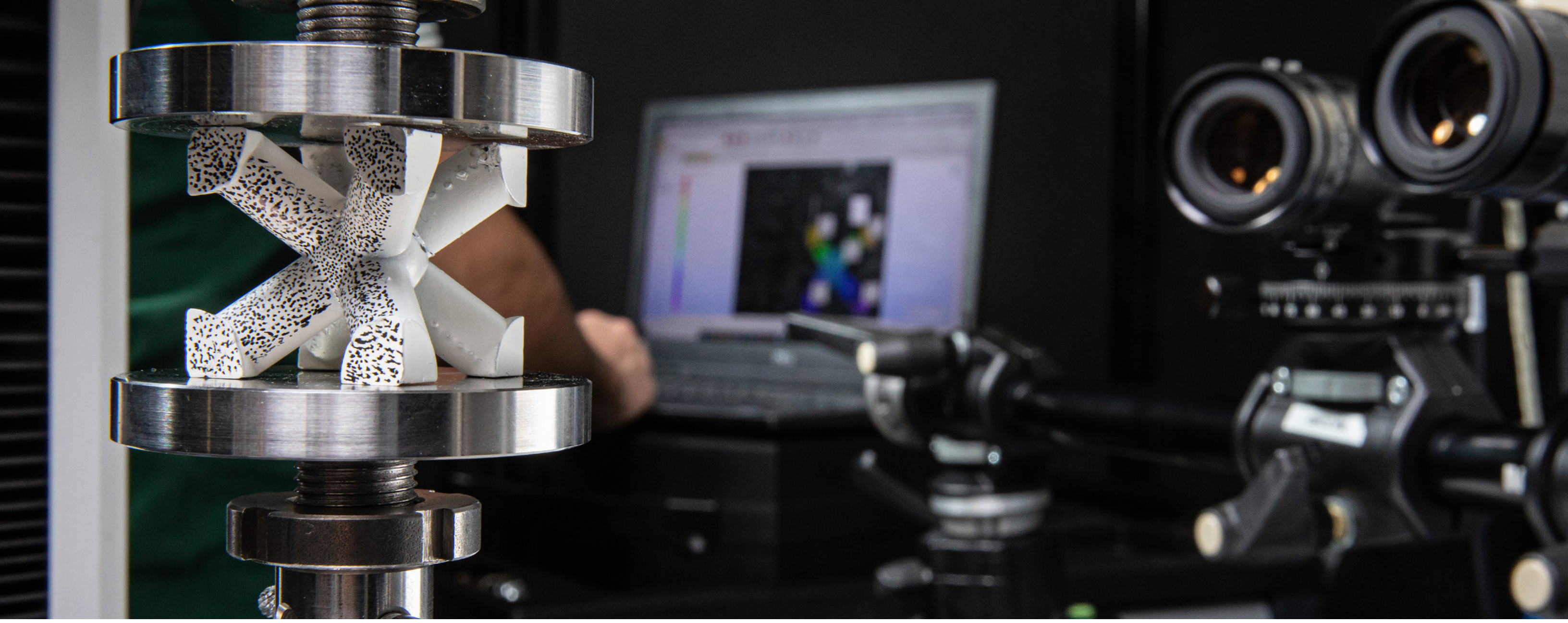

SIEMENS DIGITAL INDUSTRIES SOFTWARE

Using DIC to measure **3D full-field data**

Solution brief

Use Digital Image Correlation (DIC) to characterize the mechanical behavior of materials and structures

Characterizing the mechanical behavior of materials and structures under load is a key enabler to improve designs and develop high-performance products. Standard measurement techniques, employing strain gauges or accelerometers for point measurements, only provide limited and local information. The fast development of digital camera technology in combination with high-performance digital image correlation (DIC) techniques is currently bringing a radical change in this domain. Thanks to DIC, it is now possible to extract full-field 3D geometry, displacement, strain and acceleration under any load and for almost any type of material, with limited instrumentation. These data are crucial in the materials engineering process, as they allow identifying material properties, validating numerical models and assessing the strength of materials and components without the risk of overlooking key local phenomena. DIC is also applicable to analyze structural vibrations and dynamic responses and can be used to characterize rotating and lightweight structures that would otherwise be extremely difficult to test with standard techniques.

Digital image correlation in practice

Simcenter™ Testlab™ software, which is part of the Xcelerator™ portfolio, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, offers a complete and modular solution for acquiring images of a structure during a test and extracting key measurement information to identify and characterize the mechanical behavior of materials and structures under load. As the technique solely relies on digital images captured with cameras, no additional instrumentation is needed during the experiment, except for some additional light to ensure good visibility of the object.

