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# Design of an Experimental Testbed for an Electric-Vehicle Suspension System

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## Abstract

**Abstract:** This project consists of designing and testing an experimental testbed to validate computational results obtained from the analysis of a transverse third-damper suspension system. This experiment aims to investigate the frequency analysis of a suspension system, including the transverse third-damper, as the unsprung mass of the system is incrementally increased by 40 kg, 60 kg, and 80 kg. The objective is to evaluate the road-holding capabilities of the vehicle, with the ultimate goal of developing a system for mounting electric motors in the wheels of an electric vehicle. To achieve this, a motor-powered conveyor belt is utilized to test the frequency of the unsprung mass of the vehicle's rear wheels, which are rotated to simulate driving on the road. A rubber block is affixed to the conveyor belt to simulate a common road obstacle. Specially designed 20 kg steel plates are incrementally added to the unsprung mass of the vehicle experimentally the unsprung mass increases by 20 kg each time. During testing, the vehicle drives over the road obstacle to enable frequency testing of the suspension system, including the transverse third-damper several STEVAL-PROTEUS are placed on the vehicle's unsprung mass to measure the resonant frequency and amplitude ratio of the suspension system at multiple locations [2]. The test bed construction confirms that the resonant frequency and amplitude ratio will change as the unsprung mass is increased by 40 kg, 60 kg, and 80 kg, respectively.

## Introduction

With the quick rise in the purchasing of electric vehicles, it appears wise to further boost the growth of these vehicles. As a result, studies have been initiated to explore the potential of in-wheel motors. Findings indicate that the addition of in-wheel motors can adversely impact either the ride comfort or the road-holding capabilities of electric vehicles by increasing their unsprung mass [1]. A frequency analysis response was carried out on a suspension system that included a transverse third-damper following the discovery of these results. This was done because a passive suspension system was favored for its ease of use, dependability, and affordability [1]. Using a transverse half-car model, the actions of both wheels are examined by inducing disruptions in one wheel. The outcomes indicate that a suitable damping ratio for the transverse damper can considerably decrease the amplitude ratio at the second resonance of one wheel, particularly for unsprung masses categorized as high or medium. Thus, owing to its passive characteristics, the suspension system design with a third-damper is a cost-effective approach that can attain the objectives of enhancing roadholding performance without compromising the comfort of the rider. This sets the stage for the experiment, which is constructed on a testbed featuring a conveyor belt.

## Design

The third-damper system is a promising addition to electric-vehicles because it mitigates the decrease in road holding because of the in-wheel weights without decreasing the overall ride comfort [1]. The in-wheel weights are substitutional weights, which mimic the weight of an electric-vehicle motor. In order to conduct this project, custom-designed weights of 40 kg, 60 kg, and 80 kg are being installed on the unsprung mass of the transverse half-car model (see Fig. 1). Additionally, four STEVAL-PROTEUS are being attached, each equipped with an accelerometer and gyroscope to detect temperature and vibration [2]. These sensors are added to the increasing unsprung masses to determine the frequency of the system as the vehicle traverses an obstacle placed on the conveyor belt. To simulate a vehicle running over an obstacle, a 2.54-5.08 cm (1-2in) thick rubber strip is securely fastened to the conveyor belt using Velcro [4]. The existing testbed design has undergone a comprehensive Ansys analysis, validating its stability and assessing the overall deformation (see Fig. 4). The resulting frequency is then analyzed to gain deeper insights into the road holding and ride comfort provided by the third-damper system. The unsprung mass is gradually increased during testing, starting with a weight of 40 kg and adding another 20 kg until reaching the target weight of 80 kg (refer to Fig. 5).

