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CONTROL STRATEGY DEVELOPMENT FOR AUTOMATED HEADLAMP LEVELING USING SERVO AND STEPPER MOTORS IN AUTOMOBILES

Dr. R. Rashmi, Associate Professor PVPIT Bavdhan Engineering College, Savitribai Phule Pune University (SPPU).

ABSTRACT
The Indian road accidents data shows the occurrence of accidents at night is disproportionately high in numbers & severity compared to day time traffic due to lesser visibility and more glare from automobile headlamps. Traditionally automotive headlamps having two types of beams; Main beam which is normally used to unlit roads where long sight distance is needed and Dipped beam which is normally used to provide good road illumination and still offer no dazzling intensity to the oncoming traffic. Automobile headlamp lighting performance depends on how accurately designed the headlamps to produce the required illumination as per the national and international standards and also how accurately controlling the beam movement depending on the on-coming traffic. There are two technologies to control the headlamp passing beam movement namely manual and automatic headlamp levelling device. The drawback of the manual headlamp levelling device is an improper adjustment and in-correct usage. However, the usage of automatic levelling devices is not possible in mid and small segment vehicles due to technology limitations, higher cost etc. Hence, developed a control strategy for automatic load detection and control of headlamp passing beam for the existing manual headlamp levelling device using a servo motor and stepper motor. Comprehensive experimental investigations have been carried out and validated as per the legal requirements.

Keywords:
Automotive, Accidents, Headlamps, Headlamp Leveling Devices, Stepper Motor, Servo Motor

I. Introduction
The automotive manufacturer always depends on new technologies for vehicular front lighting systems. The Indian road accidents data shows the occurrence of accidents at night is disproportionately high in numbers & severity compared to day time traffic due to lesser visibility and more glare from automobile headlamps[1,2]. Traditionally automotive headlamps having two types of beams; Main beam which is normally used to unlit roads where long sight distance is needed when high speeds are allowed and no on-coming traffic on the same lane; and Dipped beam which is normally used to provide good road illumination and still offer no dazzling intensity (glare) to the oncoming traffic. Automobile headlamp lighting performance depends on how accurately designed the headlamps to produce the required illumination as per the national and international standards and also how accurately controlling the beam movement depending on the on-coming traffic. 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 levelling device for the passing beam and also usage of main beams in an unconditional situation (approaching vehicles, during overtaking, in city limit etc.)[3,4,5]. Fig. 1 demonstrates the headlamp beam movement due to different loading conditions.

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

1. Types of headlamp levelling devices, limitations and solutions

There are two types of headlamp levelling systems used to control the passing beam viz; manual and automatic headlamp levelling systems[6-12]. The manual headlamp levelling system is controlled by the driver with a switch and having various positions 0-4 or 0-3 range. These levelling systems can take care of the loading effect on the vehicle where the manual switch is placed near the driver and the typical manual switch is as shown in Fig. 2. A manual headlight levelling device provides adjustment of headlight passing beam alignment according to the occupation of the occupants and loads. However, manual switch operation is purely based on the driver, sometimes the driver 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[5].

Fig. 2. Manual headlamp levelling switch placed near the driver

The automatic headlamp levelling system linked to the vehicle suspension system will keep the position of the headlamp correctly as per the requirement regardless of vehicle load and without driver intervention. A typical automatic headlamp levelling 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 for calculating the vehicle's pitch angle. However, the usage of automatic levelling devices is not possible in mid and small segment vehicles due to technology limitations, higher cost etc.[8,12]

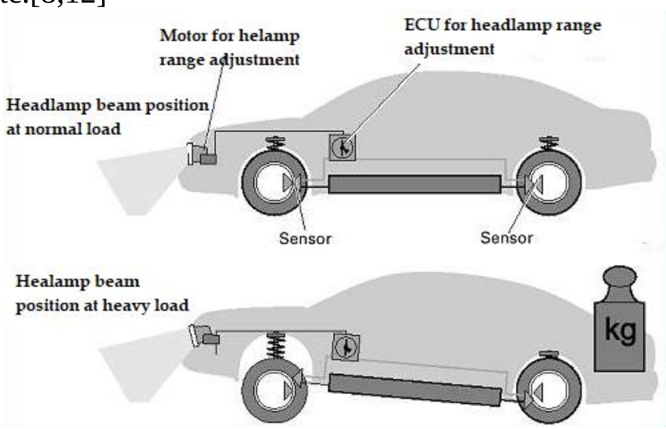

Fig. 3. System components of automatic levelling devices

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

2. **Concept and Methodology**

Considering the technology limitations and higher cost of the automatic levelling devices, developed a control strategy for automatic load detection and control the headlamp passing beam cut-off for the existing manual headlamps levelling device using a servo motor and stepper motor technologies. Comprehensive experimental investigations about this study and its night safety for different vehicle categories are addressed. This study will provide a platform for Indian auto industries/lawmaker/safety committees to choose a technology that is better than the existing manual levelling device with respect to performance as well as cost[10,11]. With this technology, India further saves lives from night accidents.

