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HEADLAMP LEVELING DEVICES AND ITS EFFECT ON NIGHT SAFETY IN INDIA- A SURVEY

Mrs. Rashmi Ramamurthy
Dr. B Ramachandra

Abstract

The automotive manufacturer always depends on new technologies for vehicular headlamps. The data shows the occurrence of road accidents at night is disproportionately high in numbers & severity compared to day time traffic accidents occurred at straight roads and head-on collisions. The reason may be due to lesser visibility and more glare in the straight driving mode. One of the reasons is the improper adjustment and in-correct usage of manual headlamp leveling device for the passing beam and also usage of main beams in un-conditional situations (approaching vehicles, during overtaking, in city limit, etc) as compared to automatic leveling devices. The survey shows that in India the usage of manual headlamp leveling devices is minimal or not aware of the system. At the same time, the usage of automatic leveling devices is not possible in mid and small segment vehicles due to technology limitations, higher cost, etc. To overcome these problems, the control strategy is developed for automatic load detection and control of the headlamp passing beam for the existing manual headlamp leveling device. Comprehensive experimental investigations have been carried out and validated as per the legal requirements. This study will provide a platform for auto industries/lawmaker/safety committees to choose a technology which shows better performance and cheap. With this technology, India further saves the lives from night accidents.

Keywords: Automotive, accidents, headlamps, headlamp leveling devices.

1. INTRODUCTION

The motor vehicle industry is one of the major pioneer activities for social and economic progress of any country. The automotive manufacturer always depends on new technologies for critical vehicular safety components and one of the important safety components is front lighting systems [1, 2]. In India, a total of 4,64,910 road accidents have been reported by States and Union Territories (UTs) in the calendar year 2017, claiming 1,47,913 lives and causing injuries to 4,70,975 persons [3, 4]. Table 1 shows Road accidents, fatalities and injuries, and Accident severity for the last 10 years.

Table 2 shows the number of accidents by the time interval of the day 2016 and 2017. This would translate, on average, into 1317 accidents and 413 accident deaths taking place on Indian roads every day; or 55 accidents and 17 deaths every hour. The occurrence of road accidents is observed to be higher during the night when visibility is at its lowest compared to the daytime. The two factors which affect visibilities are namely; insufficient illumination and glare caused by the oncoming traffic. Road accident at night is disproportionately high in number and severity, compared to day time driving traffic. It also shows about 40 % accident occurs during the night whereas around 60 % at day time. The statistics show that 40% of all road accidents take place at night when only 15% of the total traffic is plying. This shows the importance of the vehicle lighting system.

Table 1: Road accident statistics

Year	Number of Accidents		Number of Persons		Accident Severity*
	Total	Fatal	Killed	Injured	
2008	4,84,704	1,06,591 (22.0)	119,860	523,193	24.7
2009	4,86,384	1,10,993 (22.8)	125,660	515,458	25.8
2010	4,99,628	1,19,558 (23.9)	134,513	527,512	26.9
2011	4,97,686	1,21,618 (24.4)	1,42,485	5,11,394	28.6
2012	4,90,383	1,23,093 (25.1)	1,38,258	5,09,667	28.2
2013	4,86,476	1,22,589 (25.2)	1,37,572	4,94,893	28.3
2014	4,89,400	1,25,828 (25.7)	1,39,671	4,93,474	28.5
2015	5,01,423	1,31,726 (26.3)	1,46,133	5,00,279	29.1
2016	4,80,652	1,36,071 (28.3)	1,50,785	4,94,624	31.4
2017	4,64,910	1,34,796 (29.0)	1,47,913	4,70,975	31.8

Table 2: Number of road accidents by the time interval of day for 2016 and 2017

Time	2016		2017	
	Number of Accidents	% share in total accidents	Number of Accidents	% share in total accidents
06:00 - 09:00 hrs (Day)	54,522	11.3	51,551	11.1
09:00 - 12:00 hrs (Day)	75,771	15.7	71,426	15.4
12:00 - 15:00 hrs (Day)	73,380	15.3	71,594	15.4
15:00 - 18:00 hrs (Day)	85,834	17.9	82,456	17.7
18:00 - 21:00 hrs (Night)	84,555	17.6	85,686	18.4
21:00 - 24:00 hrs (Night)	50,970	10.6	49,567	10.7
00:00 - 03:00 hrs (Night)	25,976	5.4	25,050	5.4
03:00 - 06:00 hrs (Night)	29,644	6.2	27,580	5.9
Total 24 hrs	**4,80,652**	**100.0**	**4,64,910**	**100.0**

