Optimization Driven Design Process for Vehicle Suspension Systems

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April 2015

Today, experienced engineers use their prior knowledge to create an initial "best-guess" vehicle suspension design. This design is then iteratively improved in a manual process until it satisfies the design goals. This process is time consuming and can be improved by introducing an optimization driven design process, which replaces the manual iterative work.

The results of this Master's thesis shows that it is possible to obtain a satisfactory vehicle suspension design by incorporating optimization into the design process. The main objective in this Master's thesis was to develop a methodology which describes how to start with the design goals, and end up with an optimized vehicle suspension design. The resulting methodology is divided into three steps: Concept Screening, System Optimization, and Structural Optimization. The flowchart shown in Figure 1 visualize the connection between these distinct steps.

Figure 1: Flowchart on the methodology.

The design goals mentioned earlier are the ride comfort, handling performance, and noise, vibration and harshness in the suspension system during common driving maneuvers. Some typical maneuvers are cornering and driving over speed bumps. A multibody dynamics model of the suspension system is used to simulate the driving maneuvers. The suspension design can be altered by moving the attachment points and changing the bushing stiffnesses. Traditionally, these changes to the suspension design are manually set using prior experience and knowledge in an attempt to improve the suspension characteristics. Our methodology describes how to automatically generate and evaluate designs, and later on, finding the best solution.

The first step is to select a suspension concept which is appropriate for the vehicle in question. Two common suspension concepts are shown in Figure 2, the Strut & Coil Spring (left), and the Double Wishbones (right).

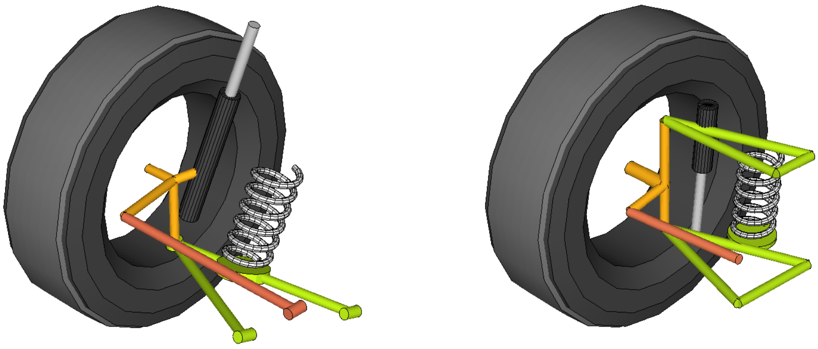

Figure 2: Suspension concepts: Strut & Coil Spring (left), Double Wishbones (right).

This is called the Concept Screening. The concept screening provides valuable information on the characteristics of the investigated suspension concepts. This is done by testing design variations. Figure 3 shows two design variations of the Strut & Coil Spring suspension.

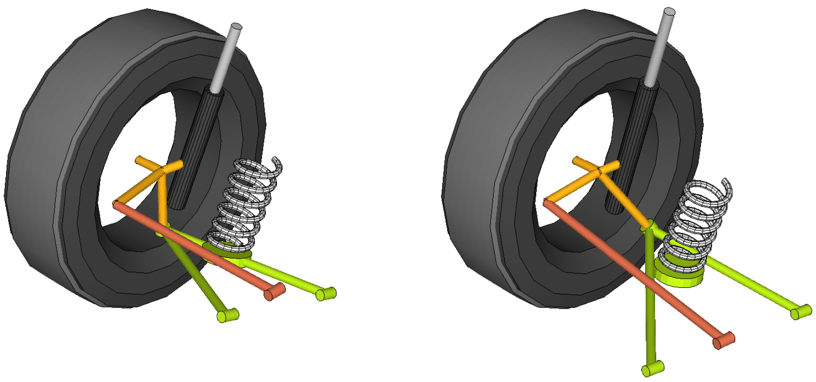

Figure 3: Design variations of the Strut & Coil Spring suspension.