The methodology followed in this investigation is as follows:

1) To identify the vehicle which is built with a manual headlamp levelling device.
2) Selection of suitable servo motor and stepper motor for the identified vehicle headlamps
3) Identify the load sensors and their placement to detect occupant and bootload in the vehicle.
4) Identify suitable electronics hardware components for load detecting and management of servo and stepper motor operation.
5) Design and development of a control strategy for the operation of the headlamp levelling system depending on different loading conditions using a servo motor and stepper motor.
6) To integrate load sensors, a microcontroller with servo motor and stepper motor one after one.
7) To calibrate and validate the developed system to meet national and international standards requirement.
8) To carry out an experimental investigation on test vehicle as a part of an automatic levelling device using a servo motor and stepper motor to control passing beam movement to address the glare problems during the night.

3. Experimental design, hardware and software requirements

The objective of this study is to develop the control strategy for servo motor and stepper motor manual head levelling device to work as an automatic levelling device by detecting the occupant weight, bootload and position the headlamp reflector to provide desired beam pattern and beam position as per standards[10,11]. The working principle of the entire system of developed levelling system is shown in Fig. 4.

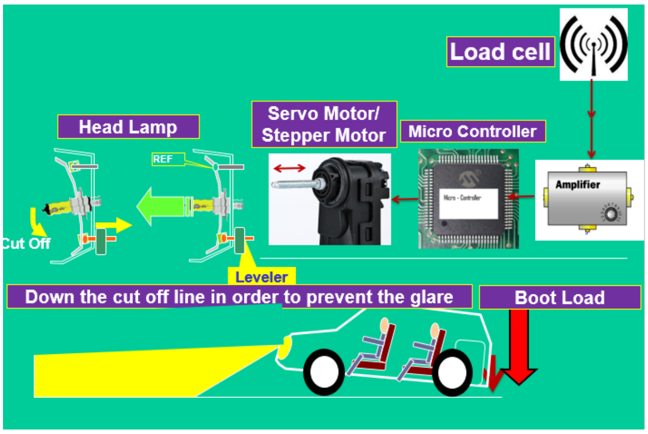

Fig. 4. Typical working principle of newly developed headlamp levelling system

The Hardware and software requirements are as follows;

A. Load detecting devices (load sensors)

The Camry digital strain gauge base weighing sensor with a resolution of 0.1 kg is used for the detection of the weight of the occupant as well as boot load as per the loading conditions of the test vehicle.

B. Amplifier

The accurate, low noise differential signal acquisition INA122 precision instrumentation amplifier is used for the amplification of signals generated in the load detecting devices for various loads. Its twoop-amp design provides excellent performance with very low quiescent current and is ideal for portable instrumentation and data acquisition systems.

C. Microcontroller

The 10 bit PIC16F877A microcontroller along with 8 bit DAC TLC7226C is used in the present work

D. Headlamp levelling Servo Motor

The motor used in the system is a 12V Servo motor, which is inbuilt within the headlamp's separate motor console. Headlamp levelling Motor is driven by an IC named TLE 4206-2G and is a protected H-Bridge Driver designed specifically for automotive headlight beam.

E. Headlamp levelling Stepper Motor

A stepper motor is a motor in which an actuator transforming an electric pulse into angular displacement. Generally, when receiving a pulse signal from the microcontroller circuit, the stepper motor will rotate at a stepping angle according to the direction set for the motor. The angular displacement can be controlled by controlling the pulse number to positioning the headlamp reflector movement accurately. The IC DRV8824 is used in stepper motor has two H-bridge drivers, a micro-stepping indexer is intended to drive bipolar stepper motors found in this application. The advanced on-chip protection of the DRV8824 reduces design complexity and enables higher system reliability. The programmable decay mode for a controller is incorporated into the system.

F. Software

- C programming is written for PIC controller
- Eagle for PCB design

4. Development of control strategy with Microcontroller unit

PIC16F/18F MCU Development kit is used to smooth the progress of developing and debugging various designs encompassing microcontrollers from Microchips used in the system. It's designed to facilitate PIC16F877A on-board Programmer for PIC Microcontroller through ISP on Universal Serial port. It integrates onboard USART, LEDs, keypads, 6 ADC inputs and LCD used in the circuit to create a stand-alone versatile test platform. Fig. 5 shows the MCU kit used in the research [13].

Fig. 5. Microcontroller unit Development kit

5. Working Principle

Fig. 6 demonstrates the complete working principle of the newly developed headlamp levelling servo motor/stepper motor and its control strategy depending on the different loading conditions in the vehicle as per configuration.

