INSTRON®

THE ULTIMATE GUIDE TO PENDULUM IMPACT TESTING MACHINES

How to Maximize Throughput, Repeatability, and Safety

INTRODUCTION

Pendulum impact testing machines are critical to validating the performance of polymer, composite, and light alloy materials when subjected to an impact. Selecting the right pendulum for the application is key to maximizing throughput, repeatability, and operator safety. This guide looks at some of the key steps that can be taken to achieve these vital results.

Choosing the most appropriate pendulum hardware and software features is critical, now more than ever. Demand for plastic, composite, and light alloy materials from industries such as automotive, electronics, and medical keeps growing. The volume and range of materials undergoing impact testing are, therefore, expanding, putting Quality Control (QC) laboratories under added pressure. This is where the latest pendulum impact testing technology comes in.

1. WHY PENDULUM IMPACT TESTING MATTERS, NOW MORE THAN EVER

1.1 What is a Pendulum Impact Test

An impact test determines a material's resistance to an impact event. It measures the amount of energy the material absorbs when it is hit by a high-rate load. The most common impact test methods are Charpy and Izod and are typically run using a pendulum impact tester. This can be either manual or motorized and consists of:

- A swinging hammer (mass)
- A rigid frame to support the hammer
- An angular measurement system to measure the absorbed energy
- A test fixture to hold the specimen

The way a pendulum works is relatively simple: a hammer, released from a specific height, hits the sample at the bottom of the pendulum and then rises again until it stops. The energy absorbed by the sample is measured by calculating the difference between the hammer's initial and final heights. The specimen is typically a notched bar that must comply with very stringent requirements in terms of size and shape as defined by international test standards.

As Table 1 illustrates, the key requirements for each impact test method can vary depending on the standard adopted.

Test Method	Standard	Direction of Impact	Sample Type
Charpy	ISO 179	Edgewise or Flatwise	A, B, C, Un-notched
	ASTM D6110	Edgewise	A
Izod	ISO 180	Flatwise	A, B, Un-notched
	ASTM D 256	Flatwise	A

Table 1: Main Impact Test Methods and Standards

There are also differences in terms of specimen size and types of hammers that are to be used.

Other types of impact tests, including Tensile Impact, Dynstat, and Pipes can be carried out using a pendulum[1].

1.2 Old Methods, New Challenges

Pendulum impact testers have been around for over a century and Charpy and Izod tests are standard practice in QC laboratories. Yet, the growing volume and variety of plastics[2] and light alloys[3] now calls for pendulum testers that offer higher flexibility, throughput, and repeatability.

There is also a growing demand for larger hammer capacity to test highly resistant high-performance polymers, composites, and light alloys used in the automotive industry. This is mainly driven by the growing demand for lightweight materials to reduce emissions and offset the weight of batteries in electric vehicles[4].

The trend towards high-performance materials such as light alloys and specialty polymers also brings other challenges. The high cost of these materials means that producers are looking to reduce the size of specimens to minimize wastage. Therefore, pendulums that can handle both standard and miniaturized samples are in high demand.

All the above challenges are also faced by universities and other research institutions that have been key to the development of new material in recent years. Faced with limited resources and space, these organizations need to keep the footprint and cost down while ensuring the safety of staff and students. Therefore, they look for compact, table-top impact testing solutions that guarantee high levels of safety.

Let's now take a closer look at how the latest pendulum impact testing technology is responding to the above challenges.

1 https://www.bpf.co.uk/plastipedia/testing/Impact_Testing_Pendulum.aspx
2 https://www.grandviewresearch.com/industry-analysis/global-plastics-market
3 https://www.businesswire.com/news/home/20201211005249/en/Global-Aluminum-Alloy-Wheel-Market-2020-2024-Inreasing-Demand-For-Lightweight-Vehicles-to-boost-the-Market-Growth---Technavio
4 https://www.grandviewresearch.com/industry-analysis/automotive-lightweight-material-market

2. THROUGHPUT: WHY IT MATTERS AND HOW TO IMPROVE IT

2.1 The Importance of Throughput

We have seen how the growing demand for plastics and alloys is resulting in larger volumes of specimens undergoing impact testing. It is not uncommon for the QC departments of large materials producers to run hundreds of tests a day, seven days a week. They may also need to test a variety of materials, changing test configurations frequently. For example, a producer may supply materials to OEMs located in different regions, meaning they might need to run impact tests according to both ISO and ASTM standards.

