A McPherson lightweight suspension arm

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Abstract

The paper deals with the design and manufacturing of a McPherson suspension arm made from PA66 with short glass fiber reinforcement. The design of the arm and the design of the molds have been made jointly. According to Industry 4.0 paradigms, a full digitalization of both the product and process has been performed. Since the mechanical behavior of the suspension arm strongly depends on constraints which are difficult to be modelled, a simpler structure with well-defined mechanical constraints has been developed. By means of such simple structure, the behavior of the material has been highlighted. Since the suspension arm is a hybrid structure, the associated simple structure is hybrid as well, featuring a metal sheet on which plastic is injected. The issues referring to material flow, material to material contact, seams welding, fatigue strength, high and low temperature behavior, creep, dynamic strength have been investigated on the simple structure. The detailed understanding gained with the simple structure has been transferred on the actual suspension arm.

The McPherson arm has been produced and withstood the technical specifications.

Introduction

The aim of the paper is to present the activities related to the development of a plastic suspension arm.

Lightweight construction is a key set of technologies enabling the deployment of electric vehicles [1].

Additionally, such technologies are contributing, since decades, to CO_2 reduction [2,3]. It is obvious that reducing the mass of a vehicle means reducing the mass of each single part of it [4]. This justifies the activities undertaken in our research.

Designing a plastic suspension means undertaking a complex activity which deals with the contemporary development of both the structure and the manufacturing process. Actually, the shape of the arm depends both on the loading and on how the resin can be injected into the mold.

Such double activity, namely designing the structure and designing the manufacturing process, is typical of automotive engineering. Nonetheless such activity has recently undergone a major evolution with digitalization. Digitalization, a paradigm of Industry 4.0, is fully adopted in our research. We pursue the full digitalization of the design process, featuring both structural design and manufacturing process design.

To achieve such a goal, we have developed a simple structure which has all of the features of the suspension arm, except the external constraints. External constraints, namely the external joints, are physically and mathematically defined in the simple structure, while are more complex in the actual suspension arm (rubber bushing are hardly modelled). The easy modeling of the external constraints makes the simple structure easy to be studied and validated.

By means of the simple structure we can develop a validated model of an actual component, starting from the properties of the different materials that are employed. Since a confident modeling is made available with the simple structure, the development of the suspension arm is now ready to be fully virtualized.

In the literature there are examples of lightweight suspensions, some of them already into production. In [6] a statically determined hybrid structure was developed.

The paper is organized as follows. At first, the concept design of the arm is presented, then the simple structure is introduced. The contemporary design and of the manufacturing process is shown. Finally, the tests on the arm are presented.

Concept design and material choice

The suspension arm to be developed is the lower link of a McPherson strut. It is shown in Fig. 1. Since PA66 with glass fiber reinforcement may undergo fragile rupture, a hybrid solution has been conceived using a thin lightweight metal sheet inside the arm to avoid full separation of broken parts. The hybrid structure that is conceived is quite complex to be modelled, referring both to structural strength and to manufacturing process, namely the injection molding. The issues are: material flow, material to material contact, seams welding, fatigue strength, high and low temperature behavior, creep, dynamic strength.

The material that has been chosen is a special formulation for PA66 with 50% of short glass fiber reinforcement. Additives to increase the adhesion with a metal (in this case Aluminum 6061) are provided. A DOE analysis, with three factors and three levels, has allowed to identify the most performing formulation among the 9 tested. DOE analysis considered the influence of the most important molding parameters. No significant effects of these parameters have been identified on the material behaviour. The tensile characteristics of the material are depicted in Fig. 2. The material was tested at -20, 23, 85, 120, 150 ° C. Fig.2 shows the results for the material both in the DAM state (DAM, Dry As Molded) and in the conditioned state.

Figure 1. 3D model of the suspension arm.