**Figure 1. Electrical Vehicle with Third-damper Suspension**
The testbed is being designed and built for the **system**, which determines various aspects of the testbed's design, such as the width of the conveyor and the distance between the two conveyors. The car being tested has an estimated weight of 408.2 kg (900 lbs). (Photography by Kayden Bingham)

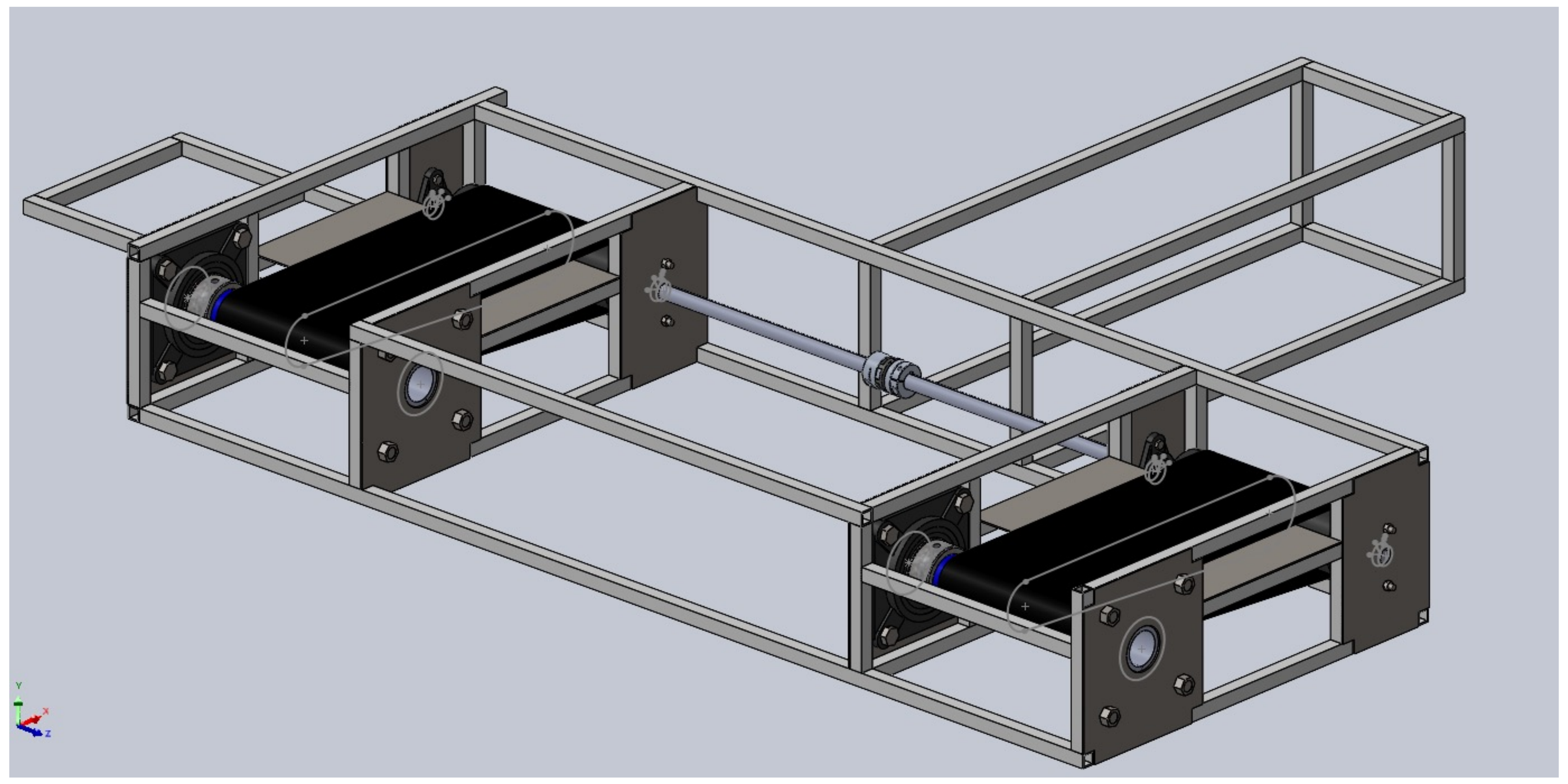


**Figure 2. Conveyor Belt Testbed**
SolidWorks has developed the current design testbed to evaluate an experimental suspension system equipped with a transverse damper and verify the computational results obtained from its analysis. This testbed has dimensions of 277.1 cm by 182.8 by 30.48 cm (109.1 in. by 72 in. by 12 in), weighs 121.93 kg (268.82 lbs), and is constructed from A36 Stainless Steel. It has a weight capacity of 533.6 kg to 613.6 kg (1176.4 lbs to 1352.8 lbs). The primary components of this conveyor testbed include a steel frame and two conveyor belts linked by two 2.54 cm (1 in) diameter steel rods measuring 106.68 cm (3.5 ft) in length. The testbed is powered by a motor with low horsepower but high torque to move a large mass. (Created by Michael Debard.)

