2022. The Ministry of New and Renewable Energy also strengthens research and development efforts related to hydrogen fuel and energy [1-3].

Fuel cell vehicles (FCVs) are efficient, light, and easy to control. However, they have significant drawbacks, including a high cost and poor endurance and reliability. The fundamental weakness of a fuel cell is its slow power dynamics, which must be overcome to extend its usable life. As a result, a hybrid source system is required for an FCV. Pure battery vehicles are the better alternatives for reducing fossil fuel dependencies. However, it faces issues like driving range, refueling time, and the cost of the battery. The battery's life depends on the charge and discharge cycles; hence, it is unsuitable for EV applications. The hybrid configuration faces the problem of long driving range. A fuel cell and supercapacitor hybrid combination is an attractive solution for this problem [4-5]. Research works with battery and supercapacitor combination is presented in various articles. A control strategy is required for the satisfactory operation of the fuel cell and supercapacitor-powered electric vehicles. It is possible to regulate the power flow between the sources in several ways. The most common and straightforward method is to use a PI controller. Although it has the advantage of removing offset from proportional control, it also has the drawback of having a limited range of stability. As a result, a fuzzy-based control topology is suggested for a fuel cell and supercapacitor hybrid storage system.

The paper's content section is organized as shown below. The modelling of energy sources is covered in Section 2. Section III presents the mathematical modelling of a hybrid electric vehicle. The use of fuzzy logic controllers is covered in section four. The vehicle's operation with fuel cell and supercapacitor as hybrid energy storage is done in the final portion, and the results are analyzed.

II. Fuel Cell-Supercapacitor Hybrid Ev Architecture (Fc-Sc HEV)

Conventional vehicles are powered by IC engines, while electric machines power EVs. A vehicle can be made as a hybrid in many ways. This section describes the hybrid nature of the source, as in Fig.1. the source side is made as a hybrid by using a fuel cell and supercapacitor [3,6]. DC-DC converters associated with the energy source allow for keeping the constant DC link voltage.

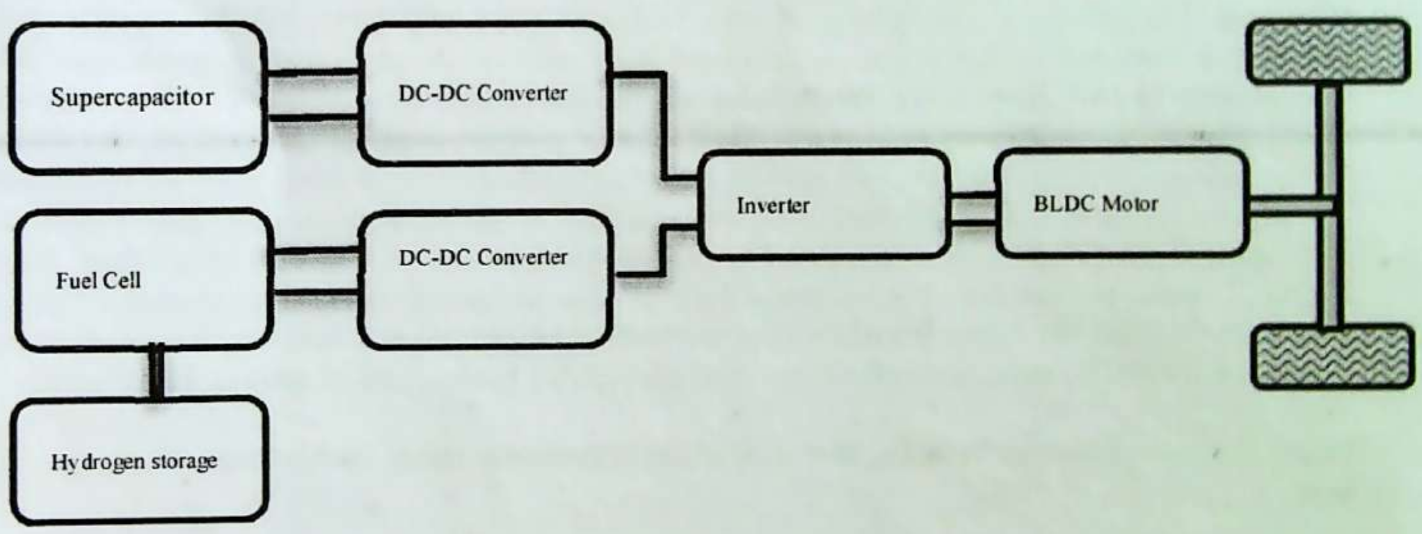

Figure.1. FC-SC Hybrid EV architecture

BLDC motor is used for the propulsion. BLDC is an ac machine with all advantages of a dc machine. Even though it is a brushless DC machine, the stator windings of the machine need ac supply since it is commutating electronically. The inverter converts energy to the required form [3,7-9].

III. Mathematical Modelling of the System

The following section covers details of the modelling of the vehicle, BLDC motor, inverter, boost converter, battery and fuel cell, and supercapacitor

A. Vehicle Model

Tractive power is the amount of power delivered to the vehicle model. The tractive power (or tractive force) is used to overcome the opposing forces like rolling resistance, gravitational force, aerodynamic drag force and gradient force. The total tractive force of a vehicle is expressed as

$$F_{TR} = F_{roll} + F_{aero} + F_{gt} + F_{acc} \quad (1)$$

B. BLDC Motor Modelling

BLDC motor is a conventional DC motor with semiconductor devices. The characteristics of BLDC and DC motors are the same when considering the power supply. Moreover, The external power input to the BLDC system is DC. The stator winding of the BLDC is exciting with the AC supply. Moreover, the stator produces a rotating magnetic field which causes the production of torque in the magnetic rotor. The stator and rotor rotate at the same speed and do not possess any slip. Hence the BLDC motor is an AC synchronous machine. The only difference is that the back emf of the AC machine is sinusoidal in place of trapezoidal or rectangular in the BLDC motor. Equivalent circuit model of the BLDC motor is shown in Fig.2.

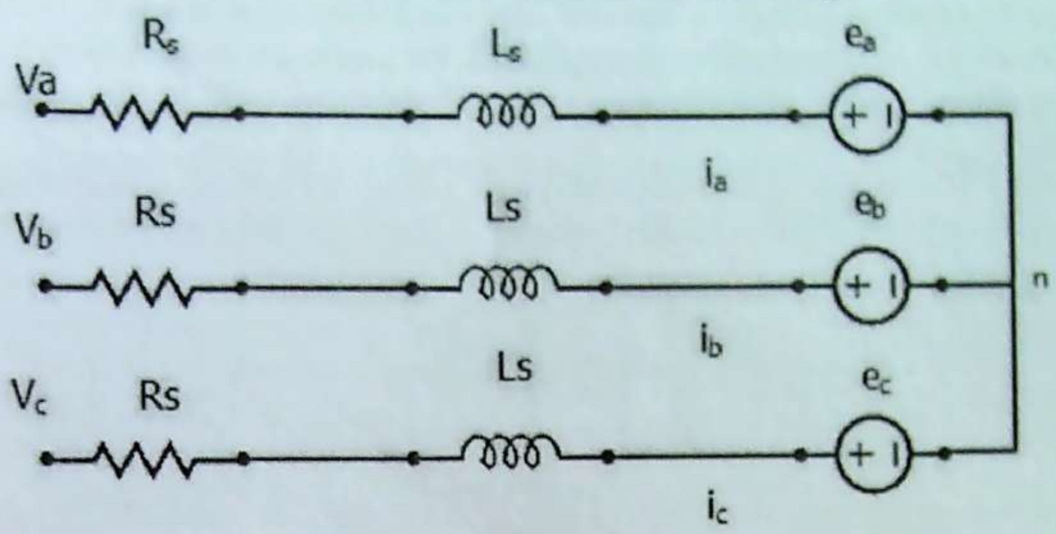

Figure.2. BLDC motor equivalent circuit model

From the equivalent circuit,

$$V_a = R_s i_a + (L - M)\frac{di_a}{dt} + e_a \quad (3)$$

$$V_b = R_s i_b + (L - M)\frac{di_b}{dt} + e_b \quad (4)$$

$$V_c = R_s i_c + (L - M)\frac{di_c}{dt} + e_c \quad (5)$$

Electromagnetic torque also related with the motor constant and the product of current and rotor position.

$$T_e = k_t\{f_a(\theta) * i_a + f_b(\theta) * i_b + f_c(\theta) * i_c\} \quad (6)$$

C. Inverter Model

A three-phase inverter is required at the front end of a BLDC motor because it is an electronically commutated motor. The inverter converts the DC input to an AC output. Hall sensors offer the data required to synchronize the motor excitation with the rotor position. Pulses for the switches are created based on the rotor position collected from the hall sensors. The three stator windings are connected to the three legs in a star pattern. The control pulses are timed so that only two stator windings are energized at any given moment.

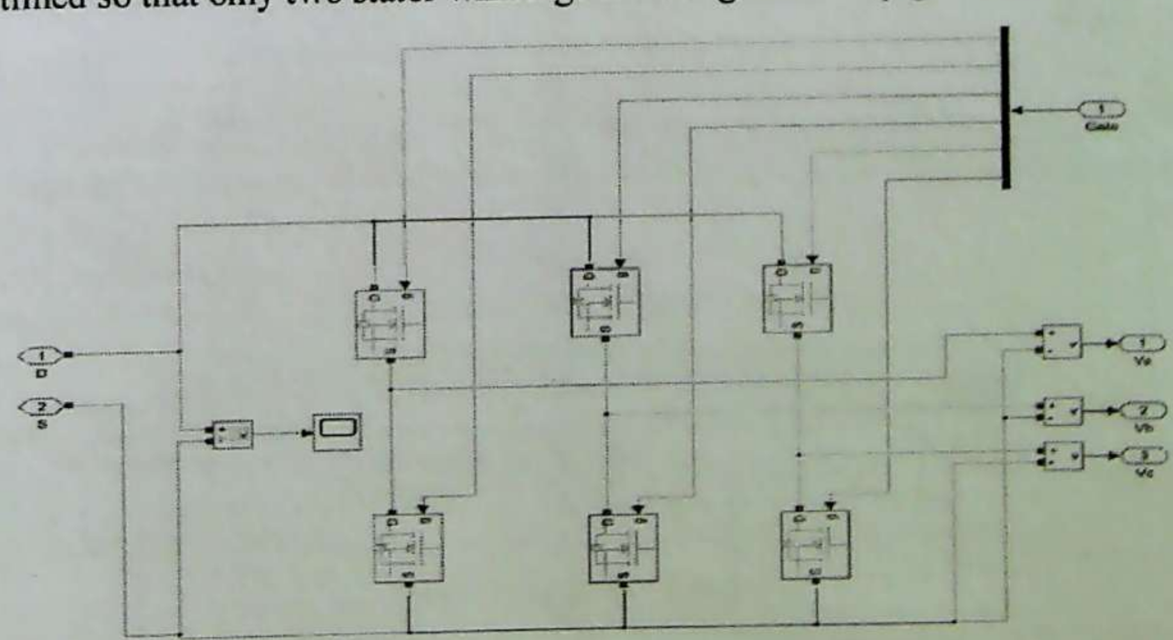

Figure.3. Inverter Model

D. Converter Model

A boost (acceleration period)/buck (regeneration period) converter (bi-directional converter) may be utilized between the source and the inverter in an EV system, particularly for low voltage battery systems. Usually, the energy source in a Light Motor Vehicle (LMV) system such as a car or a threewheeler will be in the low range (about 60V, and in heavy vehicles can be in the order of 350V), and the inverter DC input voltage required will be in the 400-500V range. The converter is used to match the AC voltage requirement of the propulsion motor.

E. Fuel Cell Model

Instead of burning fuel to produce energy, a fuel cell uses electrochemical reaction. Hydrogen and oxygen are combined to create electricity, heat, and water in a fuel cell. Fuel cells are employed in a wide range of modern applications, including the powering of residences and workplaces as well as the propulsion of automobiles, buses, trucks, forklifts, and trains.

The fuel cell is an energy source that is reliable, clean, and silent. Additionally, fuel cells may keep producing energy as long as a fuel source is available, unlike batteries, which need to be periodically recharged [10-11].

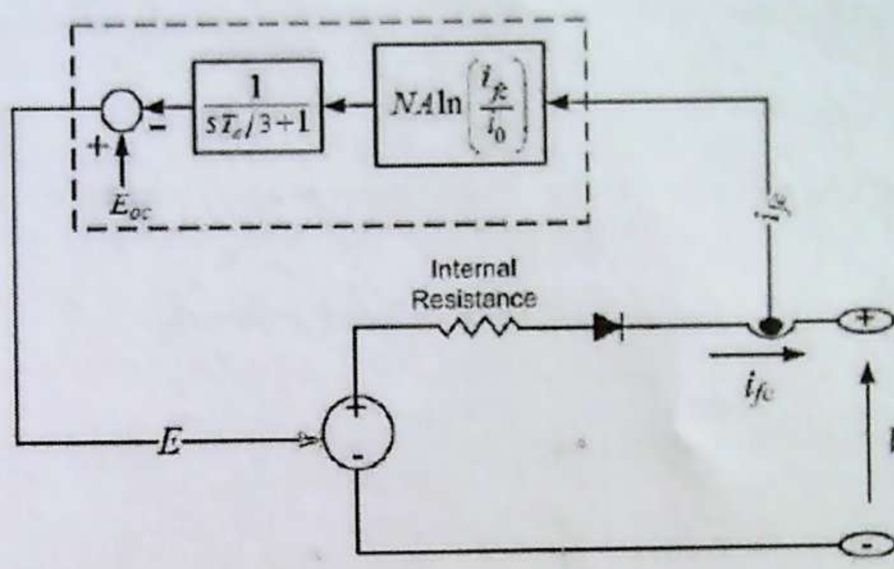

Figure.4. Equivalent Circuit of Single Cell fuel Stack

Anode, cathode, and electrolyte membrane are the three main components of a fuel cell. In a typical fuel cell, hydrogen and oxygen are provided by the anode and cathode, respectively. Utilizing a catalyst at the anode, electrons and protons are created from hydrogen molecules. Protons are transported via a porous electrolyte membrane, while electrons are forced through a circuit, producing an electric current and much heat. Protons, electrons, and oxygen combine to form water molecules at the cathode. Since they include no moving parts, fuel cells are highly reliable and quiet.

F. Supercapacitor Model

A supercapacitor (SC) is a capacitor with a capacitance value of more than ordinary capacitors but with lower voltage constraints. Supercapacitors are distinguished from standard capacitors based on the fast charge-discharge rates, longer life cycles, high power, and high energy density [12-15]. The model of the supercapacitor model is shown in Fig.8.

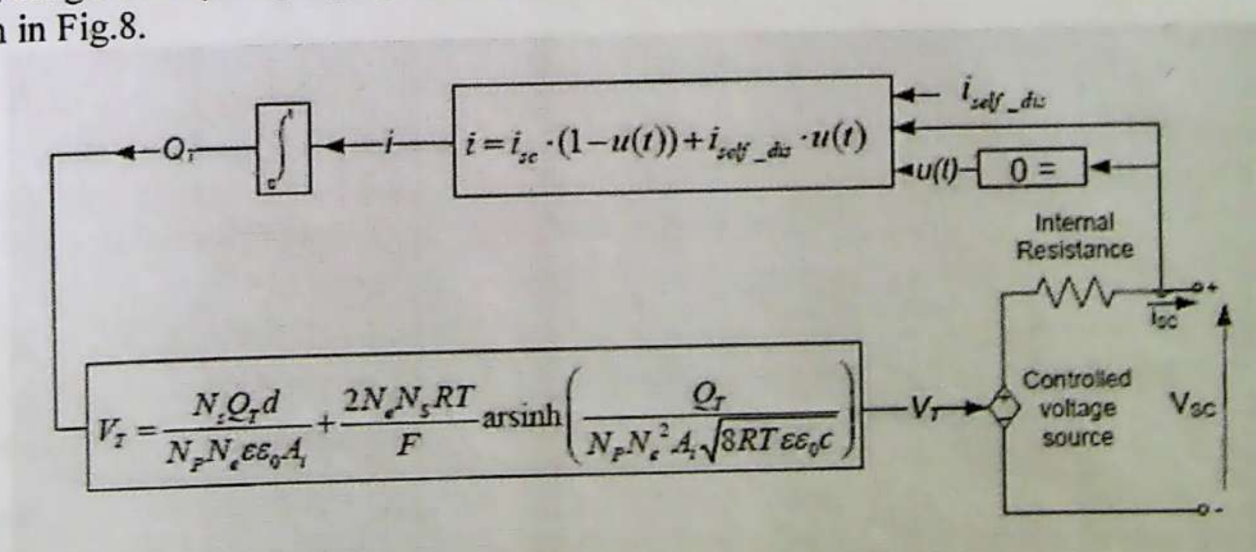

Figure.5. Supercapacitor model

IV. Fuzzy Logic Approach

A fuzzy logic controller is used to properly select the energy storage based on the supercapacitor State of Charge (SoC) and driving profile. The control strategy is shown in Fig.6.

