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THE ULTIMATE GUIDE TO LIGHTWEIGHT MATERIALS AND PARTS TESTING IN AUTOMOTIVE AND AEROSPACE

How to meet the latest drop weight impact test requirements

I INTRODUCTION

As the demand for lightweight and composite materials continues to grow,[1] impact testing is becoming more and more critical to success in design and manufacturing. But how do you ensure that added testing requirements don't translate into downtime and disruption to just-in-time workflows in automotive and aerospace?

This guide will give materials engineers and scientists working in these industries valuable insight into the latest drop weight impact testing methods and technology. It will provide you with useful guidance on how to make composite materials and parts testing simpler, faster, and more reliable, which is key to minimising disruption and optimising the time to market.

The guide will start by analysing some of the key trends in the composites industry in relation to automotive and aerospace applications. It will then look at how these trends are affecting materials and parts testing requirements and the key steps that can be taken to ensure that these are met.

LIGHT ALLOYS AND COMPOSITES: EMERGING TRENDS AND CHALLENGES

Light Alloys and composites are rapidly becoming the go-to materials for automotive and aerospace manufacturers. According to analysts Market Insight Reports, over the next five years the composite material market is set to grow at a CAGR greater than 5%, mainly due to surging demand from the automotive and aerospace industries.[2] Demand for high-performance alloys is also expected to continue growing by over 3% a year between 2020 and 2027.[3]

What makes light alloys and composites increasingly popular are their key benefits, including high durability and mechanical performance compared to traditional materials like steel and aluminium.[4] But the main USP is their low weight, which makes them ideal candidates for today's vehicles and aircrafts. The main reason for this is that both automotive and aerospace OEMs are striving to curb CO2 emissions to comply with legislation while addressing growing environmental concerns. The rising demand for electric vehicles, where keeping weight to a minimum is a top priority, is also leading manufacturers to turn to light composites such as carbon fibre.[5]

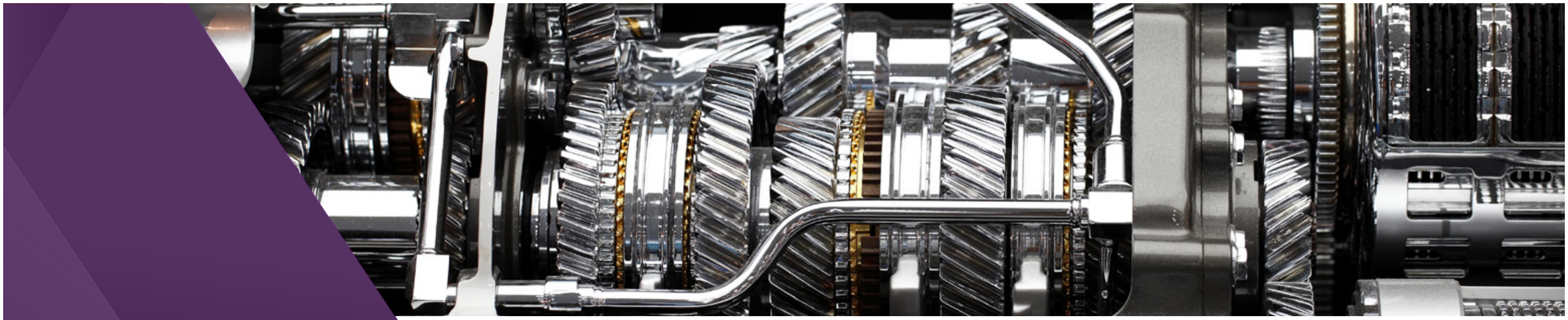
Another important trend in the industry is the move towards 3D printing. This includes the deployment of fused deposition modelling (FDM)[6] to print composites and powder-based additive manufacturing (AM) technologies to produce alloys.[7] According to analysts Fortune Business Insights, the aerospace 3D printing market is expected to grow by a staggering 22% a year, from $1.3 billion in 2018 to over $6.7 billion in 2026. According to the report, the need to reduce the weight of aircrafts is, once again, a major driver behind this growth. But there is also a trend towards 'reshoring' and bringing the production of key components back in house, which is now being accelerated by the disruption of global supply chain due to the COVID-19 pandemic.[8]

The growing variety and number of materials and manufacturing methods used in automotive and aerospace is inevitably translating into more stringent testing requirements.[9] The main reason for this is that materials such as carbon-fibre and epoxy composites can be susceptible to impact damage due to their relatively weak through-thickness strength.[10] And worse, damage may affect performance even if it is not clearly visible,[11] which makes it challenging to detect potential faults early in the design process.

