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"Automatic Braking ActionofVehicles"

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Abstract
The Automatic Braking System (ABS) system is an effective intelligentvehicle safety mechanism for avoiding any possible collision. This studydevelops a national-level road safety evaluation model which is the intelligentvehicle function. This includes the potential maximum impact and realisticimpact. Road fatalities and severe injuries trends, the proportion of differentcollisiontypes, the effectiveness ofcollisionavoidance.*

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I. Introduction:

The vehicle technology has increased rapidly over the years, especially inrelationwithaneffectivebrakingsystemtoavoidcollisions.Theintroductionofthe Anti-Lock Braking System (ABS), Traction Control (TC), Brake Assist andElectronic Stability Control (ESC) functions, Electronic Brake-ForceDistribution (EBD) system are some of the major developments which theAutomotive Industry has seen over the years. These systems are used to provideproper control over the vehicle and to minimize the accidents due touncontrollability ofthevehicles.

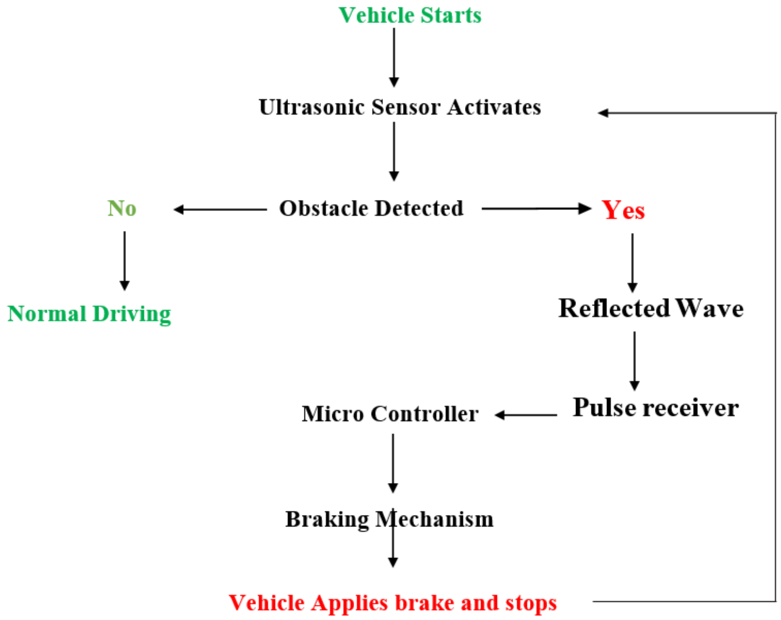
In parallel to these developments, various technologies like the SensorBased Braking System has been developed which are capable of detecting anypossible physical obstacles for example- other vehicles and pedestrians. Thiscollision avoidance system is capable of sensing any obstruction on its way andassists the driver to slow down the vehicle automatically and if necessary, thento a halt. The modern sensors are highly advanced having a quick response timein slowing downthevehiclecompared toa humanreactiontimewhichresultsin minimizing the road fatalities. But, these systems are very costly andsophisticated and hence are mostly used by premium luxury manufacturers liketheMercedes-Benz andVolvo.

II. Objective:

This paper investigates the development and implication of a simple andeconomical Self Braking System that can be installed in any economical familycar as the majority percentage of the population in India belongs to the middle-class group and affording such premium cars is not feasible. Safety in economical vehicles are limited only to the use of Airbags and ESP which mayseem beneficial for the people inside but not for any pedestrian or a personoutside the vehicle. Hence developing a low cost, easy install system is a needas 35% of accidental deaths in India are caused due to road fatalities andaccidents and out of which about 78% of the road accidents is due to thecarelessnessandnegligenceofthedriver.

Thisnewsystemisdesignedtoprovideasolutionthisproblem.Sometimesthe drivers are not be able to brake manually exactly at the required time in asituation of sudden braking action, but the vehicle can still stop automaticallyusingitssensorstodetecttheobstaclesto avoidanaccident.

III. Methodology:



IV. Requirements:

4.1 Component requirements:

1. Ultrasonicsensor(Transmitter and receiver)
2. Microprocessor(Arduino)
3. SolenoidValveand LED
4. BrakingSystemand Mechanism
5. ElectricalandElectronicssystems

4.2 Implementationaspects:

The self-braking system circuit and mechanism is different for electric vehiclesand different for the IC engine vehicles. In IC engine vehicles the methodology is same but the braking mechanism is different. In this project we will bediscussingonaprototypewhichisinconsiderationwiththewidely usedsysteminmostofthepresently on-roadvehicles.

