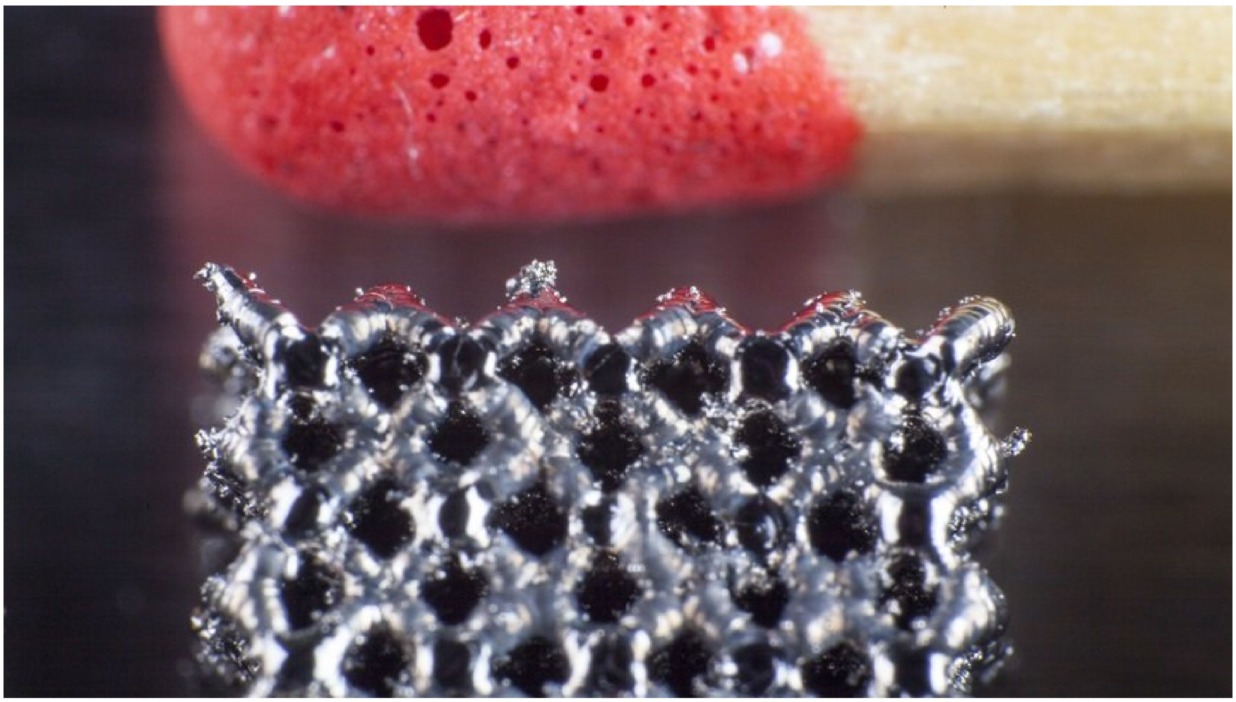
Tough nuts, cracked in a smart way

August 30 2018



Additive Manufacturing enables minuscule metal structures with a complex geometry to be produced. Here is a test piece compared with a match head. Using AI to monitor the manufacturing process acoustically guarantees that the workpiece is devoid of any interior defects. Credit: Empa

Welding, printing, crushing concrete – an Empa team monitors noisy processes with the help of artificial intelligence. This way you can literally hear production errors and imminent accidents.

Kilian Wasmer from the Empa lab for Advanced Materials Processing in Thun keeps shaking his head while speaking, as if he can't believe the success story himself. Together with his team, he recently patented a system to monitor complex production processes, which can be used in a vast range of situations – even though the prospects of this idea initially did not look particularly good at all. "I told our partners that I rated the chances of success at around 5 percent. But we'd still give it a go," recalls Wasmer about the project's early days.

Lightning strikes on concrete

The aforementioned partner is Selfrag AG from Kerzers near Bern. The company manufactures high-voltage generators, which can pre-weaken or even break concrete using lightning discharges. In contrast to a sledgehammer, which yields sharp-edged lumps of concrete with split pebbles, this method is able to break down concrete into its basic components of gravel, sand and cement – which enables them to be recycled in full.