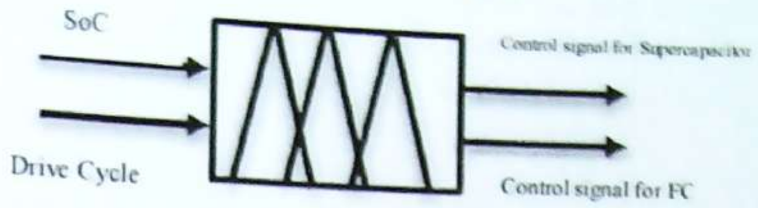

Figure 6 Fuzzy Logic Control strategy

Rules are developed based on the charge level and drive cycle. Then, the control logic is created so the fuel cell can give all the needed power during the low battery charge stage. In Fig. 7, the fuzzy logic system is depicted.

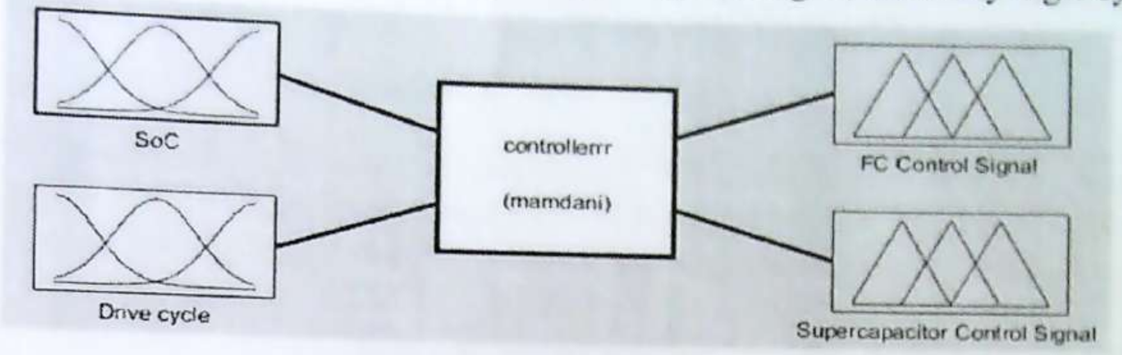

Figure 7 Proposed fuzzy logic system

For vehicle analysis and fuzzy logic implementation, the NEDC City drive cycle is chosen. When the supercapacitor's state of charge is greater than the required minimum threshold, it is used to supply power. The fuzzy controller rules are created so that the fuel cell will supply the necessary voltage when the required state of charge and speed is low. Additionally, the battery will help the fuel cell based on the charge level when the speed demand rises, and the battery has enough charge. Figure 8 displays the inputs' surface plot.

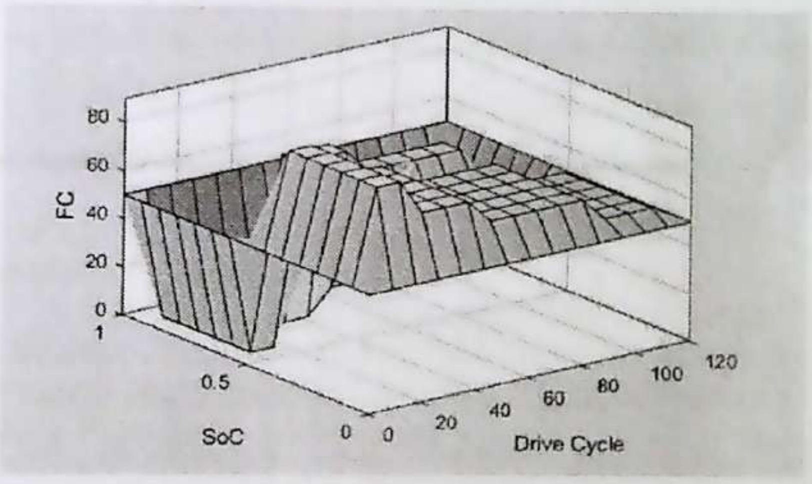

Figure.8. Surface Plot

V. Simulation Results

In order to simulate the suggested fuzzy logic-based hybrid energy storage system, MATLAB software is used. In addition, a modified NEDC drive cycle is used to test the vehicle's performance while considering the driving patterns of Trivandrum, Kerala.

TABLE I. Vehicle Modelling Parameters

Vehicle Parameters		
Parameter	Value	Unit
gross vehicle weight (gvw)	1700	Kg
Gravitational constant (g)	9.81	
Air density (gama)	1.225	
Frontal area of the vehicle (Av)	1	sq.m
aerodynamic drag coefficient (CD)	0.55	
wheel radius (whr)	0.32	m
Rolling coefficient (C0)	0.025	

The hybrid source fuel cell and supercapacitor provide the energy needed to run the BLDC motor. At the DC link, the hybrid source's power is available and delivered to an inverter. The BLDC motor receives energy from the inverter and provides the necessary tractive power to move the vehicles. The analysis uses a car with a 1700 kg gross vehicle weight. Figures 10 and 11 illustrate the total tractive power given, the total tractive power needed by the vehicle to follow the drive cycle, and the consequent wheel speed.

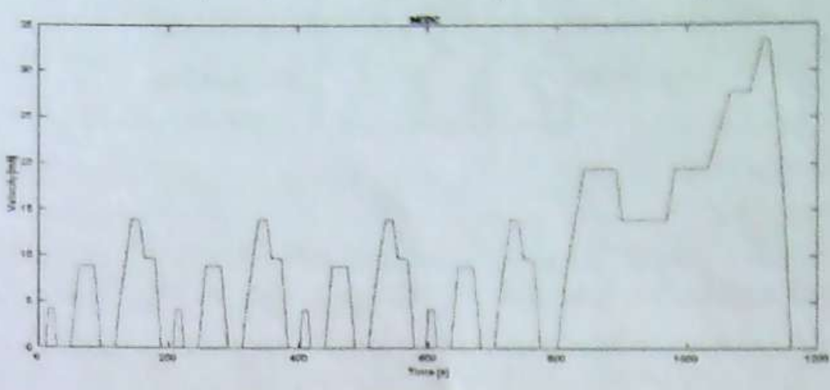

Figure.9. NEDC Drive Cycle

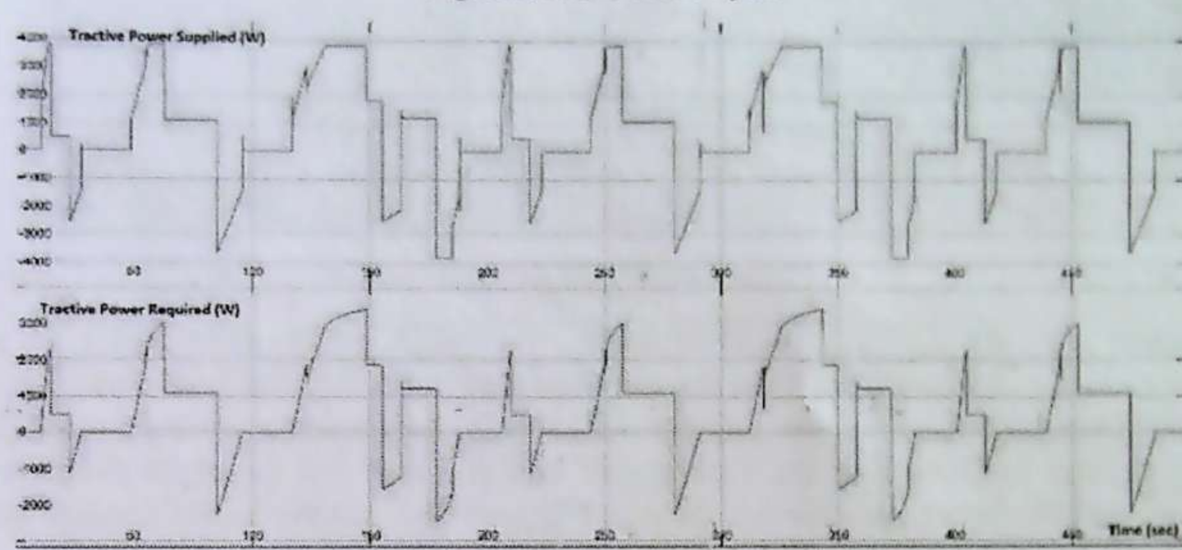

Figure.10. Tractive power supplied and tractive power required for the vehicle

The system simulation is analysed by considering the fuel cell alone and the hybrid source with the combination of fuel cell and supercapacitor. Table.2 shows the performance comparison.

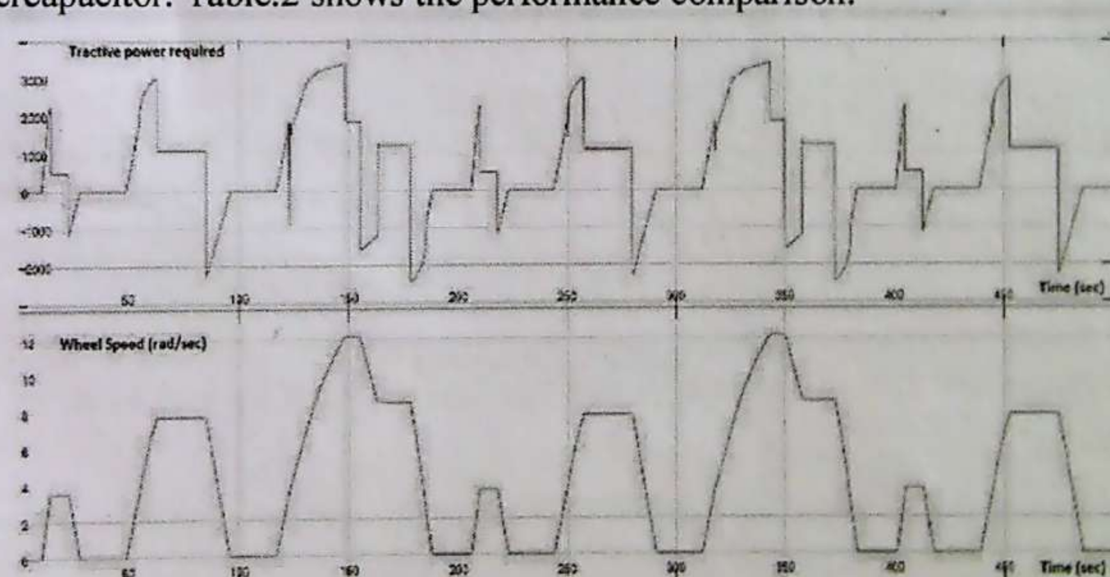

Figure. 11: Tractive Power Requirement and Wheel Speed of Vehicle

TABLE II. PERFORMANCE COMPARISON

Mode of operation	Power rating of the source required	Driving range
Fuel Cell alone	50kW	80kmph
Fuel Cell + Supercapacitor	48kW+3.8kW	85kmph

By examining the drive cycle, the energy capacity of the sources is chosen. The hybrid operation and power flow management are achieved by the fuzzy logic controller. The fuzzy logic controller takes the supercapacitor's charge level and drive cycle as input. Figure 12 depicts the supercapacitor's state of charge.

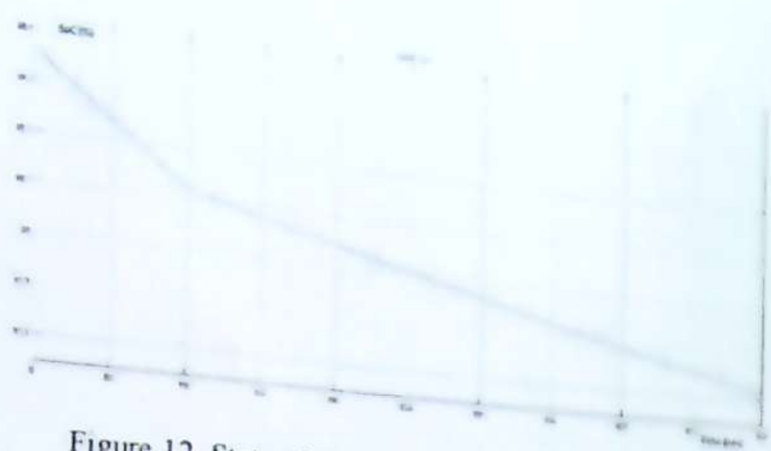

Figure 12 State of Charge of Supercapacitor

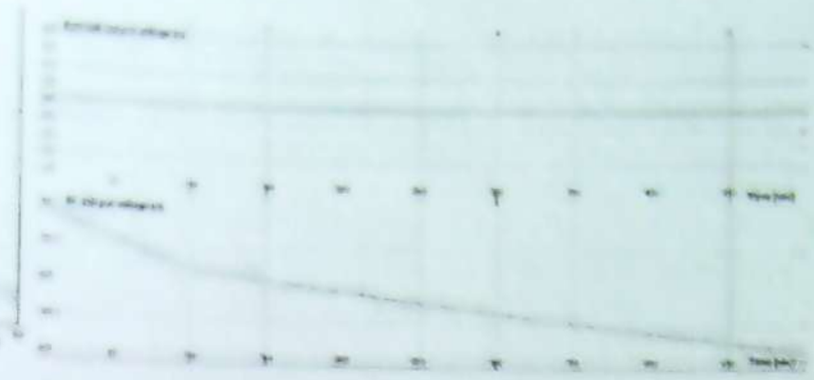

Figure 13 Output Voltage of Supercapacitor and Fuel Cell

Figure 13 illustrates the voltage output of a hybrid energy storage system based on a fuzzy logic controller. Results indicate that the fuzzy based control logic that has been suggested is appropriate for any such uncertainty behaviour in the drive cycle of

VI. Conclusion

The article describes the modelling of a hybrid electric car with fuel cells and supercapacitors as well as an adaptive control approach for enhancing the performance of a hybrid vehicle in a drive cycle with unpredictable variations. The effectiveness of the suggested fuzzy-based control technique is evaluated for several test cases. A car with a fuel cell and supercapacitor hybrid powertrain offer superior energy source sizing and a sufficient energy supply system for erratic load changes. The supercapacitor and fuel cell selection are made according to the power requirement, and the adaptive controller could satisfactorily manage the selection of the storage devices. The suggested fuzzy logic controller accomplishes a hybrid operation and power flow management. The efficiency of the designed control topology is evaluated using various drive cycles in a hybrid vehicle configuration. The efficacy of the controller under frequent acceleration and deceleration changes has been tested, and the result shows that the proposed control strategy improves the driving range by 3-4%. The result shows that fuzzy-based topology can effectively manage the operation of fuel cells and supercapacitors on any drive cycle. The results indicated that a fuzzy based approach could handle supercapacitors and fuel cells efficiently on any drive cycle. The future scope of the work upholds the development of a suitable energy management strategy for a hybrid storage system.

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Sanction order	Amount Sanctioned - 7500 /-

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REQUEST LETTER FOR FINANCIAL SUPPORT

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PRN	FEE041
Department:	EEE
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Out come/Output for the funding	Indexed paper ✓/Patent/Others specify
Details of attachment	1.Project proposal 2.Participation certificate 3.Paper acceptance letter(or published paper) ✓ 4.PhD registration certificate 5.Others specify

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Fuzzy Based Hybrid Control Topology for Fuel Cell and Battery Powered EV

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***Abstract*—The green energy revolution showcases the potential of hydrogen-powered vehicles. Moreover, hybrid energy sources are replacing the conventional energy supply system of the electric vehicle. In this context, this paper presents a fuel cell and battery-powered hybrid vehicle topology. The paper describes the mathematical modelling of a fuel cell-powered hybrid EV power train. Since a fuel cell is an energy supplier only, it requires secondary storage, like a battery. The battery can store energy during regenerative operation. A practical drive cycle generally involves uncertainty in the driving pattern on various roadways. Uncertainty in the drive cycle needs an adaptive control strategy for the performance improvement of EVs. A fuzzy logic-based control algorithm for effective utilization of energy storage units is developed. The result shows that the proposed fuzzy control is effective in the city drive cycle, which has the characteristics of frequent starting, stopping and acceleration. The potency of the proposed control strategy is validated with a case study using a modified drive cycle considering the driving pattern of Trivandrum, Kerala. The result shows that the fuzzy-based control strategy results in a significant improvement in driving range.**

***Index Terms*—Electric Vehicle, fuel cell, super capacitor, drive cycle, state of charge, fuzzy logic**

I. Introduction

Fuel Cell powered Electric Vehicles are one of the promising forms of vehicles in the upcoming future of transportation sector due to its features like long driving range, high energy efficiency, and zero emission, it does not run down or needs recharging. Fuel cells can produce electricity and heat as long the fuel is supplied. It is an energy supplier not an energy storing device. So, fuel cells always need secondary storage like a battery for regenerative energy storage and assisting the vehicle operation in the needy time. Hence fuel cell-powered vehicles are always hybrid. The use of fuel cells or hydrogen powered vehicles reduces the dependency on fossil fuels and contributes to the green energy revolution.

The green energy revolution is going on. Governing bodies of various nations support green energy sources for transportation sector. Government of India has also taken several initiatives to support the progress of hydrogen powered vehicles. The government of India Ministry of Power, on 17th February 2022, released a policy on green hydrogen and green ammonia. Hydrogen and ammonia are the future fuels that will eventually replace fossil fuels. Green hydrogen and green ammonia mean the production of hydrogen and ammonia by utilizing the power from renewable energy sector. This are one of the major requirements towards environmentally sustainable energy security of the nation. Therefore, the transition from fossil fuel/ fossil fuel-based feedstock to green hydrogen/ green ammonia has become a requirement [1]. R&D programme on Hydrogen Energy and Fuel is also supported by the Ministry of New and Renewable Energy [2].