V. Working of Automatic Braking System (ABS):

- Asthevehicleignitionstarts,thevehiclecontrolunitactivatestheultrasonicsensors.
- Theultrasonicsensorsemitultrasonicwavesforthedetectionofanyobstacle.
- On detection of any physical obstacle the emitted waves gets reflectedandarerecognized by the receiver.
- This feedback is send to the microcontroller which calculates the relativevelocitybetweenthevehicleandtheobstacle.
- A predefined value is set to identify the need of activating the bakingmechanism.
- If the calculated value is identified as a hazard, the microcontroller sendssignalto thebrakingcircuit.
- The microcontroller also sends its warning signal to the driver throughhazardbeepingsoundandnotifyingthedriverto apply brakes.
- If the driver fails to react within the allotted time then the data is sent tothe braking system andit isactivated.
- The braking system reads the data and acts accordingly by applying thebrakes of the vehicle resulting in slowing the vehicle and reducing itsspeed.
- Ifthedataiswithintheprescribedlimits,thebrakingsystemsactpartiallyjusttoslowthevehicletoasafedrivingspeed.
- If the data is beyond the predetermined limits then the braking systemacts completely andresults ina completestop.

- Once the obstruction is undetected, this data is sent to the braking systemwhich releases the applied force on the brakes resulting in free movementofthevehicle.

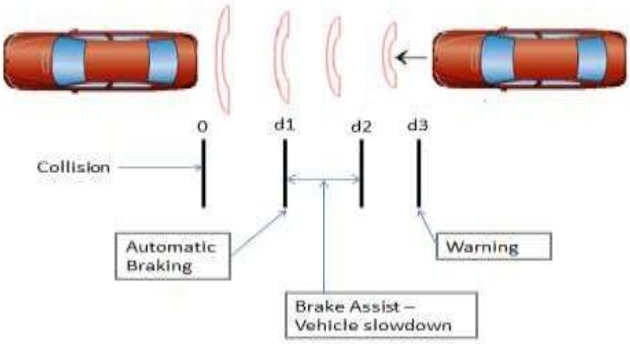


Fig:1WorkingofAutomaticBrakingSystem

4.1 IC-Enginemechanism:

In IC-Engines the braking action is caused due the friction action between thebrakes and the brake pads. In modern day vehicles, every vehicle consists of adisc and caliper setup which performs the braking action. The following stepswillhelpexplainingthebrakingconceptintoday'svehicles.

- When the brake pedal is pressed, a mechanism made of set of links work simultaneously.
- Theselinksareconnectedtoapiston-cylindersetup.
- ThePiston-1isinitiallyatitsrestpositionandonapplicationofthebrakes, the brakepedalmakesitmove.
- This movement causes the brake fluid to flow through connected brakehosepipingandenteringthebrakecaliperchamber.
- Thebrakecaliperchamberconsistsofbrakepadthemovement ofwhichiscontrolledby anotherpistonsayPiston-2.
- This Piston-2 is moved due to the pressure of the fluid caused due to thepressingofthepedal.
- Thecaliperhasalso through whichthedisc passes when thevehiclemoves.
- The Piston-2 applies the force on the disc via the brake pad causingfrictiongenerationandresultinginslowingthevehicledown
- If the pedal is pressed completely then the brakes are applied to itsmaximum limits causing maximum friction to stop the vehicle as soon aspossible.
- Once the pedal is released, the pistons move back to their initial restpositions which releases the force on the disc and making it ready for freemovement.
- ThismechanismworksintheprincipleofPascal'sLaw.

The use of self-braking system in this mechanism works by adding anotherautomated piston near the Piston-1. If the driver forgets to apply brakes on time,thisautomatedpiston doesthe work for themanually operatedPiston-1resulting in an effective braking mechanism. If the driver releases the brake inthe presence of the obstruction, the system keeps the automated piston activatedpreventingthepossiblecollision.

