HEAT DEFLECTION TEMPERATURE AND VICAT TESTING

How to maximize throughput, repeatability, and safety

INTRODUCTION

Heat Deflection Temperature (HDT) and Vicat Softening Temperature (Vicat) testing is key to validating the quality and performance of polymers, now more than ever. As the volume and range of plastic and composite materials continue to expand, laboratories across Quality Control (QC) and Research & Development (R&D) are coming under added pressure. Maintaining high throughput, repeatability, and safety is vital, which is where the latest HDT and Vicat testing technology comes in.

This e-guide looks at how advanced solutions combined with ease of use enables simpler, smarter, and safer HDT and Vicat testing. This way, lab managers can reduce downtime, increase repeatability, and better protect workers and machinery. The latest HDT and Vicat testing technology also allows for greater flexibility. It enables users to easily test a variety of plastic and composite materials while meeting the temperature requirements of high-performance polymers.

HEAT DEFLECTION TEMPERATURE AND VICAT SOFTENING TEMPERATURE TESTING: KEY TRENDS AND CHALLENGES

The high-performance and specialty polymers market is rapidly expanding. Much of this growth comes from the automotive industry, which is experiencing a major shift. Fuel-efficient technologies and electric vehicles (EV) are growing their market share as regulations and public sentiment drive the momentum towards net-zero carbon emissions[1].

There are two main applications for specialty polymers in the automotive sector.

- Polymer parts are much lighter than their metal alternatives. Lighter vehicles reduce the load on EV batteries, allowing for longer travel distances per charge. Internal combustion engine (ICE) vehicles also benefit because of the improvement in fuel efficiency.
- Lithium-ion (Li-ion) battery packs use specialty polymer materials within components such as upper and lower cases, bus bars, contactors and fuses, and cooling systems[2].

The continuous growth of the 3D printing market represents another important trend in the plastics industry. Fused Deposition Modelling (FDM), for example, builds up a model by depositing one layer of extrusion on top of another. This technique is the simplest and cheapest form of 3D printing and is increasingly used to produce parts for automotive applications[3].

The HDT and Vicat temperature are among the most critical properties used to measure the quality and performance of all these emerging composite materials as well as more established polymers.

The HDT is the temperature at which a specimen starts to deform under a specified load. The Vicat value indicates the softening temperature of a material, where a blunt needle penetrates it by 1 mm. Both are vital for approving the use of materials in a range of automotive applications, from parts used within a vehicle's interior to specialty components in EV. For example, a Li-ion cell separator is an essential barrier to thermal runaway and even explosion. If it deforms prematurely, it could have catastrophic consequences.

HOW TO INCREASE THROUGHPUT IN HDT AND VICAT TESTING

In many laboratories, HDT and Vicat tests are carried out frequently and in great numbers. Delays in test results can have severe implications including business interruption.

At the same time, test protocols are rigorous and time-consuming. Some materials have excellent thermal properties meaning the HDT could be well over 300°C. The test machine must first heat the sample at a prescribed rate to the HDT point and then cool down to room temperature again before starting the next test.

ISO and ASTM each have standard test methods for HDT and Vicat. There are some differences between the two systems, as outlined in the tables below:

Parameter	ISO 75-2	ASTM D648
Specimen positioning	Flatwise	Edgewise
Specimen size (mm)	80 x 10 x 4	127 x 13 x 3.2
Span (mm)	64	101.6 (Method A) 100 (Method B)
Applied Stress (MPa)	0.45 (Method A) 1.8 (Method B) 8 (Method C)	0.455 1.82
Temperature ramp (°C/h)	120	120
Test end condition (mm)	0.34 (depending on thickness)	0.25

Table 1: Comparison of ISO and ASTM test methods for HDT

Parameter	ISO 306	ASTM D1525
Specimen positioning	Same	Same
Specimen thickness (mm)	4	3
Applied Force (N)	10 50	10 50
Temperature ramp (°C/h)	120 50	120 50
Test end condition (mm)	1	1

Table 2: Comparison of ISO and ASTM test for Vicat

While the test methods are standard, there are ways to increase throughput using simple interfaces, innovative design, and advanced automation. For example, integrated touch screen interfaces combined with intuitive software make for effortless operation. This feature eliminates the need for an external PC with its added complexity.