The need to carry out more frequent and thorough tests may lead to bottlenecks along the design and production line, which can ultimately hinder efficiency and productivity and extend the time to market. Generally, this is due to two main factors:

- Lack of repeatability and accuracy in testing, resulting in errors that can cause problems further down the line leading to downtime or product recalls.
- An inefficient testing process, leading to unnecessary downtime.

Let's now take a look at how an effective drop weight impact testing strategy can help you address these challenges.



WHAT IS A DROP WEIGHT IMPACT TEST AND HOW CAN IT BE USED IN TESTING?

What happens when a material or component is hit by an external object at speed? This is what a drop weight impact test tries to establish. It involves striking a material/part specimen with a weight falling from a height; the higher and the heavier the weight, the greater the amount of energy impacting the specimen.

When it comes to materials, impact tests are regulated by the international standards including ISO 179,[12] ISO 6603,[13] ISO 8256,[14] and ASTM 3763,[15] which define specimen characteristics as well as test configurations and parameters. These testing standards cover some of the emerging challenges and testing needs that are associated with high-performance polymers/engineering plastics. More specific standards such as those relating to impact test for fiber-reinforced Polymer Matrix Composites (e.g. ASTM D7136[16]) play a major role in aerospace applications.

The UL 2591 standard[17]

In 2018, a new international impact testing standard for Battery Cell Separators was introduced to support the ever-growing e-mobility market. These components provide electrical insulation between the lithium-ion cell electrodes while still allowing for ion transport between the electrodes. The standard covers short-term test procedures to be used for the evaluation of these separators.

Automotive and aerospace OEMs often include in their testing requirements not only international standards but also their internal testing specifications.

Essentially, the purpose of a drop weight impact test is to ensure that:

- The right materials are used for the right parts of a vehicle/aircraft
- The lightest, safest, and most reliable design is achieved "right the first time"
- All critical parts are fit for purpose, safeguarding the safety of passengers or, in the case of vehicles, pedestrians
- All critical parts enhance the comfort of passengers (vehicles)

As illustrated in Figure 1, virtually every component of a modern vehicle normally has to undergo an impact test.