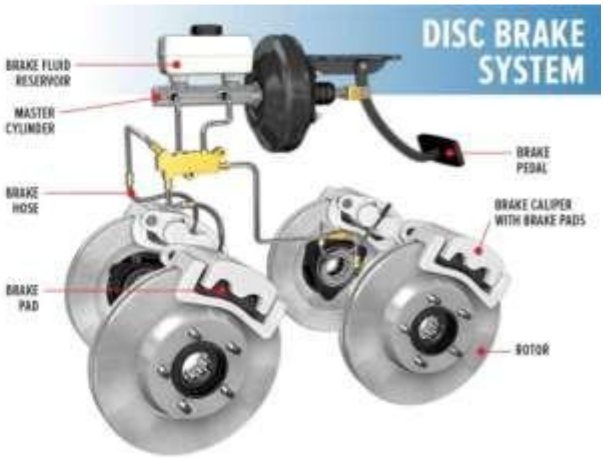


Fig:2Vehicledisc-braking system

4.2 ElectricVehicleMechanism:

In Electric Vehicles, the braking method is similar to the conventional IC-Engine braking system that is using disc-brakes but another factor is to beconsidered in EVs i.e. the motors. In EVs, the motors also participate in thebrakingactionwhichincreasesthebrakingefficiencyofthevehicleand henceforthself-brakingsysteminthesevehicles,themechanismhasan addition.

The following steps explain the additional working parts in the self-baking systemofEV.

- When the sensors detect any obstacle, they send this feedback to thebrakingsystemwhichinitiatesthediscbrakes.
- InEVs,thebrakingtechnologyalsoutilizesthemotorfor brakingaction.
- When the brakes are applied, the motor that powers the wheels starts toact as a generator. A reverse flow of current starts to flow and this alsoconvertsthekineticenergy ofthebrakingforcetoelectricalenergy.
- Thisreversingofthecircuitis controlledbytheBatteryManagementSystem(BMS).
- Thereverseflowofcurrentcreatesresistancecausingthevehicletoslowdown.
- Hence,an additionalcircuitisusedtoperformthistaskwhichisactivatedbythefeedbackdatafromthe sensor.
- Using the self-braking system in Electric vehicle needs an additional circuitwhich automatically activates the braking action without any manualapplication.

VI. Literature Review:

6.1 BrakingSystem:

In this project we are reviewing the presently used disc brake brakingmechanism as it is widely in operation in majority of the vehicles on roadtoday. In this, the automated piston is operated using a solenoid valve hencethemechatronicspartplaysanimportantroleinthemaking ofthisproject.

Solenoid valve: It is an electromagnetic component which is used toactuate the automated piston-cylinder mechanism. This part is divided intotwo parts i.e. the solenoid part and the valve part. The solenoid consists ofcoiled structure and electromagnetically operated armature which acts as apiston whereas the valve acts as the cylinder. The movement of the pistoncontrols the fluid pressure to activate the disc braking system followingPascal’sLawof hydraulics.

Ultrasonic Transducer: The ultrasonic transducer or sensor is anelectronic device used to determine the physical obstacle. The Transduceremitstheultrasonicwaveswithhighfrequencyandgetreflectedduetothepresence of any physical object. This reflected wave is captured by thereceiverwhichisconvertedto equivalentelectricalcurrent.

Tocalculatethedistancetheformulaused is:

Distance=Timex(Speedofsound/2)

Where Time is defined as the duration between which the ultrasonic wavewas emitted and the reflected wave was captured. The equation is thendividedby2becausethesoundwavetravelsto theobjectandback.

Arduino Microcontroller: The ATmega328P Arduino microcontroller isused for this project. Use of Arduino UNO or Arduino Nano can be donebut to reduce the space requirements this prototype is controlled using theArduino Nano. The construction only differs with the lack of DC powerjack and works withamini-USBcable.

Power supply: The Arduino Nano is powered by the Mini-B USBconnection and a 6-20V unregulated external power supply (pin 30) or 5Vregulated external power supply (pin 27). The power source automaticallyselects to the highest voltage source and the Ultrasonic transducer uses a12Vbatteryto start.

Input and output: The 14 digital pins on the Arduino-Nano can be used asan input or output. The functions like pinMode(), digitalRead() anddigitalWrite() can be used. They can operate at 5V and each pin has theabilitytoprovide orreceive amaximumcurrent of40 mA.Ithasaninternal pull-up resistor of up to 50 Kilo Ohms which is disconnected bydefault.

Drivers: The ULN2803APG / AFWG Series are high−voltage andhigh−current Darlington drivers which comprises eight N-P-N Darlingtonpairs. All these units feature an integral clamp diodes for switching theinductive loads. Applications are relay, hammer, lamp and display (LED)drivers.

