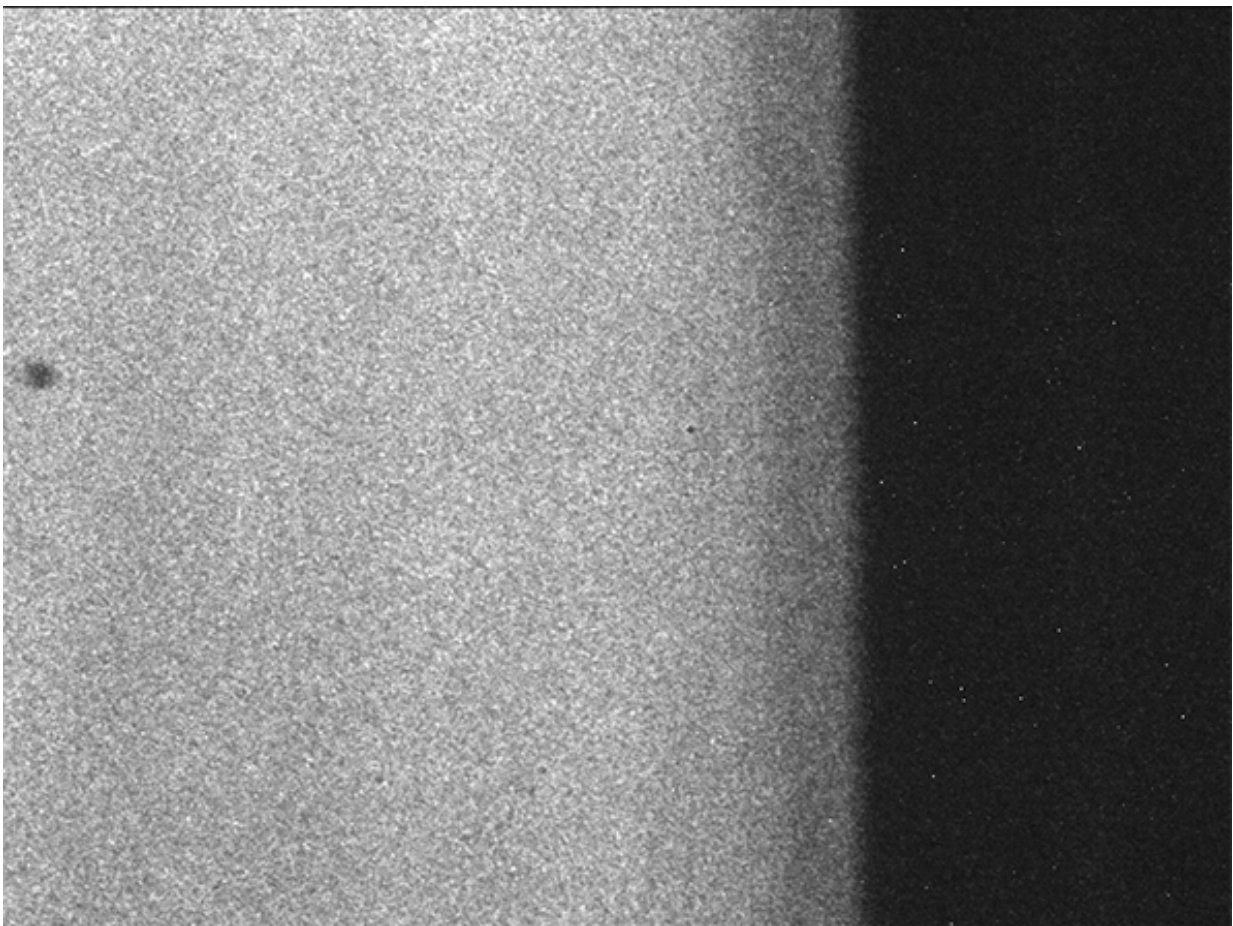


High-speed camera shows incoming particles cause damage by briefly melting surfaces as they strike

November 29 2018, by David L. Chandler



Video of the impact of a 10-micrometer particle (coming in from the left) traveling at more than 1 km/sec shows clearly the splashing away of molten material from the surface at the moment of impact. This kind of impact erosion was observed clearly for the first time in this MIT study. Credit: Massachusetts

When tiny particles strike a metal surface at high speed—for example, as coatings being sprayed or as micrometeorites pummeling a space station—the moment of impact happens so fast that the details of process haven't been clearly understood, until now.

