An Automated Headlamp Alignment Checking System For Commercial Vehicles Using Machine Vision Technology

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Abstract- *In the realm of commercial vehicle manufacturing, ensuring the proper alignment of headlamps holds paramount importance for both driver safety and customer satisfaction. The occurrence of accidents often stems from issues such as reflection or the Troxler's Effect caused by light. Compliance with Automotive Industry Standards strictly governs the orientation, luminosity, and geometric properties of a vehicle's headlamp beams. Currently, the alignment verification process in the industry relies heavily on manual adjustment, with human operators making subjective judgments regarding beam intensity. This paper introduces a fully automated system utilizing industrial machine vision technology to extract real-time geometric parameters from headlamp beam profiles. The system aims to develop an alignment algorithm capable of determining deviations in headlamp positions relative to desired alignment, considering factors like tilt, angle, and distance from a reference point such as the vehicle centerline. Integration with a feedback mechanism enables real-time operator guidance, displaying alignment results through a user-friendly interface and suggesting necessary adjustments. Visual aids, such as diagrams or graphics, assist operators in the alignment process. Furthermore, integration with existing quality control processes streamlines manufacturing or maintenance workflows. By leveraging the principles of Karakuri, a Japanese concept emphasizing simple automation, the system maximizes efficiency while minimizing costs. Experimental results across various headlamp types demonstrate the system's ability to deliver accurate measurements in accordance with regulatory standards. This approach offers comparable functionality to expensive industrial robots at a fraction of the cost, ensuring efficient headlamp alignment checks without sacrificing affordability or simplicity.*

Keywords- Industrial Automation, Cost Saving, Machine Vision System, Automatic head lamp Alignment, productivity improvement, Troxler's Effect.

I. INTRODUCTION

Modern technologies, which are used in today's modern automobile production, contain elements of automation. Automation can bring a lot of benefits for production, especially it simplifies processes and streamlines production which results to reduced time requirements and labor costs. [1] The current automobile manufacturing scenario has posed several challenges in design, operation and assembly of manufacturing systems. Increased productivity and eliminating Quality Gate Defects are among the most important issues prevailing in manufacturing industries. The performance of these assembly lines still remains unpredictable, in spite of considerable research on productivity improvement. This has led us to develop a new method of assembly process automation [2]In the Vehicle assembly process ensuring the precise headlamp alignment checking is critical for safety and optimal visibility. Currently, manual checks are more time-consuming and prone to a manual error. To address this, our project aims to automatized the headlamp alignment checking process by using Machine Vision technology.

This paper presents the design, development and implementation of a low cost assembly automation system for use in a heavy vehicle headlamp alignment checking manufacturing industry using the process improvement strategy. Keeping in mind the volatility of the market, it is preferred to resort to low cost automation (Boothroyd, 1992; Grover, 1980), a technology that creates some degree of automation around the existing resources, using mostly standard components available in the market with very low investment. Since automation is tailored around the existing machines and people, the changes are gradual, smooth and very cost effective. The hardware components are flexible, reusable and adaptable to changes in product design and market conditions. The remaining paper is organized as follows. Section 2 provides an introduction to the Headlamp Alignment automation process, Section 3 illustrates the factors considered during the development of assembly automation and Section 4 presents the results and discussions.

OBJECTIVE OF STUDY:

In this research, we proposed replacing manual headlamp alignment checking processes with an automated system that leverages process automation. By achieving precise alignment, this system aims to enhance road safety by ensuring accuracy. The outcome of this transition is expected to be a reduction in downtime and an improvement in production efficiency in automobile industry.

APPROACH:

In our approach, we integrated Programmable Logic Controllers (PLCs) to control headlamp positioning motors. Additionally, we calibrated light sensors to accurately measure headlamp angles. Subsequently, we tested various algorithms to optimize alignment, even under suboptimal conditions. This comprehensive strategy aimed to enhance headlamp performance and ensure precise alignment for improved safety and visibility on the road.

GOVERNMENT STANDARD FOR HEADLAMP ALIGNMENT CHECKING:

By referredthe Testing Procedure and Requirements for Headlamp Alignment Testing Provided by Automotive Industry Standards(AIS) Committee: The headlight tester (manual / semi-automatic / automatic) is capable of measuring the horizontal cut-off of the passing beam (low beam) when measured at a distance specified by instrument manufacturer. It shall simulate the condition of testing of passing beam when tested at 10m.

REQUIRED FEATURES:

Height: The adjustment range of the headlight tester must be capable of measuring headlamps with their centers 500 mm to 1200 mm above ground level.