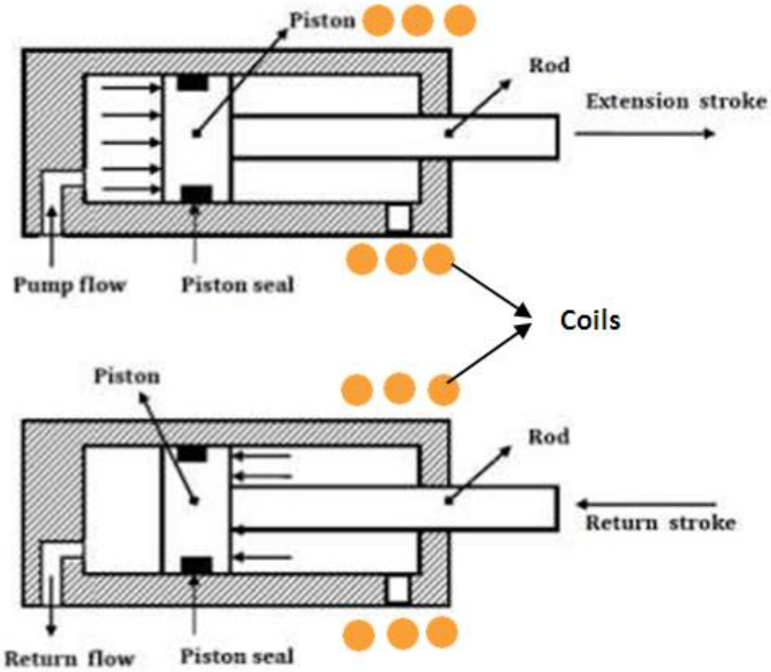


Fig:3Cross-sectionofSolenoidValvePiston-Cylinder

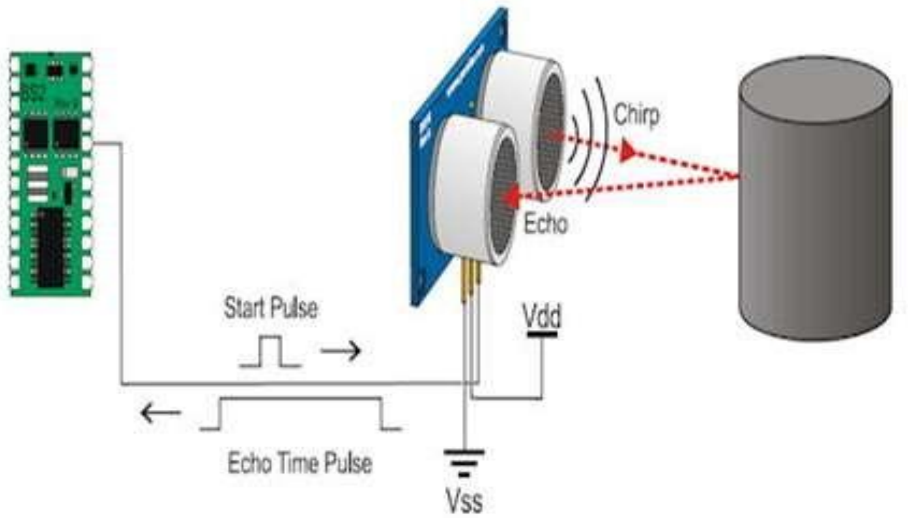


Fig:4Workingofan UltrasonicSensor

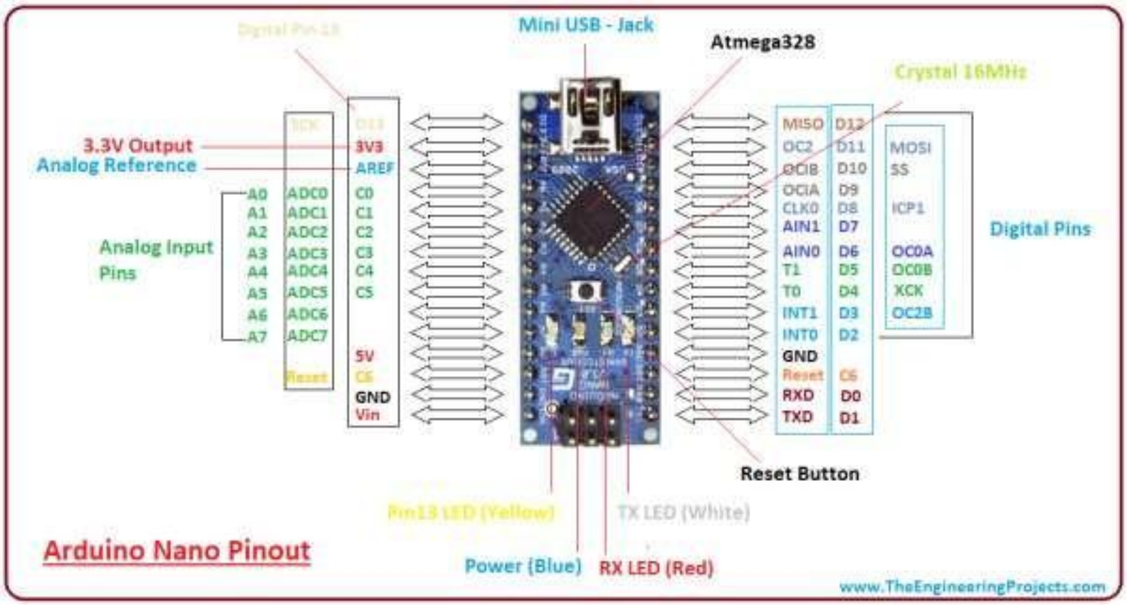


Fig:5ATmega328PArduino Nano

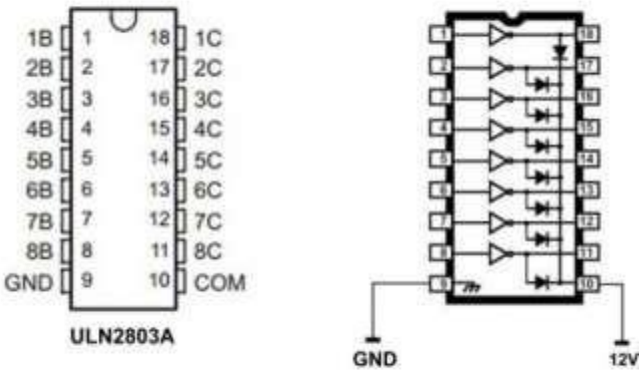


Fig:6DarlingtonDriverforLED.

6.2 **Arduino Coding:** The following is the basic code required to performthetaskofself brakingin theprototypeversion.

```
constinttrigPin = 3;
constintechoPin = 2;
constint solenoid = 9;
constint led= 13;

voidsetup()
{
Serial.begin(9600);
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);
pinMode(solenoid, OUTPUT);
pinMode(led,OUTPUT);
}
void loop()
{
long duration, cm;digitalWrite(trigPin, LOW);
delayMicroseconds(5);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
```

```
cm = duration/ 29.15 / 2;
Serial.println(cm);
if(cm<100)
{digitalWrite(solenoid,HIGH);digitalWrite(led,HIGH);delay(2000);}
if(100<cm<200)
{digitalWrite(solenoid,LOW);digitalWrite(led,HIGH);delay(2000);}
else
{digitalWrite(solenoid,LOW);digitalWrite(led,LOW);delay(2000);}
}
```

6.3 Explanation:

The above coding is for the prototype version. The distance given is incentimeters as the prototype project is a small scale version. For the applicationof life-size models, there are a number of preset distance values set according tothe speed of the vehicle as different speed requires different baking time anddistance. During the speed less than 10kmph, the minimum value is set which isuseful during parking the vehicles. At greater speeds, this value changes whichthe CPU of the vehicle does automatically. The preset reaction distance can beset manually or the user can use the default values provided in the vehicle. Wewillseethecalculation inthe later sectionofthisreport.

