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An Innovative Design and Manufacturing of a Portable and Compact Sized Automatic Wheel Alignment Kit

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ABSTRACT:

In this research paper we have worked towards design and develop a compact and portable wheel alignment kit that can be used by mechanics and car enthusiasts to align wheels quickly and easily. The study covers the various aspects of the development process, including the design, prototyping, and testing of the wheel alignment kit. The work began with a detailed analysis of the current market for wheel alignment tools and identified the need for a compact and portable solution that is both affordable and accurate. We have then outlined the design process, including the selection of materials, components, and manufacturing methods, to create a lightweight and durable kit that can withstand frequent use. To ensure the accuracy of the alignment measurements, the kit features a sensor based alignment system that is easy to use and requires minimal setup time. The report details the testing process, including the measurement of alignment parameters such as camber, caster, and toe, and the validation of the results against industry standards. Overall, the research study report provides a comprehensive overview of the design, development, and testing of a compact and portable wheel alignment kit that meets the needs of mechanics and car enthusiasts. The report concludes with recommendations for further improvements and future research opportunities.

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1. Introduction

Wheel alignment is a crucial aspect of vehicle maintenance that ensures the safety and efficiency of the vehicle's handling. However, traditional wheel alignment machines are large, stationary, and not easily transportable, making it difficult to provide alignment services on the go. This research study aims to address this issue by developing a compact and portable wheel alignment system that can be easily transported to different locations.

This research study takes into consideration various factors such as portability, accuracy, and affordability to develop a system that can cater to the needs of the automobile industry. The compact design of the system ensures that it can be easily stored in small spaces and transported to different locations without any hassle. The accuracy of the system is ensured using advanced sensors and software that provide precise alignment measurements.

The affordability of the system is also a key factor, as traditional wheel alignment machines can be expensive, making it difficult for small businesses to invest in them. There are some points on which we can easily get to know why we are working on this experiment.

Identification of Client /Need / Relevant Contemporary issue

Some of the factors that can lead to wheel misalignment issues include:

1. **Driving on rough or uneven roads:** If you frequently drive on rough or uneven roads, it can cause your wheels to become misaligned.
2. **Hitting potholes or curbs:** If you hit a pothole or curb hard enough, it can cause your wheels to become misaligned.
3. **Car accidents:** If you've been involved in a car accident, even a minor one, it can cause your wheels to become misaligned.
4. **Worn suspension parts:** If your suspension system is worn, it can cause your wheels to become misaligned.

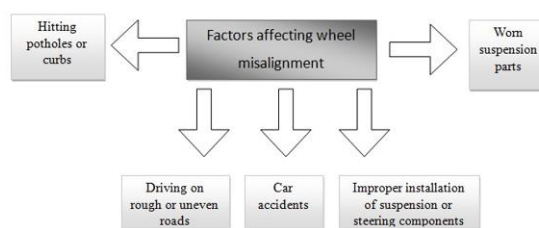


Figure 1. Factors affecting Wheel Alignment

Identification of Problem

India is a country with growing urbanisation and its dependency is mainly on connectivity, primarily on road connectivity which makes it quite hectic and costly to maintain such long highways.

Under mentioned are the major reasons of road accidents: -

Damaged roads - Damaged Roads are one of the most common reasons for road accidents as stated by the Ministry of Road Transport and Highways Transport Research Wing. Damaged highways have the greatest number of fatal accidents claiming lives.

Improper driving- Improper or rash driving leads to most fatal accidents. The road racing commonly known as road rushing leads to fatal accidents due to loss of control over sharp edges and loss of required control in highly traffic areas.

Misaligned vehicles - Misalignment of vehicles is a major reason of accidents on high-speed highways. The above mentioned both the causes are major reasons for decreased health of the vehicles on road. Rash driving and damaged roads primarily effect the alignment of the vehicle.

2. Literature Review

The compact and portable wheel alignment kit is a new and innovative approach to an old problem. In the automotive industry, proper wheel alignment has long been recognized as a crucial aspect of vehicle safety and performance. Traditional alignment solutions, however, are often bulky, expensive, and require specialized training to use effectively. The development of compact and portable wheel alignment kits has the potential to revolutionize the way that wheel alignment is performed, making it easier, more accessible, and more cost-effective for a wider range of users. In this literature review/background study, we have examined the history of wheel alignment technology, from its early beginnings to its current state of the art, as well as the development of compact and portable alignment kits and their potential impact on the industry. We will also explore the benefits and drawbacks of these kits, as well as some of the key factors that should be considered when choosing a compact and portable wheel alignment solution.

Timeline of the reported problem

Wheel alignment has been a concern for the automotive industry since the early days of the automobile. In fact, the first recorded incident of misaligned wheels causing a serious accident occurred in Paris, France in 1895, only a few years after the first cars were introduced. According to a contemporary newspaper report, a car traveling at high-speed lost control and crashed into a crowd of spectators, killing several people and injuring many more. The cause of the accident was attributed to misaligned wheels, which caused the car to swerve uncontrollably. This incident was widely reported in the press at the time and helped raise awareness of the importance of proper wheel alignment.