Table 3 shows Road accidents, fatalities, and injuries by type of collision – 2016 and 2017 it clearly shows that major accidents have occurred during a head-on collision. Table 4 shows the Accidents, fatalities, and injuries by road feature – 2017 and it exhibits a major percentage of accidents that have occurred in the straight road. This clearly shows that head-on collision during straight road may due the combination of headlamp glare lighting pattern, main beam, and passing beam switch ON / OFF and also the improper adjustment of lighting beam.

Table 3: Road accidents by type of collision 2016 and 2017

Type of collision	2016	2017	% change over the previous year
Head on collision	96466 (20.1)	87068 (18.7)	-9.7
Hit from back	59097 (12.3)	77540 (16.7)	31.2
Hit & Run	55942 (11.6)	65186 (14.0)	16.5
Hit Pedestrian	46823 *(9.7)*	62344 *(13.4)*	33.1
Hit from side	48413 *(10.1)*	42675 (9.2)	-11.9
Vehicle Overturn	48558 *(10.1)*	30037 (6.5)	-38.1
Others	125353 *(26.1)*	100060 (21.5)	---
Total	**480652**	**464910**	**-3.3**

Table 4: Accidents, fatalities, and injuries by road feature – 2017

Road feature	Number of accidents	Persons killed	Persons injured
Straight road	298351(64.2)	91203(61.7)	30295(64.3)
Curved road	54077(11.6)	17814(12.0)	57346(12.2)
Bridge	15514(3.3)	5543(3.7)	15839(3.4)
Culvert	11600(2.5)	4144(2.8)	11974(2.5)
Potholes	9423(2.0)	3597(2.4)	8792(1.9)
Steep grade	9124(2.0)	3248(2.2)	9753(2.1)
Ongoing road works/Under construction	11822(2.5)	4250(2.9)	11425(2.4)
Others*	55000(11.8)	18115(12.2)	52896(11.2)
Total	**464910**	**147913**	**470975**

Even though Govt. of India made mandatory for the fitment of certified headlamps, however in India one of the major problem for the accidents during the night is glare due to improper adjustment and in-correct usage of manual headlamp leveling device for the passing beam and also usage of main beams in the un-conditional situation (approaching vehicles, during overtaking, in city limit, etc.)[1, 2]. Fig. 1 demonstrates the headlamp beam movement due to different loading conditions.

Fig. 1. Headlamp beam movement due to different loading conditions

Automotive headlamps cannot be considered in isolation and it is a part of night driving visibility as affected by Road Environment, Traditionally automotive headlamp designs use two beams; the main beam is normally used on unlit roads where long sight distance is needed and high speeds are allowed and Dipped beam is normally used to provide good road illumination & still offer no dazzling intensity (glare) to the oncoming traffic.

National and International regulations [1,2] currently specify a limited range within which the vertical aim (illumination range) of the dipped headlamps must be maintained under various vehicle load conditions either by automatically or by manual headlamp leveling system to avoid the glare for the oncoming traffic. The primary objective for the use of headlamp leveling systems in the vehicle is to control the increase in glare that occurs with headlamps aimed too high. Dipped beam light cut off will move up-down as per the vehicle loading conditions such as co-passenger, rear seat occupants, and bootload. Due to different loading conditions, naturally, the beam will move up and certainly cause the glare for the oncoming traffic.

2. TYPES OF HEADLAMP LEVELING DEVICES, LIMITATIONS AND SOLUTIONS

To overcome glare problems presently there are two types of leveling systems available in the vehicle namely manual headlamp leveling system and automatic leveling devices[5-10]. The manual headlamp leveling system is controlled by the driver with a switch and having various positions 0-4 or 0-3 range. These leveling systems can take care of the loading effect on the vehicle where the manual switch is placed near the driver. a typical manual switch is as shown in Fig. 2. Manual headlight leveling device provides adjustment of headlight passing beam alignment according to the occupation of the occupants and loads.