But, there are an infinite number of possible design variations for each investigated suspension concept. Each design variation one would like to investigate comes with a computational cost, as it requires a simulation of the driving maneuvers to be performed. Given a limited available computational time, and thereby a limited number of possible design variations to test, an experiment planning algorithm determine which design variations to test in order to investigate as many different design variations as possible. This is known as Design of Experiments. A decision is made, based on the concept screening, on which concept to proceed with in the design process.

In the second step, System Optimization, the most optimal design variation is found. The goal is to fulfill the design goals, or at least come as close to them as possible. In comparison to the previous step, an optimization algorithm now determines which design variations to test in order to improve the characteristics of the chosen suspension concept.

The optimization algorithm used is a genetic algorithm. It is modeled after the evolutionary process theory. It starts by generating a family of random design variations. It then selects the elite members of the family as parents for the next generation. A new family of design variations is created based on genetic operations on the parents. This could be viewed as the passing of DNA from parents to their children. Mutation may occur in this process, which might be beneficial for the children. The design variations evolve towards an optimal solution over a large number of generations.

The last step is the Structural Optimization of the optimal design variation from the previous step. In this step, the weight, material and cost is optimized for each suspension component. Loads recorded in the driving maneuver simulations are used as requirements for the suspension components. Figure 4 shows how weight is minimized for a suspension component by performing a structural optimization.

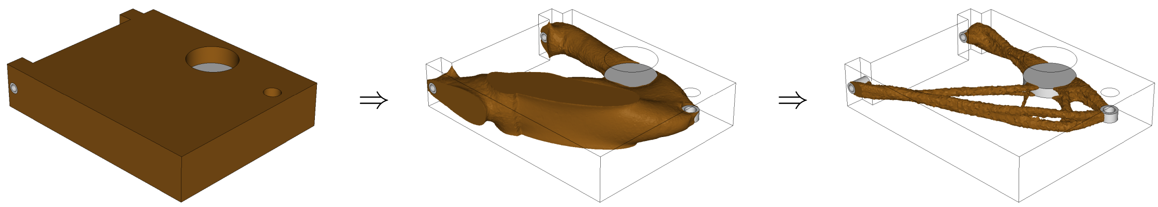

Figure 4: Structural optimization of a suspension part.

These optimized component designs have an optimal geometry. But they are unfortunately often impossible to manufacture. They are, however, excellent initial concepts for further design of components which take manufacturing constrains into consideration. Figure 5 shows how stress is distributed in an optimized light-weight suspension component during a driving maneuver simulation.

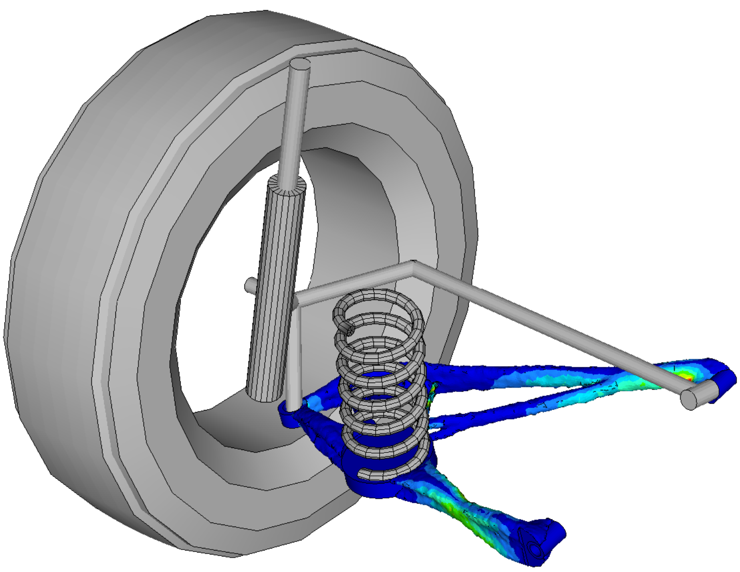

Figure 5: Stress distribution in an optimized part during a drive case simulation.

Given an initial ”best-guess” vehicle suspension design and a set of design goals, an engineer new to vehicle suspension systems can relatively easily improve the suspension design and find light-weight component designs using our methodology.