1920s	First wheel alignment machines developed
1930s	Alignment recognized as crucial for vehicle safety and performance
1950s	Introduction of four-wheel alignment systems Introduction of computerized alignment systems
1970s	Development of laser alignment technology
1980s	Introduction of advanced sensors and software for alignment
1990s	Continued advancements in computerized alignment technology
2000s	Introduction of portable alignment systems for mobile service providers
2010s	Introduction of 3D imaging technology for alignment
2020s	Ongoing developments in alignment technology for increased accuracy and efficiency

Existing solutions

Yuan Zhang et al. (2020) highlight the importance of precise and reliable four-wheel alignment in vehicles to improve their running stability, fuel efficiency, safety, and driver comfort. However, the scientific measurement of four-wheel alignment parameters, particularly those related to the kingpin, remains a significant issue in vehicle engineering.

Hwanga et al. (2006) have highlighted the increasing demand for highly precise and compact components, such as micro-optic modules for digital cameras and camera phones, due to the

rise of digital convergence. Aspheric lenses are being utilized instead of traditional spherical lenses to achieve the necessary high resolution for optical parts.

Hwaseong-Sifor et al. (2010), for many years, vehicle stability has been a significant issue in the field of vehicle dynamics, and straight-ahead stability at high speeds is one of the crucial characteristics. To maintain straight-ahead stability, pull and drift are two critical steering maneuvers.

Mundl et al. demonstrated through finite element analysis how the size of the contact area and the contour of the tyre had a significant impact on the contact shear stress and PRAT. Both internal and environmental factors contribute to steering pull and drift. Environmental factors include side wind, road roughness, and road crown angle, while asymmetric vehicle and tyre properties are internal factors.

Yuan et al. (2017) conducted a research study to develop a non-destructive inspection method for measuring the camber angle of vehicle wheels using a laser-based optical measurement system. They developed software algorithms for data processing and analysis and validated the accuracy and precision.

Shuang et al. (2019), the process of calibrating four-wheel alignment in automobiles is crucial for ensuring safety, stability, and optimal performance. Automatic calibration using the superimposing angles method is a preferred approach due to its efficiency, reliability, and accuracy. It involves comparing actual angles of each wheel with desired angles, and then adjusting those using advanced sensors and software.

Ford Motor Company (2004) presents a study on the impact of steering drift and wheel movement during braking, with an emphasis on static and dynamic measurements. Steering drift occurs when a vehicle's direction changes during braking, while wheel movement refers to lateral wheel displacement. Both phenomena can have an adverse effect on vehicle stability, handling, and braking performance. Static measurements involve determining the initial steering wheel position and its position after braking, which can be used to quantify the degree of steering drift and wheel movement. Dynamic measurements, on the other hand, involve utilizing sensors and measurement tools to analyze vehicle behavior during braking, providing more comprehensive information on the dynamics of steering drift and wheel movement, such as their frequency and amplitude.

Wang et al. (2018) highlight the negative impact of front road wheel toe dynamics on tire wear and steering wheel vibration, which can lead to decreased customer satisfaction. Despite the possibility of adjusting static toe during manufacturing, vibration can still occur due to factors such as 15.

As tire mass non-uniformity and unbalance. Suspension and steering settings can also contribute to the magnitude and frequency of the vibration.

Country-level Analysis:

Analysis based on different countries.

ID	Country	Documents	Citations	Total Link Strength
1	Australia	7	27	6
4	Brazil	4	20	2
5	Canada	5	30	4
8	England	26	324	15
10	France	8	79	7
11	Germany	10	88	4
14	India	4	30	2

18	Italy	7	107	5
19	Japan	6	40	9
23	Malaysia	3	22	2
25	Netherlands	4	49	1
29	China	37	122	7

Problem Definition

Misaligned wheels refer to a situation where the wheels of a vehicle are not aligned with each other or with the vehicle's frame.

This can occur due to a variety of factors, such as wear and tear, collisions, or improper installation of tires or suspension components. Misaligned wheels can lead to a range of problems, including uneven tire wear, reduced handling and stability, decreased fuel efficiency, and increased risk of accidents.

3. Design and Analysis

Evaluation & Selection of Specifications/Features

This simplicity is accomplished by keeping few points in mind while designing the products:-

1. **Sturdy Designs** – The alignment kit is design to be operational at very high speed on roads as well as the kit is designed to be operational at highly damaged roads efficiently.
2. **Advanced Sensors** – Highly advanced and accurate sensors are being used so that there is no hampering with data and maintain efficiency in difficult terrains.
3. **Continuous monitoring** - To avoid misinterpretation of data the alignment is monitored continuously at regular intervals.
4. **Compact Designs** – Due to shortage of space for installation and functioning, it was mandatory for designs to be compact and simple allowing them to avoid any complications during installation and functioning.
5. **Accuracy** – As a matter-of-fact wheel alignment is one of the major issues for accidents and to prevent the same, the data provided by the device must be precise and accurate.