Fig. 2. Manual headlamp leveling switch near the driver

The automatic headlamp leveling system linked to the vehicle suspension system will keep the position of the headlamps correctly as per the requirement regardless of vehicle load and without driver intervention. The automatic headlight leveling control system falls into two categories: Static and dynamic. The static leveling control system compensates for load variations of seating and loads. However, the dynamic systems correct headlamp aim during acceleration, braking, etc. A typical headlight leveling control system is shown in Fig. 3 where sensors on the vehicle axles do precisely measure the vehicle's inclination or tilt. An Electronically Control Unit (ECU) uses the sensor signals as the basis of calculating the vehicle's pitch angle. The ECU compares these data with the specified values as set by the vehicle manufacturer and responds to deviations by transmitting appropriate control signals to the headlamps motor, which in turn will adjust the lamp to the correct angle[11].

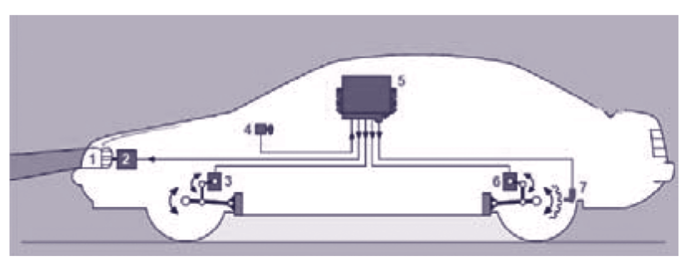

Fig. 3. System components of automatic leveling devices

Headlamp 2. Actuator 3.Front suspension travel sensor 4. Light switch (ON/OFF) 5. ECU 6. Front suspension travel sensor, 7. Wheel speed sensor

In both the systems, aiming is achieved by movement of headlamp reflector by a servo motor or stepper motor actuator present in the headlamp. The signals either from automatic or manual leveling received by actuator depend on load conditions of the vehicle and the actuator will rotate the reflector of the headlamp to achieve the required beam level.

Table 5 explains the comparison of types of leveling devices for different light sources as per National and International standards. The same is defined in the Central Motor Vehicle Rule (CMVR) as per Govt. of India.

Table 5: Comparison of types of leveling devices for different light sources as per national and international standards

Types of lamps	Manual leveling devices	Automatic leveling devices	Remarks
Tungsten	YES	YES	As per CMVR Rule, manual / Automatic leveling devices are allowed, if light sources total luminous flux is less than 2000 lumen. If exceeds 2000 lumen, automatic leveling device is mandatory
Tungsten Halogen	YES	YES	
High-intensity discharge (HID) less than 2000 lumen	YES	YES	
LEDs – less than 2000 lumen	YES	YES	
High-intensity discharge (HID) less than 2000 lumen	No	YES	
LEDs – more than 2000 lumen	No	YES	

3. TYPES OF VEHICLE POPULATION AND USE OF HEADLAMP LEVELING DEVICES IN INDIA

The data was collected for the total sales of most popular M1 category vehicles in India for four financial years namely 2016-17 to 2019-20. These data were collected with the aim of vehicle population distribution with regard to manual headlamp leveling device and automatic leveling devices. The data collection was concentred only M1 category vehicles because the rest of the category vehicles have only manual headlamp leveling devices. Table 6 shows four years Segment & Company wise domestic Sales having manual headlamps leveling devices in India. Table 7 shows four years Segment & Company wise Domestic Sales having automatic headlamps leveling devices in India.

Table 6: Segment & Company wise domestic sales having manual headlamps leveling devices in India

Manufacturer	2016-17	2017-18	2018-2019	2019-2020
FIAT INDIA AUTOMOBILES Private Limited	5,666	1,860	798	125
Ford India Pvt Ltd	36,386	33,364	40,843	22,101
Honda Cars India Ltd	1,30,344	1,10,109	1,44,716	87,257
Hyundai Motor India Ltd	4,11,207	4,27,284	4,19,405	3,08,535
Mahindra & Mahindra Ltd	3,219	725	1,538	858
Maruti Suzuki India Ltd	10,95,891	12,34,571	12,87,023	10,60,644
Nissan Motor India Pvt Ltd	46,780	43,703	27,988	12,751
Renault India Pvt Ltd	1,11,690	83,140	64,913	46,766
SkodaAuto India Pvt Ltd	13,680	15,988	14,423	12,854
Tata Motors Ltd	1,34,499	1,35,430	1,31,387	71,816
Toyota Kirloskar Motor Pvt Ltd	50,760	41,990	51,300	47,168
Volkswagen India Pvt Ltd	50,042	44,243	33,805	24,531
Total	**20,90,164**	**21,72,407**	**22,18,139**	**16,95,406**