Suppliers of materials to just-in-time manufacturers cannot afford bottlenecks caused by slow or inefficient testing. Therefore, maintaining high throughput is critical to minimizing downtime and maximizing productivity throughout the supply chain.

2.2 Key Steps to Optimizing Throughput

Several technology features are available to help improve throughput by speeding up test setup and sample preparation. Here are some key considerations when selecting pendulum impact testing machines:

- **Pre-defined test methods:** Some pendulum testers come with integrated touch-screen PCs featuring software with pre-installed test method templates according to ASTM/ISO standards. This way, users can quickly switch from one configuration to another without having to manually input all settings from scratch each time.
- **Automatic hammer verification/identification:** Built-in automatic hammer identification/verification enables the user to easily match the hammer to the correct test method. Such systems automatically recognize the installed hammer and retrieve all of the relevant data (test standard, nominal impact energy and impact speed) from an installed database. This eliminates the need for repetitive data input and the risk of errors.
- **Quick-change:** Some pendulums come with hammers and fixtures that are designed to be removed and installed with virtually no tools.
- **Automatic notching machine:** Using an automatic notching machine to notch the specimens is another important consideration. Some of the latest equipment can notch up to 50 specimens in a single cycle and store all key parameters, meaning the system doesn't need to be reconfigured manually each time. This way, samples can be prepared quickly, with minimum downtime.

3. REPEATABILITY: HOW PENDULUM DESIGN CAN AFFECT RESULTS

3.1 Accuracy is Key

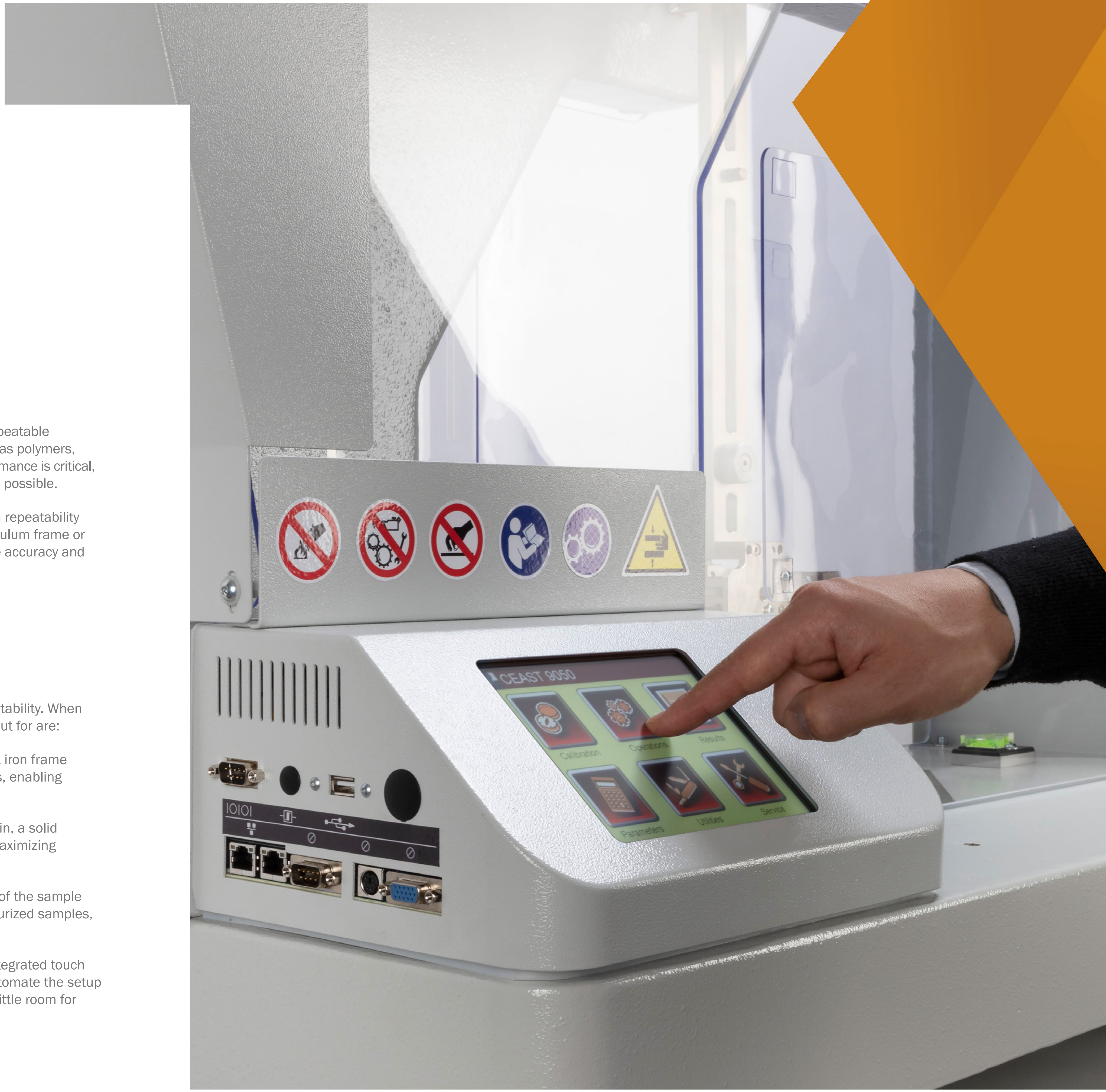
When measuring impact resistance, producing accurate and repeatable test results is paramount. The reason is simple. Materials such as polymers, composites, and light alloys are used in applications where performance is critical, so their impact resistance must be determined as accurately as possible.