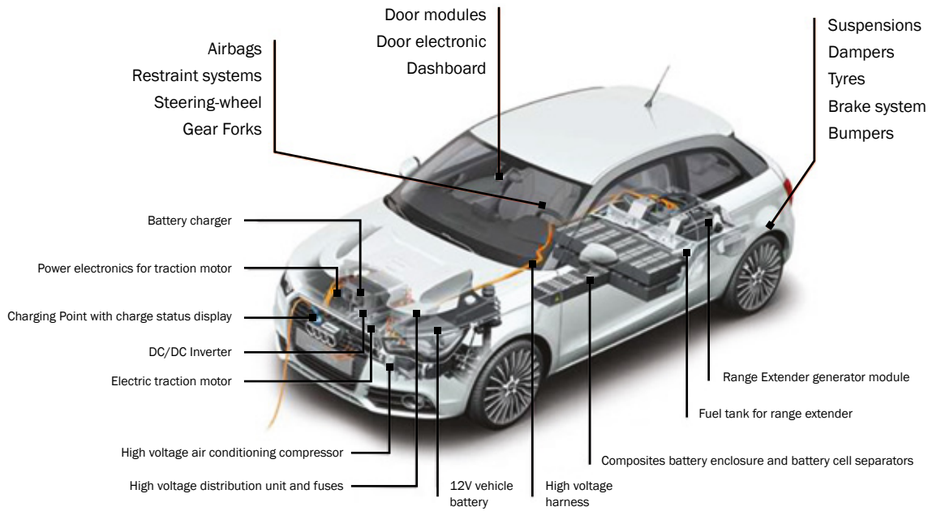


Figure 1: vehicle components requiring impact testing

The use of computer-aided engineering (CAE) tools such as LS-Dyna or Abaqus now enable engineers to simulate how materials and parts perform during impact. However, it is always recommended that virtual tests are validated by a physical impact test. This is key to improving the reliability of CAE-based testing

As illustrated in the table below, impact testing often needs to be adapted to individual components.

Test application	Description	Common standards
Adhesives Testing Wedge Peel Test	Measures dynamic resistance to cleavage [N/mm] by pushing wedge between adherents	ISO11343[18]
Tensile impact test	Measures the force needed to break a specimen under a high speed tensile load and strain rate	ISO 8256[19]
Puncture test	Involves a striker hitting a specimen perpendicularly to determine the rupture characteristics of a materials	ISO 6603-2[20] and ASTM D3763[21]
Compression After Impact (CAI)	A two-step process that assesses Barely Visible Impact Damage (BVID) to composites. An impact test causes BVID to a specimen, which then undergoes a compression test, using an electromechanical machine, to measure its residual strength.	ASTM D7136[22]
Occupant safety test	Strikers with different shapes are used to simulate human body impact	Internal test standards
Pedestrian safety test	Bumper impacted at room temperature (safe testing environment) or with special thermostatic chamber	Internal test standards
Vehicle active safety test	Test performed at different temperatures to guarantee the functionality of brakes and shock absorbers/ suspensions under varying environmental conditions	Internal test standards
Vehicle passive safety test	Test performed at different temperatures to investigate the performance of airbag's cover	Internal test standards

Essentially, two types of testing equipment can be deployed to carry out impact tests: home-made drop weight solutions and manufactured drop towers. Some automotive and OEMs may still use home-made solutions due to their low cost. But home-made solutions can be very tall, requiring large open spaces with high ceilings that, for example, may simply not be an option for smaller component manufacturers in the automotive or aerospace supply chain. By contrast, drop towers replace height with a high-energy system and data acquisition device meaning they have a much smaller footprint and more reliable and repeatable data.

Let's now look at how some of the latest drop tower technology available can help overcome today's key challenges.

HOW TO INCREASE TESTING CAPACITY WITHOUT REDUCING THROUGHPUT

We've seen how the volume and variety of materials and parts requiring impact testing is on the rise across automotive and aerospace applications. Ensuring a reliable, repeatable, and efficient testing process is, therefore, key to minimising downtime. There are three key steps you can take to achieve this ambitious goal.

1. Simplify setup: a fast, easy, and flexible setup process is key to switching between different samples quickly and smoothly. Look for drop tower solutions that allow for simple setup of carriage, masses, force sensors (also known as 'tups'), and supports, so that you can easily switch from high to low loads and from coupon to component testing.

2. Make data acquisition faster: integrating impact testing software into your drop tower can help increase productivity by giving you immediate access, through an easy-to-use touch screen dashboard, to a set of pre-configured methods covering the most common impact testing scenarios. The latest algorithm-based software also increases the speed of data acquisition, meaning you can obtain test results in a matter of milliseconds.

3. Reduce the likelihood of human errors: if a test isn't accurate enough, faults may not be picked up until later in the manufacturing process, causing costly downtime or even product recalls. Features such as user-friendly, integrated touch panels with step-by-step instructions guide users through the entire testing process, ensuring tests remain repeatable, simple, and error-free. Automated calibration alerts can also help ensure tups are always up and running, minimising the risk of inaccurate results.