Table 7: Segment &Company wise Domestic Sales having automatic headlamps leveling devices in India

Manufacturer	2016-17	2017-18	2018-2019	2019-2020
BMW India	9641	1105	9800	7500
Mercedes-Benz India	13231	15538	15538	13786
Audi India	2016	6463	6463	4594
Jaguar Land Rover	2942	4596	4596	5000
Volvo cars	750	2638	2638	2687
Total	**28580**	**30340**	**39035**	**33567**

Table 8 exhibits the domestic Sales and distribution of two types of headlamp leveling devices in India and Table 9 shows Domestic Sales and its % distribution of types of headlamp leveling devices in India

Table 8: shows domestic Sales and distribution of two types of headlamp leveling devices in India

Year	Manual headlamp devices	Automatic headlamp devices	Total
2016-2017	2090164	28580	2118744
2017-2018	2172407	30340	2202747
2018-2019	2218139	39035	2257174
2019-2020	1695406	33567	1728973

Table 9: shows Domestic Sales and its % distribution of types of headlamp leveling devices in India

Domestic Sales and its % distribution of type of headlamp leveling devices in India			
Year	**Total**	**% of Manual headlamp devices**	**% of Automatic headlamp devices**
2016-2017	2118744	98.65	1.35
2017-2018	2202747	98.62	1.38
2018-2019	2257174	98.27	1.73
2019-2020	1728973	98.06	1.94

The data shows that the percentage of automatic headlamp devices in the range of 1.35 to 1.98 % compared to manual headlamp devices in the range of 98.65 to 98.06. Hence it is necessary to consider and evaluate the effect of manual headlamp leveling device at night. However, manual switch operation is purely based on the driver, sometimes drive may operate or the manual adjustment switch can be manipulated, as necessary, to achieve the desired relationship between headlight alignment and his visibility requirements without understanding the effect on approaching vehicle driver performance [12]. However, the usage of automatic leveling devices is not possible in mid and small segment vehicles due to technology limitations, higher cost, etc. Considering the above facts, developed a control strategy for automatic load detection and control the headlamp passing beam cut-off for the existing manual headlamps leveling device which is operated by a stepper motor actuator. Comprehensive experimental investigations about this research and its night safety for different vehicle categories are addressed. This study will provide a platform for Indian auto industries/ law maker/safety committees to choose a technology which is better than the existing manual leveling device with respect to performance as well as cost[9,10]. With this technology, India further saves the lives from night accidents.

4. DRIVERS OPINION POOL ON THE EXISTING MANUAL HEADLAMP LEVELING SYSTEM

Is a manual leveling system known to users in India?

An opinion poll was conducted to know the status of the existing manual leveling system and its usages in India. This