Pure battery vehicles are the better alternatives for reducing fossil fuel dependencies. Hybrid Vehicles are also a solution to reduce fuel dependencies. Hybrid source systems can take power from any source, based on operational and performance characteristics. Hybrid electric vehicles are the very good examples of dual source systems or hybrid source systems. Depending upon the powering nature of hybrid sources many configurations are available. However, the major challenge is to manage the power flow from the source to the wheel with a minimum fuel consumption and pollution rate. The complexity of the vehicle configuration demands an intelligent and efficient hybrid controller to ensure consistent and stable operation of the vehicle.

A control strategy is required for satisfactory fuel cell and battery-powered hybrid electric vehicles [3-7]. The control of power flow among the source can be achieved in various ways. The most common and simple method is the use of a PI controller. The method has the advantage of eliminating offset in proportional control, and also, at the same time, it has the problem of a narrow range of stability.

The control strategies used for vehicle control can be broadly classified into the following categories 1) Experimental methods based on laboratory results 2) Optimal control 3) Intelligent methods like a fuzzy, neural network ...

Controller is the overall manager of the whole power train, which decides how to distribute the power flow among the sources. The controller should decide so that the vehicle performance should meet the expected driving criteria and cover all driving criteria[8-10].

Hence, a fuzzy-based control topology for a hybrid storage system with the fuel cell and the battery is proposed in this

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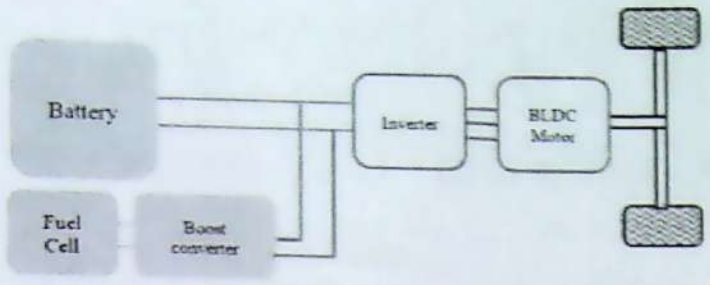

Fig. 1: Hybrid EV Architecture

paper. The content of the paper is structured as follows section two describes the hybrid EV configuration. In section three, mathematical modelling of hybrid electric vehicle is presented. Fuzzy logic controller implementation is discussed in section four, and in last section operation of the vehicle with fuel cell and battery as hybrid energy storage and results are analysed.

II. HYBRID EV CONFIGURATION

Conventional vehicles and Electric Vehicles differ in their powering system. In an electric vehicle, the entire traction power required for the operation is solely provided by the electric machine, while in conventional vehicle, it gets power from IC engines [11-13]. The use of more than one source makes the system a hybrid one. Furthermore, different topologies are available for the hybrid configuration. The system used for the work is shown in Fig.1.

Here batteries and fuel cells are used as energy sources and thus making the system hybrid [14-16]. A boost converter is used with the fuel cell to match the voltage of the fuel cell with the battery. The inverter converts the dc power into ac and supplies it to the BLDC motor. BLDC motor provides the necessary tractive power to propel the vehicle forward [17].

III. MATHEMATICAL MODELLING OF THE SYSTEM

Mathematical modelling of the system is inevitable in the development phase. The modelling of the vehicle, BLDC motor, inverter, boost converter, battery and fuel cell is described below.

A. Vehicle Model

The main force for the motion of an EV is obtained from the traction unit or propulsion unit. Moreover, various forces are acting in opposition to the vehicle movement. Therefore, vehicle dynamics play an integral role in vehicle design and modelling, including the vehicle's acceleration, range, and speed.

Modelling of the vehicle dynamics can be of two types. One is lateral vehicle dynamics, and the other one is longitudinal vehicle dynamics. When a vehicle moves in a one-dimensional direction, it requires only longitudinal dynamics. On the other hand, lateral dynamics is required when it needs more than one direction.

The tractive force $F_t(t)$ helps to propel the vehicle forward by overcoming the forces rolling resistance, gravitational force, aero-dynamic drag force and gradient force (for level surface=0)

1) Aerodynamic Drag Force : The aerodynamic drag force is caused by viscous resistance and pressure distribution across the air body, which works against the vehicle's velocity.

The aerodynamic drag force is given by

$$\mathrm{F}_{aero} = 0.5 \times C_D \times A_v \times V^2 \times \gamma \quad (1)$$

Where,
γ = density of air in $\mathrm{kg/m^3}$
C_D= aerodynamic drag coefficient (typically $0.2<C_D<0.4$)
A_v= frontal area of the vehicle
V^2= vehicle velocity

2) Rolling resistance force: The hysteresis of the tyre material at the contact surface of the roadway causes the rolling resistance. The centroid of the vertical forces on the wheel shifts forward from beneath the axle towards the vehicle's motion when the tyre rolls. The weight of the wheel and the normal force are misaligned due to the hysteresis of the tyre. They exert a retarding torque on the wheel. Rolling resistance force opposes the motion of the wheel and is tangential to the road, assisting in breaking and retarding motion of the vehicle. It can be reduced by keeping the tyres as enacted as possible and reducing hysteresis.

The rolling resistance force can be written as

$$\mathrm{F}_{roll} = C_0 \times m \times g \quad (2)$$

For a sloppy area

$$\mathrm{F}_{roll} = C_0 \times m \times g \times \cos\theta \quad (3)$$

Where,
C_0=coecient of rolling resistance
m= vehicle mass in kg
g= acceleration due to gravity $\mathrm{m/s^2}$

3) Gravitational force: The gravitational force is affected by the slope of the road. The force is positive when climbing a hill; when descending a descent, the force is negative. The gravitational force to be overcome by the vehicle moving forward is

$$\mathrm{F}_{gt} = m \times g \times \sin\beta \quad (4)$$

Where,
m= vehicle mass in kg
g= acceleration due to gravity $\mathrm{m/s^2}$
β=grade angle

4) Acceleration force: Force required for the linear acceleration, or when we need to change the vehicle velocity, then the force required is the acceleration force, it is given by

$$\mathrm{F} = m \times a = m \times (dv/dt) \quad (5)$$

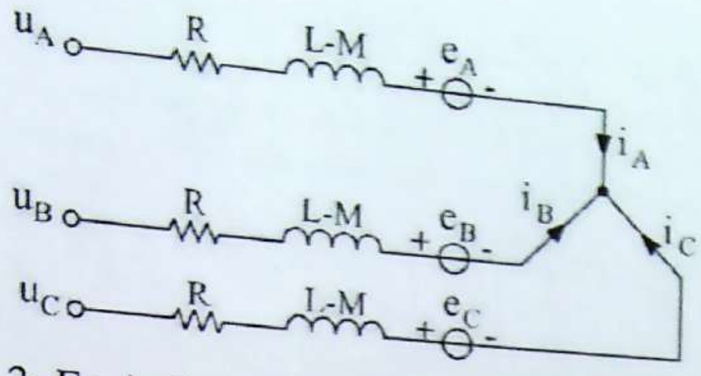

Fig. 2: Equivalent Circuit Model of BLDC Motor

So the total tractive forces required to support and accelerate the vehicle can be written as

$$F_{TR} = F_{roll} + F_{aero} + F_{gt} + F_{acc} \quad (6)$$

Where,
F_{TR} = Tractive force (N)
F_{roll} = Rolling resistance force
F_{aero} = Aerodynamic drag force
F_{gt}= Accelerating force
F_{acc}= Gravitational force

Vehicle modelling is completed with the parameters given in Table.1.

Table I: Vehicle Modelling Parameters

Parameters	Value	Unit
gross vehicle weight (gvw)	1700	Kg
Gravitational constant (g)	9.81	
Air density (gama)	1.225	
Frontal area of the vehicle (Av)	1	sq.m
aerodynamic drag coeeficient (CD)	0.55	
wheel radius (whr)	0.32	m
Rolling coefficient (C0)	0.025	

B. BLDC Motor Modellling

BLDC motors are becoming increasingly common machines. They are commutated electronically, have a high power density, and are simple to control. It consists of a permanent magnet rotor (eg Alnico, ceramic, NdFB etc.) and a three phase wound field stator. The emf induced in the stator winding is trapezoidal. Stator winding is energized from a voltage source inverter. The switches of the inverter are controlled in such a way that only two of the three windings are energized at a time. For the proper switching of the inverter, rotor position sensing is essential. Furthermore, the absence of brushes reduces the motor length, so it can be used in applications where the size of the machine is a critical factor.

From the equivalent circuit,

$$V_a = Ri_a + L(di_a/dt) + e_a \quad (7)$$

$$V_b = Ri_b + L(di_b/dt) + e_b \quad (8)$$

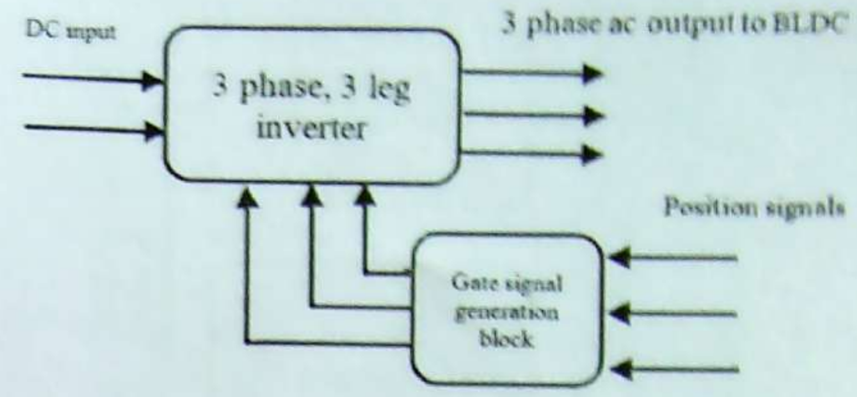

Fig. 3: Inverter Block Diagram

$$V_c = Ri_c + L(di_c/dt) + e_c \quad (9)$$

Where,
L is self-inductance of the armature [H],
R - resistance of the armature Ω,
Va, Vb, Vc - phase voltage [V],
ia, ib, ic - input current to the motor [A], and
ea, eb, ec - back-EMF of the motor [V].
from above

$$i_a = (V_a - e_a)/(R + sL) \quad (10)$$

$$i_b = (V_b - e_b)/(R + sL) \quad (11)$$

$$i_c = (V_c - e_c)/(R + sL) \quad (12)$$

Torque

$$T_e = (e_a * i_a + e_b * i_b + e_c * i_c)/\omega \quad (13)$$

$$T_e - T_l = J(d\omega/dt) + B\omega \quad (14)$$

Where,
Tl is torque of the load [Nm],
J - rotor and coupled shaft inertia [kgm2],
B - friction constant [Nms.rad-1]

The torque and power required for the vehicle is providing by the motor for propelling the vehicle. The motor requirement is shown in Table.2.

Table II: Performance requirement of Motor

Parameters	Value	Unit
Peak Torque of motor	364.8318	Nm
Motor speed	2381.568	rpm
Motor power	79.61783	kW

C. Inverter Model

The basic three leg inverter topology is considered. The switching pattern for the inverter switches are generated from the rotor position. Hall sensors are used for sensing the rotor position. Based on the position of the rotor, control signals for the inverter switches are generated. The block diagram of the inverter model is shown in Fig.3.

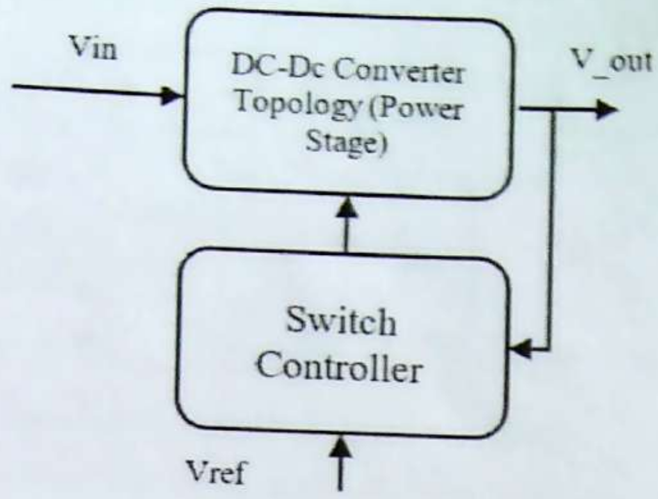

Fig. 4: Block Diagram of Converter

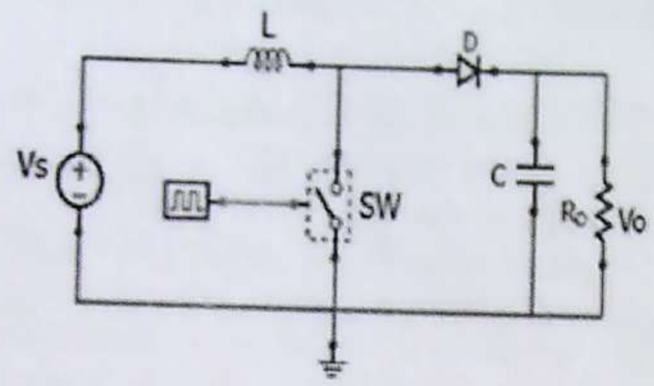

Fig. 5: Boost Converter

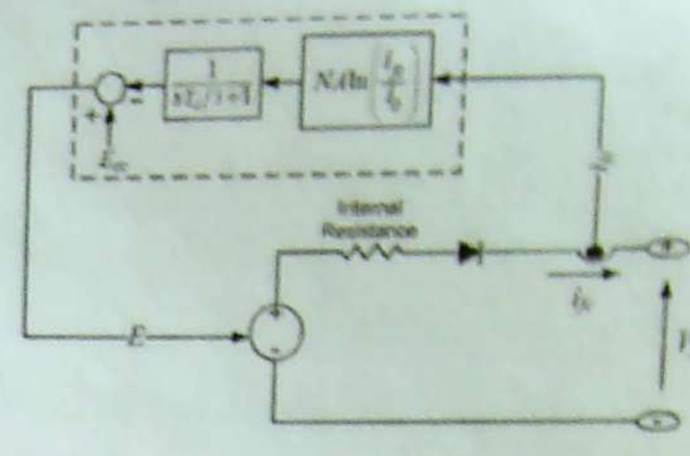

Fig. 6: Equivalent Circuit of Single Cell Fuel Stack

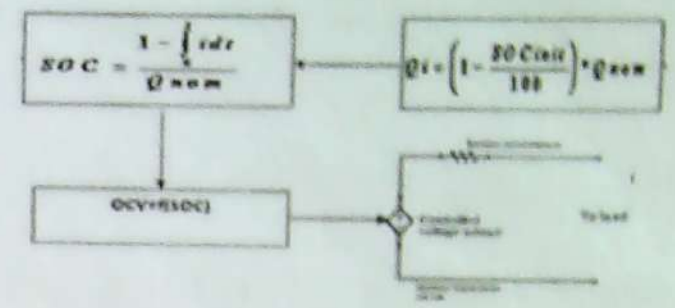
Fig. 7: Single Cell Battery Model

D. Converter Model

The majority of DC-DC converters are made up of two functional components. The first is the power stage, while the second is the switch controller. The power stage converts the source voltage to the desired load voltage by rectifying and filtering it. For chopping operations, the switch controller transmits command or control signals. The output of the switch controller determines the duty ratio of the overall converter. The block schematic of a DC-DC converter is given in Fig.4.

A boost converter is used in series with fuel cell to make the dc output voltage the same as the voltage level of the dc link. The circuit model of the boost converter is shown in Fig.5.

In case of the boost converter the input voltage and output voltage are related as

$$V_o = (V_in)/(1 - D) \tag{15}$$

Where D is the duty ratio of the converter circuit.

E. Fuel Cell Model

A fuel cell is a device that creates electricity by electrochemical reaction rather than burning. A fuel cell produces electricity, heat, and water by combining hydrogen and oxygen. Fuel cells are utilized in a variety of applications today, including providing power to homes and businesses, keeping important facilities such as hospitals, grocery shops, and data centers operational, and moving a variety of vehicles, such as cars, buses, trucks, forklifts, trains, and more. Fuel cell devices are a stable, clean, and silent energy source. Fuel cells, unlike batteries, do not require periodic recharge and can continue to create energy as long as a fuel source is available.

A fuel cell consists of an anode, cathode, and electrolyte membrane. In a conventional fuel cell, hydrogen is supplied through the anode and oxygen via the cathode. Electrons and protons are produced at the anode from hydrogen molecules by using catalyst. A porous electrolyte membrane carries the protons, while electrons are driven through a circuit, resulting in an electric current and excessive heat: protons, electrons, and oxygen mix at the cathode to form water molecules. Fuel cells are highly quiet and dependable since they have no moving parts.

F. Battery Model

The portable electrical energy source is one of the criteria of the electric vehicle. Vehicles use batteries as a portable source of energy. One or more electrochemical cells are used to produce electrical energy from chemical energy by electrochemical reaction. The cells are connected in series and parallel to form a battery bank to obtain the desired voltage level. The State Of Charge is usually the parameter of interest when modelling a battery (SOC). The SOC indicates how much energy is left in the battery as compared to its total capacity. The modelling can be done in different ways. Here modelling is finished so that current and SOC are used to express the battery's voltage. A good battery performance prediction has many advantages. It extends the battery's life by preventing overcharging and discharging, permitting the battery's full capacity, and allowing the user to see how much energy is left in the battery pack. The fig 7 shows the model of a single cell battery.

Generally, the single cell battery model is connected in series and parallel to obtain the required voltage level, which results in a battery bank. Hence the above single cell model can be extended to the battery bank by connecting several cells in series and parallel.