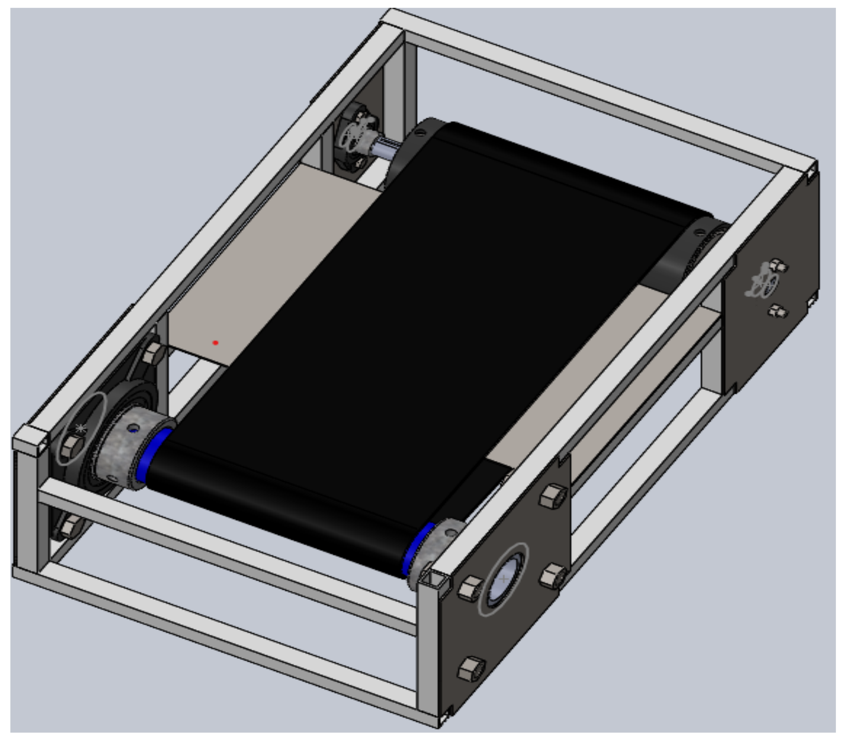


**Figure 3. Conveyor Belt**
The current configuration of the conveyor belt comprises a head and tail pulley with a diameter of 2.54 cm (1 in), both of which are made of steel and coated with rubber to enhance the grip between the belt and the pulleys. The head pulley has a diameter of 11.43 cm (4.5 in) and drives the belt, while the tail pulley has a diameter of 7.62 cm (3 in). The belt used is a 30.48 cm (12 in) wide High-Grip Multi-Ply Conveyor Belt, which was selected to replicate the frictional forces experienced by a rubber tire on asphalt [3]. (Created by Michael Debard.)