Design Constraints

Economic Impact: The basic objective of this research study is to reduce the cost included in monitoring of wheel alignment and suspension health while maintaining the quality of inspections being conducted. To achieve the same, presented model has been updated constantly to reduce the cost of production allowing it to be cost-effective, affordable and easy to use product for the end user.

Environmental Impact: Misaligned wheels can also contribute to increased carbon emissions and environmental pollution. For example, when tires wear unevenly due to poor alignment, they may need to be replaced more frequently, leading to increased tire waste and disposal. This can have negative environmental impacts, including resource depletion and pollution associated with tire production and disposal.

Safety Impacts: Properly aligned wheels are essential for safe driving. A misaligned wheel can cause uneven tire wear, reduced fuel efficiency, and poor handling, which can increase the risk of accidents. If a wheel alignment kit is not used properly or if it is of poor quality, it could lead to improper alignment, compromising safety and ethical considerations related to protecting human life and well-being.

Health Impacts: The presented model has no positive or negative health impacts on human life. On contrary it provides data to monitor the health of the suspension and wheel alignment which directly or indirectly affects the overall health of the vehicle.

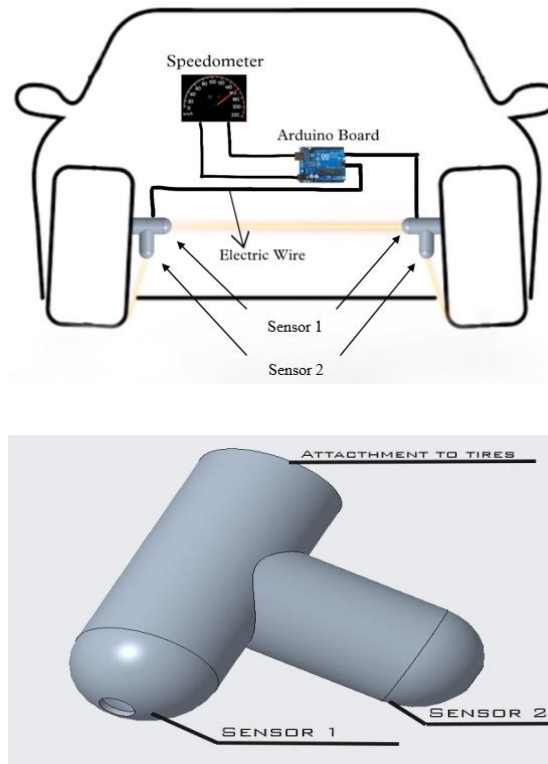


Figure 2. Basic layout of system

Design Flow

In this section the team has presented the theory and the various prototypes designed for the research study.

With the help of 2D designs, majorly front and side views, we have tried to present various models that can be used to solve the mentioned problem statement

The figure mentioned displays the deformation caused to the model due to excessive or rigorous application of the centrifugal force.

This model is also designed to the prior theories to measure camber and toe angles for the four vehicles. The mentioned model consists of an attachments made of internal threads which allows it to connect to the centre of wheels from inside with the help of welded screws.

4. Future Implications

The presented model is one of the very first attempts made after decades to improve the technology involved in the wheel balancing and wheel alignment. Hence, there are number of tasks that need to be performed to gain more efficiency and accuracy in the model provided, such as:

1. Creating a scope of continuation of research study via prototyping [10-11].
2. The addition of features or the advancements/up-gradation in the current model to cover the remaining aspects.

3. Repetitive usage to generate a data base and increase its efficiency using data analysis and AI Integration
4. Removal of false alarms by reducing the margin errors.
5. Designing of a model adjustable for maximum models of four-wheelers.

5. Conclusion

In conclusion, the device for measuring wheel alignment angles is a significant development in the automobile industry. It has made wheel alignment more accessible, accurate, and affordable. With its scalability, adaptability, and durability, it is a tool that is here to stay. Therefore, it is a must-have tool for any automobile enthusiast or professional who wants to provide quality services to their clients

- The device for measuring wheel alignment angles is a game-changer in the automobile industry.
- It is easy to use and provides accurate measurements, making it popular among mechanics and enthusiasts.
- Its affordability has made it accessible to small-scale automobile workshops, ensuring quality services to clients.
- The device is highly scalable and compatible with most vehicle models, making it suitable for both large and small-scale workshops.
- It can measure wheel alignment angles even while the car is running, saving time and providing an accurate diagnosis of problems.
- The device is adaptable to different vehicle designs, making it a valuable tool for various vehicle sizes and designs
- It is durable, requires no maintenance, and has a long lifespan, making it a cost-effective investment for automobile workshops.
- In conclusion, the device for measuring wheel alignment angles is a significant development in the automobile industry, providing accessibility, accuracy, and affordability.

It is a must-have tool for any automobile enthusiast or professional who wants to provide quality services to their clients.

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