However, when running large volumes of tests, maintaining high repeatability can be a challenge. Over time, some fastenings within the pendulum frame or hammer may come loose, causing vibrations that can affect the accuracy and consistency of the results.

3.2 Choosing the Right Pendulum Design to Maximize Repeatability

There are different steps that users can take to enhance repeatability. When selecting a pendulum tester, some of the key features to look out for are:

- **Frame:** Opting for a pendulum with a solid monolithic cast iron frame minimizes the risk of vibrations due to loosened fastenings, enabling maximum rigidity and accuracy.
- **Hammer:** The hammer structure is just as important. Again, a solid monolithic hammer structure can go a long way towards maximizing the accuracy and consistency of the test results.
- **Fixtures:** Fixtures that are designed around the thickness of the sample ensure maximum grip during testing, including with miniaturized samples, keeping vibrations to a minimum.
- **Software:** We have seen how some pendulums feature integrated touch panel PCs with pre-defined test parameters that largely automate the setup and configuration process. These software features leave little room for manual errors, maximizing accuracy.



4. FLEXIBILITY: MEETING DIFFERENT ENERGY AND SIZE REQUIREMENTS

4.1 Changing Requirements

We have seen how QC laboratories today are finding themselves testing an increasing variety of materials. Different materials have different requirements when it comes to hammer energy and specimen size.

For example, high-performance polymers, composites, and alloys may require the use of high-energy hammers, while other plastic materials may require lower energy. Typically, switching from high- to low-energy hammers (and vice versa) involves changing the pendulum frame too.

Different materials also need to undergo different tests according to different standards requiring specific specimen sizes and shapes. As noted above, when it comes to high-cost specialty polymers and alloys there is also a trend towards specimen miniaturization to reduce costs. All these variations generally involve switching frequently from one set of fixtures to another.

4.2 The Key to Flexibility

The above challenges can be addressed by selecting the appropriate pendulum testing machines and accessories.

For example, some of the most advanced pendulum testers are designed to cover a wide energy range. All-in-one solutions enable users to easily switch from high (50J) to low (0,5J) energy hammers (and vice versa) and from Charpy to Izod configuration without having to change the frame.

Similarly, some of the latest fixtures are designed with flexibility in mind, adapting to a range of specimen sizes and test methods.

There is also a variety of pendulum designs and sizes to choose from, to suit different testing environments. For example, compact, table-top versions are designed to meet the needs of universities and other research institutions.

5. SAFETY: HOW TO PROTECT OPERATORS DURING IMPACT TESTING

5.1 Risks to Operators During Impact Testing

Without appropriate safety measures in place, pendulum impact tests can expose operators to various hazards. The most common are hand injuries that can occur if the hammer is accidentally released when the operator is positioning the specimen. With impact speeds as high as 3.8 m/s and hammer energies of up to 50 J, injuries can be severe.

Injuries may also occur when operators are hit by flying debris that may occur when the specimen is impacted. Not only that. Some polymers and composites may also release toxic fumes, vapors, or dust when they are hit by the hammer. According to a Health and Safety Executive study, 3D-printed polymer filaments can emit airborne toxic particles that can enter the lungs[5]. Other studies found that materials such as carbon fiber[6] can emit toxic dust while unsaturated polyester (UP) resins[7] can produce toxic vapors.