Cooling time can also contribute significantly to lab throughput. The higher the HDT and Vicat of the material, the longer it takes to cool the machine down again. However, well-designed water coolers can make a substantial difference. New generation machines reduce the cooling time by up to 50% compared to older models.

Advanced electronics can also bring significant benefits:

- Preprogrammed test method templates automatically set the test parameters like heat rate and applied force and test end conditions. Having fewer operator steps in the process saves time and increases test throughput.
- Calibration is a labor-intensive operator task. Linear Variable Displacement Transducers (LVDTs) must be zero-checked before each test to ensure accuracy. Automated calibration checks save a significant amount of operator time in modern HDT and Vicat testers.

HOW TO MAXIMIZE REPEATABILITY IN HDT AND VICAT TESTING

Test repeatability is a critical concept in quality control. If a test is not repeatable, there can be no confidence in the accuracy of the result and, therefore, in the quality of the material. The advanced electronics of modern HDT and Vicat testing machines can help optimize the repeatability of results.

Silicone oil level and quality contribute to repeatability. There are oil losses over time from continuous heating and cooling and a low level of oil in the bath can influence the accuracy of a test. Also, as the oil degrades, its performance deteriorates.

Automation systems perform oil level checks automatically at the start of each run, stopping the test, if necessary until a low level is resolved. They also compare oil usage with manufacturer-supplied data so that the system can generate an alert when the oil needs to be changed. This way, the risk of user errors is reduced to a minimum.

Automated LVDT calibration does not only save operator time. This process also contributes significantly to the accuracy of results. Advanced electronics perform zero tests before each cycle without operator intervention, thus ensuring a high accuracy level.

Software is another important consideration. The latest software comes with pre-formatted templates that reduce the risk of human errors during setup. Test settings are then saved automatically, ensuring consistency in test methods, and preventing inadvertent changes, over multiple shifts and operators.

HOW TO TEST COMPOSITES AT HIGH HDT/VICAT TEMPERATURES

Oil-based HDT and Vicat instruments have some limitations. They have a high-temperature limit of 300 °C due to the flashpoint of silicon oil. Exceeding this limit creates a risk of ignition and fire. This means that oil-based HDT and Vicat systems cannot test the properties of new families of materials known as techno-polymers, which have HDT values of up to 500 °C.

New HDT and Vicat testing systems use an alternative to silicon oil for heating: aluminum oxide (Aloxide) powder in a fluidized bed. This powerful heating medium enables machines to measure HDT and Vicat temperatures of up to 500 °C, meeting the requirements of techno-polymers.

Aloxide is not flammable, eliminating the risk of ignition from the fluid bed. It cools down faster than silicon oil, reducing the total test time. This material remains stable over time and does not need to be replaced like silicone oil.