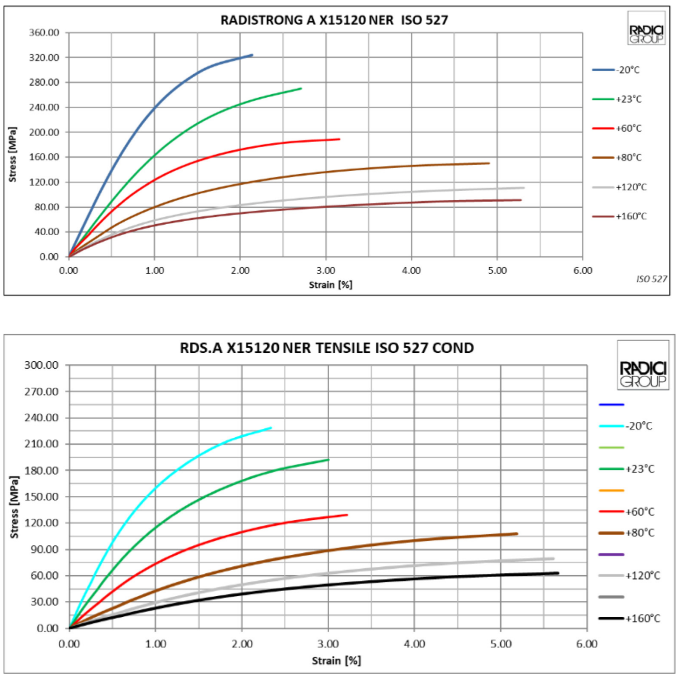

Figure 2. Upper panel: Tensile test of the PA66 50% material, DAM state. Lower panel: Tensile test at fully conditioned state of the material.

Simple structure

Non statically determined external constraints prevent an easy validation of mathematical models describing the mechanical behavior of hybrid structures. Since the mathematical description of the mechanical behavior of hybrid structures is a complex task, we ended up designing a simple structure which mimics an actual structural component, but free from uncertainties coming from non statically determined external constraints. Such a simple structure is presented in Fig.3.

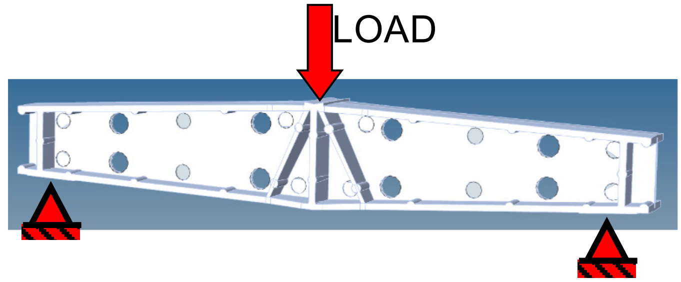

Figure 3. Simple structure, useful to gain knowledge on the mechanical behaviour of hybrid structures, without uncertainty coming from non statically determined external constraints.

The simple structure in Fig. 3 is just a simply supported beam, loaded with a single load at the center of the span.

Contemporary design of the arm and of the manufacturing process

The arm is produced by injection molding. Weak points may be created in the structure at the seam surfaces, where two or more flows of melted polymer join together. A proper and accurate modeling of the process is crucial to define the shape of the structure. Obviously, the structure must withstand the external forces, so the final shape is a compromise between the requests from the technological manufacturing constraints and the structural ones.

We have gained full modeling control on the contemporary design of the arm and of the manufacturing process by exploiting the simple structure.

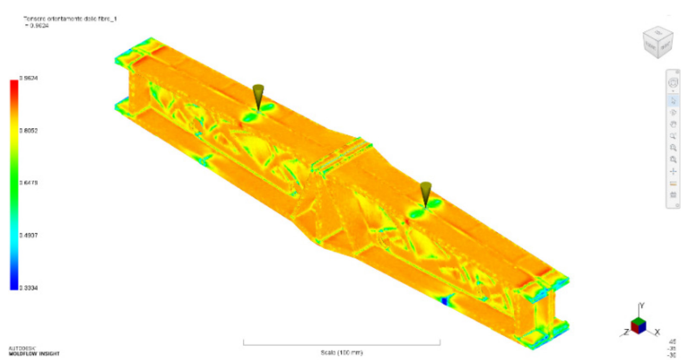

Figure 4. Simple structure, simulation of the injection molding process.

Extensive tests have been made on the simple structure referring to

- static loading
- fatigue loading
- creep
- shock loading
- loading at high and low temperature

The results of such tests are briefly commented here for sake of space. Fig. 5 shows the simple structure under test.

For what concerns the creep behaviour a specific testing machine has been developed to test the simplified structure, in creep condition, in the three points bending configuration. Two different load levels and three levels of temperatures were investigated. The results has shown as the temperature is the most influencing factor. For what concerns the shock loading, a drop dart testing machine has been used to carry out the impact tests in three points bending configuration. The influence of the impact mass and of the impact energy has been investigated. Failure of the specimens has been obtained between 15 and 20 J. The metal insert has shown significant contribution the polymer failure. The complete separation of the component has been obtained after 25 J, that is a quite high value as deductible from [X]

By the simple structure, a proper understanding has been gained on melted material flow, material to material contact, seams welding, fatigue strength, high and low temperature behavior, creep, dynamic strength. Such knowledge has been applied for the final design of the suspension arm, shown in Fig. 6.

