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S14 Smart materials and structures

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MASONRY WALLS STRENGTHENED WITH SHAPE MEMORY ALLOY AND ENGINEERED CEMENTITIOUS COMPOSITE

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Brittle construction materials, such as unreinforced concrete and unreinforced masonry (URM), do not exhibit considerable ductility when subjected to seismic loadings. As a result, engineers have recognized retrofitting URM-based structures as a key issue that must be addressed. Traditional strengthening procedures may fail to provide sufficient structural strength to withstand the maximum projected seismicity. Other technologies and materials, such as shape memory alloy (SMA), can be used to adapt masonry structures. SMAs have numerous remarkable characteristics, including the capacity to revert to their original shape after being subjected to extreme deformations. This is due to a martensitic phase transition caused by either heating (the shape memory effect) or releasing the applied stress (defined as pseudoelasticity). The use of engineered cementitious composite (ECC) technology, which was initially developed in the early 1990s, is another novel way for retrofitting URM structures. The ECC is a composite material made of fibres and cement that possesses a high hysteresis. The major emphasis of this work is the behaviour of masonry shear walls reinforced with pseudoelastic Ni-Ti SMA strips and ECC sheets. The walls were analyzed using computational analytical tools and exposed to quasi-static cyclic in-plane loads. Eight masonry wall strengthening examples were studied. Three masonry walls were strengthened with varying thicknesses of ECC sheets adhered with epoxy, three walls were reinforced with different thicknesses of Ni-Ti strips in a crisscross shape adhered to both surfaces of the wall, and one was used as a comparative wall without any reinforcing element. The final prototype was a combination of strengthening technologies, with Ni-Ti strips inserted in ECC sheets. The impact of mesh density on analysis results is also addressed. A parameterization analysis was performed to investigate the impact of different factors such as the thickness of the Ni-Ti strips and the thickness of the ECC sheets. The results reveal that combining the ECC sheet with pseudoelastic Ni-Ti SMA strips increases the energy absorption capacity and stiffness of masonry walls by up to 318 per cent, proving its viability as a reinforcing approach.

MODULAR ROBOTS AS DISTRIBUTED COMPUTERS OF THEIR OWN MECHANICAL STATE

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Modular robots are ensembles of simple robotic units, called modules, which can form complex structures by binding together. Modules can communicate with their neighbors, sense certain signals from the environment, store information and perform simple computations, move over other modules and attach to them. The movement of modules from one place to another within a robotic structure, called reconfiguration, is a major mechanism by which modular robots can change their overall shape. As an assembly of modules becomes more numerous, and the modules themselves smaller and simpler, the system starts to resemble an active, shape-changing material, possessing both computational and mechanical capabilities. Such futuristic, not-yet-made materials are frequently referred to as Programmable Matter.

Reconfiguration of modular robots poses a number of challanges. One of them is preservation of mechanical stability and integrity of a modular structure during reconfiguration. As modules change their positions in the structure, detaching from one place, then moving, and finally attaching at their destination, some inter-modular connections, which have limited strength, may become overloaded and break under gravity. Similarly, the movement of modules may shift the center of mass of the structure in such a way that the structure may lose stability and fall. Failures of this kind should be predicted before reconfiguration, preferably by the modular robot itself.

The present work addresses the problem of autonomous prediction by a modular robot of its possible future breakage or instability as a result of reconfiguration. The assessment is performed collectively by the modules in a distributed fashion, with each module doing simple computations and exchanging information with its direct neighbors. A simple Finite Element model of a modular robot is used, with pieces of the model data and state variables stored locally in each module's memory. The system is augmented by considering unilateral contact conditions between support modules and the ground, allowing the method to cope with the problem of stability as well. A simple iterative technique, the weighted Jacobi scheme, is employed to solve the resulting system of equations. Slow convergence of the weighted Jacobi method can be significantly improved by using a distributed Conjugate Gradient solver, although at the cost of difficulties with handling contact conditions.

The proposed method is verified in the modular-robot simulator VisibleSim, and on the robotic hardware Blinky Blocks. Although the focus is on cubic modules attached side to side, the method can also be applied to other shapes and arrangements of modules.