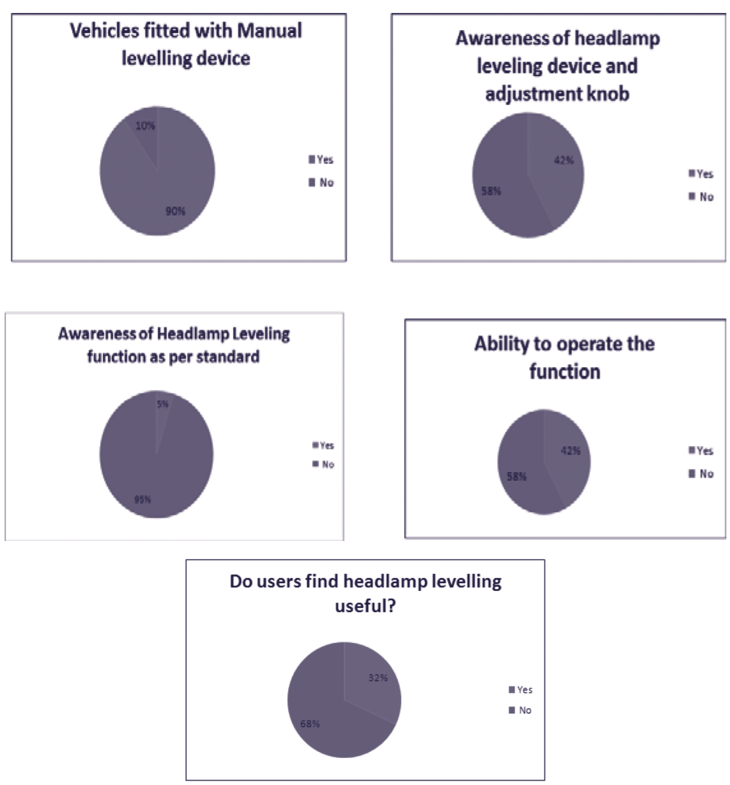

Fig. 4 India population opinion poll

study was limited only for the M1 category of vehicle drivers. The outcome of the survey is as follows [13] and Fig. 4 shows the India population opinion poll on the usage of headlamp leveling devices.

- Drivers not aware of the headlamp leveling function and it's relation with passenger occupancy and loading pattern
- Drivers using the headlamp leveling function on Highways for better visibility by pulling up the beam irrespective of any load
- Drivers using the headlamp leveling function in low lit areas by pulling down the beam
- Maximum drivers do not change the company setting for headlamp leveling device ever in the vehicle life span
- No awareness of the existence of headlamp switch or knob by 40 % of drivers

5. PROBLEM FORMULATION AND METHODOLOGY

5.1 Problem Formulation

To overcome this situation low-cost automatic headlamp leveling devices concept is developed based on the occupant and load detection in the vehicle. In this system, the presence of occupant and bootload is detected by load sensors located below each passenger seat and luggage compartment. Load sensors located in different seating positions and bootload will provide the signals to the headlamp actuator to maintain the required beam pattern. The total system is to be integrated and calibrated as per the norms.

5.2 Methodology

The following methodology adopted for the study.

- To identify test vehicle this is inbuilt with a manual headlamp leveling device with servo motor.
- Identify the load pads and its placement to detect occupant and bootload in the vehicle.
- Identify suitable electronics hardware components for load detecting and management of servo motor operation.
- Design and development of a control strategy for the operation of the headlamp leveling system depending on different loading conditions.
- To integrate load pads, microcontroller, and stepper motor this is inbuilt in the headlamp system.
- To calibrate and validate the developed system to meet national and international standard requirements.
- To carry out an experimental investigation on test vehicles as a part of an automatic leveling device to control passing beam movement to address the glare problems at night.

Fig. 5 shows the flow chart of the total system and is as follows;