Inclination (vertical orientation) maximum deviation: The maximum deviation of inclination for vertical orientation shall not be more than ±0.1%. Alignment with the longitudinal axis of the vehicle: The apparatus shall be capable of being accurately aligned with the longitudinal axis of the vehicle.

PASSING CRITERIA:

Horizontal cut off of passing beam shall always be below headlamp centerline and the deviation shall be within 0.5% to 2.5%.

II. THE HEADLAMP ALIGNMENT AUTOMATION PROCESS

Figure 1 shows the isometric projection of the Headlamp& Figure 2 Shows the actual headlamp Mounted with Bumper. The Headlamp Alignment Checking process is carried out in eight stages. In the first stage, Remove the bezel from the head lamp and remove the screws by using the battery impact wrench. In the second stage, Move the head lamp alignment machine in front of the vehicle as shown in the Figure.Take out the tape from the machine and place on the left side of low beam head lamp in the third stage. In the fourth stage **-** The plates fixed on the machine should come straightly and match with the arrow mark in the top side of low beam head lamp. During this stage, the distance between the head lamp and machine should be 4.4 feet. In the fifth stage, turn on the ignition switch and vehicle gets started and turn on the low beam head lamp switch. Later, Loosen the screws mounted over the head lamp by using the screw driver. Then The beam from the head lamp passes through the glass in the machine and hits the alignment chart. In the sixth stage, Set the head lamp beam level setting switch in the 0 level. During this, make some tightening in screws if necessary in aligning in head lamp. The horizontal line in beam should lie on the 1.5% level in chart as shown in fig 3 The slanting line in beam should cut the 2% vertical level in the chart.In the seventh stage, Adjust the beam level setting switch to 1, 2, 3. The beam varies accordingly changing the beam level setting switch. In the seventh stage Set the level switch to 0 and the beam comes to the initial position. At finally After aligning the headlamp, it should not be in loose fit condition and Fix the head lamp bezel over the head lamp and tighten the screws by using the battery impact wrench. Do the same process on the RH side head lamp also. The current procedure for Alignment Checking is leads to the time consumption & manual error rate. Increase in production rate added more stress on the assembly operators. In order to reduce the operator stress and increase productivity, it was proposed to resort to some amount of automation. Consequently, time study was carried out and the results of time study, as shown in Table 1, revealed that the existing assembly line used more cycle time during Head lamp assembly stage compared to other stages of assembly. In view of this, it was proposed to implement a low cost automation system to reduce the cycle time required for headlamp alignment assembly.

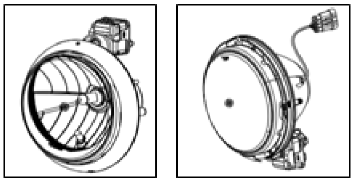

Fig 1Headlamp Isometric View

Fig 2Headlamp with Bumper

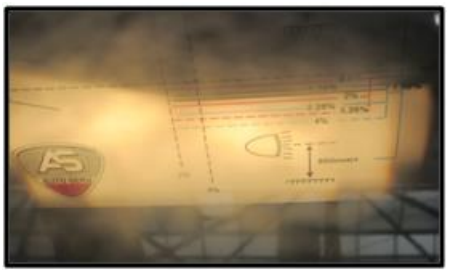

Fig 3Beam Projection Cart

Alignment Checking stages		***Cycle time (seconds)***					
		Trial 1	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Average***
S 1	***Remove the bezel***	*41*	*39*	*47*	*42*	*38*	***41.4***
S 2	***Move the headlamp aligner***	*28*	*30*	*29*	*29*	*30*	***29.2***
S 3	***positioning beam setter***	*39*	*38*	*40*	*40*	*37*	***38.8***
S 4	***turn on the ignition switch***	*25*	*27*	*26*	*25*	*25*	***25.6***
S 5	***Loosen the screws***	*37*	*39*	*35*	*39*	*37*	***37.4***
S 6	***Check alignment chart***	*35*	*33*	*35*	*34*	*37*	***34.8***
S 7	***Adjust the beam level***	*37*	*40*	*39*	*36*	*40*	***38.4***
S 8	***Fix the head lamp bezel***	*41*	*39*	*37*	*39*	*39*	***39***
Total Time		***283***	***285***	***288***	***284***	***283***	***284.6***

Table 1 Average cycle times of existing assembly line for headlamp alignment checking