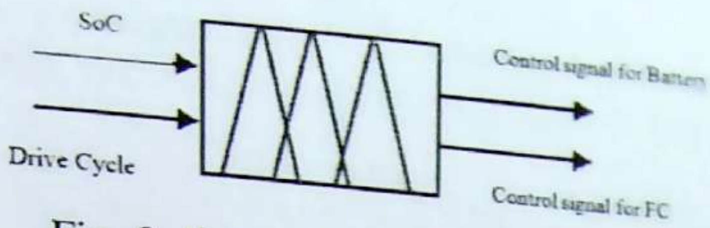

Fig. 8: Fuzzy Logic Control Strategy

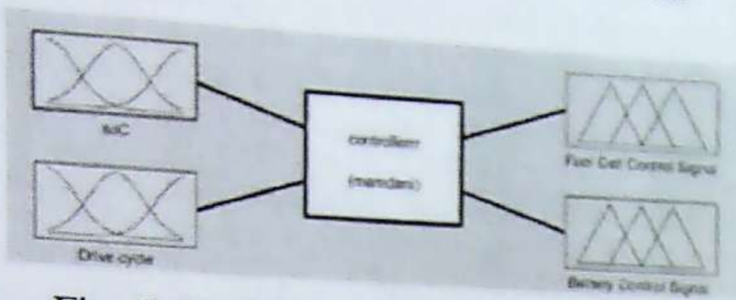

Fig. 9: Proposed Fuzzy Logic System

IV. FUZZY LOGIC APPROACH

Fuzzy logic controller is used to properly select the energy storage based on the State of Charge (SoC) of the battery and driving profile. The control strategy is shown in Fig.8.

Based on the state of charge and drive cycle, rules are formulated. Control logic is developed so that during the low state of battery charge, the supply for the power demand can be met by the fuel cell alone. The fuzzy logic system is shown in Fig.9.

City drive cycle NEDC is selected for vehicle analysis and fuzzy logic implementation. The battery is used for supplying the power when the state of charge is above the specified minimum threshold. The rules for the fuzzy controller are developed such that when the state of charge and speed required are low, then the fuel cell will provide the required voltage. Furthermore, when the speed requirement increases and the battery has sufficient charge, that source will also assist the fuel cell depending on the charge level. The surface plot for the inputs is shown in Fig.10.

V. SIMULATION RESULTS

The simulation experiment is done in MATLAB software for the proposed fuzzy logic-based hybrid energy storage system. The performance requirement of the selected vehicle is shown in Table.3.

The vehicle performance is analysed with a modified NEDC drive cycle considering the driving pattern in the Trivandrum city in Kerala.

The power required for the operation of the BLDC motor is supplied by the hybrid source fuel cell and battery. The

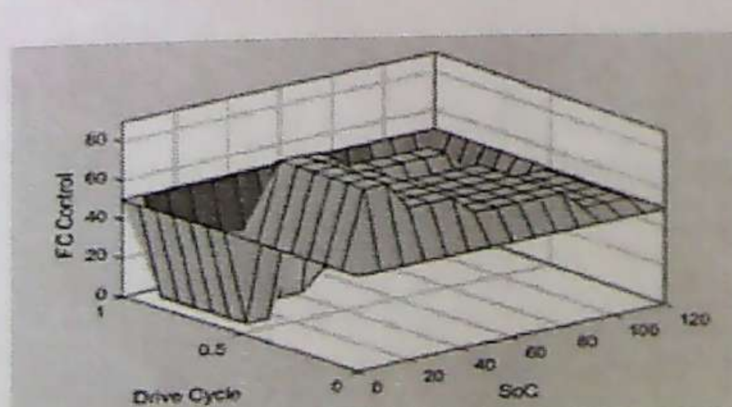

Fig. 10: Surface Plot

Table III: Performance Requirement

Parameters	Value	Unit
Vehicle speed (kmph)	120	kmph
acceleration a at given kmph	5.554	
wheel speed (Wwh)	104.1667	rad/sec
Froll	416.925	N
Faero	374.3056	N
Fgt	0	N
Faccresistive	680	N
Facc	9441.8	N
FTR	10913.03	N

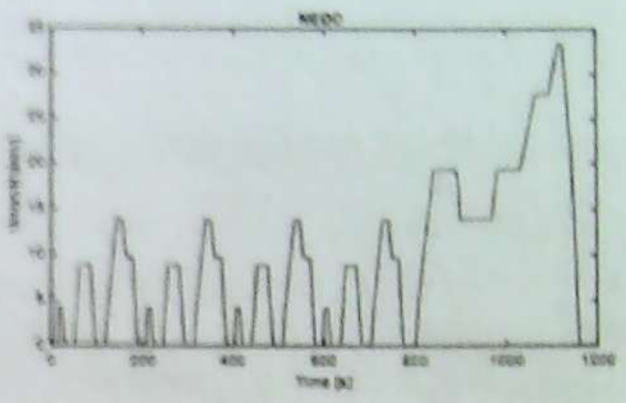

Fig. 11: NEDC Drive Cycle

power from the hybrid source is available at the DC link and which is given to an inverter. The inverter supplies the power to the BLDC motor, and motor drives the vehicles by supplying required tractive power. A vehicle with a gross vehicle weight of 1700 kg is used for the analysis. The total tractive power required by the vehicle to follow the drive cycle and resulting wheel speed are shown in Fig.12.

The performance of the vehicle is analyzed in three different cases. In the first case, the battery alone is considered as the driving source, and the second case fuel cell alone is treated and the third case hybrid source of battery and fuel cell is used. Table.4. illustrate the performance comparison of three modes of operation

Table IV: Performance comparison

Case	Power rating required for the source
Battery alone	30 kWh
Fuel Cell alone	29 kW
Battery + fuel Cell	22.45 kWh +6 kW

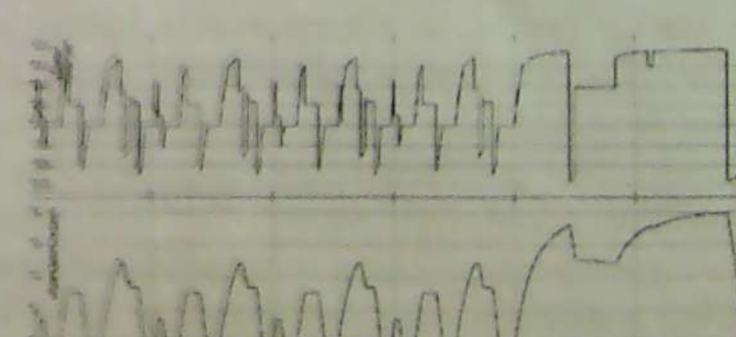

Fig. 12: Tractive Power Requirement and Wheel of Vehicle

Fig. 13: State of Charge of Battery

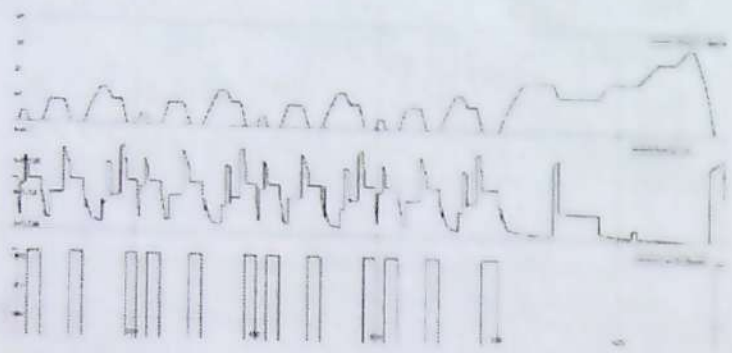

Fig. 14: Drive cycle and Voltage Output of Battery and Fuel Cell

The energy capacity of the sources is selected by analyzing the drive cycle. The fuzzy logic controller achieves hybrid operation power flow control. The drive cycle and state of charge of the battery are taken as the input by the fuzzy logic controller. The variation of the state of charge of the battery based on the drive cycle is shown in Fig.13.

The voltage output of hybrid energy storage system based on the fuzzy logic controller is shown on Fig.14.

Results shows that proposed fuzzy based control logic is suitable to any such uncertainty behaviour in the drive cycle of any vehicle.

VI. CONCLUSION

The article presents the modelling of a fuel cell and battery-powered hybrid electric vehicle and an adaptive control strategy for performance improvement of a hybrid vehicle in a drive cycle with random changes. Fuzzy logic was used to construct the controller due to the nonlinear effects of power train components on fuel consumption and the requirement of monitoring several parameters that must be adjusted at once.

The performance of the proposed fuzzy-based control strategy is tested for different test cases. The experiment was conducted with the battery alone, fuel cell alone and hybrid mode with a battery and a fuel cell. The results show that the required energy source capacity increases while operating with a single energy source such as a battery or fuel cell. Moreover, the driving range is limited when operated with a battery energy source. A vehicle with a hybrid source of batteries and fuel cells provides a better sizing of energy sources and is an adequate energy supply system for sudden load variations. The proposed fuzzy logic controller achieves hybrid operation power flow control. The developed control topology's effectiveness is tested with hybrid electric vehicle configuration in different drive cycles. Results show that fuzzy based topology can effectively manage the operation of fuel cells and batteries on any drive cycle. The work is continuing with development of various energy management strategies for fuel cell and Battery powered hybrid Electric Vehicle

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SANCTION LETTER

Manager,Vimal Jyothi Engineering college, Chemperi is pleased to sanction funding/incentives for the proposal as detailed below: -

Name of the Staff/faculty:	MS.Shelma George
Department :	EEE
Purpose:	Paper publication/Professional Boady membership/Participating FDP, Conference, Seminar/Patent/Travel Abroad/Travel Grant/PhD allowance/ Laptop loan/Others specify
Out come/Output for the funding	Indexed paper/Patent/Others specify
Relevance of this Funding	~~NAAC/NBA/NIRF~~/Others specify Staff welfare
Sanction order	Amount Sanctioned - 7500/-

Date: 03/01/2023

Manager

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REQUEST LETTER FOR FINANCIAL SUPPORT

Name of the Staff/faculty:	MS.Shelma George
PRN	FEE041
Department:	EEE
Purpose:	1.Paper publication 2.Professional Body membership 3.PhD allowance 4.Participating FDP, Conference, Seminar 5.Patent 6.Travel Abroad/Travel Grant 7. Laptop loan 8.Others specify
Out come/Output for the funding	Indexed paper/Patent/Others specify
Details of attachment	1.Project proposal 2.Participation certificate 3.Paper acceptance letter(or published paper) 4.PhD registration certificate 5.Others specify

Signature of the applicant

Date: 20/12/22

Ph: 0460 2212240, 2213399 E-mail: office@vjec.ac.in Website: www.vjec.ac.in

Signature Not Verified
Principal.VJEC

Fuzzy-Based Control Strategy for Supercapacitor Assisted Battery Powered EV

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***Abstract*—Hybrid Energy Storage Systems (HESS) are now being explored the most for performance improvement of EVs. HESS utilizes one or more energy storage systems, taking advantage of each. A hybrid topology of sources with complementary characteristics and an adaptive control strategy reduces battery-powered EVs' frequent charging and discharging need. In this context, a battery and supercapacitor combination with a fuzzy control strategy is proposed in this paper. Supercapacitors can handle peak power in short time intervals. The battery can supply loads continuously for extended periods. A tiny battery with a lower peak power output is all needed when using a hybrid system. The high power density of SC results in performance improvement with reduced battery size. The results show that the proposed fuzzy controller operates satisfactorily with a supercapacitor-assisted battery-powered EV. The frequent charging and discharging of the battery can be reduced, thereby improving the life span of the battery.**

***Index Terms*—Hybrid Energy Storage Systems (HESS), Supercapacitor, Battery, Electric Vehicle, Hybrid Electric Vehicle**

I. Introduction

The need to switch from fossil fuels to more sustainable energy sources is urgent. As a result of the fast rising amount of electricity being produced from unpredictable and variable sources, the energy landscape is drastically shifting. The rapidly growing awareness of energy storage is due to the degrading state of the energy market in developing nations and changes in the transportation industry [1-5].

Since most consumer electronics are powered by battery-like technologies and the use of renewable energy sources for electricity generation is expanding quickly, energy storage has emerged as one of the essential needs in industries.

The utilisation of this rechargeable electrochemical storage or battery technology is most frequently observed. A battery is a tiny, portable power source that can be placed anywhere and transforms electrochemical energy into electricity. Lead acid, redox flow, sodium sulphur, and lithium-ion are the most frequently used battery cells. Due to their long lifespan, high potential density, smaller weights, and less self-discharge, lithium-ion batteries are chosen over other battery technologies in various applications, aircraft, EVs, satellites, maritime systems, smartphones, computers, and other consumer gadgets.

Rechargeable batteries and SCs store and convert energy through ion diffusion and migration, and their chemical structures are generally comparable. However, the SCs offer a few benefits that will be helpful for storage systems. A double-layer electrochemical capacitor called an SC has a far higher energy storage capacity than a typical capacitor . Additionally, they have a long lifespan with virtually no losses [6]. They can conduct far more charge and discharge cycles than lead-acid batteries, which can only process a few thousand and produce much higher currents than batteries [7-9].

A control technique is needed for successful SC and battery-powered hybrid electric cars. The following categories can be used to categorize the control strategies used for vehicle control broadly:1) Experimental techniques based on lab findings 2) Optimal management 3) Intelligent techniques, such as a fuzzy neural network. The controller, who oversees the entire power train, selects how to divide the flow of power among the sources. The controller should make decisions to ensure that the vehicle's performance meets all driving and anticipated driving criteria. As a result, this research proposes a fuzzy-based control architecture for a hybrid storage system using an SC and a battery [10].

The content of the paper is organized as follows. Section two details the hybrid electric vehicle configuration. Section three thoroughly examines the physical and electrical properties, operating principles, benefits, and limitations of SCs, batteries, and their structural makeup. The mathematical modelling of a hybrid electric vehicle is described in section four, and the use of fuzzy logic controllers is described in section five. The operation of the vehicle with an SC and batteries as a hybrid energy storage system is examined in the last section.

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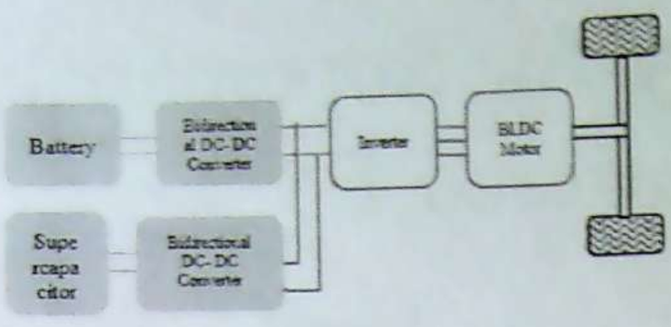

Fig. 1: Hybrid EV Architecture

II. ARCTITECTURE OF HYBRID ELECTRIC VEHICLE

The powering systems of conventional and electric automobiles are different. The only source of traction power in an electric vehicle is the electric machine, as opposed to conventional vehicles, which rely on internal combustion (IC) engines [11]. The system is hybrid because it uses multiple sources. Additionally, there are various topologies accessible for the hybrid arrangement. Fig. 1 depicts the system used for the project. Here, the system is hybrid because it uses batteries and SCs as energy sources [12-13]. The battery/SC may be used with a boost converter to match the voltage levels with the DC link. The BLDC motor receives the ac power that the inverter transformed from the dc electricity. BLDC motor offers the required tractive force.

III. ENERGY STORAGE SYSTEMS

A. Overview of Battery Technology

A battery is a collection of one or more electrochemical cells that can transform chemical energy that has been stored into electrical energy. A battery's chemical structure and composition will determine how much chemical energy it contains and, consequently, how much electrical energy it can produce. Additionally, it will determine the potential difference between the battery's poles.

The battery serves as an essential storage medium for energy in vehicles. It has been used for a while. The battery can be viewed from the perspective of the designer of an electric vehicle as a "black box" with various performance requirements. These standards will incorporate the following:

- specific energy
- energy density
- specific power
- typical voltages
- amp hour efficiency
- energy efficiency
- commercial availability
- cost
- operating temperatures
- self-discharge rates
- number of life cycles
- recharge rates

Additionally, the designer must know how energy availability fluctuates depending on factors like ambient temperature, charge and discharge rates, battery geometry, optimal temperature, charging techniques, and cooling requirements. However, it is crucial to have at least a fundamental grasp of battery chemistry to avoid most of the drawbacks associated with using batteries, including their short lifespan, self-discharge, and decreased efficiency at higher currents.

The main components of a battery are the anode, cathode, and separator. The anode is negatively charged, and the cathode is positive. The lithium ions flow in an electrolyte through a separator to the cathode in the lithium battery scenario. That leaves the negative charge of electrodes to the anode, and connecting load means that the electrons may travel from the anode to the cathode. In general, when there is no load connected to the battery, we will have an open circuit. And no electrons will be able to travel from the anode to the cathode [14-16].

B. Overview of Supercapacitor Technology

The capacitor is one of the fundamental components in circuit design. With capacitance serving as its most fundamental defining characteristic is the quantity of charge held per volt applied; that is, it stores an electric charge. Capacitors can be used various applications, such as in a radio receiver, to pick signals of interest by manipulating the pace and signals of interest, by manipulating the pace and manner by which they are charged and discharged.

Capacitors are used in power supply design because they store energy when charged. The development of supercapacitors centered enhancing the fundamental capacitor's capacity for energy storage and is opening up new possibilities in a range of power-related applications.

