Composite-lightweight rear suspension knuckle for a high volume passenger vehicle

Ford Motor Company, in collaboration with Warwick Manufacturing Group (University of Warwick), Gestamp and GRM consulting, have developed a composite rear suspension knuckle for a c-segment vehicle with Innovate UK. A combination of unique carbon fibre deployment and a bespoke manufacturing process have resulted in 50 % weight reduction compared to the current fabricated steel component. The processing technology introduced in the project is the first of its kind and offers a very short cycle (sub 5 minutes). The design of the part is complete and manufacturing trials of the component are currently ongoing to develop the full scale mass production process.

Introduction

The entire automotive industry across the globe is pushing for tighter mass targets in order to satisfy the ever increasing stringency over emissions, concern of depleting fossil fuels and the customers demand for extended ranges of electric vehicles. Global Ford Research and Advance group teamed up with Chassis Engineering in the UK to take a development step by picking up a serial steel suspension component and changing the design to be able to manufacture as a light weight composite component. The weight savings in this specific un-sprung component increases the effectiveness of the springs and dampers, leading to the enhancement of passenger comfort and driver handling. This newly developed composite part proved appropriate for a high performance C-segment vehicle. A delicate and perfect balance obtained between the material and process selection led to a total cycle time of under 5 minutes. This short cycle time is the result of a detailed and bespoke manufacturing process that is an industry first for carbon fibre manufacturing

Collaboration is essential

This success story is a result of 2 year long project part-funded by Innovate UK and executed by a cluster of organisations including Ford Motor Company, Gestamp, WMG (University of Warwick) and GRM Consulting. The project was titled Composite Light weight Automobile Suspension System (CLASS). The technology of composite materials has had to evolve from academia and space/aerospace industries to mainstream automotive engineering practices to offset weight increases inherent in electrified and autonomous vehicle. The complexity of the composite material behaviour still remains a challenge to be overcome for the mainstream automotive industry as a whole. The complexities lie in the areas of manufacturing, prediction and highly specialised design methods. It is a well-known fact that the performance of a composite part is primarily determined by the way it is manufactured. WMG (University of Warwick) were able to use their extensive knowledge of the material behaviour and state of the art manufacturing cells to enable Gestamp, one of the very worlds' best automotive chassis manufacturers, to play a vital role in designing a component that meets the required functional requirements. Although, a vast amount of research has been dedicated to understand composite materials in both industry and academia, the art of prediction of composite material behaviour is still in its infancy. GRM consulting, who have decades' worth of experience in developing predictive tools for carbon fibre structures in the motorsport industry, have made a significant contribution to the project by bypassing a traditional approach and also reducing the amount of physical testing required. This has been required to understand the failure mechanisms of the sheer number of combinations of fibre orientations that make the predictive analysis methods viable for a topology efficient design.

Design approach:

During the course of two years of the project, the design of the composite part has evolved from a single material part to a multi-material design. Initial surveys based on various articles [1,2] indicated that the idea of composite light weight knuckle could be realised by single material (SMC). However, rigorous in-house testing of the SMC samples highlighted two drawbacks, namely longer cure times and lack of mechanical properties to meet the load requirements. In the case of SMC, higher mechanical properties required for a robust automotive suspension system could only be met by higher gauge levels. But, processing of higher gauge levels of SMC required longer cycle times which reduced the manufacturing quality and were not suitable for large volume manufacturing. These underlying issues led the design engineering team toward a multi-material system; where layers of prepreg give the required mechanical properties and co-moulding of SMC allow the complicated geometric profiles. It is worth noting that such technology has been proposed in academia and in the aerospace industry [3], however the requirements for automotive application are different and this project is likely to be the first time such technology is implemented. This has been possible as prepreg manufacturing costs are being reduced globally [4]. The approach of combining uni/bi axial prepreg with SMC suggested that the composite component could satisfy the majority of the mechanical strength targets. Other design challenges have meant that further innovations have had to be introduced while staying within the design brief without affecting the manufacturing process. The design was finalised only after the completion of extensive simulation and experimental work. This has optimised the design for OEM durability and NVH targets.

Figure 1: Steel Knuckle-Tie Blade

Figure 2: Finished Composite Knuckle-Tie Blade

Innovative manufacturing technology:

A compression moulding manufacturing technology has been developed capable of mass manufacturing the high strength, stiff and complex shaped suspension knuckle. The processing technology will be fully automated, achieving a cycle time below 5 minutes, with manufacturing trials due in the second quarter of 2017 producing a demonstration part for evaluation by physical testing. With the aid of a press, the pre-cut prepreg will be preformed to the required shape in a die. The preformed prepreg will then be transferred to the compression moulding press. The

strike the best balance between cost, performance and weight.