III. LITERATURE REVIEW

3.1 ADVANTAGES OF INDUSTRY 4.0 CONCEPT IMPLEMENTATION IN MANUFACTURING COMPANIES

In general, Industry 4.0 can bring a lot of advantages for manufacturing companies: [12,13,14]

- Agile supply chain **-** technologies in a very efficient way help with logistics concepts such as JIT (just-in-time). It is possible to modify orders very easily and quickly, respond in a timely manner and adapt the process to your needs **-** either on the supplier's side or on the customer's side.
- Prediction and monitoring tools **-** production companies usually operate continuously in 24**-**hour operation; it is therefore, necessary to prevent possible outages or interruptions in production on the part of IT systems and production technologies. Robust monitoring tools, which help to detect faults or failures on individual systems in good time, serve us perfectly within the framework of the Industry 4.0 concept.
- Ability to adapt systems – before, there was not much room for adaptation within the production process. Industry 4.0 technologies make it possible to set up and program devices so that different models of the manufactured product (different colors, different parts on the line, etc.) can be produced simultaneously on one line **-** of course, following the expected sequence.
- Flexibility of network technologies **-** this is not just about configuration network elements in terms of communication speed, which is very important directly in the production part. But it is also a possibility of connection and communication to the outside world. This makes the whole production process more compatible and dynamic. Of course, using the required security rules when communicating out of the organization.
- Digitization of documents and processes **-** this can also be understood as a prerequisite for the implementation of automation processes. Digitization should also take place at the horizontal (supplier **-** company **-** customer) chain, but also at the vertical level (across departments of the organization).
- Increase of production capacity and efficiency **-** this advantage is provided by Industry 4.0 technologies that

can be used to optimize energy consumption, the production process itself, improve the redistribution of resources, produce larger volumes on the production line and at the same time identify places for new improvements.

- We can always justify cost savings as another benefit. Technologies are ensured by regular maintenance and timely monitoring, which prevents unexpected outages and the consequent impact resulting from such outages - for example, not only damage to the equipment, but also downtime, which transforms into a negative number in the cumulative production plan. As a result of properly functioning technologies, the number of errors and accidents at work is naturally reduced. [15]
- Deloitte's current resources and insights highlight automation, high-speed connectivity, machine learning and lowcost computing as current challenges and topical issues in Industry 4.0 concepts in the automotive industry. Among the main conditions for the prosperity of today's businesses, it is recommended to digitize all processes and invest in the latest available technologies. New technologies are new carriers of competitive advantage. [12]
- The company also outlines key questions that a company should ask if it wants to be successful in Industry 4.0: What will the future customer demand? Which innovation benefits will hit the automotive industry hardest? How will we sponsor investments needed for development or research? The current direction in the production of the automotive industry will focus mainly on electric cars and alternative forms of motor drives. Petrol and diesel engines replace hybrid drives or electric motors. Autonomous vehicles with their own control algorithms are a separate phenomenon. An important prerequisite for the sale and successful operation of such cars is to ensure a functioning infrastructure in the country, such as charging station. However, the state should also provide significant support. In this case, a natural demand for the right type of car will be created. Currently, the largest players in the market are countries such as the USA, India, Germany, China, South Korea and Japan. [16]

3.2 HEADLAMP AUTOMATION IN THE CONTEXT OF INDUSTRY 4.0

- The term automation in the sense of Industry 4.0 can be perceived as a set of technologies that allow to perform machine operations and operations within systems, without significant human intervention. [2] This is the main difference from manual work. Such a system or device should have the following characteristics: sufficiently inform about the running / operating mode of the device, warn of dangerous threats and the possibility of manual restriction, or human intervention.
- Among such systems, we can include e.g. HMI panels (Human Machine Interface), SCADA visualizations (Supervisory Control and Data Acquisition), PLC programmable devices, industrial robots, autonomous logistics devices and others. Then there is the possibility of automatic processes converging even at the system level. Such systems either perform, back up, or monitor something (automated monitoring). [17]
- Nowadays automobile sector plays an important role in day to day life. Most of the people were using private vehicle instead of public vehicle for their convenient. Amount of usage of vehicle in the year 2016 is increased by 4 times while comparing to the year 2011. At the same time accidents are also increased simultaneously. Even though latest technologies are implemented. As such most of the accidents are happened during night time. Most of the accidents are happened due to reflection or Troxler's Effect of light. So far the vehicles are manufactured with manual head light control. Our project is providing an automatic control of head lamp even for the old model vehicles

IV. METHODOLOGY FOR ALIGNMENT CHECKING AUTOMATION

The proposed methodology for alignment checking automation consists of four steps. The first step is to perform a Concept Creation by the Pugh matrix (**decision-making matrix**) to get an overview of the current checking process conditions, and used to analyze different ideas and to determine the optimal choice. Identify the key productivity measures for the alignment process and to form the basis for a detailed study of improved quality. The output from the Pugh Matrix is a numerical score that identifies the Solution which perfect for the current problem. The second Step is Feasibility Study on the Shop Floor. The third step is to develop aFixture and Frame designing with combination of PLC circuits and Light Calibrating Sensor. The final step is implementation of the Machine assembly and sensor integration.