Supercapacitors, often referred to as ultracapacitors or electrochemical capacitors, make use of thin electrolytic dielectrics and high surface area electrode materials to produce capacitances that are many orders of magnitude greater than those of regular capacitors []. By doing this, supercapacitors can preserve the typical high-power density of normal capacitors while also achieving higher energy densities [18-20].

Supercapacitors have several characteristics, including:

- Low ESR
- Leakage current is very low
- Better life cycle
- A broad operating temperature range
- Increased usable capacity

IV. MATHEMATICAL MODELLING OF THE SYSTEM

Energy flow between electrical and mechanical subsystems is evaluated by modelling the electric vehicle power train. During the development stage, mathematical modelling of the system is unavoidable. Below is a description of the modelling

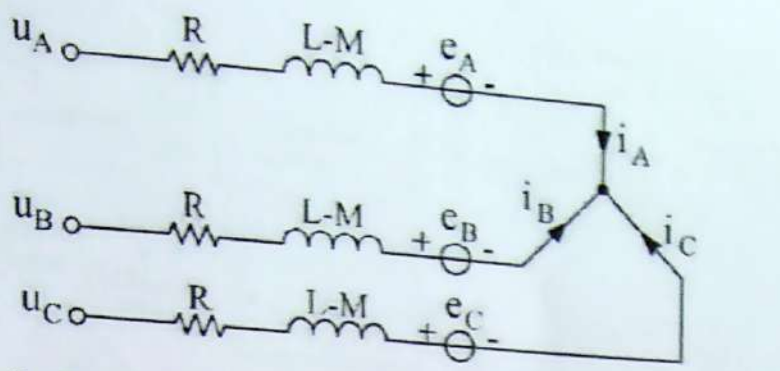

Fig. 2: Equivalent Circuit Model of BLDC Motor

of the vehicle, BLDC motor, inverter, boost converter, battery, and super capacitor.

A. Vehicle Model

The EV design should meet performance parameters such as acceleration, maximum speed, and gradient conditions. The power given to the vehicle model from the power train is known as tractive power. The tractive power (or we can say the tractive force) is used to overcome the following forces

- Rolling resistance
- Gravitational force
- Aero-dynamic drag force
- Accelerating force
- Gradient force (for level surface=0)

The forces can be calculated by considering a level surface is shown below

$$F_{TR} = F_{roll} + F_{aero} + F_{gt} + F_{acc} \quad (1)$$

Where,

F_{TR} = Tractive force (N)

$$F_{roll} = C_0 \times m \times g \quad (2)$$

$$F_{aero} = 0.5 \times C_D \times A_v \times V^2 \times \gamma \quad (3)$$

$$F = m \times a = m \times (dv/dt) \quad (4)$$

$$F_{gt} = m \times g \times \sin\beta \quad (5)$$

B. BLDC Motor Model

The following is what the motor model assumes.

- Harmonic fields in the stator that induce current in the rotor are ignored
- Iron and accidental losses are ignored
- There are no damper windings Utilizing the similar circuit depicted in figure, the motor model is finished.

By applying KVL we can write the voltage equations as

$$V_a = Ri_a + L(di_a/dt) + M(di_b/dt) + M(di_c/dt) + e_a \quad (6)$$

$$V_b = Ri_b + L(di_b/dt) + M(di_c/dt) + M(di_a/dt) + e_b \quad (7)$$

$$V_c = Ri_c + L(di_c/dt) + M(di_a/dt) + M(di_b/dt) + e_c \quad (8)$$

For symmetrical winding,

$$i_a + i_b + i_c = 0 \quad (9)$$

Therefore, we can write

$$V_a = Ri_a + (L - M)(di_a/dt) + e_a \quad (10)$$

$$V_b = Ri_b + (L - M)(di_b/dt) + e_b \quad (11)$$

$$V_c = Ri_c + (L - M)(di_c/dt) + e_c \quad (12)$$

Electromagnetic torque

$$T_e = (e_a * i_a + e_b * i_b + e_c * i_c)/\omega \quad (13)$$

C. Converter and Inverter

Depending on the voltage level of selected sources, a DC-DC converter may be present in the circuit. Furthermore, there must be one inverter at the front end of the BLDC motor for the electronic commutation process. The inverter used for the simulation is of basic three-leg topology.

D. Battery modelling

A portable source of electrical energy is one of the prerequisites for an electric vehicle. An apparatus of one or more electrochemical cells that transform chemical energy stored into electrical energy is known as a battery. The cells are connected in series and parallel to attain the appropriate voltage level and create a battery bank. Because the battery accounts for a sizable amount of the overall cost in these applications, we need to be able to estimate its performance accurately and dynamically. Therefore, monitoring battery performance as accurately as possible in real-time is essential to enhance battery life by preventing over (or under)charging.

State of Charge (SOC) is typically the parameter of interest when modelling batteries. The SOC shows how much energy is left in the battery relative to its capacity at full charge. In the modelling, the battery voltage is expressed as a function of current and SOC. There are many benefits to a reliable battery performance prediction method. 1) It prolongs battery life by limiting excessive charging or discharging. 2) It enables the battery to be used to its full potential. 3) It also gives the user access to information on the battery pack's energy capacity

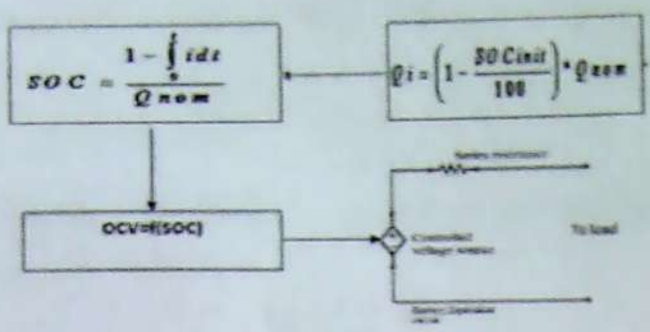

Fig. 3: Single Cell Battery Model

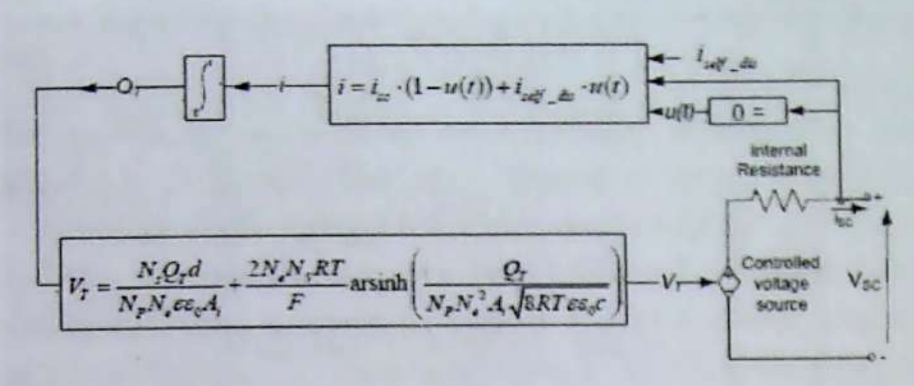

Fig. 4: Supercapacitor model

1) Lithium-Ion battery modelling: The main features of this battery include high energy density, high reliability and safety. Figure 5.15 shows the battery model used for this application. Where,
SoC-State Of Charge
Qnom- Nominal rating of single cell (2.9Ahr)
Qi- Initial charge on the battery
OCV- Open Circuit Voltage
Rs- Series resistance
Battery bank equations are listed below.

$$Q_i = (1 - (SoCinit/100)) * Qnom * Np \tag{14}$$

$$SoC = \frac{1 - \int_0^t i\, dt}{Qnom * Np} \tag{15}$$

$$OCV = f(SoC) * Ns \tag{16}$$

$$R_{seq} = R_s * (N_s/N_p) \tag{17}$$

Where, Ns- Number of series cells

$$N_s = V_{bank}/V_{cell} \tag{18}$$

Np- Number of parallel cells

$$N_p = Q_{bank}/Q_{cell} \tag{19}$$

E. Supercapacitor Model

A supercapacitor (SC) is a capacitor with a value of capacitance larger than ordinary capacitors but with lower voltage constraints. Supercapacitors are distinguished from standard capacitors by their fast charge–discharge rates, longer life cycles, high power, and high energy density. [9,10,14]. The model of the supercapacitor model is shown below.

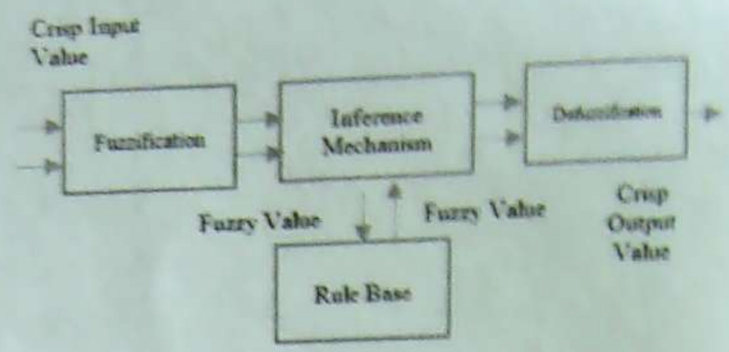

Fig. 5: Block diagram of FLC

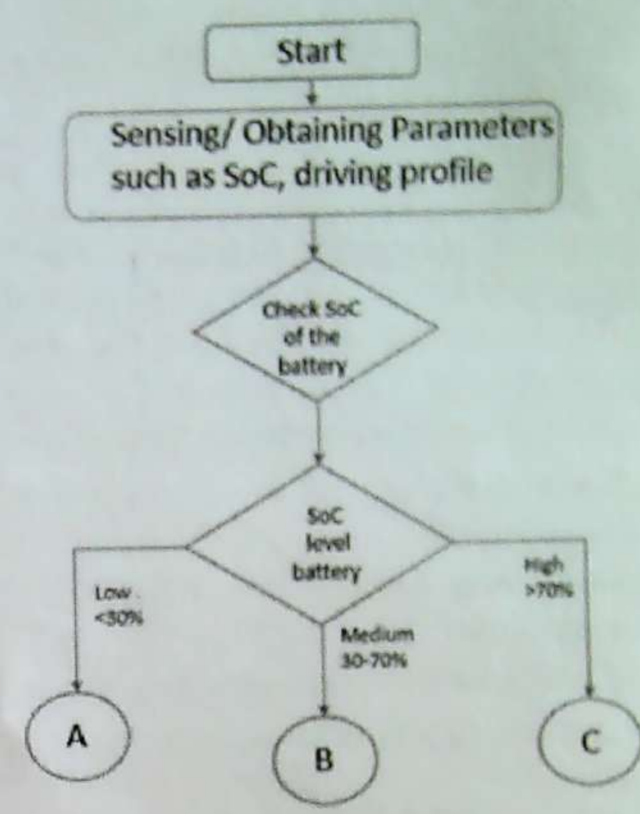

Fig. 6: FLC Operation

V. Fuzzy Logic Controller

Unlike other controllers, the FLC is used to represent systems with no precise values for the process flow. Fuzzy logic can also be described as "control with a language rather than equations" and "calculating words rather than numbers." The figure below depicts a basic block diagram of the FLC, which highlights its three key operations. The incoming data is first fuzzified to create a crisp value or linguistic variable.

In order to simulate the decision-making process as done by humans, a rule is then constructed using this crisp value or fuzzy set in the inference making block. Fuzzy inference systems (FIS) come in two primary varieties: Mamdani and Takagi-Sugeno-Kang FIS. The final stage of defuzzification involves turning language variables into numerical values or crisp outputs. Control signal for the selection of energy storage is determined by the FLC. There are two inputs to the FLC. They are
1. Drive Cycle
2. SoC
Based on these signals control signals are generated. The flowchart of the controller operation is depicted below.

The battery SoC is categorized into three groups. Low, medium and high. Rules are developed for each category of the SoC. When the battery SoC is low, the controller will perform like below.

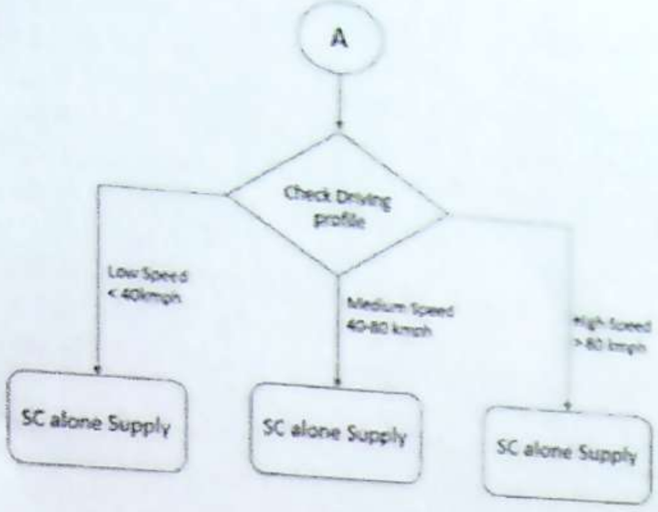

Fig. 7: FLC Operation when SoC is low

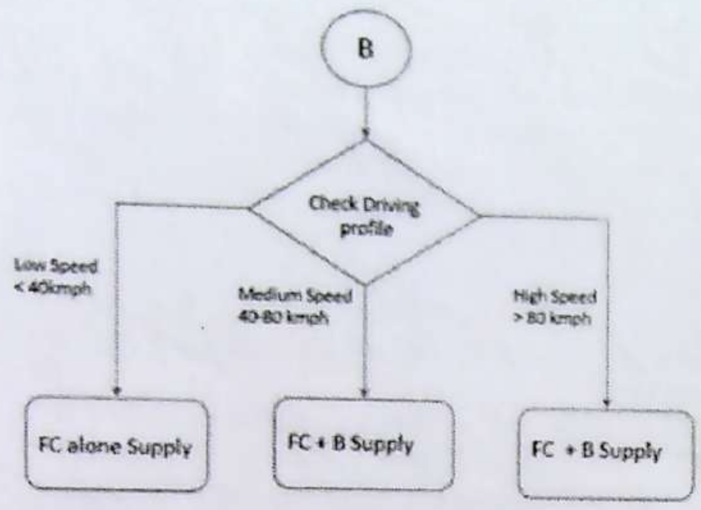

Fig. 8: FLC Operation when SoC is medium

When the battery SoC is medium, that is when it is in between 40

When the battery SoC is high, the controller will perform like below.

VI. OFFLINE SIMULATION MODELLING AND ANALYSIS OF RESULTS

The modelling of the EV power train is explained as a backward approach. Initially, the vehicle parameters are fixed, and a suitable motor rating for the propulsion is selected. Then for this motor stator voltage requirement inverter, converter, battery and a supercapacitor model are selected. While during the simulation analysis, the forward modelling is considered. That is the energy source model result that is

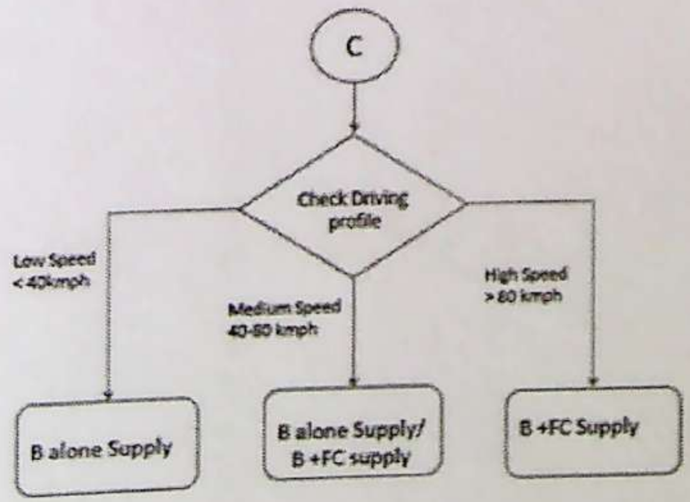

Fig. 9: FLC Operation when SoC is high

Fig. 10: State of Charge of Supercapacitor

Fig. 11: State of Charge of Battery

going to discuss first. Moreover, the converter, inverter, and motor and vehicle models follow.

Energy source are designed to obtain a voltage of 325 V. The SoC variation of SC and battery are shown on fig.10 and fig.11.

The MATLAB model of the inverter and BLDC is shown in fig.12. The motor parameters are set to deliver a torque of about 245 NM.

The vehicle model is analyzed on the basis of drive cycle. Fig.13 shows the drive cycle input to the vehicle model.

The vehicle response for the corresponding drive cycle is shown by figure 14. The results show that the proposed fuzzy controller operates satisfactorily with a supercapacitor-assisted battery-powered EV.)