CAI Test

Carbon fibres have excellent mechanical properties than make them a great fit for a range automotive and aerospace parts. But they can be quite sensitive to impact-related damage, which can be hard to spot. This is where the CAI (Compression After Impact) test comes in. After inducing Barely Visible Impact Damage using a drop tower, the damaged coupon undergoes a compression test that measures its residual strength. The resistance to damage of a composite structure depends on several factors, including tup geometry, impact mass, and velocity, which is why high accuracy is key to obtaining reliable results "right the first time", reducing downtime.

HOW TO ADAPT TESTING TO NEW MATERIALS AND MANUFACTURING METHODS

Adapting to growing volumes of composites isn't the only challenge testing is up against. It also needs to meet new requirements deriving from the use of new lightweight materials and manufacturing methods.

For example, 3D-woven composites are becoming a popular choice in the production of various aircraft and vehicles parts due to their unique properties. But a recent study found that small variations occurring in the weaving process can affect physical and mechanical properties quite significantly . Similarly, the mechanical properties of 3D-printed materials such as thermoplastics are not always consistent in terms of performance[24]. Testing is, therefore, vital now more than ever.

One element that deserves special attention here is the crashworthiness of the materials and parts that a vehicle are made of, which ultimately determines their ability to protect passengers during an impact. The challenge here is ensuring that light alloys and composite materials and parts guarantee at least the same level of crash performance of more traditional materials such as metal, but at significantly lower weight and without increasing cost. This is where testing comes in and there are several steps you can take to ensure all the requirements of new materials and parts, including 3D prints, are met.

- Fine-tune your force scale: an easy-to-refine force scale enables you to quickly adapt testing resolution to specific materials/parts requirements. The use of tups calibrated over different percentages of the maximum capacity enable you to refine the force scale according to your needs.

- Gain an extra pair of eyes: integrating a high-speed camera into your drop tower can be an effective way to increase your characterisation data. Make sure there is a camera connection so that high-speed video data acquisition happens simultaneously and is synchronised with the force profile.

- Be transparent: opting for a transparent panel enables you to use your camera to view and record a test from any side. This can save you time as you don't need to move and reset any of your equipment whenever you change specimens or test methods.

Dashboard test

In today's vehicles, dashboards normally feature a PVC cover that is designed to break when an airbag is triggered. Impact tests are performed on samples of the materials used as well as the finished cover itself at varying temperatures and speeds. By testing both the raw materials and the finished product, engineers can investigate how changes in material selection, design, and manufacturing processes affect the cover's impact performance.

HOW TO INTEGRATE VIRTUAL AND REAL TESTING

Increasingly, CAE is becoming an integral part of impact testing in automotive and aerospace applications. It has the potential to make the process faster and more flexible enabling engineers to perform multiple tests in multiple scenarios. It can also help reduce the number of physical tests required and the cost associated with specimens.

However, as mentioned above, virtual testing should be validated by real impact testing. This is why integrating the two is key to making the overall process as seamless and accurate as possible. One effective way in which you can achieve this goal is by equipping your drop tower with data capture and analysis software. The key benefits here are:

- As mentioned above, you can capture a more comprehensive set of data by integrating a high-speed camera into your drop tower.

- You can share raw data, including tracking of all methods and results of tests carried out, automatically within your company or directly with your customers via a local, secure database.

- You can compare data from physical tests with those from virtual tests and identify anomalies and inconsistent results automatically. In this way, you can improve test accuracy and build reliable CAE models that can help predict the impact strength of composite materials and components.