At the outset, the Solution Selection Matrix plays a pivotal role in identifying the optimal solution for the given use case. By evaluating various criteria, it guides decision-makers toward the most suitable approach. In this context, four distinct alignment checking system options have emerged, shaped by collaborative brainstorming sessions involving industry experts. These options are meticulously designed to align with the principles and advancements of Industry 4.0 a paradigm that integrates automation, data integration, and smart technologies to revolutionize manufacturing and production processes. By ensuring alignment with Industry 4.0, these solutions aim to enhance efficiency, productivity, and competitiveness in the rapidly evolving industrial landscape.

4.1 PUGH MATRIX:

The Pugh Matrix, a valuable decision-making tool, aids in evaluating and prioritizing potential solution ideas. It systematically assesses various criteria to guide concept selection. The critical factors considered include:

- **IMPLEMENTATION COST**: This metric gauges the financial investment required for each solution. Lower costs are preferred.
- **TIME TO IMPLEMENTATION**: The speed at which a solution can be put into practice is crucial. Faster implementation is advantageous.
- **EFFICIENCY**: Solutions are evaluated based on their effectiveness in achieving the desired outcome. Higher efficiency scores are favorable.
- **DURABILITY**: Long-lasting solutions are prioritized over those with shorter lifespans.
- **STANDARDIZATION**: Solutions conforming to established standards and practices receive positive ratings.
- **MANPOWER INVOLVED**: The level of human resources needed for implementation is considered. Solutions requiring fewer personnel are advantageous.

In the Pugh Matrix, each criterion is assigned a weightage from 0 to 5, reflecting its relative importance. A higher weight indicates greater significance. The concept selection process categorizes solutions as follows: **Positive (1)**: Solutions that excel in most criteria and align well with project goals.**Same (0)**: Solutions with comparable performance across criteria.**Negative (-1)**: Solutions that fall short in critical areas or have significant drawbacks.

Brainstormed Solutions and Concepts:

1. Dual Mast Alignment System
2. In-Floor Alignment System
3. Gantry Style Alignment System
4. Off-Line Alignment System

Key Criteria	Weight	Outsourcing Alignment	Off-Line Alignment	Gantry style headlamp aimer	In-Floor headlamp aimer	Dual mast headlamp aimer	Current Baseline Datum
Implementation cost	5	-	S	S	S	-	S
Time to implement	5	-	+	+	+	+	S
Standardization	5	-	+	S	+	S	S
Manpower	4	+	+	S	+	+	S
Efficiency	4	-	+	+	-	+	S
Durability	5	S	+	S	S	+	S

	Outsourcing Alignment	Off-Line Alignment	Gantry style headlamp aimer	In-Floor headlamp aimer	Dual mast headlamp aimer
Sum of Positives (+):	1	5	2	3	4
Sum of Negatives(-):	4	0	0	1	1
Sum of Same (S):	1	1	4	2	1
Positives - Negatives:	-3	5	2	2	3
Weighted Sum of Positives (+):	4	23	9	14	18
Weighted Sum of Negatives (-):	19	0	0	4	5
Weighted Sum of Same (S):	5	5	19	10	5
Weighted Positives - Weighted Negatives:	-15	23	9	10	13

Table 2 Solution selection matrix for identifying the optimal solution

Upon evaluating the matrix, it became evident that the off-line alignment process garnered the highest weightage. This preference stems from several compelling factors. Firstly, in comparison to alternative solution ideas, the off-line alignment process proves to be cost-effective. Its implementation incurs minimal expenses, making it an attractive choice. Secondly, this approach boasts superior efficiency. By streamlining processes and minimizing resource wastage, it optimizes performance. Lastly, the off-line alignment process stands out due to its swift time-to-implementation. Rapid deployment ensures timely results, aligning with project objectives. Overall, this solution strikes a balance between effectiveness, economy, and expedience