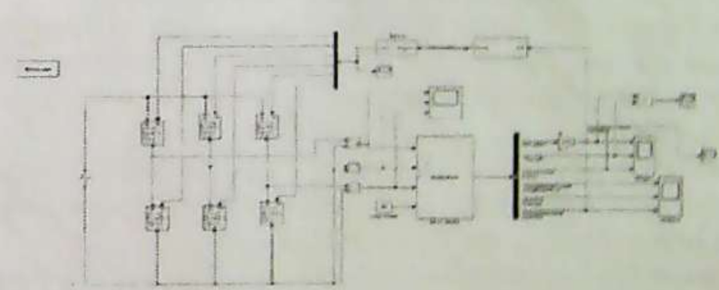

Fig. 12: MATLAB Model of inverter and BLDC Motor

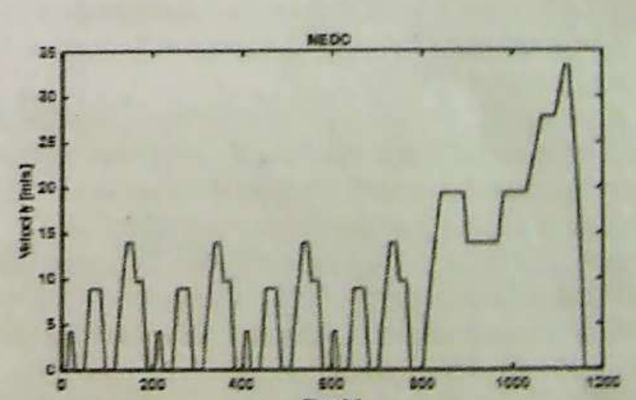

Fig. 13: NEDC Drive Cycle

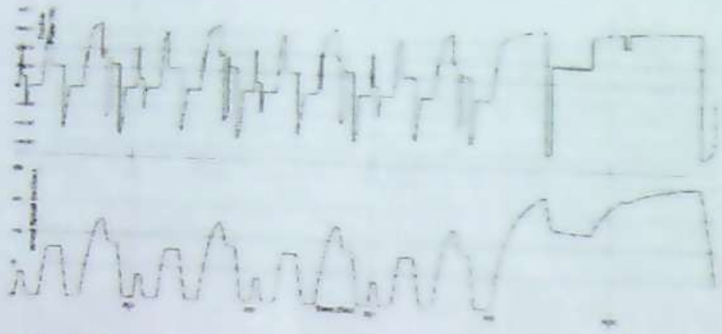

Fig. 14: Vehicle power requirement and wheel speed

VII. Conclusion

This paper presents the modelling and simulation of the fuzzy-based control strategy of a supercapacitor-assisted battery-powered EV. The most popular battery types, LIBs, have a high energy density but a low power density compared to an SC of the same size. Additionally, LIBs have a short lifespan compared to an SC, which has a life cycle that is about 1000 times longer than that of LIBs. The FLC enables the appropriate selection of storage units based on the input parameter. FLC is implemented based on the two inputs SoC and drive cycle, for the energy source selection. When the system modelling is subjected to a drive cycle simulation, the offline simulation can thoroughly examine the power/energy flow in the vehicle power train. The simulation offers the following capabilities:

- Evaluation of various subsystems' dynamic performance during drive cycles.
- Examine vehicle performance, such as maximum acceleration, gradability, and range.

Results show that FLC responds better to the selection of energy sources. In future work, additional input will be added to the FLC and planning to control the DC-DC converter for battery and SC charging/ discharging operation.

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Tribological and mechanical properties Mg-Zn-xSr-HA hybrid nanocomposites prepared by powder metallurgy technique

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ABSTRACT

In this work, biocompatible minerals such as zinc (Zn), strontium (Sr), and hydroxyapatite (HA) were combined with magnesium (Mg) to create a biomaterial with enhanced mechanical and tribological properties via powder metallurgy. Mg, Mg-4Zn-1Sr, Mg-4Zn-2Sr, Mg-4Zn-1Sr-0.3HA, Mg-4Zn-2Sr-0.3HA were produced by varying the strontium content from 1 to 2 wt%. The powder compositions were homogeneously mixed in a ball mill before being compressed in a die with a weight of 200 kN. The green preform was sintered in a muffle furnace at 520 °C for 2 h before being cooled to room temperature. The hardness has been improved, this is due to the inclusion of Zn and Sr with HA into the Mg hybrid nanocomposites and also the decrease in porosity is also one the reason for increase in hardness. The mass loss, wear volume loss and wear rate increases with applied load for Mg and decreases linearly for hybrid nanocomposites. The coefficient of friction (CoF) increases for Mg and decreases gradually for Hybrid nanocomposites with applied load. The SEM image of the worn surfaces area shows better wear resistance of the Mg Hybrid nanocomposites is reduced compare to that of the Mg.

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1. Introduction

Magnesium (Mg) alloys with suitable elastic modulus corresponding to nature bone desired and respectable biocompatibility provide potential uses for a new era of biodegradable and bioabsorbable implants [1]. Metallic materials are chosen for orthopaedic transplants owing to their mechanical strength and fracture toughness when related to composite materials [2]. The non-toxic oxides or hydroxides created through the breakdown development will improve the movement of osteoblast and diminish the volume of osteoclast in the advancement of bone renewal. As a consequence, the progress of biodegradable Mg-based implants annoyed the interest of many people [3]. Powder metallurgy has been shown to be one of the most advantageous processes for fabricating composites owing to its processing ability [4,8]. Manufacturing Mg hybrid nanocomposites may also be difficult, due to porosities in the composites [5–7]. However, due to variances in their deprivation rates and bone-healing times, poor mechanical and low wear properties, there are stalled tasks in using these decomposable materials as biomedical implants [9–11]. Furthermore, wear fragments caused by excessive wear and a higher COF among metal-matrix bone boundaries be able to promote osteolysis and sepsis, as well as implant failure [12–15]. The wear particles released by hip and knee joint substitutes were distributed to neighboring tissues and important organs, containing the liver and spleen.

2. Experimental details

Magnesium, zinc, and strontium powders were acquired from Coimbatore metal mart in Tamilnadu, India. The Magnesium, Zinc, and Strontium metal powders were 60 m in size, while the hydroxyapatite was generated by a chemical procedure with an 80 nm nanometer. The various formulations were initially made by weight ratio and homogeneously combined in a ball mill. The combined powders were placed in a die with a 15 mm diameter and a height of 30 mm to create the cylindrical specimen for compression testing. The constructed preform specimens were sintered in

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a muffle furnace at 520 °C for 2 h before being cooled to room temperature in the furnace. The sintered sample was cleaned using grit paper to remove slags and smooth the sample surface for hardness and wear testing. The samples' hardness was determined using a Rockwell hardness tester. The sliding wear test was performed on a pin-on-disc machine, and the experimental density (ED) was calibrated using Archimedes' principle. The samples' worn surfaces were observed by a scanning electron microscope.

3. Result and discussion

3.1. Density and hardness

Using Archimedes' principle, the experimental density was calibrated and it was discovered that the relative density was around 97% and the porosity in the sample was 3%. The relative density was reached by applying a compaction force of roughly 200kN during the processing of the green sample. Fig. 1(a) depicts the sample's experimental and theoretical densities. The theoretical density was calculated using the rule of mixtures, while the ED was measured by the Archimedes principle. The inclusion of Zn, Sr, and HA to the Mg hybrid composites raises the theoretical density. Because the relative density is around 97%, the experimental density grows linearly with the theoretical density. The addition of Zn, Sr, and HA to the matrix materials enhanced the hardness. The hardness was gradually raised owing to the [illegible] of Zn and Sr into the Mg, and by adding HA, the hardness was marginally increased, as shown in Fig. 1(b).

3.2. Friction and wear

Fig. 2(a) shows the coefficient of friction (COF) vs samples and variable load with a constant sliding distance of 2500 m, a track radius of 35 mm, and a constant speed of 700 rpm, resulting in a sliding velocity of 73.33 m/s. The COF of the samples was tested using these parameters on a pin-on-disc machine. The materials were evaluated for COF with a load ranging from 5 to 20 N, with each step increasing by 5 N. This figure makes it clear that the CoF value decreases significantly as the load rises. As a result of the increased load, the oxide film's influence is eliminated, reducing friction. Furthermore, the production of a transfer film that results from sliding is discovered to be stable for longer periods of time and a wide range of normal loads [14]. The Zn phase may be present in all the produced composites, which would explain the reported reduction. They frequently serve as lubricants between the mating surfaces, lowering the CoF readings. It is possible that the increase in load led to thermal softening brought on by the mating part's temperature rising. The frictional force was

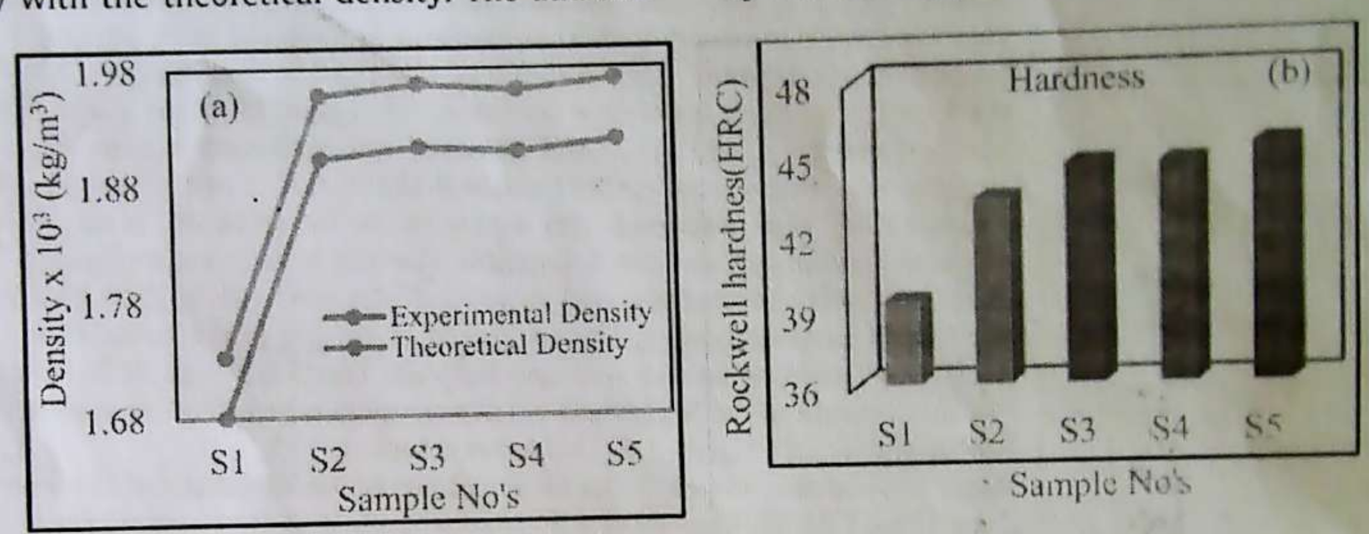

Fig. 1. (a) Density of the compositions and (b) hardness of the compositions.

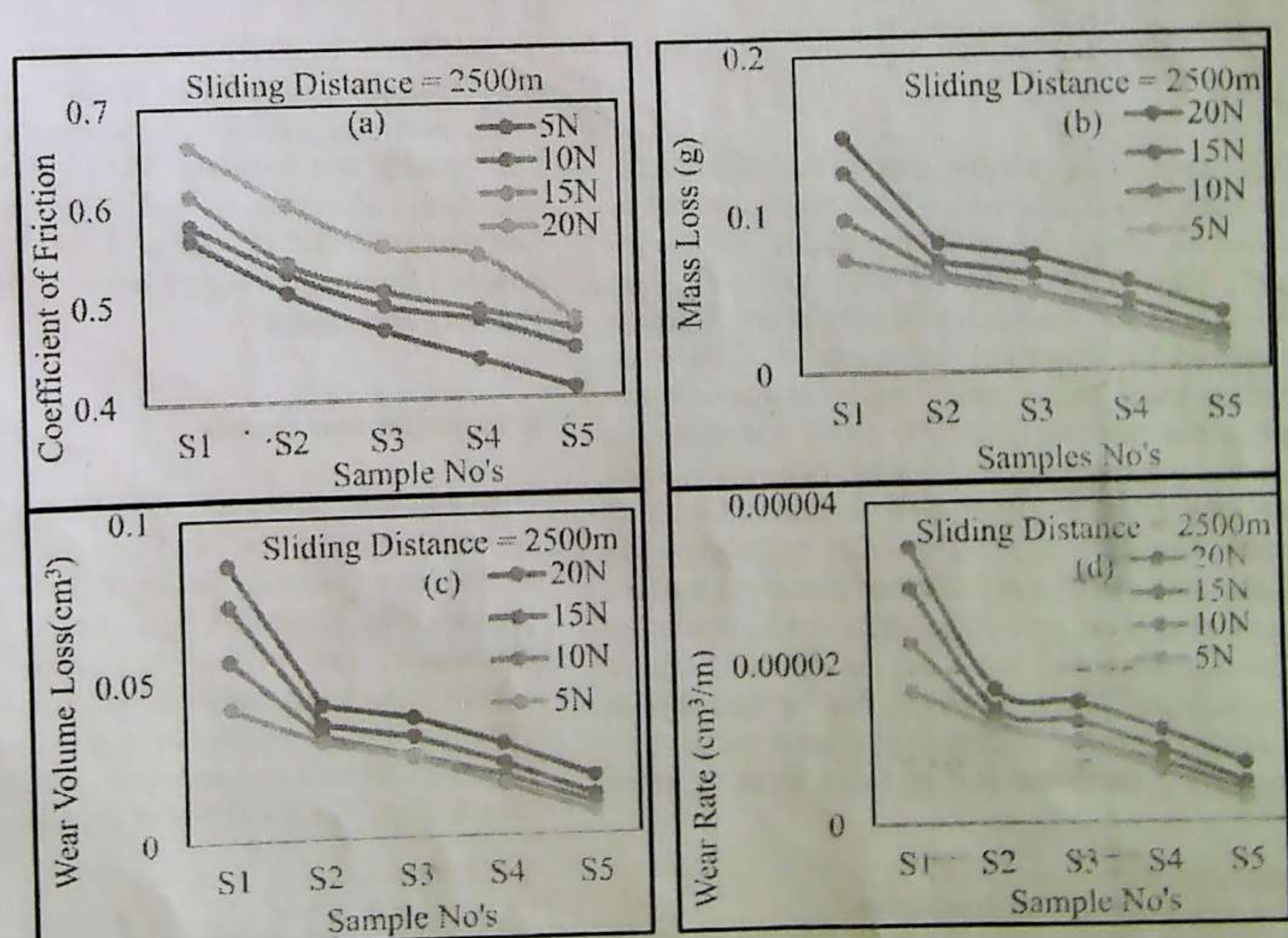

Fig. 2. (a) Coefficient of friction, (b) mass loss, (c) wear volume loss, and (d) wear rate.

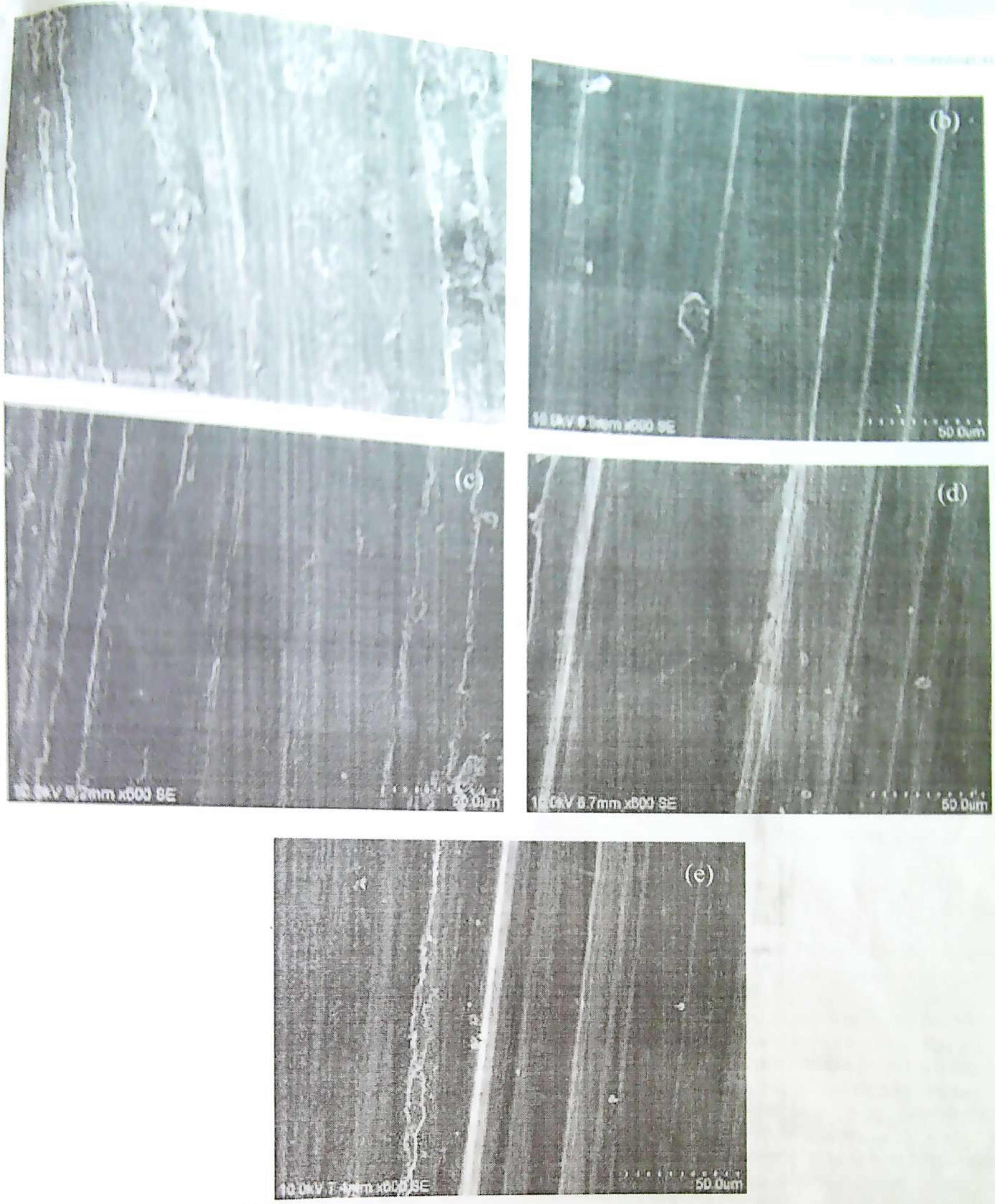

Fig. 3 The worn surface analysis of (a) Mg, (b) Mg-4Zn-1Sr, (c) Mg-4Zn-2Sr, (d) Mg-4Zn-1Sr-0.3HA, and (e) Mg-4Zn-2Sr-0.3HA.

measured using a monitor, and the mean value was taken into account for each and every load for individual samples. The COF of the samples is calculated by dividing the frictional force by the load [8]. The COF lowers when Zn and Sr are added to Mg, and it also decreases when Nano hydroxyl apatite is introduced to Mg-Zn-Sr. As a result, the COF of the Mg-4Zn-2Sr-0.3HA hybrid nanocomposites was lower than that of pure Mg. Because of the low COF with other combinations, this particular composition Mg-4Zn-2Sr-0.3HA hybrid nanocomposites can be employed for orthopaedic implants.