In the code, as sound travels with the speed of 343 meters per second,which means it needs 29.155 microseconds per centimeter. So we divide thistotal duration by 29.155 and then by 2 as the sound has to travel the distancetwotimes.

Therearethreeconditionsgivenduringtheoutput.

1. **Solenoid (HIGH),led(HIGH):** This means that if the distance betweenthe vehicle and the obstruction is less than 100cm, the solenoid valve isactivated resulting in creating brake pressure and the LED turns onindicatingthedriverofthehazardasawarning sign.
2. **Solenoid (LOW),led(HIGH):** This condition is satisfied when thedistance between the vehicle and the obstruction is between 200cm to100cm. It means that if this condition is identified by the controller unit,the solenoids doesn't act immediately, rather it just sends a warningsignalto thedriverforthepossiblehazard ahead.
3. **Solenoid (LOW),led(LOW):** This is the else statement commanding noaction is required if the above two conditions are not satisfied. Nowarningsignisgivenandnormaldrivingconditionisavailable.

The trigPin is called as the trigger pin. It is the input pin which is used toinitialize the measurement by transmitting the ultrasonic waves by keepingthis pin high.

The echoPin is an output pin which is in the high mode for a specific timeperiod and it is equivalent to the duration of the time for the wave to return tothesensor.