A team of researchers at MIT has just accomplished the first detailed high-speed imaging and analysis of the microparticle impact process, and used that data to predict when the particles will bounce away, stick, or knock material off the [surface](#) and weaken it. The new findings are described in a paper appearing today in the journal *Nature Communications*.

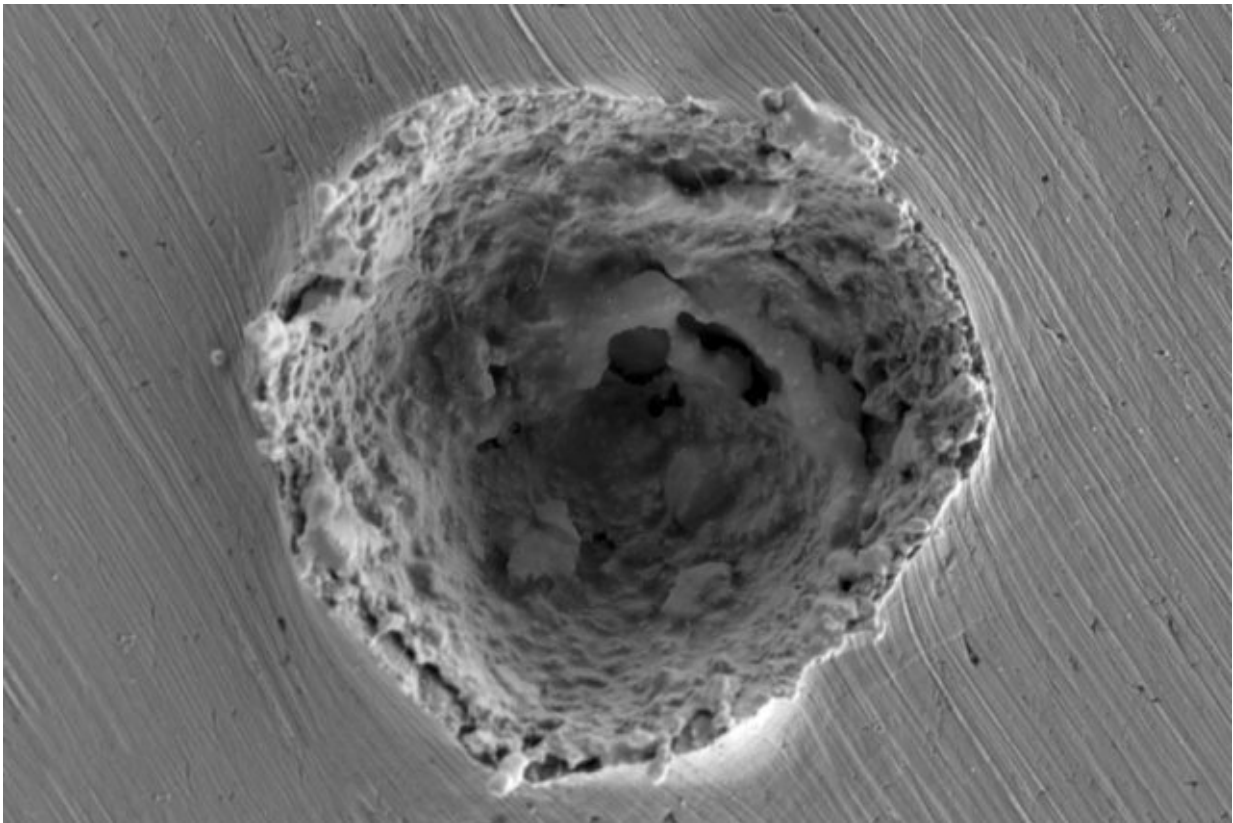
Mostafa Hassani-Gangaraj, an MIT postdoc and the paper's lead author, explains that high-speed microparticle impacts are used for many purposes in industry, for example, for applying coatings, cleaning surfaces, and cutting materials. They're applied in a kind of superpowered version of sandblasting that propels the particles at supersonic speeds. Such blasting with microparticles can also be used to strengthen metallic surfaces. But until now these processes have been controlled without a solid understanding of the underlying physics of the process.

