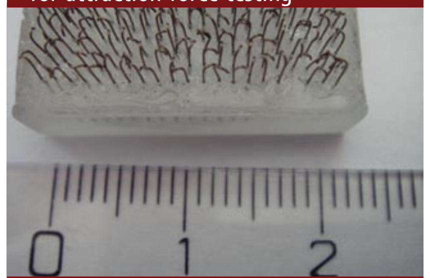
# Tearing apart Velcro design for silent use

★ Shape memory alloy (SMA) is an exciting material that offers all the benefits of Velcro but without the noise. **Dr David Vokoun**, research assistant on the Cerinka project, talks about this exciting new material and how it could very soon be brought to the commercial and industrial arenas

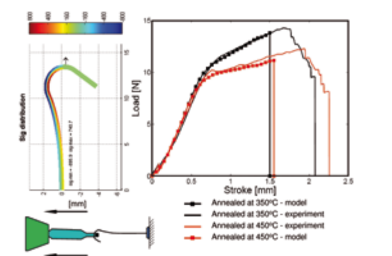
Velcro is a widely used material. The simplicity of its design – two thin plastic strips, one strip covered with tiny loops and the other with flexible hooks – has made it a popular choice of releasable fastener used to adjoin one element with another. Indeed, Velcro is such a popular material it can be found in almost every facet of society, including: shoes, clothes, backpacks, briefcases and in cars to name but a few applications. Velcro is also widely used in the emergency services, armed forces and even in space exploration. However, despite being popular with manufacturers and despite the success it has enjoyed over the last 60 years, it has one major flaw – the awful tearing noise produced when pulled apart. This flaw has inspired the Cerinka project.

"We would like to develop releasable fasteners made of shape memory alloy (SMA) wires and containing permanent magnets," says David Vokoun while describing the Cerinka project's overall goal. "These fasteners should work in the similar way as the Velcro-type fasteners do but they should avoid any sharp sound during release." In addition, continues Vokoun, the project has a few minor goals too, including the development of a model for predicting the firmness on the proposed new fastener, and also, a model that predicts magnetic attraction force of two arrays of permanent magnets of a certain shape and saturation magnetisation. Both of these additional project goals, Vokoun explains, are because they "found when testing some of the Velcro-type fasteners (in research), that as well as the releasing noise another issue was that their firmness varied extensively over a wide range, dropped

Permanent magnets ready for attraction force testing



An array of superelastic SMA hooks embedded in matrix




Loading of a single SMA hook, experiment vers. model

completely after the fibre part wore out and were not heat resistant."

The Cerinka project's research on SMAs is being spearheaded by their research team at the Institute of Physics, Prague. Their work – which is predominantly dealing with SMA textiles – forms the central part of the project and is concerned with applying and modelling the functional properties of SMAs, namely their pseudoelastic (an elastic, impermanent response to relatively high stress caused by a phase transformation between the austenitic and martensitic phases of a crystal) effect (PE).

The PE of SMAs has been successfully utilised in many engineering applications, mainly as surgical instruments or devices in the medical field (stents, catheter guidewires, orthodontic arch wires) but also as mobile phone antennas, spectacle frames and many others. Vokoun and the Cerinka project believe it holds the requisite properties to act as a silent, consistently firm and heat impervious releasable fastener. However, since the SMA hooks would work in the releasable fastener through pseudoelastic forces, the modelling of these forces as a part of hysteretic stress-strain-temperature behaviours is of key importance to the project.

## The technical challenges of SMA

The behaviour of SMA wires is strongly non-linear, dependant on temperature since it is due to the stress-induced martensitic phase transition. Furthermore, during the bending of SMA wires, non-homogeneous stress state is present in modelled releases of the interlocked SMA hooks, and there is an unknown frictional force. To be able to simulate the strength of the fastener, notes Vokoun, "the project collaborators have developed a unique FEM implementation of their SMA model. They divided the SMA hook into regions of approximately constant uniaxial stress (tensile or compressive). The input parameters for the SMA model were evaluated from uniaxial tensile tests on straight wire at room temperature."

Now, since the compression behaviour of SMA is asymmetric with respect to the tension behaviour, the project has had to derive the parameters for compression from the input parameters for tension. The boundary conditions are given by the fixation of the straight end of the hook (fixation of displacement and rotation) and by placing the loading force to the point where the force direction is perpendicular to the beam axis (thus neglecting the friction between hook and its counterpart). By utilising this path the project obtains a movement of the loading point within the hook arc, which adds another non-linearity to the problem (in addition to the material and geometrical ones). Interestingly, the project has found that the searching for a mechanical response is equivalent to the problem of minimising energy.

## How SMA eliminates noise

So how does SMA, through its PE effect, actually eliminate the noise prevalent in Velcro and other releasable fasteners? In fact, says Vokoun, "we are not absolutely sure what the reason for that is. The noise is created by the mechanical oscillations of the released SMA hooks hitting each other in sharp events occurring during peeling of the fastener. Due to the nonlinear hysteretic mechanical response of the SMA material, mechanical oscillations are damped much faster compared to elastically strained hooks in convential Velcro. It is thus probably a combination of the excellent strain energy absorption and damping abilities of superelastic SMA material which quiets down the Vokoun's SMA based fastener. Another fascinating property of SMA - the ability to restore original shape after unloading or heating is obviously important for the SMA fastener as well since it only allows for multiple use of it."

## A commercial future

Commercially, the SMA releasable fastener has the potential to be used anywhere that Velcro has been traditionally used. Additionally, the material could be used in areas where quiet releasing is essential as well as in areas where conventional Velcro might be from some reason inappropriate (temperatures above 100°C, chemically aggressive and dusty environments etc.) Vokoun also points out that due to the phase transformation driven increase of the firmness of the joint made by the SMA fastener with increasing temperature, there is a great potential of CERINKA fasteners for various high temperature applications. Additional feature of potential application interest is the fact that the fastener locks extremely smoothly when the surfaces come into contact and no additional compression is needed to improve its firmness. These are all viable reasons why there seems to be a huge potential to bring the CERINKA SMA fastener to market.

Indeed, Vokoun is absolutely convinced that the work done on the Cerinka project can offer much to future society. Even though there are still technological problems to be overcome, it is highly likely, that in near future some almost silent superelastic Velcro-like fasteners reinforced with magnets will be developed.

"A completely silent, releasable fastener is obviously possible to be made if permanent magnets without SMA hooks are used or if SMA locks similar to hooks open on an external stimulus – such as by heating them up by environmental temperature or directly by electrical current," states Vokoun. Such solutions, although very interesting as well, have some disadvantages and were already patented by others so they have not been addressed in CERINKA project. ★

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## At a glance

**Full Project Title**
Development and study of a new class of shape memory releasable fasteners

**Project objectives**
- The development of a new releasable fastener with the same function as a Velcro releasable fastener but without the sharp sound upon releasing
- Modelling the pseudoelastic effect in the shape memory alloy hooks

**Contractors**
Institute of Physics Academy of Sciences of the Czech Republic, v.v.i.
Project funder: European Commission within the Sixth Framework Programme (2002-2006)

**Contract details**
Total EC contribution €80,000.
Quantitative indicators of progress and success:
- International aspects – joint research proposals
- Level of satisfaction of the researcher and the scientist-in-charge
- Scientific results achieved

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Dr David Vokoun joined the Department of Metals of the Institute of Physics - Academy of Sciences, the Czech Republic in 2006 after his previous research stay at the National Tsing-hua University in Hsinchu, Taiwan. He obtained his PhD in the Academy of Science of the Czech Republic in 1997.

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