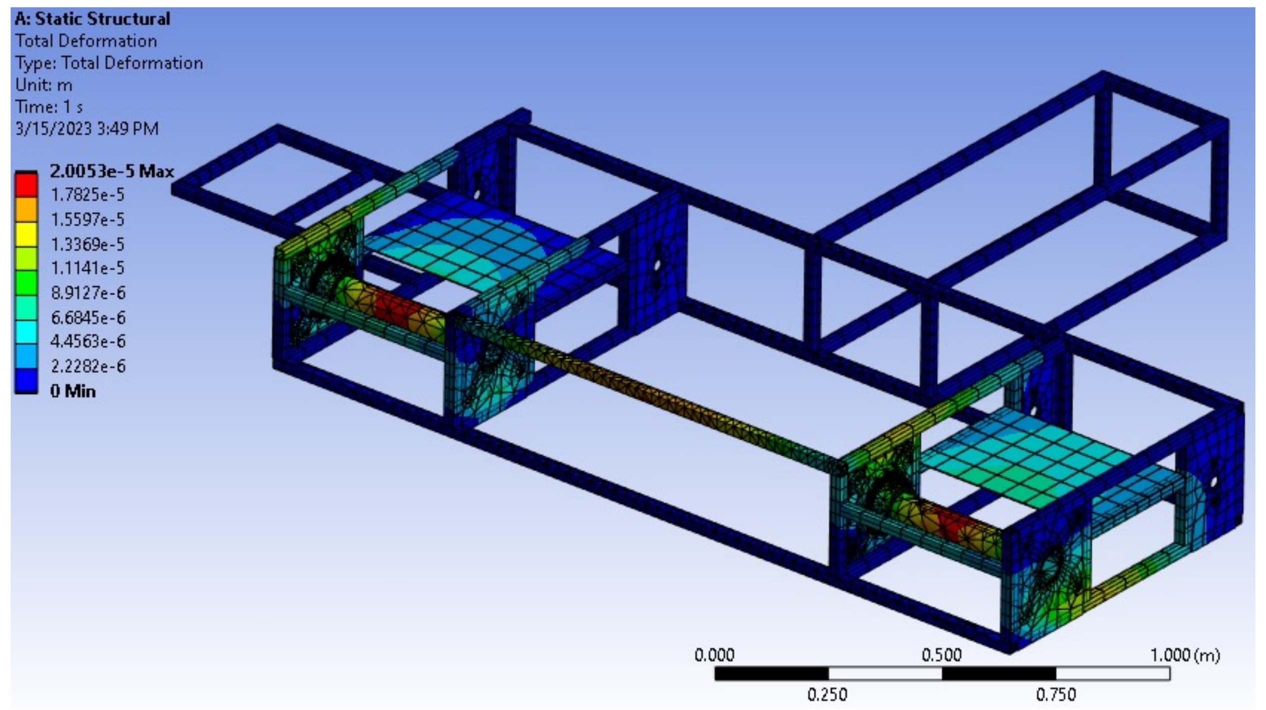
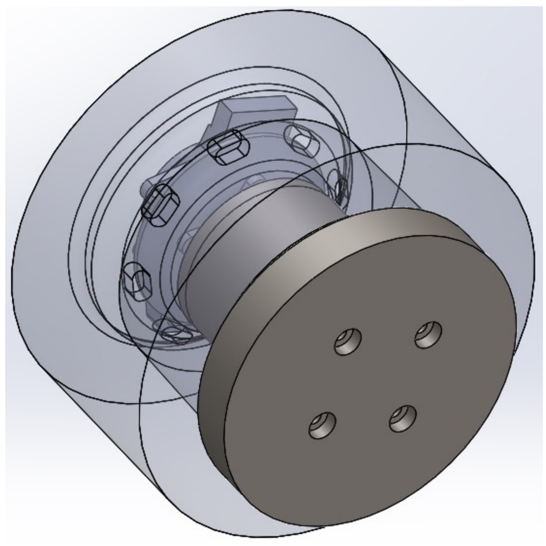



**Figure 4. Total Deformation Evaluation**
Based on the Ansys simulation, it has been determined that the current testbed design is capable of withstanding the applied force. This force is spread across the testbed, with the primary pressure points being the two conveyor belts where the wheels apply force. Additionally, the image of the testbed shows a sturdy steel base at the back, providing structural stability for the half-car model while distributing weight evenly. The testbed is constructed using ASTM A513 steel for the idler pulley and steel tubes, and ASTM A1011 steel for the metal plates.
(Evaluation: Idler Pulley Young's Modulus is 190 GPa and the deformation does not result in material failure for the idler pulley building the vehicle weight.) (Created by Michael Debard.)

A.