"There are many different phenomena that can take place" at the moment of impact, Hassani-Gangaraj says, but now for the first time the researchers have found that a brief period of melting upon impact plays a crucial role in eroding the surface when the particles are moving at speeds above a certain threshold.

That's important information because the rule of thumb in [industrial](#)

[applications](#) is that higher velocities will always lead to better results. The new findings show that this is not always the case, and "we should be aware that there is this region at the high end" of the range of impact velocities, where the effectiveness of the coating (or strengthening) declines instead of improving, Hassani-Gangaraj says. "To avoid that, we need to be able to predict" the speed at which the effects change.

The results may also shed light on situations where the impacts are uncontrolled, such as when wind-borne particles hit the blades of wind turbines, when microparticles strike spacecraft and satellites, or when bits of rock and grit carried along in a flow of oil or gas erode the walls of pipelines. "We want to understand the mechanisms and exact conditions when these erosion processes can happen," Hassani-Gangaraj says.



This scanning electron micrograph shows the crater left by the impact of a 10-micrometer particle traveling at more than 1 kilometer per second. Impacts at that speed produce some melting and erosion of the surface, as revealed by this research. Credit: Massachusetts Institute of Technology

The challenge of measuring the details of these impacts was twofold. First, the impact events take place extremely quickly, with particles travelling at upward of one kilometer per second (three or four times faster than passenger jet airplanes). And second, the particles themselves are so tiny, about a tenth of the thickness of a hair, that observing them requires very high magnification as well. The team used a microparticle impact testbed developed at MIT, which can record impact videos with frame rates of up to 100 million frames per second, to perform a series of experiments that have now clearly delineated the conditions that determine whether a particle will bounce off a surface, stick to it, or erode the surface by melting.

For their experiments, the team used tin particles of about 10 micrometers (hundred thousandths of a meter) in diameter, accelerated to speeds ranging up to 1 kilometer per second and hitting a tin surface. The particles were accelerated using a laser beam that instantly evaporates a substrate surface and ejects the particles in the process. A second laser beam was used to illuminate the flying particles as they struck the surface.

Previous studies had relied on post-mortem analysis—studying the surface after the impact has taken place. But that did not allow for an understanding of the complex dynamics of the process. It was only the high-speed imaging that revealed that melting of both the particle and the surface took place at the moment of impact, in the high-speed cases.

The team used the data from these experiments to develop a general model to predict the response of particles of a given size travelling at a given speed, says David Veysset, a staff researcher at MIT and co-author of the paper. So far, he says, they have used pure metals, but the team plans further tests using alloys and other materials. They also intend to test impacts at a variety of angles other than the straight-down impacts tested so far. "We can extend this to every situation where erosion is important," he says. The aim is to develop "one function that can tell us whether erosion will happen or not."

That could help engineers "to design materials for erosion protection, whether it's in space or on the ground, wherever they want to resist erosion," Veysset says.

"The authors explore a new regime of high-speed impact in which the impacting particles actually melt," says H. Jay Melosh, a professor of physics and aerospace engineering at Purdue University and a specialist on impacts, who was not involved in this study. He adds, "In this regime they can add material from the impacting [particles](#) as well as eroding the target. This may eventually find a technological application, but the work presented in the paper is mainly an analysis of the impact mechanics and gives a quantitative assessment of how much of the target (substrate) is eroded as a function of the [impact](#) velocity."

Melosh says, "The experimental work is of very high quality. ... I could imagine that it might have applications to some types of surface milling, similar to sandblasting but more aggressive than that method."

More information: Mostafa Hassani-Gangaraj et al. Melt-driven erosion in microparticle impact, *Nature Communications* (2018). [DOI: 10.1038/s41467-018-07509-y](https://doi.org/10.1038/s41467-018-07509-y)

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Provided by Massachusetts Institute of Technology

Citation: High-speed camera shows incoming particles cause damage by briefly melting surfaces as they strike (2018, November 29) retrieved 15 May 2024 from <https://phys.org/news/2018-11-high-speed-camera-incoming-particles-briefly.html>

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