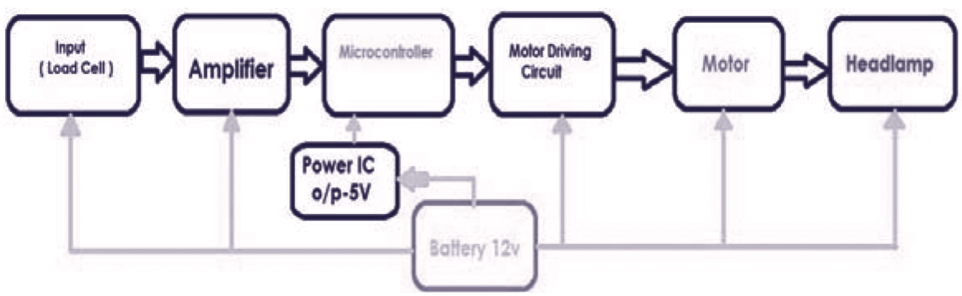

Fig. 5 Flow chart of the total system

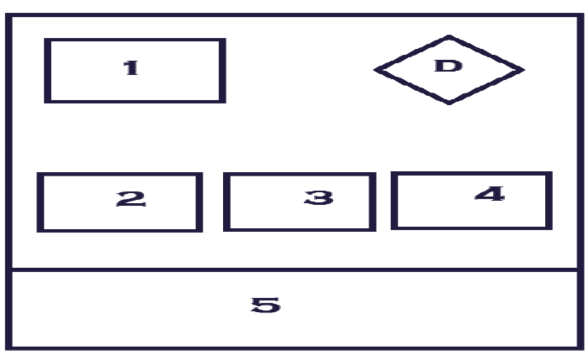

Fig. 6. M1 category seating layout

Load cell position

D: Driver seat: setting done by the vehicle manufacturer

1.: Co-Driver position

2,3,4: Rear seat Load cells (3 Nos.) position

5.: Trunk load as per the vehicle max load

The Fig. 6 shows the load cell placement in the M1 category vehicle. The load cells generate an electrical signal in response to the substrate being stressed by the weight. The electrical signal changes as a function of the weight of the seat occupant. The system was integrated with the consideration of electrical signal output v/s load of each load cell and the same is connected to the headlamp leveling motor through an amplifier and microcontroller. The system tested as per the procedure defined in ECE R 48 / AIS: 008 and set each loading position in such a way that headlamp cut-off retains within the specified range in the standards.

6. EXPERIMENTAL RESULTS AND DISCUSSIONS

Table 10, Fig. 7 and Fig.8 shows the comparison of passing beam cut-off inclination for three types of leveling methods namely the headlamp levelling without switch operation, with operation and automatic stepper motor headlamp. The comparison shows that auto Stepper motor inclination is much closer to reference inclination angle -1% as compared to manual headlamp device. The maximum variation was observed in (Driver + Co-Driver+ 3Passengers+100% Boot (25+25+25) kg) load condition in manual switch reading is -1.725% whereas auto stepper motor reading is -1.095%. This proves that stepper motor with automatic load detecting methods is the better option to use in the automotive headlamp leveling system. Conducted repeatability and reproducibility of the test and observed results are satisfactory.

Table 10: Comparison of passing beam cut-off inclination of various leveling devices

Load Configuration	Without Switch (%)	With Switch (%)	Auto stepper motor (%)
Only Driver	-1	-1	-1
Driver + Co-Driver	-1.025	-1.12	-0.98
Driver+Co-Driver+3Passengers	0.245	-1.35	-0.96
Driver + Co-Driver+ 3Passengers+100% Boot (25+25+25)kg	0.74	-1.72	-1.09
Driver + 100% Boot (85+85+85)kg	1.36	-1.44	-1.00
Maximum inclination out of all loading configuration	1.36	-1.72	-1.09
Maximum % of deviation from reference inclination	136%	72.5%	9.5%