ELECTRO-MAGNETO-ELASTIC FIELDS OF GENERAL LINE SOURCE IN PIEZOELECTRIC-PIEZOMAGNETIC STRIP

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Modern technologies often employ anisotropic materials with multi-coupling effects. Long-range internal electro-magneto-elastic fields of line defects in such media might be dangerous for functioning of devices. The description of these fields is especially important but non-trivial when the considered medium is a thin film. Our earlier theory was developed for a purely piezoelectric anisotropic strip. Now the theory is extended from 8 D to 10 D case of the strip with piezoelectric, piezomagnetic and magnetoelectric coupled fields.
The 2 D electro-magneto-elastic coupled fields excited by the straight general line source parallel to surfaces of the infinite anisotropic strip with piezoelectric, piezomagnetic and magnetoelectric properties are implicitly found. The source of these fields consists of the five coinciding sources: the line of forces, the charged line, the line of electric current and the generalized 5 D dislocation line. The strip is supposed to be electrically and magnetically closed, i.e. its faces are covered by a thin superconducting film. Mechanically, three boundary conditions are considered:
(i) the both faces are free;
(ii) the both faces are clamped; and
(iii) one surface is free and the other is clamped.
The solutions obtained for a general case of unrestricted anisotropy are expressed in the form of convergent Fourier integrals, in terms of the eigenvectors and eigenvalues of the generalized 10 D Stroh matrix. Specific features of the derived solutions at infinity are analysed.

THERMAL STRESSES IN PERIODIC CELLULAR AUXETIC STRUCTURES

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Materials with a negative Poisson's ratio (auxetics) have been known for over 100 years [1]. In the early 1900s, physicist Voigt was the first who reported this property [2] and his work suggested that the crystals can become thicker laterally when stretched longitudinally, unfortunately, it was ignored for a few decades [3-8].
Based on the deformation mechanism, the auxetic cellular structures have been classified by Lim [9] into three main types: 1) re-entrant type; 2) chiral type; and 3) rotating units. These types of structures have been recently investigated by many researchers [10-17].
Compared to materials with negative thermal expansion (NTE) [14], the properties of materials with negative Poisson's ratio (NPR) (auxetics) are not often investigated. In this research, thermal properties of periodic cellular auxetic materials [18-19] are simulated using the finite element method. The influence of Poisson's ratio of auxetic structure on their thermal properties is observed.

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TI-BETA ALLOY - GUM METAL AND TINI SHAPE MEMORY ALLOY SUBJECTED TO COMPRESSION LOADING IN WIDE RANGE OF THE STRAIN RATES

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Multifunctional Β-Ti alloy named Gum Metal, developed by the Toyota Central Research and Development Laboratories at the beginning of the 21st century, was compared to TiNi Shape Memory Alloy (SMA). To this end, the samples of both Ti alloys were subjected to compression test conducted at various strain rates. Gum Metal is characterized for the unique mechanical performance; low Young's modulus, large nonlinear recoverable deformation, and high strength [1-3]. In turn, TiNi SMA is well known material for the shape memory properties and high fatigue performance. Understanding of mechanical behaviour of the both Ti alloys subjected to loading at various strain rates is critical for its application.

The research concerns investigation of Gum Metal and TiNi SMA in compression under quasi-static and dynamic loadings. An MTS testing machine was used to measure the quasi-static behaviour of the alloys with strain rates 10-3 s-1 and 100 s-1. High strain rate uniaxial testing was performed using a Split Hopkinson Pressure Bar (SHPB) system obtaining strain rates of 940, 1460 and 2200 s-1. Cylindrical material samples of 5 mm x 5 mm were used. It was found that both Gum Metal, as well as TiNi SMA are very sensitive to the strain rate applied during the compression loading. Elastic-plastic transition during quasi-static compression of the Gum Metal appears at the stress level between 900 MPa and 1000 MPa, whereas under high strain rate loading condition the peak flow stresses are on the level between 1200-1400 MPa. Moreover, almost no strain hardening is observed for the strain rate of 10-3 s-1. Strain softening is also visible for the strain rate of 100 s-1, as well as for high strain rate range.

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