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Challenges

- Design and engineer innovative materials
- Accelerate component and system structural validation testing
- Increase accuracy and reliability of simulation models

Solutions

- Measure contactless with multiple cameras
- Rely on DIC to extract 3D full-field displacement, strain and acceleration
- Identify material model parameters with VFM
- Identify modeling errors and update structural models

Results

- Measure thousands of points contactless
- Characterize a range of materials under any kind of loading
- Combine static, quasi-static and dynamic structural testing in a single platform
- Validate simulation models with test

Solution focus

Once the setup is calibrated, the DIC algorithm compares all images with a reference one and extracts shape and displacement quantities in the region of interest on thousands of measurement points and with a maximum measurement resolution around one-hundredth of a pixel. Once displacements are available, strains, stresses and other derived kinematic quantities can be immediately calculated. As a result, it is possible to obtain a detailed view of the complete deformation field of the object under test as the loads evolve, monitor the strain level and identify regions with critical stress levels.

Digital image correlation can be used when testing material samples, mechanical components or part of a structure in operating conditions, with no limits on the size of the object except for those imposed by the field-of-view of the cameras. And even in this case, we offer dedicated capabilities to combine information from more than two cameras.

Accurate data beyond colors

Despite being an experimental technique, digital image correlation allows the user to measure structures with a spatial resolution comparable to that of a finite element (FE) model. This results in full-field displacement, strain, stress and curvature analysis, when thanks to colorful representation you can visualize these quantities on the structure as it deforms as you would do with a finite element model. Behind these nice colorful images lie quantitative and accurate results, which enhances confidence resulting from an integrated error assessment. This will help you not only determine the quality of the results, but also correctly assess the accuracy of simulation models against the reference experimental data.

A new paradigm in materials testing

Digital image correlation originates in the material engineering domain as a way of solving the problems associated with the use of strain gauges. When characterizing the mechanical properties of a material, samples with specific shapes are created and installed on a testing machine. Here, loads are applied and by recording the deformation of the sample, the mechanical properties of the materials are identified. However, strain gauges only offer localized information on material behavior, and as the sample approaches its breaking point, the reliability of the sensor reading decreases. As a contactless and full-field technique, digital image correlation overcomes all these limitations, allowing the user to follow the behavior of the sample and monitor crack propagation until failure. Additionally, being a contactless technique, it can be used to test and characterize any type of materials, from concrete to polymer and metals to composites, including lightweight samples to which no sensors could be applied without dramatically impacting its properties.

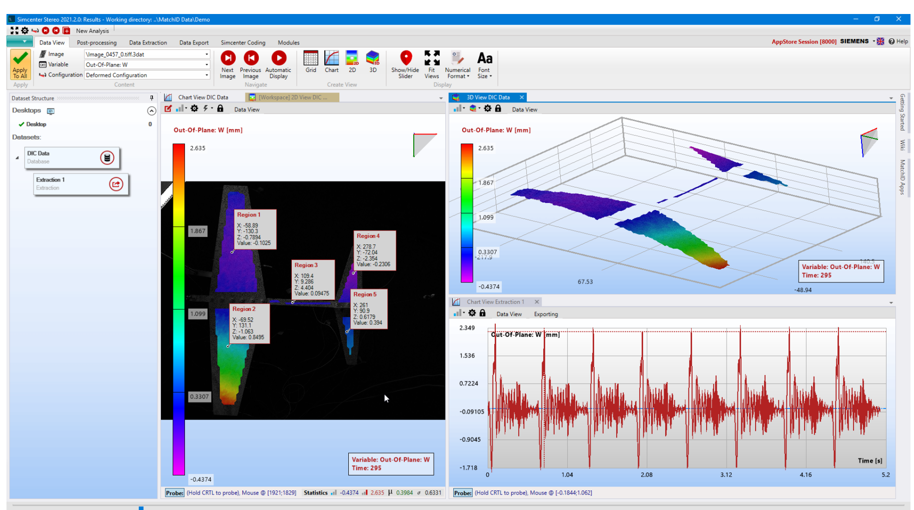
Enabling the material digital twin

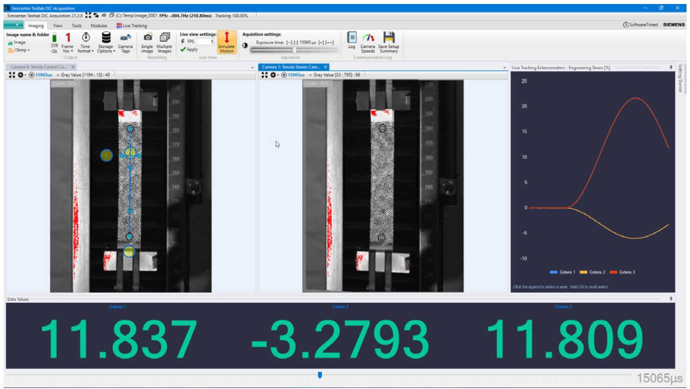
As the industry evolves toward virtual-based product design, having accurate information on material properties is critical. Moreover, the need to balance performance has pushed industry to search for innovative materials and take advantage of their orthotropic or even anisotropic properties. Being able to confidently identify these properties from experimental data becomes then even more crucial. Thanks to a wide library of material models and