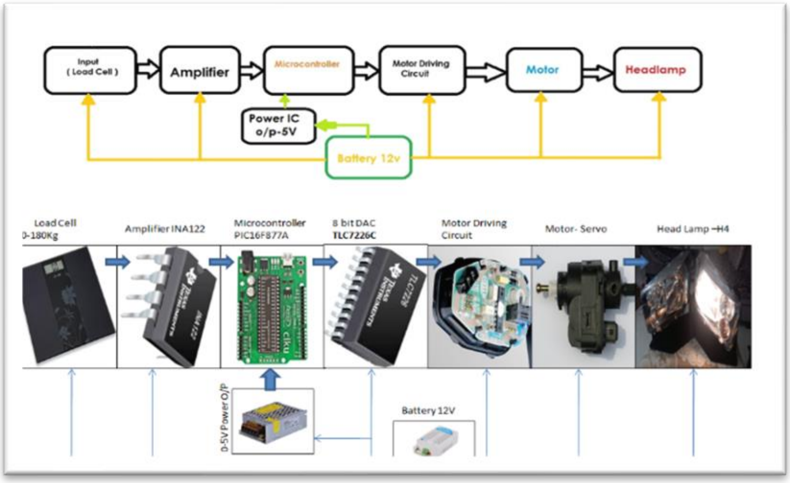

Fig. 6 Block diagram of the working principle of the automatic headlamp levelling device using a control strategy

The output of load sensors in terms of millivolt is amplified by using IC INA 122 instrumentation amplifier. The amplified signals for different loads in terms of voltage are given to the micro-controller IC PIC 16F877A.

The controlled digital output from microcontroller is converted into an analog voltage by a digital-to-analog converter (DAC) with the help of IC 7226. The TLC7226 consist of four 8-bit voltage-output digital-to-analog converters (DACs) with output buffer amplifiers and interface logic on a single monolithic chip. Separate on-chip latches are provided for each of the four DACs. Data is transferred into one of these data latches through a common 8-bit TTL/CMOS-compatible 5-V input port

Each DAC includes an output buffer amplifier capable of sourcing up to 5 mA of output current. The TLC7226 performance is specified for input reference voltages from 2 V to VDD – 4 V with dual supplies. The voltage mode configuration of the DACs allows the TLC7226 to be operated from a single power supply rail at a reference of 10 V.

The output of DAC is connected to the motor through servo motor controller IC TLE 4206-2G which is inbuilt in the motor. The headlamp levelling motor either servo or stepper will adjust the headlamp reflector by push or pull motor actuator as per the input received by the motor controller[13].

6. Motor calibration

A. Servo Motor calibration

The servo motor was calibrated for its total effective shaft stroke in terms of effective angle of headlamp passing beam up-down movement versus voltage requirements. Fig. 7 shows the total effective angle of the servo motor. The total effective angle is 3.207° for 12V. Hence, the shaft rotation for one volt is 0.267284° and for one-degree shaft, the rotation required voltage is 3.741342V. This factor is used further for the programming of the microcontroller during the experiments.

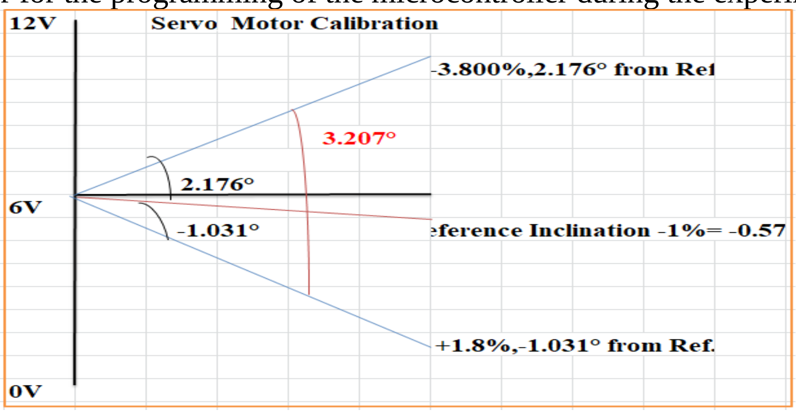

Fig. 7. Total effective angle of the servo motor

B. Stepper Motor Calibration

The stepper motor was calibrated for the total effective angle of headlamp passing beam up-down movement versus the number of steps required. The objective of the calibration of the stepper motor is to calculate the effective angular movement of the headlamp actuated by the stepper motor with respect to the steps. The number of steps for the complete operation of the stepper motor headlamp is 3030. Effective angle of a selected stepper motor, number of steps required for one-degree rotation of stepper motor and shaft rotation in degrees for one step is observed by the calibration experiment. Headlamp reflector movement with the push-pull action of the stepper motor shaft corresponding to the steps given by the controller is measured on the chart as h1 in mm. The total effective angle is 6.695° for 3030 steps. Hence, the degree of headlamp movement for one step is 0.0022096° and for one-degree shaft, rotation required steps are 452.55steps (calculated). Fig. 8 shows the total effective angle of the stepper motor.