5.2 Key Health and Safety Measures

Different safety measures can be put in place to protect laboratory operators during testing. The most important features to look out for when selecting a pendulum are:

- **Enclosure of the testing area:** This safety feature prevents operators from accessing the impact area during testing while also protecting them from debris and toxic dust, vapors, and fumes.
- **Manual safety mechanism:** In some manual pendulums, the hammer can only be released with both hands, by simultaneously pulling a knob and pressing a safety lever. This way, the hammer cannot physically be released if one hand is still in the impact area.
- **Pneumatic release system:** When it comes to motorized pendulums, the hammer is often activated pneumatically so the frame is entirely enclosed. The enclosure includes safety interlocks that put the pendulum into a safe mode when any access door is opened – preventing the hammer from releasing.

[5] https://www.hse.gov.uk/research/rrpdf/rr1146.pdf
[6] https://www.monash.edu/ohs/info-docs/safety-topics/chemical-management/carbon-fibre-composites-ohs-information-sheet#:~:-text=Health%20effects%20of%20carbon%20fibre,to%20that%20of%20glass%20fibres.&text=These%20micro%20fibres%20if%20uncontrolled,the%20mucous%20membranes%20causing%20irritation
[7] https://www.upresins.org/wp-content/uploads/2021/06/170731_UPR_SHG2_EN.pdf

6. IMPACT TESTING AT LOW TEMPERATURES

6.1 Why Temperature Matters: The Ductile-to-Brittle Transition

Temperature is one of the most important extrinsic factors that can affect the impact resistance of materials. At low temperatures, materials can transition from ductile to brittle, which can lead to catastrophic failure[8]. A well-known example of this is the sinking of the RMS Titanic[9]. The steel used to build the hull of the ship was below the ductile-to-brittle transition temperature when exposed to the icy Atlantic water, which contributed to fracturing when it hit the iceberg.

Polymer, composite, and alloy materials used in automotive applications must demonstrate high impact resistance even at low temperatures. Therefore, impact tests need to be run in sub-zero conditions. To recreate these conditions in a laboratory environment, both specimens and fixtures need to be cooled using an external cooling chamber. However, this can be a time-consuming process that can cause unnecessary downtime. Also, results may not be entirely accurate and consistent due to temperature variations as soon as the samples and fixtures are taken out of the cooling chamber.

6.2 How to Make Cooling More Efficient

Integrated thermal conditioning chambers can be a simple way to speed up the cooling process and minimize the risk of temperature variations.

Some of the latest pendulum testers come with chambers that are positioned directly on the impact area, surrounding the fixtures and specimen. Up to 11 specimens can be cooled down to a temperature of -60 °C all in one go while the fixtures are cooled simultaneously, greatly reducing setup time. This way, downtime is minimized while accuracy is maximized. As the fixtures are already in position and at the right temperature when the test is run, exposure to room temperature is kept to a minimum so that results are as accurate as possible.