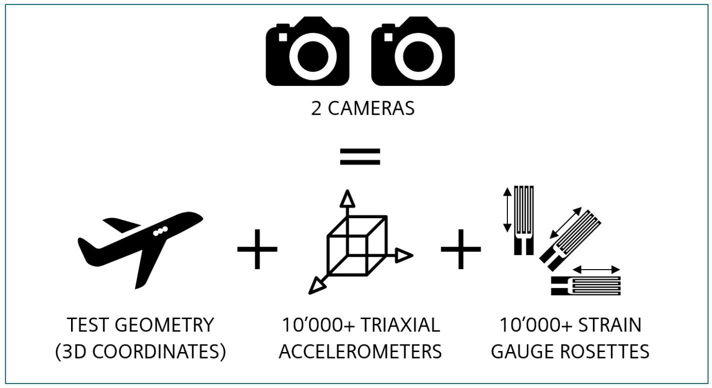
implementing the virtual fields method (VFM), our solution offers a unique environment to take advantage of full-field experimental results and extract material parameters directly from measured data. This dramatically reduces time compared to standard inverse approaches based on finite element optimization.

Accelerate component and system validation testing

One of the main benefits of digital image correlation is the setup is extremely simple. Forget about the lengthy and often challenging process of accurately placing hundreds of sensors, measuring their position and







orientation, managing all their cables and ensuring the channel setup is correctly defined. With DIC, you will only need two cameras, a speckle pattern applied to the region of interest and some artificial light to brighten the scene you want to analyze. This is sufficient to deliver thousands of data points, at which deformations and strains for different loading or operating conditions will be available, regardless of whether the test structure is a concrete pillar, a metal frame, a composite panel or a foam layer to absorb noise and vibrations.

A dedicated and unique model validation module will then allow you to bring your FE model into the DIC software, generate virtual images corresponding to the FE load steps, and then apply the same DIC processing used for the experimental images to the virtually generated ones. Only this unique approach allows you to fully compare DIC measurements with FE simulations. The differences between the numerical and experimental behavior are reported in a full-field correlation map, which immediately highlights the areas where it might be required to update the FE model to better match the test reality.

Full-field vibration testing

Although historically the primary application of DIC has been to measure strains during static or quasi-static loading, the increase in camera resolution and speed has allowed the user to use this technology to also measure full-field vibrations, taking advantage of the contactless nature of DIC. When measuring vibrations on lightweight components, the mass of the sensors can have a significant impact on their vibration response. On the other hand, complex setups based on sliprings would be necessary for rotating structures. DIC offers a simple solution in scenarios where attaching a sensor to the structure and connecting it to the data acquisition system with a cable is difficult. Also, in more standard testing scenarios, it offers an alternative to collect vibration data, in particular when a fine spatial resolution is needed or the size of the object makes it difficult to properly resolve the phenomena of interest. DIC does not necessarily require high-speed cameras to measure vibrations. More affordable low-speed cameras can also be used. In this case, an automatic resampling technique is used to extract vibrations at frequencies above the maximum frame rate of the cameras. Finally, DIC can be used for vibration testing as a standalone system or in combination with the Simcenter SCADAS™ hardware. For example, the latter scenario enables you to derive frequency response functions (FRFs) from the measured displacement time histories, or combine the global structural behavior captured with accelerometers with local full-field information from a DIC system. Also, as DIC only can be used to measure what the camera can physically see, a hybrid setup allows more flexibility in capturing all needed information. Once DIC data are processed, they will be available in all other Simcenter Testlab applications, where they can be used for modal or operational analysis.

More insights with limited instrumentation time

Simcenter Testlab Digital Image Correlation is a trusted instrument for measuring full-field 3D data everywhere at once. It allows you to characterize advanced materials and identify their properties thanks to the full-field nature of the technology, which will make sure you will not miss any information in the area of interest by misplacing a sensor. It also drastically simplifies the instrumentation and reduces the time required to prepare a test setup, as it relies on limited instrumentation. Just by using a pair of digital cameras, you can extract 3D displacements, strains, stresses and accelerations without the need for dedicated sensors for each quantity. And finally, it offers unique capabilities to derive a comprehensive digital twin by enabling quantitative test validation and updating of mechanical simulation models.

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