4.2 DONE A FEASIBILITY STUDY:

- **TECHNICAL FEASIBILITY:** The shop floor assessment begins with a focus on technical feasibility. The initial step involves **Sensor Integration**. Leveraging Light Calibrating Sensors (LDR sensors), which are both **readily available and cost-effective**, ensures accurate data collection. Additionally, **PLC Programming** using S7-1200 and 1214C DC RLY microcontrollers enables real-time adjustments, enhancing precision and responsiveness.
- **ECONOMIC FEASIBILITY:** A **Cost-Benefit Analysis** is essential for evaluating economic feasibility. By comparing the implementation costs of automation with the anticipated benefits—such as improved safety and reduced error rates. We can make informed decisions. Long-term **Maintenance Costs** are also factored in, ensuring sustainable financial viability.
- **OPERATIONAL FEASIBILITY:** User acceptance plays a pivotal role in operational feasibility. We evaluate how operators perceive and interact with the proposed solution. Ensuring ease of use and addressing any potential challenges are critical. Additionally, **Integration with Existing Systems**—specifically compatibility with the vehicle electronic module—ensures seamless adoption.

- **LEGAL AND ENVIRONMENTAL FEASIBILITY:** In terms of legal compliance, we delve into **Regulatory Requirements** related to headlamp alignment. Investigating local, national, and industry-specific regulations ensures adherence. Simultaneously, we assess the **Environmental Impact** of the solution. This involves considering any ecological implications arising from its implementation.
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4.3 DESIGN A FIXTURE

Develop an alignment algorithm to calculate the deviation of headlamp positions from the desired alignment. Consider factors such as tilt, angle, and distance from a reference point (e.g., vehicle centerline). Determine acceptable tolerance levels for alignment deviations. Integrate the alignment algorithm with a feedback mechanism to provide real-time feedback to the operator. Display alignment results on a user interface, indicating whether adjustments are necessary and in which direction. Develop a user-friendly interface for operators to interact with the system. Display visual aids such as diagrams or graphics to assist with alignment. Integrate the machine vision system with existing quality control processes in the manufacturing or maintenance workflow. Automate the alignment process as much as possible to reduce manual intervention and increase efficiency

Data Collection and Calibration: Data from Light Calibrating Sensors and LDR sensors was collected to measure headlamp positions. A reference point (the vehicle centerline) was established. Sensors were carefully calibrated for accurate measurements.Alignment Calculation: Considerations included tilt (pitch and roll), angle (yaw), and distance from the reference point. A mathematical model was developed to relate sensor data to headlamp alignment parameters. Tolerance Levels and Acceptance Criteria:Acceptable tolerance levels for alignment deviations were defined. Deviations were categorized as positive (adjustment needed in one direction), same (within tolerance), or negative (adjustment needed in the opposite direction).Feedback Mechanism and Real-Time Updates:Integration with a feedback mechanism provided real-time guidance to operators regarding necessary adjustments.User Interface Development: A user-friendly interface displayed alignment results. Visual aids, such as diagrams and graphics, assisted operators during alignment. Integrationwith Quality Control Processes: The alignment system seamlessly integrated with existing quality control processes. Machine vision techniques validated alignment accuracy, ensuring quality. Automation and Efficiency Enhancement: Headlamp adjustments were automated whenever feasible. Workflow optimization minimized manual intervention, enhancing overall efficiency in manufacturing or maintenance.

V. HARDWARE REQUIREMENTS

5.1 PLC

A Programmable Logic Controller (PLC) is a specialized computer designed for reliable operation in harsh industrial environments. It manages electromechanical processes, such as those in manufacturing plants, assembly lines, or wastewater treatment facilities. Similar to a personal computer, a PLC has a Central Processing Unit (CPU), inputs and outputs (I/O), memory, and operating software. However, it excels in discrete and continuous functions that a PC cannot perform. Unlike hard-wired control systems, a PLC allows easy reprogramming without rewiring.

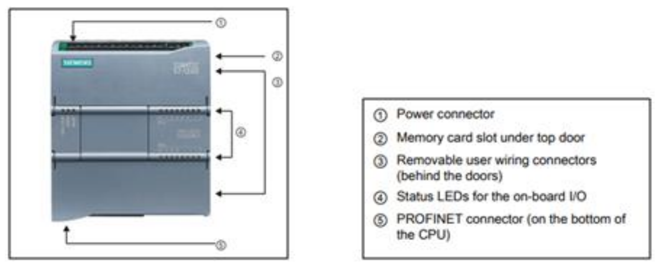


Fig 4SIMATIC S7-1200

Figure 4 shows the SIMATIC S7-1200 series by Siemens is a family of compact automation controllers designed for industrial applications. These PLCs offer a balance of performance, communication options, and integrated technology functions. They are suitable for low to medium performance automation tasks.