Fig. 2(b) shows that the mass loss decreased linearly with the addition of Zn and Sr, as well as with the addition of Nano HA, with varied load and constant sliding distance. This demonstrates that compaction plays a significant effect in reducing porosity and hence boosting the wear resistance of hybrid nanocomposites. The addition of alloys and HA to the Mg has also boosted the hardness of the composites. When related to hybrid nanocomposites of the materials, Mg wears down faster. The mass loss for hybrid nanocomposites was reduced due to the inclusion of Zn and Sr in samples S2 and S3, and it was somewhat reduced when we added HA to samples S4 and S5. Fig. 2(c) depicts the wear volume loss of hybrid nanocomposites with various samples vs the wear volume loss with constant sliding distance and varied loads. Wear volume loss in Fig. 2(c) suggests that hybrid composites have greater wear resistance than Mg. Fig. 2(d) depicts the wear rate of hybrid nanocomposites subjected to similar load conditions and sliding distance. The wear rate of the composites falls progressively for samples S1 to S5, and as the load is increased, the wear rate increases linearly and lowers for the hybrid nanocomposites. This suggests that the inclusion of Zn and Sr to the Mg has boosted the wear resistance of the hybrid composites. Furthermore, when HA is added to the matrix material, it displays a lowering tendency in the wear rate of the hybrid nanocomposites.

This is because the oxidation of Mg hybrid nanocomposites generates an oxide layer at higher interfacial temperatures, sliding surfaces by decreasing the wear rate. Kumar et al. [9] and Brar et al. [10] revealed that Mg was oxidised throughout the wearing process and shown that oxide layers, namely Mg layers formed during wear, work as solid lubricants and aid in the reduction of wear rates. For all loads, the wear rate of the unreinforced alloy is greater than that of the composites. In related to the unreinforced alloy, the introduction of Zn, Sr, and HA into the Mg hybrid composites enhances the dry sliding wear resistance. This type of behaviour has already been noticed by Liu et al. [3].

3.3. Worn surface

Fig. 3 depicts the worn surface area of the Mg and Mg hybrid nanocomposites samples S1, S2, S3, S4, S5, taken on SEM at 20 N load and 2500 m sliding distance for each sample. The SEM image reveals that the wear rate is higher due to Mg, and when Zn and Sr are added to the Mg for samples S2 and S3, the wear rate is lowered and the surface becomes smoother due to the alloy materials, and the plouging and wear debris are not observed in the samples [4,8]. Samples S4 and S5 have smooth surfaces and lower wear rates when HA is added to the matrix of the Mg hybrid composites, and sample S5 has a better composition when compared to other samples [12].

4. Conclusion

The Mg-4Zn-xSr-HA hybrid nanocomposites samples were prepared by powder metallurgy using cold compaction technique. The experimental density increases with decrease in porosity the of the Mg-hybrid nanocomposites. The inclusion of Zn and Sr with HA into the Mg-hybrid nanocomposites increases the hardness of the samples. The Mg-hybrid nanocomposites shows better wear resistance due to the increase in hardness and decrease in porosity. The COF increases with applied load for Mg and linearly decreases for the Mg hybrid nanocomposites. The Mg-4Zn-2Sr-0.3HA hybrid nanocomposites has decrease in mass loss, wear volume loss and the wear rate for constant sliding distance and varying load compared to that of pure Mg. The worn surface analysis shows better wear resistance to Mg-hybrid nanocomposites compared to that of Mg.

Further Research should be carried out to test the wear resistance using body fluid, since it can be used as implant material.

CRediT authorship contribution statement

Rosh George: Conceptualization, Methodology, Investigation. **Cris Benny:** Conceptualization, Methodology, Investigation. **Thomaskutty Mathew:** Conceptualization, Methodology, Investigation. **M. Shyamlal:** Conceptualization, Methodology, Investigation. **S. Christopher Ezhil Singh:** Data curation, Writing – original draft, Supervision. **T. Mary Little Flower:** R. Ma[illegible] **Rasalin Prince:** Validation, Visualization.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: 'Rosh George reports article publishing charges was provided by Vimal Jyothi Engineering College, Kannur, Kerala'.

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Out come/Output for the funding	Indexed paper ✓/Patent/Others specify
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Signature of the applicant

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Compression behaviour Mg-Zn-xSr-HA hybrid nanocomposites through powder metallurgy method

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ABSTRACT

In the present work, biocompatible materials such as zinc (Zn), Strontium (Sr) and Hydroxyapatite (HA) have been mixed with magnesium (Mg) to fabricate a biomaterial with enhance strength by powder metallurgy technique. The composites prepared are Mg, Mg-4Zn-1Sr, Mg-4Zn-2Sr, Mg-4Zn-1Sr-0.3HA, Mg-4Zn-2Sr-0.3HA by varying the strontium from 1 to 2 wt%. The powder compositions were blended in ball mill for homogenous mixing and compacted with a load of 200kN in die. The green preform were sintered in muffle furnace at 520 °C for 2hr and thereby furnace cooled to room temperature. The sintered samples were refined by grated paper for removing the slags and to make the surface smooth. The density, hardness and wear studies were carried out. The hardness has been improved for the composites due to the inclusion of zinc, further it has been increased when incorporating strontium. The relative density has been around 97 % due to that the porosity has been reduced to 3 %. The strength has been increased for the nanocomposites related to that of the Mg. The axial stress (σ_z), hoop stress (σ_h), and hydrostatic stress (σ_m) were increased with relative density of the nanocomposites related to that of pure Mg. The σ_z, σ_h, and σ_m were increased with axial strain of the nanocomposites related to that of pure Mg.

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1. Introduction

A new generation of bio-degradable and bio-absorbable implants are Magnesium (Mg) alloys as of reasonable elastic modulus corresponding to nature bone desirable and respectable biocompatibility provides the potential applications [1]. Orthopaedic implants are mostly chosen were metallic materials, owing to their mechanical strength and fracture toughness as related to that of composite materials. During the degradation process the non-toxic oxides or hydroxides which formed will improve the bustle of osteoblast and reduce the volume of osteoclast in the progression of bone regeneration [2]. Consequently, the development of biodegradable Mg based implants attracted great attention due to the intriguing characters. Powder metallurgy was evidenced to be unique of the favorable methods for fabricating composites owing to its processing ability [3]. Compressive forces are applied to the work piece during a number of operations in manufacturing processes as forging, rolling, extrusion, etc. [4]. Compressively loaded specimens provide information that is helpful for these operations. The ability of a material to be forged in either cold or warm circumstances without breaking is assessed using the standard test of uniaxial compression of cylinders [5]. This test is significant because it provides a representative behaviour of room-temperature metal formation [6]. The presence of frictional limitations among the dies and the sample during uniaxial compression testing directly affects the plastic deformation [7]. A solid cylinder can be "barreled" when it is crushed axially among the top and bottom platens. This process causes the workpiece to go through heterogeneous deformation [8]. The plastic flow of metal at and near the surface is slowed down by friction at the points of contact. As a result, the platens endure high stresses and swell out in the shape of a barrel, while the rest of the cylinder forms a tapering wedge of a comparatively undisturbed metal adjacent to them [9]. This displays the point of least resistance a renowned principle of plastic deformation, which is the nearest free surface to the

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metal [10]. Manufacturing magnesium hybrid nanocomposites could moreover be very difficult as it can offer porosities in the composites. The hot workability performance of cast-extruded AZ31B Mg alloy is deliberated by hot compression testing, mathematical modeling and microstructural investigates [11]. Cold upsetting investigation were conceded out on sintered Al–Fe samples so as to calculate their deformation performances. Additional it was initiated that the samples of greater iron particles displays larger values of deformation behavior comparable the σ_z and the Poisson's ratio than less/without iron samples as long as that the preliminary fractional density taken is kept constant [12].

2. Experimental details

The as received powders such as Magnesium, Zinc, and Strontium were purchased from Coimbatore metal mart, Tamilnadu, India. The size of the Magnesium, Zinc, and Strontium metal powder were 60 µm in Size and the hydroxyapatite was prepared by chemical process with a nanometer of size 80 nm. The varying compositions were initially prepared by taking weight ratio and mixed together in ball mill for homogenous mixing. The mixed powders were put in a die of diameter 15 mm for a height of 30 mm to prepare the cylindrical specimen using compaction in compression testing machine (CTM). The prepared preform specimens were sintered in a muffle furnace about 520 °C for 2hr and thereby furnace cooled to room temperature. The sintered sample (S1 = Mg, S2 = Mg-4Zn-1Sr, S3 = Mg-4Zn-2Sr, S4 = Mg-4Zn-1Sr-0.3HA, S5 = Mg-4Zn-2Sr-0.3HA) were cleaned by grit paper to remove the slags present on it and to make the sample surface smooth for hardness and compression test. The hardness of the samples were tested by Rockwell hardness tester. The experimental density was calibrated using Archimedes' principle and the compression test was done on CTM.

3. Result and discussion

3.1. Density and hardness

The experimental density were calibrated using Archimedes' principle and found that the relative density was around 97 % and the porosity present in the sample were 3 %. The relative density was achieved due to the compaction force applied during the preparation of the green sample at around 200kN. Fig. 1(a) depicts the sample's experimental and theoretical densities. The theoretical density was deliberated by means of the rule of mixtures, while the ED was measured by the Archimedes principle. The inclusion of Zn, Sr, and HA to the Mg hybrid composites raises the theoretical density. Because the relative density is around 97 %, the experimental density grows linearly with the theoretical density [illegible]. The hardness has been increased gradually due to the inclusion of Zn and Sr into the Mg it was gradually increasing and thereby adding HA the hardness slightly increases as shown in Fig. 1(b).

3.2. Effect of stresses (σ_z, σ_h, and σ_m) on axial strain (ε_z)

The relation between the axial stress (σ_z), hoop stress (σ_h), and hydrostatic stress (σ_m) with reference to axial strain (εz) for the preforms is shown in Fig. 2(a), Fig. 2(b) and Fig. 2(c). Correspondingly, S1, S2, S3, S4, and S5. In a triaxial stress state, they are plotted for the compositions S1, S2, S3, S4, and S5. All of the preforms' curves formed exactly basically the same way [14].

Experimental data on the correlation between the axial stress and axial strain are presented in Fig. 2(a) shows the axial strain versus axial stress with the sample's no's. The axial stress grows quickly during the first stage of densification; after that, as densification progresses, it continues to increase but at a slower rate [15]. The joint effects of densification on the geometry and overall work-hardening are responsible for the rise in axial stress. The plots shows that the inclusion of Zn and Sr increases the axial stress with samples S1 has low stress compared to that of sample S5 and show that at first the true axial stress increases rapidly with increasing axial strain, followed by its gradual increase [16–17]. It is seen that a preform with a Sr exhibits a greater increase in stress compared to that for the other samples.

The relation between the σ_z, σ_h, and σ_m with regard to εz for the preforms S1, S2, S3, S4 and S5 is displayed in Fig. 2(a-c). Fig. 2(a) shows the εz versus σ_z with the sample's no's, Fig. 2(b) shows the εz versus $\sigma_h$with the sample's no's and Fig. 2(c) shows the εz versus σ_m with the sample's no's, respectively. Plots of them are shown for the following compositions: S1, S2, S3, S4, and S5 with an aspect ratio of 0.6. All of the preforms' curve forming processes were essentially identical. This curve's creation is compatible with Selvakumar and Narayanasamy findings [5]. For all of the preforms, the values of all stresses increased as the amount of axial stains increased. This outcome is congruent with research conducted by others [1,4]. The axial stress and all other stresses are tensile in character meanwhile the applied force is compressive in nature [9]. The value of σ_h is lower than the axial stress for any

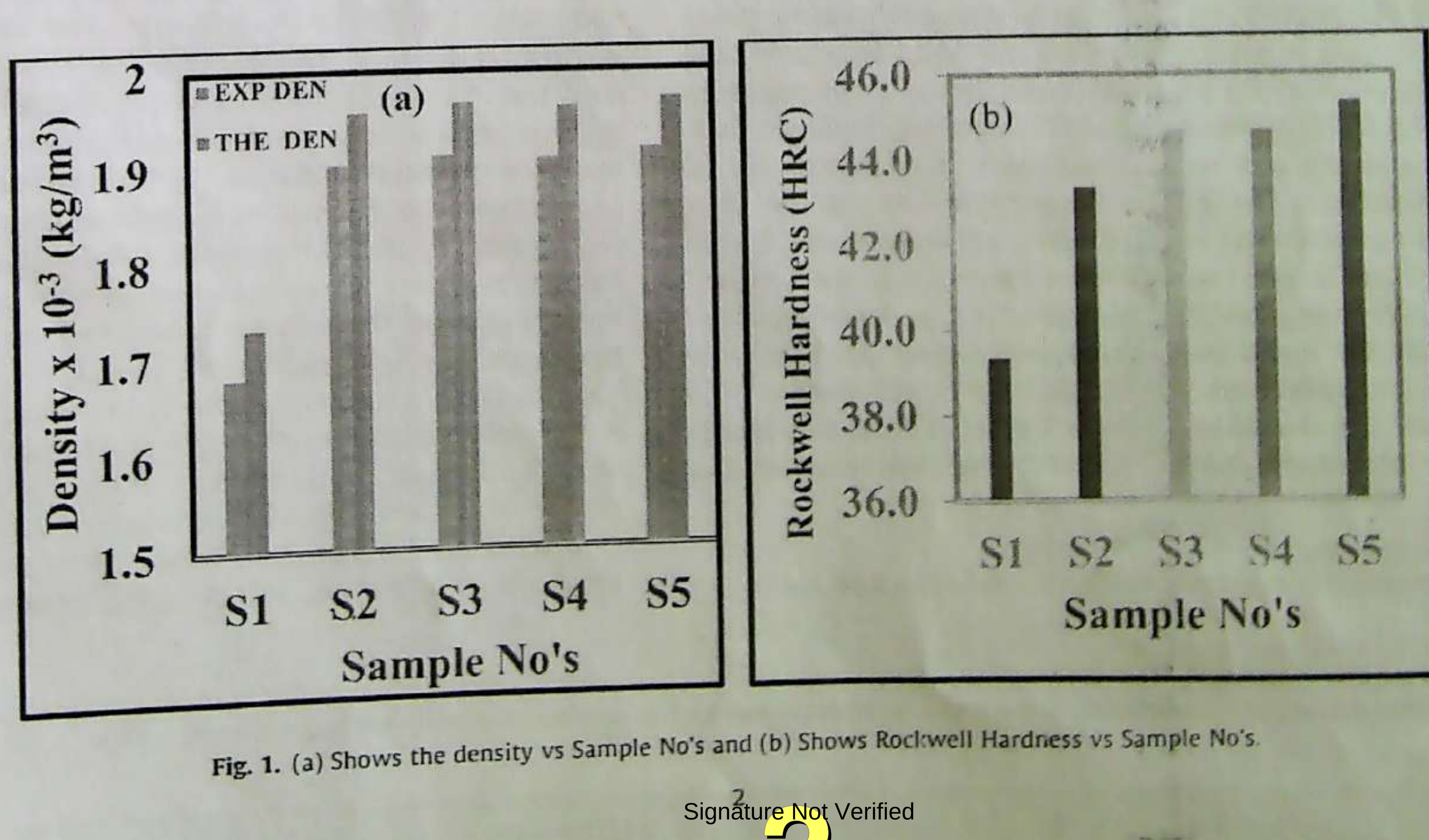
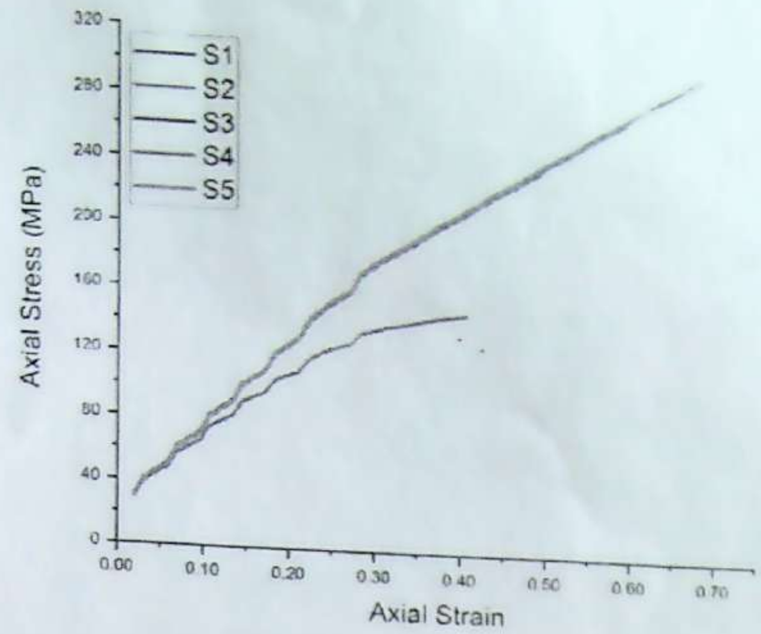
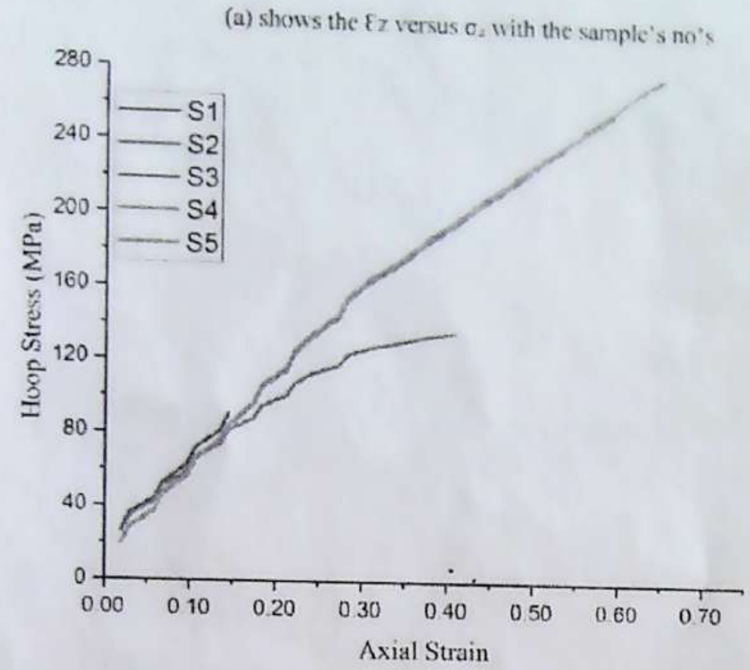


