EMPA
Materials Science & Technology

NRP 62 "Smart Materials"

"Superelastic Compliant Surgery Tools"

Executive Summary

The target of the project consisted in the use of reversible, stress-induced generation of marten-sitic variants in Shape Memory Alloys (the so-called superelastic effect) to provide novel, mono-lithically built surgery instruments with a high degree of compliance.
The main trade-off in the design of solid-state hinges and compliant systems is the one between range of motion of one side, which calls for a high degree of elastic deformability, and stiffness and strength on the other side, which reduces parasitic motion and allow for carrying and trans-ferring large loads. As far as materials are concerned, these requirements translate into the need for high values of allowable strain, elasticity modulus and strength.
Superelastic Shape-Memory Alloys (SMA) generate a very high level of reversible strain (up to 10%) at high ultimate strength (up to 2 GPa) and are hence highly promising in this framework. The use of pseudoelastic Shape Memory Alloys for solid-state hinges, however, presents several challenges from the point of view of analysis and design as compared to conventional materials, mostly related to their complex constitutive behaviour. One of the central points is represented by the multiaxial loading conditions typically present in the most promising class of compliant mechanisms, i.e. compliant mechanisms with selective compliance. Most available constitutive models are expressed or validated for uniaxial loading. Reliable criteria (equivalent stress) for the prediction of the occurrence of the martensitic transformation as well as for functional fatigue and failure in presence of multiaxial states of stress are still missing.
The main target of the project was the development of first essential steps towards the industrialisation of superelastic Shape Memory Alloys as constructive material for compliant mechanisms with selective compliance by identifying and approaching key questions in the above mentioned framework. Two aspects were in the focus of the project: The reliable pre-diction of the load-deformation behaviour (including the stress and strain distribution and prediction of degradation phenomena at a low number of cycles) on one side and the predic-tion of fatigue life on the other side.
A large number of valuable data could be generated within the projects: test data for more than 40 specimens on seven different set-ups, a large number of simulations with state-of the art modelling techniques as well as based on updated constitutive laws. Substantial progress could be reached on the front of the simulation techniques: A novel limit function could be defined which allows for a better prediction of the martensitic transformation onset in the presence of multiaxial states of stress and under consideration of anisotropic behav-iour generated by the particular texture imposed by the rolling process. On the front of the prediction of fatigue life, no conclusive insight into the relationship between material loading and fatigue life could be attained. The obtained results, however, give valuable indications on the conditions for future investigations on this topic (optimised geometry of specimens, surface treatment and kind of loading).