VII. Case Study:

7.1 VehicleBrakingConditionSimulation:

The following are the aspects to be considered for the chassis simulation toinvestigatetheuseofanoveralldistributedcontrolsysteminvehicles.

A. Wheel/ChassisDynamics:

For this paper, single wheel model is employed shown in the followingfigure:

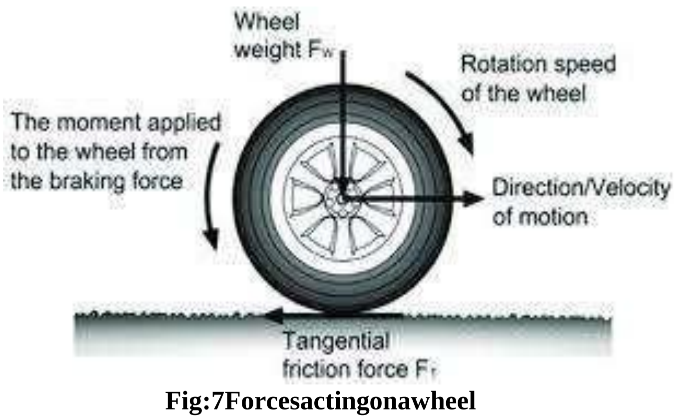


Fig:7Forcesactingonawheel

The followingassumptionsaremadeforcalculating:
i) Theoverallbrakingforceisdistributedevenlytoallfourwheels.
ii) Eachwheelexperiencessameroadconditions.
iii) Vehiclescenterofgravity isinthemid-way between thewheel-base.

B. Tyre/RoadInteraction:
Under normal conditions, the rotational velocity of the wheel (w) matchesthe forward velocity of the car (Vx). Any difference between the twoindicates an issue with tyre grip. This difference is defined as wheel slip(Ω)condition, whichcanbecalculatedusingthe following formula:

$$\Omega = \frac{Vx - R.w}{Vx}$$

Where R is theeffectiveradiusof tyre.
A zero slip indicates that the car is free-wheeling whereas a slip value ofunity or say 1 denotes the wheel is locked and is skidding. Frictionbetweenthetyre andtheroadsurfaceisdescribedbyμ.

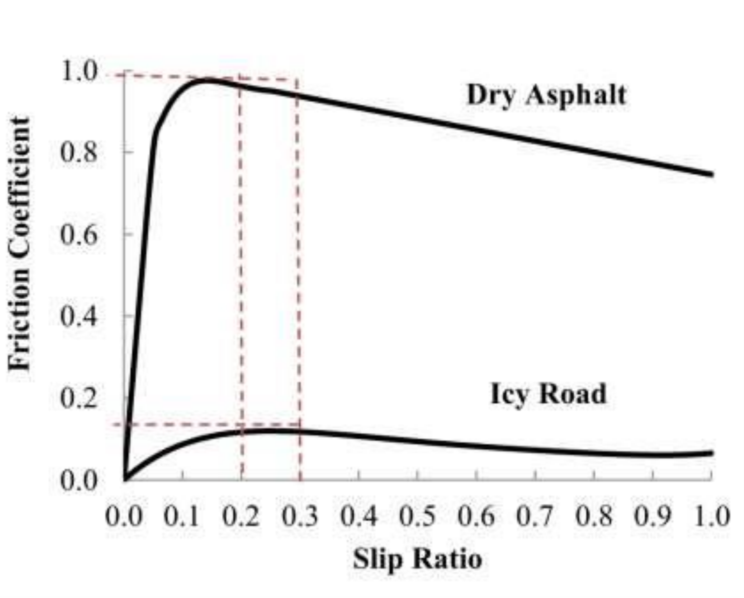


Fig:8Graph showingthewheelslipfactor

The above graph shows the importance of the friction coefficient indetermining the slip of a wheel. If the friction coefficient is low, thewheelslip isincreasedrapidlybutifthefriction is high,thewheelslipisnotinstantaneous.
Theabovetwodiscussedaspectsareimportantinefficientworkingoftheself-braking system in different road conditions. The braking systemsneeds to know the road condition and work accordingly for the road safety management and hence these are the two major considerations that Needstobeunderstoodbeforethedevelopmentofthemodule.