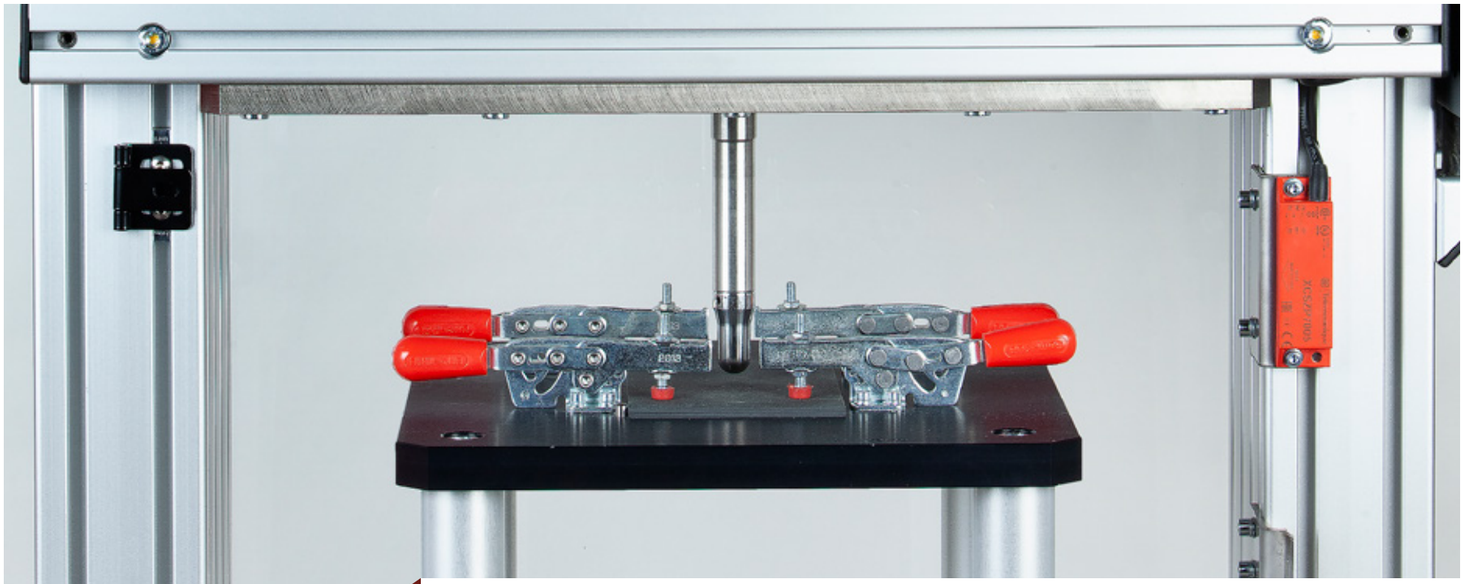
HOW TO MAKE TESTING SAFE

Safety is another key consideration when selecting and using drop weight impact testing technology. With test conditions involving impact masses weighing up to 70 kg or pushed to a speed of 24 m/s, it is not difficult to understand why protecting the workers operating the machine from impact-related injuries is paramount.

Another common risk workers may face is exposure to toxic fumes, vapours, or dust that can be released by specimens of composites when they are hit by the drop tower striker. A study by the Health and Safety Executive, for example, found that 3D-printed polymer filaments can emit airborne toxic particles that can enter the lungs.[26] Similarly, materials such as carbon fibre[27] and unsaturated polyester (UP) resins[28] can put workers at risk of inhaling toxic dust and vapours respectively.

To protect workers against such risks, select drop towers with:

- A fully enclosed design with integrated safety circuits that disable the system automatically whenever an enclosure door is open.
- An optional fan extractor to prevent toxic particles from being released in the surrounding work environment.
- Automatic safety notifications providing clear visual information on the instrument status, so you always know when a test is in progress.



CONCLUSION

Ligthweight materials and composites are rapidly becoming the material of choice for many automotive and aerospace manufacturers and are now used in many of the components that vehicles and aircrafts are made of. This guide has illustrated how this trend is leading to added impact testing requirements that can only be met by adopting an effective drop weight impact testing strategy.

The guide has provided insight into the latest drop tower technology, walking you through some useful steps you can take to meet the evolving requirements of materials and parts. These involve the use of a user-friendly HMI, simplified setup and the use of data acquisition and analysis software to ensure a fast, repeatable, and reliable testing process that minimises errors and downtime in the design and manufacturing workflow.

About the author

Alessandro Tomaiuolo, Drop Tower Application Expert, has been providing technical and application support to worldwide customers since he joined Instron in 2016.

Alessandro obtained a MS (Hons) in Material Science from the University of Turin with a Master dissertation on ‘High Performance Materials for the Automotive Industry’.

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