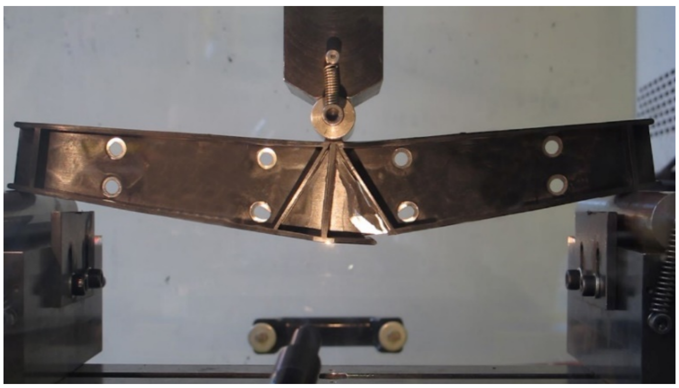

Figure 5. Simple structure under quasi static test. The aluminum sheet prevents the full separation of the broken pieces.

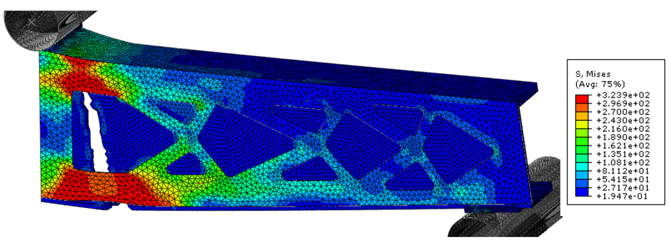

Figure 6. Final design of the suspension arm.

Molds and production

After sufficient knowledge has been gained with the simple structure, the arm has been manufactured. Fig. 7 shows the mold, conceived according with recommendations coming from simulations of the injection molding. Fig.8 shows the suspension arm, a made from the hybrid structure composed with aluminum and PA66 with short glass fiber reinforcement.

Figure 7. Mold of the suspension arm.

Figure 8. Suspension arm.

Testing

Proper testing of the suspension arm has been performed to validate the entire design and manufacturing process and the component itself.

We cannot describe here the tests for sake of space. Fig. 9 shows the suspension arm in a climatic chamber, ready to be loaded to check the structural strength under varying environmental conditions.

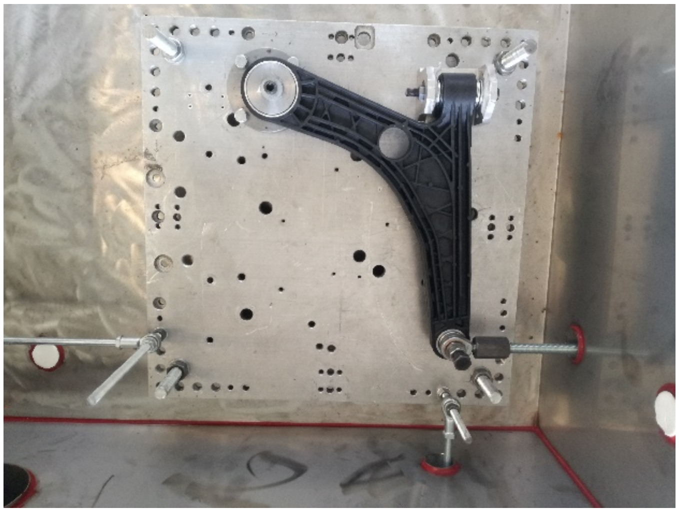

Figure 9. Suspension arm loaded in a climatic chamber.

Conclusions

The design of a McPherson suspension arm, where both the design and the manufacturing processes have been made jointly, has been presented. The component has been made of aluminum 6061T6 and PA66 with 50% short glass fiber reinforcement.. A full virtualization of such a combined process has been performed by means of a simple hybrid structure. Proper confidence in dealing with the design and production process has been gained by means of the simple structure. By exploiting the acquired knowledge, the suspension arm has been designed, manufactured and tested with satisfactory results.

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Definitions/Abbreviations

DAM	Dry As Molded
DOE	Design Of Experiments