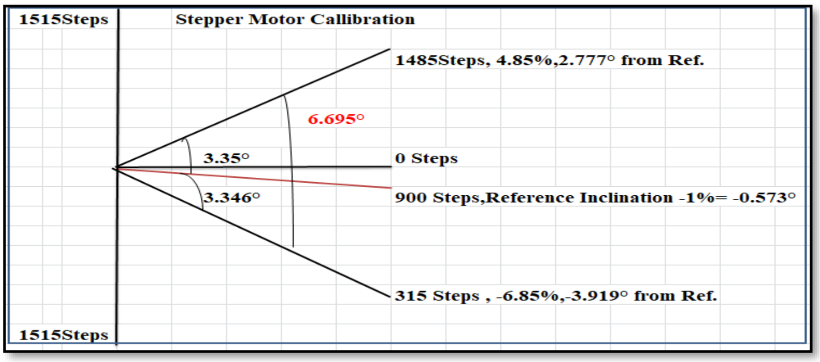

Fig. 8 Total effective angle of the stepper motor

7. Experimentation

A. Experimentation setup

The experiments were conducted on the M1 category test vehicle having 5 seating capacity designated as Driver, Co-driver, passenger occupied at the rear and bootload as declared by the vehicle manufacturer. The test procedure followed to conduct the experiment is as per AIS:008, Rev1[10,11], which is followed for certification of installation requirements of headlamps in vehicles. The measurement of initial inclination, Vehicle preparation, loading conditions is as per AIS:008, Rev1[10,11]. Fig. 9 shows the experimental setup for the measurement of headlamp vertical orientation which includes vehicle and measurement screen which is placed at 10 m (L) from the headlamp reference point. The headlamp reference point is also known as headlamp bulb filament reference position and this point is used to set the headlamp initial height from the ground (h2). The vertical beam movement measurement h1 was taken on a test screen placed at a distance of 10 m (L) and it is measured from the ground. The beam inclination in percentage is calculated using formula; [(h1-h2)/L]X100 and degrees; tanØ=(h1-h2)/L

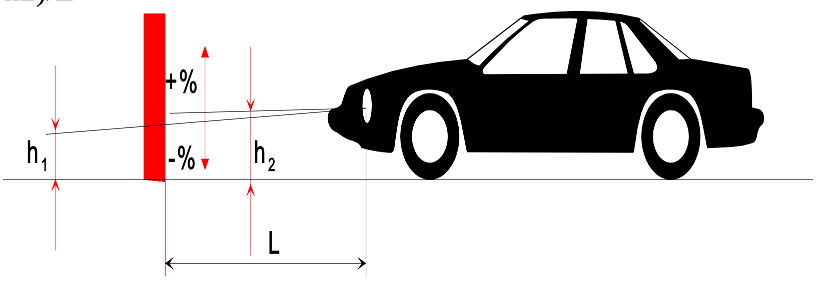

Fig. 9. Headlamp beam inclination

The following experiments were conducted on newly developed adaptive Headlamp levelling experiments and results were compared, analyzed, and concluded.

- Without operating the Manual Headlamp Levelling System
- With the operation of Manual Headlamp Levelling motor switch
- Automated Headlamp Levelling system using Servo Motor
- Automated Headlamp Levelling using system Stepper Motor

During experimentation, 5 loading configuration was considered as per standard as mentioned in the following tables.

B. Experimentation without the operation of headlamp levelling switch

The experiments were conducted without the operation of the headlamp levelling switch[10,11]. Table 1and Fig. 10 shows the passing beam cut-off inclination of the LH and RH side headlamp. The result shows that without operating a manual levelling switch doesn't meet the standard requirements -0.5% to -2.5% in some of the loading conditions. This indicates the requirements of headlamp levelling device in the vehicles to meet night safety. Hence, developed the new concept of occupant and bootload detecting mechanism and control strategy for operation of the system to meet automatic levelling device.

Load Configuration	Vehicle Weight (kg)	Switch Position	Inclination (%)	Avg. Inclination (%)	Inclination (deg)	Change in Inclination (deg)
Only Driver	1035	0	-1.00	-1.000	-0.573	0.000
			-1.00		-0.573	0.000
Driver + Co-Driver	1110	0	-0.90	-1.025	-0.516	0.057
			-1.15		-0.659	-0.086
Driver + Co-Driver + 3 Passengers	1335	***0***	***0.28***	0.245	0.161	0.734
			0.21		0.120	0.693
Driver + Co-Driver + 3Passengers + 100% Boot	1410	***0***	***0.77***	0.74	0.441	1.014
			0.71		0.407	0.980
Driver + 100% Boot	1350	***0***	***1.40***	1.36	0.802	1.375
			1.32		0.757	1.330

