EDITORIAL

Design Against Failure of the Next Generation of Alloys for Lightweight Electric Vehicle Structures

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A brave new World is upon us and true to say, our evolution as a species is at a key turning point where we will either prosper or face the age of extinction. The strive to save planet Earth from the catastrophic effects of climate change is now at a critical point. This battle will pit human imagination, ingenuity, and spirit against the almighty forces of nature. It is up to us all and as Engineers, we can and will make a significant impact on this global challenge.

Consider that an average passenger vehicle emits 4.6 metric tons of carbon dioxide per year [1]. As conventional internal combustion engines are ultimately phased out, a key factor toward reducing carbon emissions is creating the next generation of ultraefficient electric vehicles. This is particularly the case with engineering structures that are lighter weight and agile, while allowing for more exotic and futuristic designs to be manufactured. Lighter weight structures made from cast aluminum alloy, advanced high strength steel grades and in some cases composite materials are all required. Now is the time to change from the conventional and come up with radical new technologies.

There is significant weight saving potential of between 25 and 35% that can be achieved when using advanced materials to manufacture. However, there are a range of engineering challenges that need to be overcome. Recent work I have undertaken has involved assessing new alloys and testing new vehicle designs to the point of destruction to understand their failure modes. Downgauging materials used in chassis and suspension will reduce the mass of a structure; however, we still need to maintain durability and safety standards. This is significant when it comes to

electric vehicle structures as there is significant potential to increase mileage range and improve vehicle performance.

New alloys include advanced cast aluminum alloys and the second generation of advanced high strength steels, which are vital in this push to reducing vehicle mass. Enhancing the fatigue lives of such structures beyond those of conventional vehicle structures is important. These are initially assessed in the laboratory to evaluate the performance of such structures as shown in Fig. 1. Low load high cycle fatigue testing regimes are used to determine the cyclical performance of these materials. With this data, we can confidently specify that structures can be designed to be 2.5 times the designed safety margin while not

Fig. 1 Assessment of advanced cast aluminum alloy (ACAA) in sheet form, high strength steel (HSS) and the next generation advanced high strength steel (AHSS) grades. These structures are each assessed using high cycle four-point fatigue loading.

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sacrificing safety requirements. Laboratory testing is carried out to ensure these structural materials can survive 100 million cycles at 20% of the yield point of the material. Any deformation of the structure is observed by automated camera system to monitor a test carried out at 30Hz which can take up to 40 days to complete.

The microstructure of these new alloys is complex and has many desirable durability properties. Particularly, the work hardening properties of some of these advanced microstructures will often result in fatigue crack growth resistance [2] and resistance to distortion under loading. During the next stage of the design, again failure process is

understanding and assessing the microstructural properties under testing to failure. Next, questions can be answered such as whether microstructures are resistant to fatigue, cyclic constitutive behavior, crack initiation and subsequent crack-propagation. Here, we can characterize failure modes, further identifying the intrinsic mechanisms associated with the microstructural mechanisms of failure. It is important to grow fatigue cracks to test the crack growth properties of the material [3]. The manufacturing and surface finish is also important in failure assessment. This is analyzed using specific coupon notch testing as shown in Fig. 2. Here, the microstructural properties and fatigue

Fig. 2 (a) Coupon notch testing of an advanced cast aluminum plate for the next generation of vehicle chassis structures and (b) the initiation of a fatigue crack from the point of highest stress. Microstructural properties of (c) advanced cast aluminum alloy microstructure (d) the resulting fatigue crack formed under high cycle fatigue loading (e) advanced high strength steel microstructure and (f) the resulting fatigue crack formed under high cycle fatigue loading. These new alloys display amazing properties that will become the materials of choice well into this century. The fight against climate change requires everyone to work together. We can draw tremendous hope from the fact that we have the technology, materials and technical know how to make a significant impact on climate change. It is now time to bridge the gap between learning in the laboratory and engineer the solutions we need with spirit and decisiveness.

crack growth through the microstructure are understood. These observations are vital to understand and draw confidence in these new materials [4].

References

1. <https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle>
2. R.O. Ritchie, C.J. Gilbert, J.M. McNaney, Mechanics and mechanisms of fatigue damage and crack growth in advanced materials. *Int. J. Solids Struct.* **37**, 311–329 (2000)
3. J. Walker, D.J. Thomas, Y. Gao, Effects of shot peening and pre-strain on the fatigue life of dual phase Martensitic and Bainitic steels. *J. Manuf. Processes.* **26**, 419–424 (2017)
4. D.J. Thomas, The effect of laser cutting parameters on the formability of complex phase steel. *Int. J. Adv. Manuf. Technol.* **64**, 9–12 (2013)

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