The Empa scientists started bombarding small test pieces made of Plexiglas with high-voltage lightning bolts. The acoustic signature of every lightning bolt was recorded and the corresponding Plexiglas test piece examined for cracks and surface damage under the microscope. Sergey Shevchik, the team's specialist in artificial intelligence, tested a number of different strategies to recognize revealing patterns from the data. Eventually, not only did he succeed in distinguishing successful lightning strikes from misses, but also in spotting surface hits. For the first time, this gave Selfrag an online monitoring possibility for its lightning technology.

The success in real-time lightning analysis gave the team the idea of analyzing other extremely noisy processes as well: squeaking, rattling machines.

When bearings seize up and machines die

If rolling bearings and other moving metal parts are not properly oiled, they may scuff. The problem causes considerable damage worldwide. Unfortunately, temperature sensors integrated in vulnerable components only detect a temperature increase once the scuffing has begun and the parts are already ruined.

However, just because something is creaking in a machine does not necessarily mean the machine needs complete revision. Anyone who dismantles and services his or her production machines more frequently than necessary causes unnecessary costs. But those who wait too long run the risk of a moving part scuffing, breaking apart and thus destroying other parts of the machine, which would be disastrous. The goal, therefore, is to hear the "crucial" creak from the cacophony of noises – and to stop the machine just in time before it is damaged.

Wasmer's team allowed a bearing made of hardened steel to rub against a cast-iron base on a tribometer, an instrument for measuring friction, recorded the noises, halted the experiment in different phases and studied the damage under a microscope. The Empa researchers managed to discern the vital clues from this cacophony. They are now able to recognize the jamming with 80 percent certainty. Even more importantly, however: The crucial pre-scuffing phase can be recognized with 65 percent certainty – and even predict a few minutes before the catastrophic conclusion comes about. This would be sufficient to halt many industrial machines in time and prevent serious damage.

Quality management in additive manufacturing

Wasmer's latest project is devoted to additive manufacturing (AM) – the production of metallic components made of metal powder, which is melted with a laser beam. This novel manufacturing technique does not use any casting molds and is just the ticket for geometrically complex individual parts. Until today, however, it has been necessary to strictly adhere to the process parameters (e.g. laser power and speed, powder specification etc.) for a particular alloy or application. Any deviation can cause pores, cracks or internal stress in the workpiece, rendering it useless.

Wasmer and Co. combined acoustic sensors with machine learning and analyzed the data using an algorithm called SCNN ("Spectral Convolutional Neural Network") and first described in 2016. Using this machine-learning method, they succeeded in distinguishing whether the laser melting process was too hot or too cold with a hit ratio of over 83 percent. The results were published in Additive Manufacturing in May 2018.

Listening in during laser welding

The researchers are confident that the method can also be applied to things other than laser 3-D printers. Other AM techniques such as laser sintering, stereolithography or multi-jet printing are based on similar physical principles. The Empa method for process and quality monitoring in real time could thus be valuable for all these techniques.

Another industrial partner has already benefited from Empa's knowhow: Coherent Switzerland, based in Belp, has been manufacturing laser sources and tool heads for welding devices for 44 years. Thanks to the Empa results, the company now has a sensor system at its disposal that monitors and documents the welding process optically and acoustically. The data obtained in this way could help optimize future welding processes and maintain the high quality standard that the automotive industry demands from its suppliers.

More information: S.A. Shevchik et al. Acoustic emission for in situ quality monitoring in additive manufacturing using spectral convolutional neural networks, *Additive Manufacturing* (2017). DOI: 10.1016/j.addma.2017.11.012

Sergey A. Shevchik et al. Prediction of Failure in Lubricated Surfaces Using Acoustic Time–Frequency Features and Random Forest Algorithm, *IEEE Transactions on Industrial Informatics* (2016). DOI: 10.1109/TII.2016.2635082

Provided by Swiss Federal Laboratories for Materials Science and Technology