Table 1. Beam inclination without operating the Manual Headlamp Levelling System

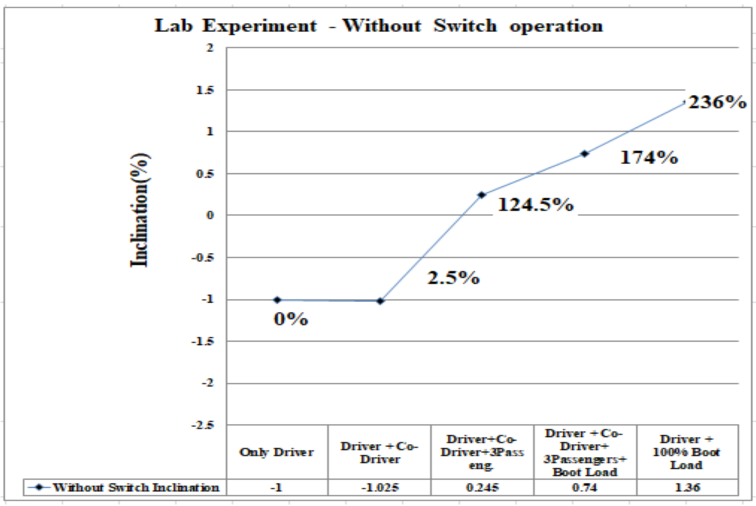

Fig. 10. Percentage deviation of beam inclination from the initial reference value without operating the Manual Headlamp Levelling System

Table 1 also shows the errors in inclination calculated in all loading conditions to bring down the beam inclination cut-off as close as to reference value -0.573° (-1.0%) to enhance the performance of the headlamp visibility and meet the automatic levelling device requirements. These correction factors are used to develop the control strategy using a microcontroller unit which is used to control the headlamp levelling motor position during experiments. The microcontroller unit controls the headlamp levelling stepper motor position as per the loading conditions of the vehicle in such a way that, headlamp beam inclination remains in the initial set position without manual intervention of driver as the objective of the study was set.

C. Experimentation with the operation of headlamp levelling motor switch

Since the head beam inclination requirements do not meet the requirements without operating the switch, manually operated the switch position to adjust the levelling motor to set the headlamp inclination level in the range of -0.5% to -2.5% to meet the standard requirements. Table 2 and Fig. 11 shows the switch positions for the percentage of beam inclination required for the tested vehicle to meet the standard requirements,

Load Configuration	Vehicle Weight (kg)	Switch Position	Inclination (%)	Avg. Inclination (%)	Inclination (deg)	Error in Inclination (deg)
Only Driver	1035	0	-1	-1	-1.000	-0.573
			-1		-1.000	-0.573
Driver + Co-Driver	1110	0	-1.120	-1.125	-0.642	-0.069
			-1.130		-0.648	-0.075
Driver+Co-Driver+3Passengers	1335	1	-1.220	-1.355	-0.699	-0.126
			-1.490		-0.854	-0.281
Driver + Co-Driver+ 3Passengers+ 100% Boot	1410	2	-1.700	-1.725	-0.974	-0.401
			-1.750		-1.003	-0.430
Driver + 100% Boot	1350	3	-1.450	-1.44	-0.831	-0.258
			-1.430		-0.820	-0.247

Table 2. Beam inclination with the operation of headlamp levelling motor switch

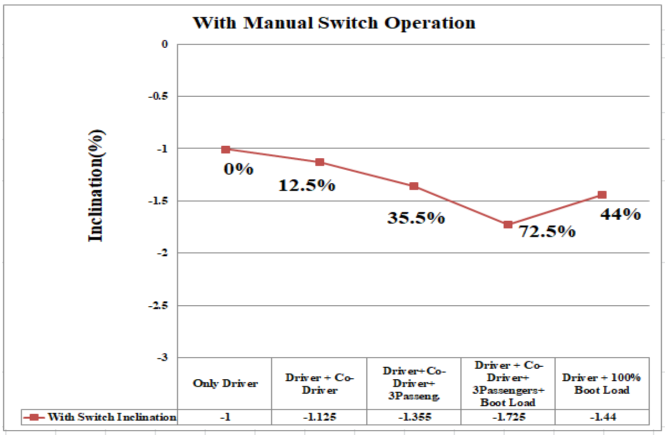

Fig. 11. Percentage deviation of beam inclination from the initial reference value with the operation of headlamp levelling motor switch

D. Experimentation on Automated Headlamp Levelling system using Servo Motor

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Change in the inclination of without operating switch is used for the calculation of DAC for programing to the controller and development of control strategy. The controller will give the appropriate voltage to the servo motor for its shaft rotation as per the DAC value.
For each loading condition, the controller will give a DAC value corresponding to the amplifier output. Voltages for each DAC values are shown in Table 3.