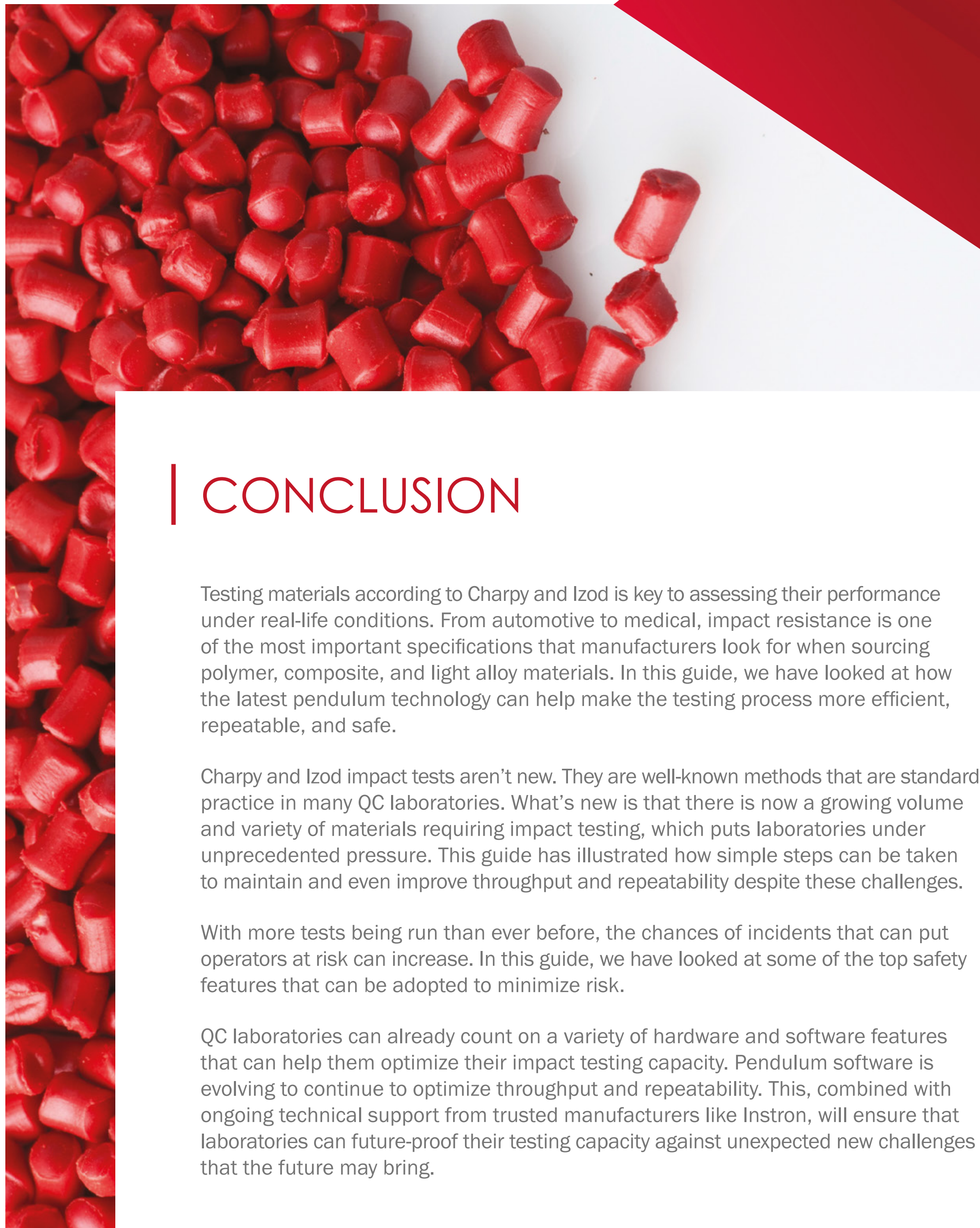
7. SOFTWARE EVOLUTION

We have seen how pendulum software is key to simplifying setup and optimizing repeatability. From pre-defined test method templates to automatic hammer recognition, the latest software features are already helping simplify impact testing.

The software installed on the latest integrated touch panel PCs also displays information such as the percentage of the absorbed energy. This is key to ensuring that the test is compliant with the relevant standards. The software can also be used to analyze test data and generate detailed reports and CSV files that can be exported from an integrated PC panel to an external PC via USB.

In the future, new software will enable test data to be automatically transferred from a local machine to a server system through various wireless communications protocols. This will make test data widely accessible to anyone wherever they are. This can help improve repeatability further particularly when it comes to large materials producers with testing laboratories scattered across different regions.

[8] https://www.materials.unsw.edu.au/study-us/high-school-students-and-teachers/online-tutorials/crack-theory/brittle-fracture/ductile-brittle-transition
[9] https://www.materials.unsw.edu.au/study-us/high-school-students-and-teachers/online-tutorials/crack-theory/brittle-fracture/ductile-brittle-transition



CONCLUSION

Testing materials according to Charpy and Izod is key to assessing their performance under real-life conditions. From automotive to medical, impact resistance is one of the most important specifications that manufacturers look for when sourcing polymer, composite, and light alloy materials. In this guide, we have looked at how the latest pendulum technology can help make the testing process more efficient, repeatable, and safe.

Charpy and Izod impact tests aren't new. They are well-known methods that are standard practice in many QC laboratories. What's new is that there is now a growing volume and variety of materials requiring impact testing, which puts laboratories under unprecedented pressure. This guide has illustrated how simple steps can be taken to maintain and even improve throughput and repeatability despite these challenges.

With more tests being run than ever before, the chances of incidents that can put operators at risk can increase. In this guide, we have looked at some of the top safety features that can be adopted to minimize risk.

QC laboratories can already count on a variety of hardware and software features that can help them optimize their impact testing capacity. Pendulum software is evolving to continue to optimize throughput and repeatability. This, combined with ongoing technical support from trusted manufacturers like Instron, will ensure that laboratories can future-proof their testing capacity against unexpected new challenges that the future may bring.

About the author

Stephanie Williams, Senior Product Specialist, has been providing technical and application support on impact products since 1989. She started with Dynatup in 1989 coming to Instron in 1997.

About Instron®

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