Formula: The braking distance is the main factor to be taken intoconsideration in this system. Braking distance is the distance between the pointwhere the brakes were applied and the point at which the vehicle stopscompletelyfromthecurrentspeed.Itiscalculatedbyusingfollowing formula.

$$d = u^2/2\mu g$$

Where,
d = Stopping distance (m)u = Initial Velocity (m/s)μ=Frictioncoefficient
g=Acceleration dueto gravity(9.8)

Derivation:
Thebrakingdistancehas severalvariablefunctionsto betaken into consideration.
1. **Slope** – The gravity helps to stop the vehicle quickly during uphill driveand works against during the downhill drive by increasing brakingdistance.
2. **Frictional Resistance** – Old and worn-out tyres on wet roads increasesthebrakingdistanceascomparedto a dryroad.

3. **Initial velocity**- More the initial velocity, more will be the time requiredtostopthevehicle.
Using basic equation of motion from physics: $\mathbf{v^2 = u^2 + 2ad}$, where '**v**' is finalvelocity, '**u**' is initial velocity, '**a**' is acceleration rate and'd'is distancetraveled.
Asthefinalvelocityafterbrakingis0,theequationcanbewrittenas$0=u^2+2ad$fromthe aboveequation,$d=-u^2/2a$.
The deceleration of a vehicle depends on the coefficient of friction and the slopeof the path it is travelling on. The acceleration due to gravity is multiplied by thegrade of the road which gives us an approximated estimation of the accelerationcauseddue to the slope ofthe road.
Acceleration rate (a) = Acceleration due to gravity (g) x (friction coefficient (μ) + grade(G))

Thereforethefinalformulabecomes:$\mathbf{d = u^2/2g(\mu+G)}$

For this project demonstration, grade factor is neglected and hence equationaboveisconsidered.
Calculations: For calculations, the following python coding was adaptedforaccurateand exactresults.Thiswasonlyforexperimentalpurpose.

```
>>>print ("Calculatethestoppingdistance")
>>>speed=int(input("Entertheinitialspeedinkm/hr:"))
>>>v=speed/ 0.2777778
>>>g=9.8
>>>coef= int(input("Enterthefriction coefficient:"))

>>>dist= (v*v) /(2*g*coef)

>>>print ("Thedistancetravelledbeforestoppingis",dist,"metres")
```

VIII. Results:

Consideringthecoefficientoffrictionindifferentseasons:

a) Duringdrysummerday,μ=0.7

Speed(kmph)	Brakingdistance(m)
10	0.58
20	2.24
30	5.05
40	9.00
50	14.07

b) Duringrainy season,μ=0.4

Speed(kmph)	Brakingdistance(m)
10	0.98
20	3.93
30	8.85
40	15.74
50	24.60

Fromtheaboveresultswecanseethat thebrakingdistanceislessindry roads as compared to wet roads and as the speed increases, the braking distance alsoincreases. Hence, the systems needs to adapt the road conditions beforeperformingitstask which can be doneeither manually orautomatically.

Understandingroadconditions:
The condition of road is an important factor for the effective braking of avehicle. The road condition can be either selected using the default preset valuesor by manually entering the variable values or automatically using some moresensorslikethehygrometerwhichmeasuresthe moisturecontentin air.
This device is called PSYCHROMETER. It is a type of hygrometer which isused to determine the moisture content in the air. As during rainy season, themoisturecontentintheatmospherewillbemorecomparedtoadrysummerday. This reading can be used to change the data values and hence the variablescanbechangedaccordingly.

Advantages andApplications:

- IncreasedRoadSafety
- Parkingassist
- Automatedguidedvehiclesinindustries
- Applicableinself-drivingvehicletechnology
- SpeedControl
- TrafficDiscipline
- Minimizedbackward/reversecollisions
- Safetymeasureincheapervehicles

Effectiveness of Self-Baking system and Manual braking system:

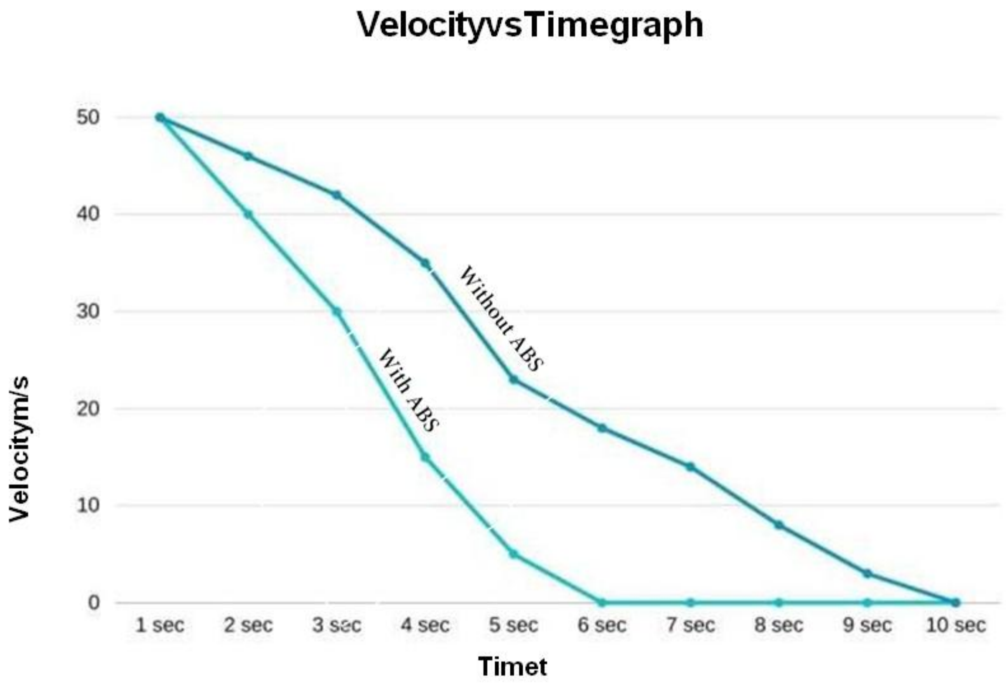


Fig:9VelocityvsTimegraphfordifferenceinbraking time

From the above graph we can see that a human reaction and braking effect takesmore time to perform than the automated self-braking mechanism. We can seethat there is a difference between WITH and WITHOUT Automatic BrakingSystem (ABS) and hence this system is effective in its performance in providingsafety.

AdvancedResearch:

In2020,the InternationalJournalofEnvironmentalResearchandPublicHealthpublished a report by the **State Key Laboratory of Automotive Safety andEnergy, Tsinghua University, Beijing** which stated that using the self-brakingsystem in vehicles helps to increase road safety and they collected dataregarding the same. The following graphs shows the estimated increase in roadsafetyby2030whenmajorityofthevehicleswill behavingthissystem.

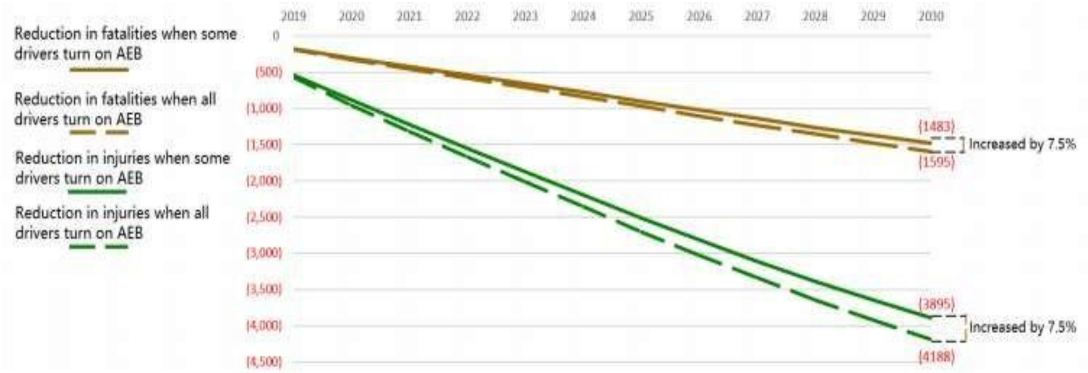


Fig: 10 Reduction in fatalities & injuries in China for different ABS activationrates.

We can see the term AEB (Automatic Emergency Braking) used which issimilar to ABS, but the only difference is that AEB only works in emergencysituation whereas the ABS is in continuous use. We can see the increase in thereductionpercentagesinroadinjuriesandfatalitiesbytheuseof thissystem.

IX. Conclusion:

The Automatic Braking System using Ultrasonic Sensor is capable ofperforming effectively in prototype testing. This project looks into theimplementation of an Automatic Braking System for Collision Avoidance andwith the intention to be used effectively in vehicles where the drivers may notbrake manually. With the help of this system the speed of the vehicle can bereduced automatically due to the sensing of the obstacles. This system reducesthe number of accidents and collisions and tends to save the lives of people. Bydoing this project practically, we gained the knowledge about the workingmechanism of an automatic braking system and with this future study andresearch, we hope to develop the system into an even more advanced vehiclespeed control system for automobile safety. To achieve this, lot of work andlearning, like the programming and operation of microcontrollers and theautomobile structure is required but development is the necessity for survivaland hence making these types of safety features available to common people isanecessarystepthathasto betaken.

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