Load Configuration	Change in Inclination (deg.) (RH & LH)	Voltage Change Required (RH &LH)	Absolute Voltage Required (RH & LH)	Calculated DAC Output (RH & LH)	Tuned DAC Output (RH & LH)	Observed Voltage
Only Driver	0.000	-0.001	2.49	64.69	65	2.44
	-0.086	-0.323	2.17	56.36	56	
Driver +Co-Driver	0.028	0.106	2.60	67.46	67	2.52
	0.000	-0.001	2.49	64.69	65	
Driver+Co-Driver+3Passengers	0.716	2.680	5.18	134.08	134	5.10
	0.774	2.894	5.39	139.63	140	
Driver +Co-Driver+ 3Passengers+ Boot Load	1.204	4.503	7.00	181.26	181	6.91
	1.204	4.503	7.00	181.26	181	
Driver +BootLoad	1.777	6.647	9.14	236.76	237	9.11
	1.834	6.861	9.36	242.31	242	

Table 3 Calculation of DAC for change in inclination

Table 4 and Fig. 12 shows the percentage of deviation of beam inclination from the initial set value (-1.0%) of Automatic servo motor headlamp operation for all load conditions as per standard. The maximum percentage variation from the reference value shows 34.5 % which is equal to -1.345% inclinations as against -1.0%. However, in the manual switch operation, the maximum percentage variation from the reference value shows 72.5 % which is equal to -1.725% inclinations as against -1.0%.

Load Configuration	Vehicle Weight (kg)	Switch Position	Inclination (%)	Avg. Inclination (%)
Only Driver	1035	0	-1.00	-1.00
			-1.00	
Driver + Co-Driver	1110	0	-0.90	-0.89
			-0.88	
Driver + Co-Driver + 3Passengers	1335	0	-1.25	-1.28
			-1.31	
Driver + Co-Driver + 3 Passengers + 100% Boot kg	1410	0	-1.37	-1.345
			-1.32	
Driver + 100% Boot kg	1350	0	-1.32	-1.315
			-1.31	

Table 4 Beam inclination of Automated Headlamp Levelling system using Servo Motor with a control strategy

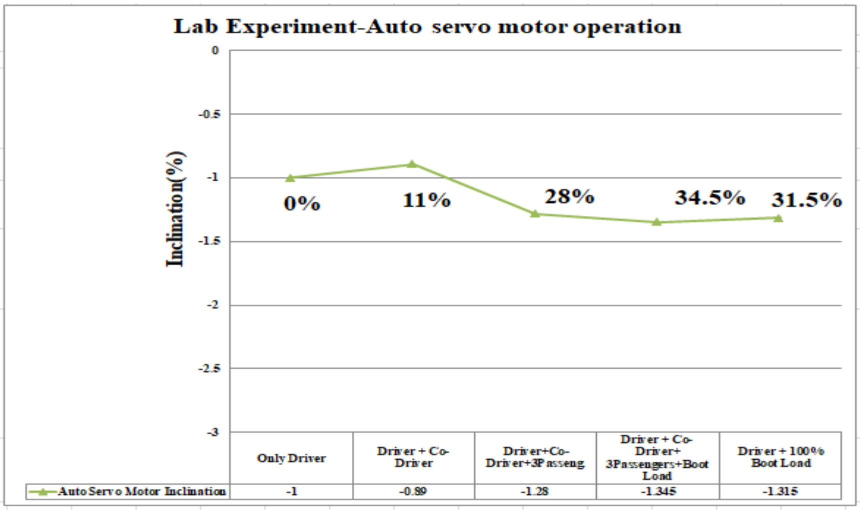

Fig. 12. Percentage of deviation of beam inclination from the initial reference value for the automatic servo motor headlamp

E. Experimentation on Automated Headlamp Levelling system using Stepper Motor

The correction factors calculated during the experiment without operating switch were used for the calculation of the number of steps required for the stepper motor and the programming of the microcontroller unit and to development of control strategy. The controller unit will deliver appropriate steps to the stepper motor for its shaft rotation which is used to control the headlamp levelling motor position during experiments. Table 5 shows the number of steps required for each loading configuration as per the change in inclination. The table also shows the absolute steps required and steps programmed.

Load Configuration	Steps Change Required	Absolute Steps Required	Steps Calculated	Steps Programmed
Only Driver	0	0	0	0
	0	0		
Driver + Co-Driver	26	-26	6.5	47
	-39	39		
Driver+Co-Driver+3Passengers	332	-332	-323	-243
	314	-314		
Driver + Co-Driver + 3Passengers+ 100% Boot	459	-459	-451.5	-402
	444	-444		
Driver + 100% Boot	622	-622	-612	-612
	602	-602		

Table 5. Steps of stepper motor rotation based on correction factors obtained during without switch operation

Table 6 and Fig. 13 shows the percentage of deviation of beam inclination from the initial set value (-1.0%) of Automatic stepper motor headlamp operation for all load conditions as per standard. The maximum percentage variation from the reference value shows 9.65% which is equal to -0.965% inclinations as against -1.0%. However, in the manual switch operation, the maximum percentage variation from the reference value shows 72.5 % which is equal to -1.725% inclinations as against -1.0%.