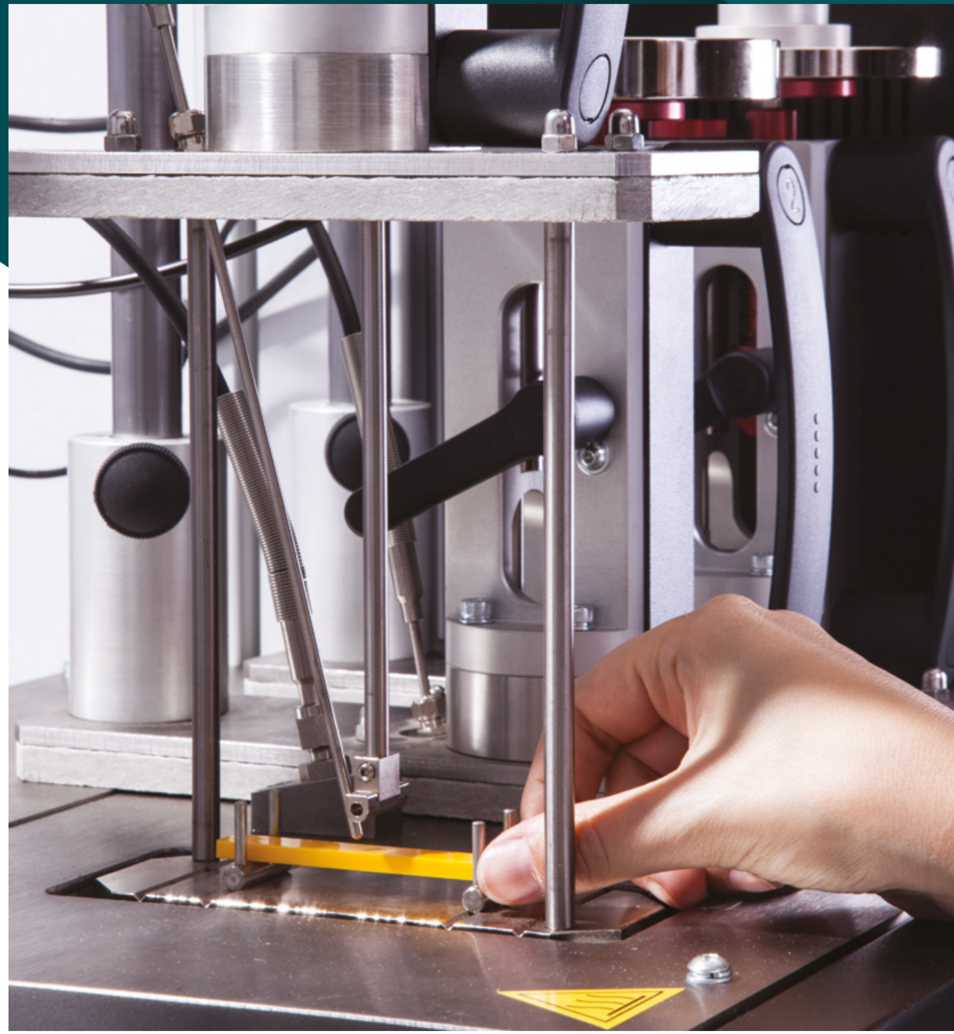
HOW TO OPTIMIZE SAFETY DURING HDT/VICAT TESTING

Ergonomics is an often-overlooked component of workplace safety. Repetitive tasks in unnatural positions have the potential to cause long-term musculoskeletal issues. The latest HDT and Vicat testing machines are designed with the human body in mind.

There are no overhead movements, and guidance columns make for smooth lifting and lowering actions. These actions are two-hand operations to ensure safety and control.

The latest machines also feature protective covers to prevent operator access to moving parts and hot oil during use. A pneumatic system lowers the stations at the beginning of a test and raises them at the end. As an additional safety measure, the cover over the fluid bath remains closed until it has cooled sufficiently.

When oil overheats, it releases noxious fumes and could even ignite if the temperature reaches the flashpoint of the material. Intelligent automation systems can help prevent these unsafe conditions, protect both operators and machines. Maximum temperature limits can be set to automatically prevent overheating, based on the type of oil in the machine.



CONCLUSION

HDT and Vicat test technology is moving forward to keep up with the demands of new plastics for automotive and other applications. Modern silicon oil machines have ergonomic designs with safety features built-in to protect operators. In addition, advanced electronics and software prevent tests without checking the calibration. They also keep track of oil levels and quality to preserve the accuracy of the results.

The plastics industry will likely continue to see rapid growth and new materials development. There remains a need for high-speed, safe, and repeatable HDT and Vicat testing. Instron has been on the cutting-edge testing developments so far and continues to pioneer innovations in the industry.

ABOUT THE AUTHOR

Dr. Andrea Calzolari, Research and Application Engineer, has been providing technical and application support since he joined Instron in 2007. Andrea obtained a Ph.D. in Physics from the University of Turin, where he then worked as a researcher. As an expert in HDT and Vicat testing methods, Andrea has been recently appointed Convenor of ISO/TC 61/SC 2/WG 5.

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1 https://www.researchandmarkets.com/reports/4773690/specialty-polymers-market-growth-trends-covid
2 https://warwick.ac.uk/fac/sci/wmg/business/automotive_batteries_101_wmg-apc.pdf
3 https://all3dp.com/2/fused-deposition-modeling-fdm-3d-printing-simply-explained/