A. HARDWARE FEATURES:

Power Supply:Provides electrical power to the PLC. **Central ProcessingUnit**: The brain of the system, responsible for executing control logic.**Input/output Modules (I/O)**: Connect to sensors, actuators, and other devices.**Communication Modules**: Enable data exchange with other devices or systems.

B. SOFTWARE FEATURES:

TIA Portal (Totally Integrated Automation): The programming environment for creating, configuring, and monitoring S7-1200 PLCs.

C. COMMUNICATION OPTIONS:

Supports **PROFINET, MODBUS TCP/IP**, and other protocols. Seamless integration into industrial networks

D. TECHNOLOGY FUNCTIONS:

PID Control: For precise regulation. Counters, Timers, and Math Functions. High-Speed Counting for fast processes. Data Logging for diagnostics.

5.2 LIGHT CALIBRATING SENSOR - LUJAN LJN5421

A Light Calibrating Sensor is an essential device used to ensure accurate measurements of light levels.

A. TECHNICAL FEATURES:

Wavelength Resolution: These sensors can provide detailed information across different wavelengths, allowing precise characterization of light.

Calibration Capability: Light calibrating sensors can be calibrated against reference instruments to maintain accuracy.

Robustness: Designed to withstand varying temperatures and light intensities.

Machine Learning Integration: Some modern sensors utilize machine learning algorithms for calibration.

5.3 SMPS

A switched-mode power supply, sometimes known as a switch-mode power supply or 'SMPS', is an electronic power supply that integrates a switching regulator for efficient electrical power conversion. Like other supplies, an SMPS transfers power from a DC or AC source to DC loads while converting voltage and current. Unlike in linear power supplies, the pass transistor of a switched-mode supply is constantly switching between low-dissipation, full-on, and full-off states. It spends very little time in high dissipation transitions, and this minimizes the amount of electricity that is wasted.

The core concept of a SMPS is that regulation is handled by using a switching regulator. This uses a series switching element that turns the current supply to a smoothing capacitor between on and off states. The time that the series element is turned on for is controlled by the voltage on the capacitor. If the voltage is higher than what's needed, the switching element is turned off. If lower than required, it's turned on the head lamp.

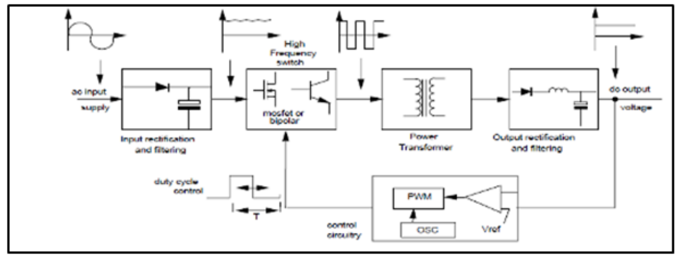


Fig5.SMPS Circuit

5.4 MCB

An MCB is an automatically operated electrical switch. Miniature circuit breakers are intended to prevent damage to an electrical circuit as a result of excess current. They are designed to trip during an overload or short circuit to protect against electrical faults and equipment failure.

MCBs are widely used as isolating components in domestic, commercial, and industrial settings. They form part of a broader family of more powerful circuit-breaking components