Load Configuration	Vehicle Weight (kg)	Switch Position	Inclination (%)	**Avg. Inclination (%)**
Only Driver	1035	0	-1.00	-1.0

			-1.00	
Driver + Co-Driver	1110	0	-1.02 -0.95	-0.985
Driver + Co-Driver + 3Passengers	1335	0	-0.960 -0.970	-0.965
Driver + Co-Driver + 3 Passengers + 100% Boot	1410	0	-1.110 -1.080	-1.095
Driver + 100% Boot	1350	0	-0.950 -1.050	-1.0

Table 6. Beam inclination for Automated Headlamp Levelling system using Stepper Motor with a control strategy

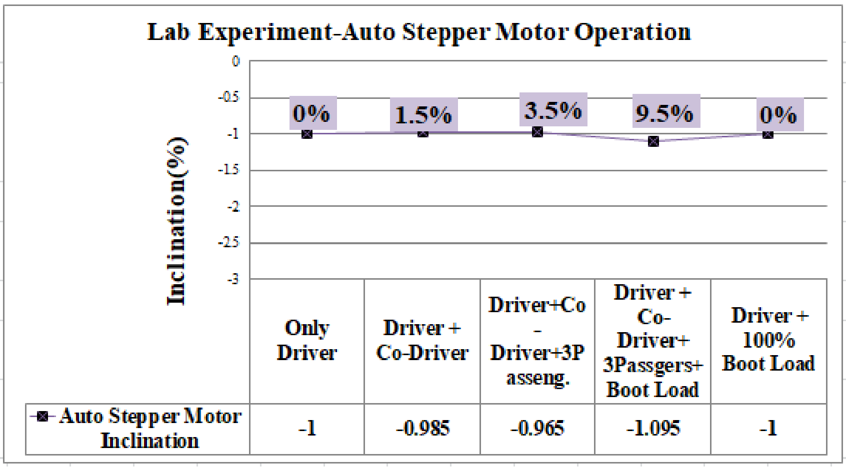

Fig. 13. Percentage deviation of beam inclination from the initial reference value for the Automated Headlamp Levelling system using Stepper Motor

8. Comparison of Test Results

Table 7, and Fig. 14. shows the comparison of passing beam cut-off inclination for four types of levelling methods. The comparison shows that auto Stepper motor inclination is much closer to reference inclination angle -1% as compared to a manual headlamp device and auto servo motor system. The maximum variation was observed in (Driver + Co-Driver+ 3Passengers+100% Boot load condition in manual switch reading is -1.725%, the auto servo is -1.345% whereas auto is stepper motor reading is -1.095%. This proves that a stepper motor with automatic load detecting methods is the better option to use in the automotive headlamp levelling system.

Load Configuration	Without Switch (%)	With Switch (%)	Auto servo motor (%)	Auto stepper motor (%)
Only Driver	-1	-1	-1.0	-1
Driver + Co-Driver	-1.025	-1.125	-0.89	-0.985
Driver+Co-Driver+3Passengers	0.245	-1.355	-1.28	-0.965
Driver + Co-Driver+ 3Passengers+100% Boot	0.74	-1.725	-1.345	-1.095
Driver + 100% Boot	1.36	-1.44	-1.315	-1
Maximum inclination out of all loading configuration	1.36	-1.725	-1.345	-1.095
Maximum % of deviation from reference inclination	136%	72.5%	34.5%	9.5%

Table 7. Comparison of passing beam cut-off inclination of various levelling devices