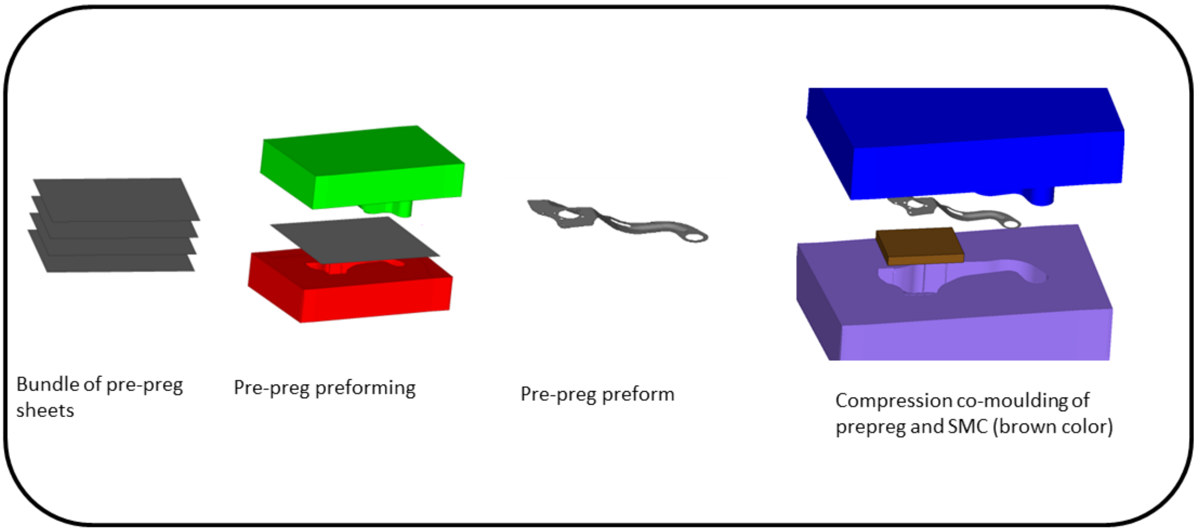

Figure 3: Steps in the manufacture of composite part

compression moulding tool has been manufactured by a UK based tool maker and features sensors to track SMC flow, monitor process parameters and investigate the cure of the prepreg and SMC resins. The SMC is composed of 53% weight fraction and 15k filament count, and the prepreg is a woven fabric with 60% weight fraction and 12k filament count, all supplied by Mitsubishi Rayon Corporation. An illustration of the basic tooling is shown in the Figure 3. Prior to embarking on manufacturing of the composite knuckle tie blade, CLASS candidate carbon fibre materials were moulded at Ford Research and Innovation Centre based at Dearborn in the USA. This experience helped the project to optimise the process parameters so that the maximum mechanical performance and geometrical accuracy can be obtained.

Lessons learned

Meeting the projects' cost objectives was the biggest challenge since its inception, however the experience gained during the project helped engineers understand how to

The project started with an aim of developing a 100% SMC composite knuckle. As it progressed, the engineers learned that low cost grade composites cannot offer the required mechanical stiffness properties and therefore had to be more creative in the material selection to ensure that the manufacturing process could stay within the cycle times whilst meeting the objectives set out at the beginning of the project.

[1] Design for Success-A Design & Technology Manual for SMC/BMC, The European Alliance for SMC/BMC, [online], Available: http://smcbmc-europe.org/design-for-success.php, [Accessed 16/02/17]

[2] LAMBORGHINI "Forged composite" technology for the suspension arms of the sesto elemento, [online], Available: http://www.quantumcomposites.com/pdf/papers/2011-ASC-montreal-forged-suspens.pdf, [Accessed 16/02/17]

[3] Combination of carbon fibre sheet moulding compound and Prepreg compression moulding in aerospace industry, 11th international conference on technology of plasticity, ICTP 2014, 19-24 October 2014, Nagoya Congress Centre, Nagoya, Japan

[4] Composite volume production, [online], Available: http://www.materialsforengineering.co.uk/engineering-materials-features/composite-volume-production-lightweight-material-challenge/116537/, [Accessed 16/02/17]