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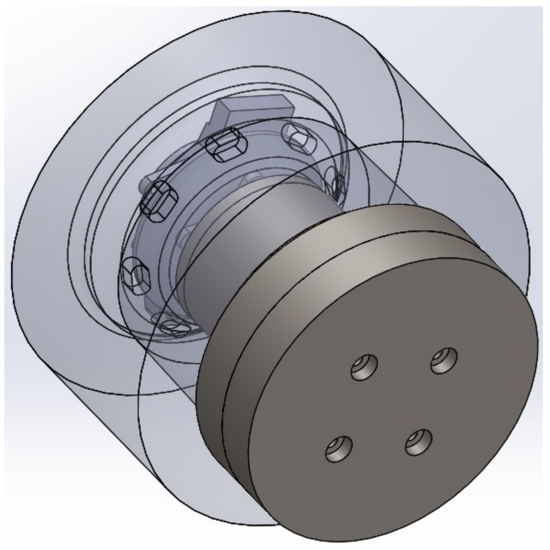

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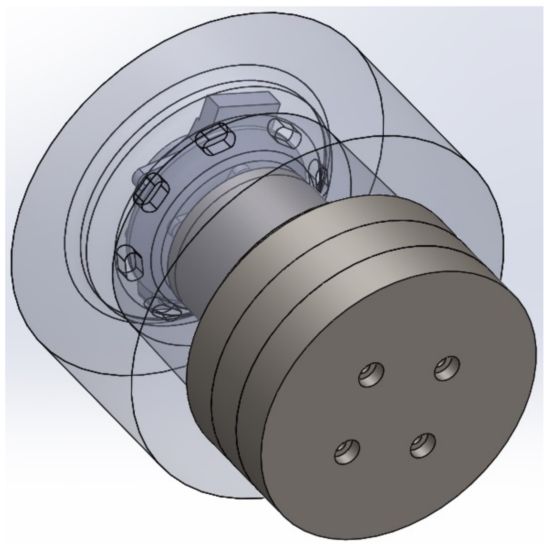

**Figure 5. In-wheel weight**
Here are the present designs for the in-wheel weights, with each customized weight made of A36 Steel. The first design (A) has a total mass of 40 kg, the second design (B) has a total mass of 60 kg, and the third design (C) has a total mass of 80 kg. A 25.4 cm (10 inch) long bolt made of steel is utilized to secure the weights, and each weight contributes to the unsprung mass. The in-wheel weight itself has a mass of 20 kg and is designed to fit inside the wheel. The outer in-wheel weights also weigh 20 kg each and have a diameter of 28 cm (11 inches) and a thickness of 4.2 cm (1.6 inches). (Created by Kayden Bingham.)

## Results and/or Conclusion

**Conclusions**

The research conducted has indicated that a testbed would be an effective and valuable tool in achieving the objective of frequency analysis with the addition of in-wheel weights. To this end, a 2-conveyor testbed powered by a low-horsepower motor (refer to Fig. 2) will be constructed. The testbed is designed to withstand the force applied by the half-car model and to replicate the action of a vehicle driving on asphalt. Furthermore, the testbed will enable the replication of a vehicle's tires running over a road obstacle, which will be simulated by running over a piece of rubber on the conveyor belt. This will allow the STEVAL-PROTEUS to analyze the frequency sensed in four different locations on the left and right of the unsprung mass. The findings of Dr. Hector Medina and Natasha Carpenter will be supported by the data [1].

## Future Work

The first step towards advancing this experiment involves finalizing the testbed design. One way to achieve this is by exploring more economical materials to reduce costs. The current steel-based design is quite costly. To reduce expenses and achieve a lightweight structure, an alternative all-wood design has already been researched. The second priority is to finalize the design of the in-wheel weights, potentially by identifying ways to optimize manufacturing costs. The present design features numerous cuts and holes that contribute to its elevated cost. To reduce expenses, additional research can be conducted to improve the manufacturing cost-effectiveness of the in-wheel weights. The third step involves procuring the necessary materials for constructing the testbed and analyzing their availability. Next, the testbed should be built and prepared for the experiment. The final phase of the experiment involves analyzing the frequency analysis results to draw conclusions.

## References and/or Acknowledgments

**Initial Research**

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