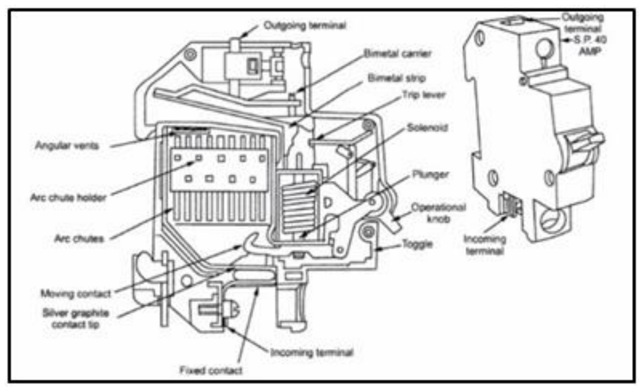


Fig6.Relay

5.5 DC POWER RELAY

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

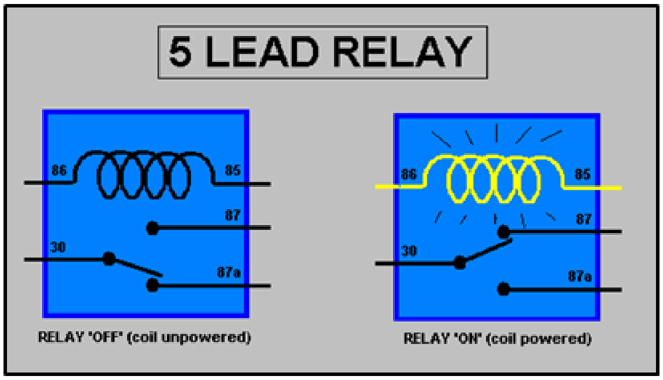


Fig7.Relay

VI. WORKING PRINCIPLE

S7-1200 plays a vital role in this concept, the system is powered up using the DC Power supply source within the fixer.

STEP I - FIXER DEVELOPMENT: The **Fixer** is developed using **PLC Logic** and **motor control circuits**. The PLC program includes logic for: **Sensor feedback**: Gathering information from sensors. **Motor control**: Managing the movement of components. **Safety interlocks**: Ensuring safe operation.

STEP II - BUMPER AND HEADLAMP INSTALLATION: Once the bumper is fixed in the gigs, the **right-hand (RH)** and **left-hand (LH)** side headlamps are positioned. The headlamp turns on, projecting a beam onto an **alignment chart**.

STEP III - BEAM INTENSITY DETECTION: A **sensor** detects the intensity concentration of the beam. This information is fed to the PLC as input.

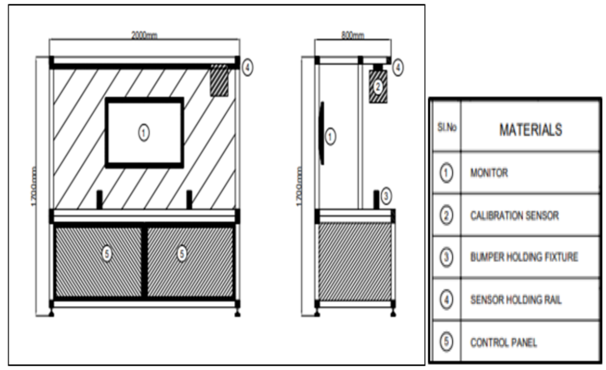
STEP IV - CALCULATING ADJUSTMENT: Based on the beam's intensity concentration, the PLC calculates the **required adjustment**. The gigs (fixtures) within the fixer then move the headlamp to the correct position. This adjustment ensures **proper alignment**.

STEP V -VERIFICATION AND STATUS: After adjusting the headlamp alignment, the system **verifies** it. If the alignment falls within **acceptable limits**, the status is considered **"OK."** Otherwise, corrective actions are taken.

STEP VI - PRINTING AND VEHICLE REFERENCE: If the alignment is successful, the **status** (e.g., "OK") is printed. This printed status is **pasted onto the vehicle** for reference

VII. LAYOUT/COST

7.1 SOLUTION LAYOUT MODEL



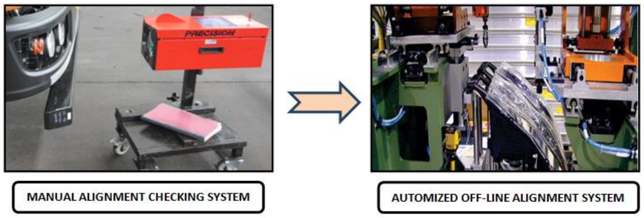
7.2 INSTALLATION COST

Table 3Used Equipment's Cost and their Specification

SL.NO	EQUIPMENT	SPECIFICATION	QUANTITY	COST
1	PLC Board	S7-1200, 1214C DC,DC,RLY	1	27,000 RS
2	PC	i5 with 16GB RAM & 512GB, Monitor, Wireless Keyboard & Mouse	1	60,000 Rs
3	Light Calibrating Sensor & Controller	Lujan LJN5421	1	30,000 Rs
4	Panel Components	SMPS, Switches, Cables, Relays, Terminal Blocks & MCB	Nos	50,000 Rs
5	Frame Assembly	Aluminum profile frame with fixtures	Nos	40,000 Rs
6	Pneumatic Components	Locking cylinders, valves and FRL	Nos	40,000 Rs
TOTAL				2,47,000 Rs