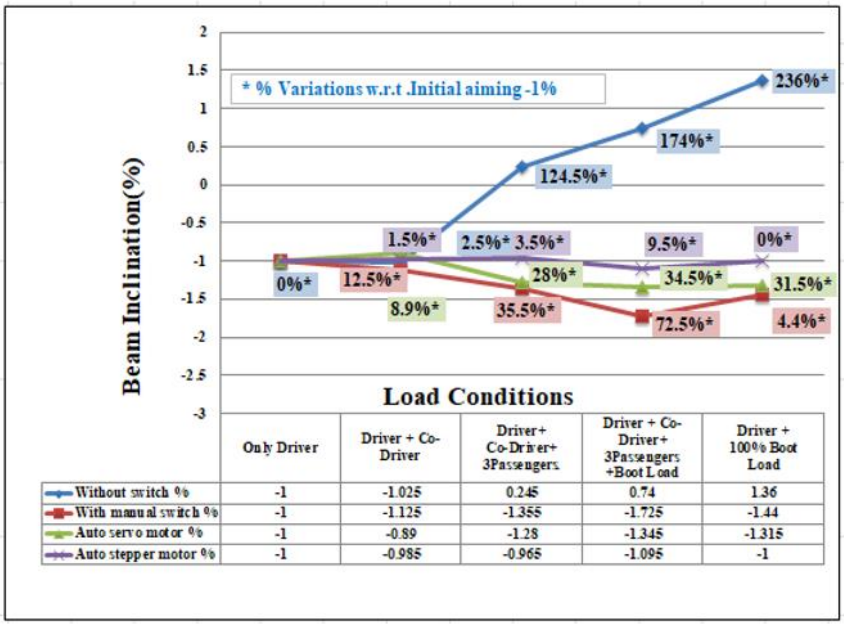

Fig. 14. Percentage deviation of beam inclinations from the initial reference value without, with and auto stepper motor operation

9. Conclusion

Experiments were conducted for four types of headlamp levelling devices to control the passing beam movement in the vehicle. Which includes; with and without operation of manual headlamp levelling switch, auto servo motor and auto stepper motor with newly developed control strategy for automatic levelling devices. Results show that the developed control strategy in conjunction with occupant and bootload detecting mechanism, auto stepper motor gives better performance in the order of 63% close to the initial aiming than manual levelling device and auto servo motor. This 63% upward movement of the passing beam will help for better visibility during night driving and a developed control strategy works as an automatic levelling device. This study will provide a platform for auto industries/lawmaker/safety committees to choose a technology that shows better performance and cheaper. With this technology, India further saves lives from night accidents.

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REFERENCES

[1] http://www.newindianexpress.com/nation/17-people-killed-every-hour-in-road-accidents-in-India/2016/06/10/article3474499.eceIntro 2.

[2] Ministry Of Road Transport & Highways Transport Research Wing, “Road Accidents In India," Government Of India, New Delhi,2017.

[3] J. D. Bullough, N. P. Skinner, R. M. Pysar, L. C. Radetsky, A. M. Smith, and M. S. Rea, “Nighttime Glare and Driving Performance Research Findings,” National Highway Traffic Safety Administration (NHTSA), Report No. DOT HS 811 043, 2008.

[4] Singh A, and Perel M, “ Drivers’ perceptions of headlight glare from oncoming and following vehicles," National Highway Traffic Safety Administration (NHTSA), Report No. DOT HS 809 669,2004.

[5] M.Siva, Vishakha Bhagat, B.V.Shamsundara, and A.V.Mannikar, "Necessity to mandate Automatic Headlamp Leveling, Driver perception and behaviour towards manual headlamp levelling in India," Technical Paper, International Forum of Automotive Lighting (IFAL), Shanghai, China, June 2014.
[6] Dr Rainer Neumann, "Importance of Auto-Leveling to avoid Glare for Road Users," International auto lighting and signalling Expert group, GRE-68-October **2012**.
[7] James Fennelly, "Method and apparatus for determining the inclination of a moving vehicle with respect to the road and for performing dynamic headlight levelling," US patent No. US 20160001695 A1, 7 Jan 2016.
[8] AtsushiYamaZaki, Shizuoka (JP) "Automatic levelling apparatus and method of a headlamp for the vehicle in an automatic levelling apparatus," US patent No. US 7350944 B2 - Apr. 1, 2008.
[9] Yusuke Kasaba, ShiZuoka (JP); Masashi Yamazaki, ShiZuoka (JP); Atsushi Toda, and ShiZuoka (JP) "Vehicle lamp control device and vehicle lamp system," US patent No. US 20120310486 A1 - Dec. 6, 2012.
[10] Ministry Of Road Transport & Highways (Department Of Road Transport & Highways), Government Of India, "AIS-008_Installation Requirements of Lighting and Light - Signalling Devices for Motor Vehicle having more than Three Wheels, Trailer and Semi-Trailer excluding Agricultural Tractor and Special Purpose Vehicle," The Automotive Research Association Of India, Pune, 28th September 2016.
[11] United Nations, "Uniform provisions concerning the approval of vehicles with regard to the installation of lighting and light-signalling devices, Regulation No. 48 (Revision-12)," United Nations, 16 October 2014.
[12] Robert Bosch Gmbh, "Automotive Lighting Technology Windshield and Rear-Window Cleaning", "THE BOSH YELLOW JOKETS," German edition, January 1, 2003.
[13] J. Kirscher, M. Lenz, D. Metzner and G. Pelz, "Verification of an Automotive Headlight Leveling Circuit and Application Using Smart Component Property Extraction," IEEE International Behavioral Modeling and Simulation Workshop, San Jose, CA, 2008, pp. 1-6. doi: 10.1109/BMAS.2008.4751230