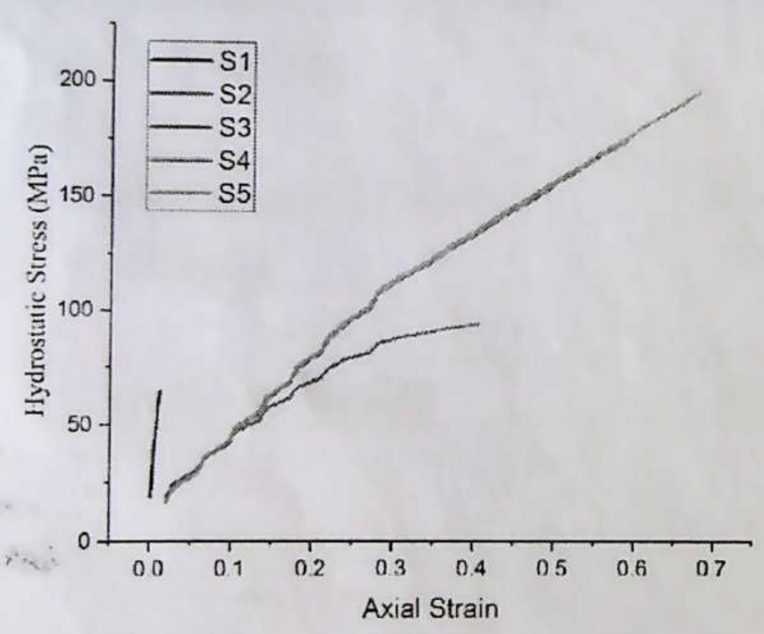
Fig. 1. (a) Shows the density vs Sample No's and (b) Shows Rockwell Hardness vs Sample No's.



(a) shows the εz versus σ_z with the sample's no's



(b) shows the εz versus σ_h with the sample's no's



(c) shows the εz versus σ_m with the sample's no's

Fig. 2. (a) shows the εz versus σ_z with the sample's no's. (b) shows the εz versus σ_h with the sample's no's. (c) shows the εz versus σ_m with the sample's no's.

instant of deformation level. The σ_m is tensile in nature and has a value that is significantly lower than all other stresses, including axial stress and hoop stress [10–11]. Owing to the preform's resistance to initial deformation, all stress levels are increasing at the beginning, which shows that the matrix is hardening [12]. Then, the εz values, which denote the geometrical work hardening behaviour, the rate of increase is slow. Finally, there will be a slight rise in matrix work hardening just prior to the creation of cracks.

4. Conclusion

The Mg hybrid nanocomposite preform's workability and work-hardening behaviour were critically analysed, leading to the conclusions listed below.

The initial resistance provided by means of the matrix material caused the preforms to undergo developed matrix work-hardening at that phase of deformation, while the middle stage metal flow into the pores caused them to undergo higher geometrical work-hardening rates. Once more, a matrix work hardening was observed at the end stage as a result of the pores being fully filled.

The Mg-4Zn-2Sr-0.3HA hybrid nanocomposites (S5) shown better workability and deformation behaviour as compared to the Mg-based preforms tested that had constant Zn, HA, and varying Sr content. This was caused by the larger initial pore closure, finer grains, higher initial fractional density, and increased content of Zn, Sr, and HA in the matrix compared to other metallic compounds.

It is possible to compute the stresses, namely the σ_z, σ_h, and σ_m, and it is discovered that these increase as the degree of deformation increases. The applied stress did, however, rise quickly in the initial phases of deformation and before continued to rise, albeit more slowly, as the deformation progressed. The level of total stress also rises for a given aspect ratio when preform density and Sr content rise.

Further Research should be carried out to test the different aspect ratio of the hybrid nanocomposites, since it can be used as implant material.

CRediT authorship contribution statement

George Recklin: Conceptualization, Methodology, Investigation. **P.V. Pranav:** Conceptualization, Methodology, Investigation. **S. Christopher Ezhil Singh:** Data curation, Writing – original draft, Supervision. **Rajkumar S. Rai:** Validation. **T. Mary Little Flower:** . **P. Sridharan:** Visualization.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [George Recklin reports article publishing charges was provided by Vimal Jyothi Engineering College, Kannur, Kerala.]

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Department :	CSE
Purpose:	Paper publication/Professional Boady membership/Participating FDP, Conference, Seminar/Patent/Travel Abroad/Travel Grant/PhD allowance/ Laptop loan/Others specify
Out come/Output for the funding	Indexed paper/Patent/Others specify
Relevance of this Funding	~~NAAC/NBA/NIRF~~/Others specify staff welfare
Sanction order	Amount Sanctioned - 7500/-

Date: 29/12/22

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Customer Evaluation And Profit Maximization Using Machine Learning for Offline Stores

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***Abstract*—Proper planning is essential for a long-term business. This can be done by implementing proper marketing strategies from time to time. Machine learning can play a key role in decision-making. Machine learning can play a key role in decision-making. This paper proposes a systematic approach which can help offline stores target their customers and obtain maximum profit by using the clustering application of machine learning. It helps offline stores get the benefits of the latest technologies in their business. The initial step for this system is to analyse the acquired sales data based on the purchase history, which will be used to group the customers. K-Means clustering is used to segment customers. Later, the most preferred product of each cluster is determined, and the result of this can be used by the shopkeepers to analyse their business and make good decisions for the long life of the business. It can assist offline stores in finding different groups of customers rather than viewing the entire customer as a single unit.**

***Index Terms*—Data Mining, Customer Relationship Management, K-Means.**

I. Introduction

Customer relationship management (CRM) [5] is a marketing approach that allows a store to learn about its customers' behaviour and wants to build a strong relationship and customer loyalty. It can help in increasing the sales and profit of the store. Advancements in technology can facilitate the above-mentioned objectives successfully and more efficiently. Stores may recognise their important customers and anticipate their future actions and their favourite items by using data mining and extraction of hidden patterns of client purchases from massive databases. This paper aims to use such technologies to improve the business of offline stores. This can help the stores make good decisions. The two intelligent components of Customer Relationship Management are customer clustering and buyer targeting. In this paper, it proposes an approach that can help offline stores cluster customers according to their purchase behaviour and find out the best-selling product in each group. It can help the stores analyse their customers and their needs. The stores can get an idea about the products their customers prefer and provide those products with high quality to satisfy them.

This system proposes an approach that helps the stores group the customers according to their behaviour and other patterns to enhance the existing marketing model.

II. General Background

Machine learning is a branch of artificial intelligence that focuses on using data and algorithms to copy how humans learn and eventually improve accuracy. It can assist the system in automatically improving through experience and the utilisation of data. Nowadays, it is used for a variety of applications such as security, predictions, agriculture, engineering, etc.

Supervised learning, unsupervised learning, and reinforcement learning are the three types of machine learning. In supervised learning, models are trained using a labelled dataset where the model learns about each category of input [1]. The model is tested on test data when the training process is completed, and it then predicts the output. An optimal scenario will allow the algorithm to correctly identify the class labels for unseen instances.

In Unsupervised learning is an algorithm that learns patterns from untagged data. It is the process of deducing underlying patterns of interest from historical data. A machine learning model can try to detect any similarities, differences, patterns, or structure in data on its own using this approach. No prior human intervention is needed. Some examples of unsupervised learning algorithms include K-Means Clustering, Principal Component Analysis, and Hierarchical Clustering.

In Reinforcement Learning, it enables the agent to learn from the result of actions in a specific environment. It provides data analysis feedback that directs the user to the best result. One of the common applications of this is in teaching a robot new tricks, making recommendations on YouTube, etc.

III. LITERATURE SURVEY

The proposed method in [1] is about segmenting customers who have similar behaviours into similar segments and customers who have different patterns into different segments. This paper describes different clustering algorithms (k-Means, agglomerative, and meanshift) which can be implemented to segment the customers and finally compare the results of clusters obtained from the algorithms.

Murugeswari R. and Ramasakthi G. relate the process of classifying a small text piece into positive, negative, or neutral [2]. The process of sentiment analysis is carried out by performing a step-by-step process. First, the dataset is collected. Then, the dataset is loaded, and preprocessing is done. After that, the data is split. Then, the data is trained on the model. Finally, it categorises the comments as positive,

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PEER TO PEER LENDING: RISK PREDICTION USING MACHINE LEARNING ON AN IMBALANCED DATASET

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***Abstract*—Peer-to-Peer lending is to eliminate or take away the mediator such as banks or financial institutions. For a small-scale business firm or several individuals without adequate financial status or financial history, the best approach for loan application is Peer to Peer lending (P2P lending). The key issue on the lending of Peer to Peer is data imbalance in this system. It does not accurately evaluate the default risk of P2P lending. Lenders can fund the loan for borrowers only by the data prepared by borrowers. It will lead to unbalanced default loans and non-default loans. Unbalanced datasets are relatively ordinary in the real life. The usual machine learning schemes are not friendly with the imbalanced data. Systems without any flexible methods would be the center of attention in learning the normal repayment. Machine learning algorithm tends to bias the majority classes. The property of the minority or smaller class is important in the loaning business. For the default risk prediction of P2P lending and re-sampling to process imbalanced datasets, several machine learning schemes are present. In this paper, various machine learning methods are compared in terms of random under sampling, random oversampling and SMOTE. It is observed that random under-sampling shows greater performance in terms of accuracy for default risk prediction.**

***Index Terms*—P2P lending, machine learning, Random Forest Classifier, Decision Tree, Logistic Regression, Smote, imbalanced dataset.**

I. INTRODUCTION

Recently, Peer-to-Peer (P2P) lending has advanced quickly in the world. Peer-to-Peer is a technique to acquire credit without a money related firm included such as banks and to acquire preferable than in the conventional system of banking [1]. P2P lending also produces a platform for an online face-to-face connection for lenders and borrowers without intermediaries. To remove the brick and mortar working cost, lending peer to peer can deliver reduced rates of interest for borrowers compared to that of banks and more benefits for lenders. So, for some individuals with no or enough financial history, lending peer to peer is an alternative method for small-scale businesses. Information asymmetry becomes a primitive drawback of Peer-to-Peer lending because lenders know only the information of loan that is supplied by borrowers [1].

In the actual world, there exist many imbalanced datasets like medical diagnosis, risk management, and fraud detection. So, it is tough to produce a prediction on an imbalanced dataset because the classifiers are susceptible to finding the majority or larger class instead of the minority or smaller class. So, the classification outcome will be biased. Machine learning algorithm tends to bias the majority classes. Therefore, problem addressing in the imbalanced dataset classification is highly important. Generally, P2P lending has imbalanced datasets because fully paid and non-paid loans are non-uniform. The proportion of default and non-default loans is distinct. The majority class is more huge than the opposition (minority class).

The paper studies under sampling and over sampling techniques for handling the imbalanced datasets. Therefore, some machine learning techniques like decision tree, logistic regression and random forest for predicting Peer to Peer lending default risk, are applied.

II. LITERATURE SURVEY

A discussion on existing methods is given in this section. Yen-Ru Chen et al [1] and Gudipati Thanuja [2] discuss the past of peer to peer lending. The authors investigate the positives and negatives of P2P lending and describe how and why peer-to-peer lending works and describe the dissimilarity between the conventional system of banking and Peer to Peer lending. They list a few advantages of P2P lending. But P2P lending has a primary complication because of the imbalanced dataset. The system employs many machine learning algorithms like Neural Network, Logistic Regression and Random Forest to see the default risk of peer-to-peer lending and uses cost-sensitive mechanisms and re-sampling techniques for processing datasets that are imbalanced. In this study, Random under-sampling has shown better performance among different classifiers. After doing preprocessing and selecting features,

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PEER TRACKING AND COLLISION FREE NAVIGATION FOR VISUALLY IMPAIRED

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***Abstract*—In the indoor space, the chances of a visually impaired person (VIP) getting lost on their way to their destination are very high. Unable to detect the terrain and surrounding environment, it makes it difficult for visually impaired people to move independently. Since the Global Positioning System (GPS) does not work well in the indoor environment and the existing indoor navigation systems are not very accurate, blind people find it difficult to locate and meet their peers without assistance. It is very difficult for them, as well as their family members or peers, to locate and get them back to the destination. Different connectivity technologies such as RFID (Radio Frequency Identification), ZigBee, or Bluetooth are deployed in real-life scenarios, but most of these technologies have limitations in terms of reliability, coverage, and implementation cost. Hence, this paper aims to implement a system that will help blind people in peer tracking and enable them to navigate in the indoor space with voice assistance to reach the desired location. The system includes a feature that detects and warns of any obstacles found in the desired path. Implementation of an effective indoor navigation system will turn out to be a visionary service for the disabled community.**

***Index Terms*—Wi-Fi, Tensorflow API, SSD, MQTT protocol.**

I. Introduction

Blind humans do lead an ordinary life with their very personal style of doing things. They do, however, face challenges due to inaccessible infrastructure and socially irritating conditions. According to the World Health Organization (WHO), 285 million humans are predicted to be visually impaired worldwide; 39 million are blind and 246 have low vision [7]. Whether it occurred by chance or as a result of the effects of a disease, this physical impairment has profound effects on day-to-day life-sustaining activities. As a matter of fact, motion is significantly restrained. Moreover, visually impaired people can also lose orientation and function at a higher risk of falling. But, humans need to move, whether at home or at work or at leisure. We have assembled a world that serves the majority. Any person who is not average has to deal with a slew of issues because they are no longer considered average. Indoor navigation in a complex environment can be very vital for blind humans to move independently and securely. Among activities affected by vision impairment, navigation plays an important role, as it lets the person move independently and safely. Independent navigation in new environments, where the chances of getting lost are high, is a difficult task for visually impaired people. In comparison to the outdoors, visiting inner public regions is a different story, because many signals pertaining to the indoor environment have their own complexities and cannot be used. When visiting indoors, most of the outdoor irritating conditions are not present, but head-level and trip accidents, or may be movable devices, are to be considered [2]. To promote the tracking, navigation, and creation of better technology for visually impaired people, it is vital to understand the facts and actual troubles that they face and what behaviours and strategies they use to overcome these troubles.

One of the most famous positioning technologies is the Global Positioning System (GPS) [3], which fits very well within the outdoor environment and facilitates different types of applications, which include mobile phones, vehicle navigation, ships, planes, and so on. However, it is unsuccessful within the indoor environment as it requires a line of sight transmitter and receiver, and this is considered the number one venture for this technology within the indoor environment (non-line of sight) [3], [4]. Indoor area technology is applied in various types of commercial, naval, and public safety applications [3]. Nonetheless, current systems suffer from inconvenient conditions in terms of accuracy, real-time, low charge, and reliability [1]. The inaccuracy is due to the indoor environment elements like barriers, which, on the side of humans, walls, and fixtures, have a massive impact on the signal strength. This necessitates the need for a device that might provide peer tracking and navigation with obstacle detection. The proposed device, if implemented, will prove to be a promising one, helping the visually impaired experience and enjoy independence.

II. Related Work

K. Chaccour and G. Badr discuss a computer vision guidance algorithm [1]. Obstacle detection is provided and it assists the user in reaching his destination. A mobile

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