VIII. RESULTS AND DISCUSSIONS

The key intention behind this research work is to enhance productivity by time saving of the assembly line with most of the existing resources, both man and machine, while keeping the human stress at lowest levels. As a first step, time study is carried out to find out the stage-wise time requirement during alignment Checking. Table 1 show the detailed time break-up required for completing each stage in the alignment process for five alignment checking trials. As seen in the table, the average total cycle time for the entire headlamp alignment checking process is *284.6* seconds. Table 2 illustrates the results of Pugh Matrix. It can be seen in the table that the offline alignment process has scored maximum. Hence, the headlamp alignment checking process is clearly the bottleneck to be taken care of to enhance productivity. In order to handle this bottleneck, a low cost machine vison automation system has been proposed, designed, developed and successfully implemented in the chassis assembly line by replacing the existing manual checking system at resulting cost effective.



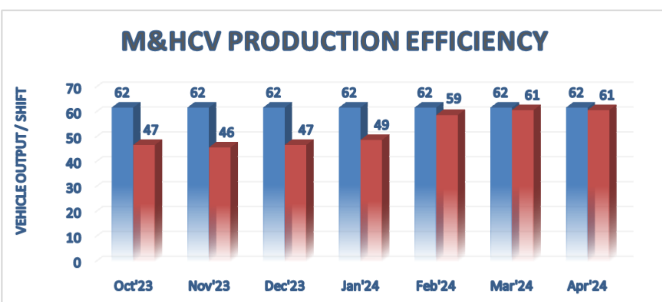
8.1 TIME SAVING CALCULATION

	Alignment Checking stages	*Cycle time (seconds)*					
		Trial 1	*Trial 2*	*Trial 3*	*Trial 4*	*Trial 5*	*Average*
1	*Bumper positioning on the Fixer*	45	43	41	43	40	42.4
2	*Headlamp fixing on LH & RH*	34	30	33	33	30	32
3	*Turn on the Headlamp by Power Supply*	17	14	16	14	13	14.8
4	*Check alignment position on Chart*	32	30	31	32	33	31.6
5	*Adjust the beam level*	35	39	35	39	37	37
6	*Remove from the Fixer*	35	33	35	34	37	34.8
Total Time		198	189	191	195	190	192.6

Table 4 Average cycle times of existing assembly line for headlamp alignment checking

8.2 PRODUCTION EFFICIENCY

The Value created by implementing this Automation on the Shop floor which has been achieved the productivity efficiency increased by 65 % to 90%



Graph 1production Line Efficiency for Before and After Implementation

8.3 COST SAVING CALCULATION

The implementation of the proposed solution marks a significant milestone for the shop floor.The solution acts as a bridge between traditional manufacturing practices and cutting-edge technology, creating a harmonious blend that optimizes operations.Following the implementation, substantial cost savings have been realized. These annual savings directly impact the bottom line, making the shop floor more financially resilient. The specific cost value saved per annum is a testament to the effectiveness of the solution. Whether through reduced material waste, minimized downtime, or increased throughput, the financial impact is tangible and sustainable.

- Average RPD Apr24' : 150 Cabins per day
- Total no. of Vehicle Rework eliminated : 150*1.1 = 165 Vehicle/day
- Total rework time reduced : 1.8 Minutes / Defective cab
- Total rework time reduced : 1.8*165 = 297 minutes = 4.95 Hours/day
- Man-hour cost : Rs.500
- Total Cost saved per working day: 500*4.95 = Rs. 2475 / working day
- Average working day per annum : 300 Days
- **Total cost saved per annum: 300 * 2475 = Rs. 7,42,500/ Annum**

One of the most compelling aspects of this innovation lies in its cost-effectiveness. When compared to the previous manual process, the implementation cost of the proposed solution is notably lower. This reduction in upfront expenses ensures a quicker return on investment (ROI) and positions the shop floor for long-term success. The decision to transition from manual methods to an automated or digitized approach has paid off, both in terms of operational efficiency and financial viability.

IX. CONCLUSIONS

The proposed system is successfully utilized in Alignment Checking process and it has increased productivity and reduced manual error rate. The methodology for the alignment checking process is improved same as atomized when compared with an existing manual process. In this automation system, the operator fatigue is minimized to perform the alignment checking operations, such as removing bezels and reassembling of headlamp. The cycle time study shows a considerable amount of reduction in bottleneck operation such as headlamp alignment checking. The cost involved for implementing the proposed assembly system is significantly low and makes it viable for industry. These novel features proposed in the present work can be extended to other assembly operations such as wheel alignment, brake assembly alignment and other Alignment checking stations in automobile industry.

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