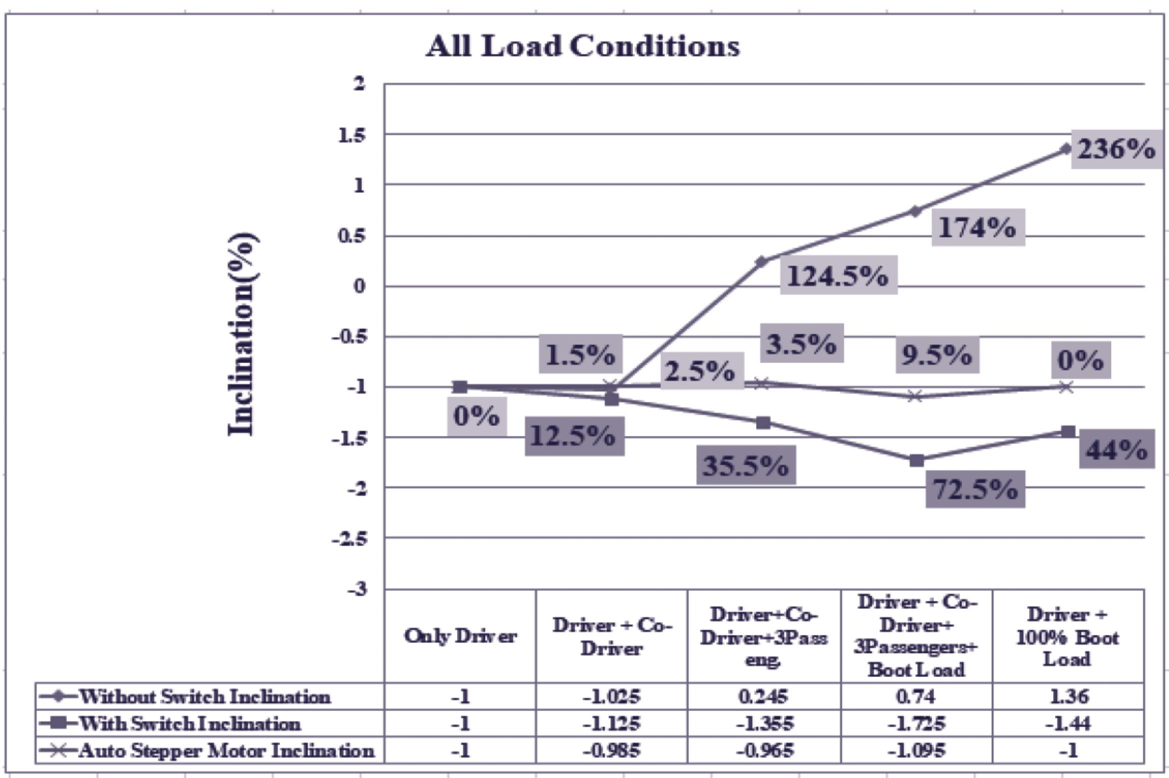

Fig. 7 Percentage of deviation of beam inclination from the initial reference value for the headlamp levelling without switch operation, with operation and automatic stepper motor headlamp

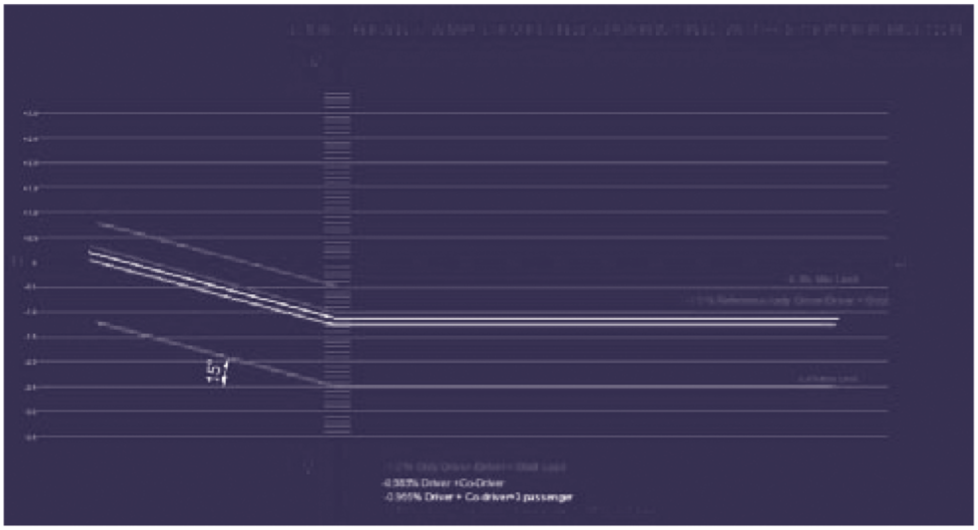

Fig. 8. Percentage of deviation of beam inclination from the initial reference value for the automatic stepper motor headlamp

7. SUMMARY

7.1 Conclusion of the study

Experiments were conducted for three types of headlamp leveling devices to control the passing beam movement in the vehicle. Which includes; with and without the operation of manual headlamp leveling switch and a stepper motor with newly developed control strategy for automatic leveling devices. Result proves the developed control strategy in conjunction with occupant and bootload detecting mechanism gives better performance in the order of 63% close to the initial aiming than manual leveling device. This 63% upward movement of the passing beam will help for better visibility during night driving and developed control strategy works as an automatic leveling device. With this system, manual leveling switch can be replaced in the system, so that malfunctioning of beam leveling is removed and will achieve more safety during night driving.

7.2 Limitations

However, a more detailed study needs to be conducted regarding the selection of load sensors, integration in the seat, calibration of load, calibration of leveling motor with respect to different load cell electrical signals, adoption in the vehicle, vehicle-level test Etc.

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AUTHORS

Mrs. Rashmi Ramamurthy, Department of Electrical & Electronics, P.E.S College of Engineering, PES Engineering Road, PES College Campus, Mandya – 571 401, (Karnataka) India
Email: rashmi09sham@gmail.com

Dr. B Ramachandra, Professor, Department of Electrical & Electronics, P.E.S. College of Engineering, PES Engineering Road, PES College Campus, Mandya – 571 401, (Karnataka) India
Email: bramachandra1@yahoo.co.in