The Hong Kong Polytechnic University
香港理工大學

國家鋼結構工程技術研究中心香港分中心
Chinese National Engineering Research Centre
For Steel Construction (Hong Kong Branch)

CNERC NEWSLETTER

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FEATURE STORY

CNERC and CEDD Signed a MoU on Collaboration for Development and Promotion of Effective Use of Ultra-high Strength S960 Steel

CNERC and Civil Engineering and Development Department (CEDD) signed a Memorandum of Understanding (MoU) on 27 June 2023 to formalize collaboration on development and promotion of effective use of ultra-high strength S960 steel. The MoU was signed by Ir Michael H.S. Fong, Director of CEDD and Professor K. F. Chung, Director of CNERC. Both CNERC and CEDD are committed to encourage innovative applications of the S960 steel in civil engineering projects as well as to formulate relevant technical guidelines and specifications.

Prof. K. F. Chung, Director of CNERC and Ir Michael H. S. Fong, Director of CEDD signed the MOU, witnessed by AECOM Asia Co. Ltd., Daewoo – Chun Wo – Kwan Lee Joint Venture, and YWL Engineering Pte Ltd.

CEDD pioneered the application of ultra-high strength S960 steel in footbridges under one of their projects, namely, Fanling North New Development Area, Phase 1 – Fanling Bypass Eastern Section (Shek Wu San Tsuen North to Lung Yeuk Tau). This is probably the world's first application of the S960 steel in long span foot bridges, and it will lay down a strong technical foundation for a wide adoption of this steel in Hong Kong and beyond.

AWARDS

National Award for Excellence in Innovation

Prof. K. F. Chung, Director of CNERC, was honoured with an Individual Award of ***the National Award for Excellence in Innovation*** on the “Celebration of National Science and Technology Workers' Day and National Innovation Award Commendation Conference” on 30 May 2023 in Beijing. Prof. Chung is the only Hong Kong party to be awarded this honour this year.

Organized by the China Science and Technology Association, ***the National Award for Excellence in Innovation*** is a state-level honour in China for science and technology, recognizing researchers who have made remarkable contributions to scientific research, key equipment development, and science popularizations.

Prof. Kwok-Fai Chung Received
National Award for Excellence in Innovation

Having devoted nearly 12 years in carrying out scientific research on high-strength steel structures, Prof. Chung is an expert and scholar in the field of steel construction. His research outcome has brought societal impacts to the construction industry in Hong Kong, and has been applied to major projects, including the double-arch steel bridge of the Cross Bay Link in Tseung Kwan O, Hong Kong SAR, and the Fourth Macau-Taipa Bridge, Macao SAR etc.. Adoption of the high-strength steel allows saving of several hundred millions dollars in construction costs and producing significant economic and social benefits.

NEWS

Thematic Forum on “Hong Kong I&T Strives Ahead”

Prof. K. F. Chung, Director of CNERC was invited to attend the Thematic Forum on “Hong Kong I&T Strives Ahead” on 30 June 2023 held in the Hong Kong Science and Technology Park. The Forum was jointly organized by the Innovation and Technology Commission, the Hong Kong Science and Technology Park and the Beijing-Hong Kong Academic Exchange Centre. Prof. K.F. Chung was commended by the Forum as the recipient of the Individual Award of the ***National Award for Excellence in Innovation*** by the China Science and Technology Association.

NEWS

Funding from Chinese National Natural Science Foundation

Dr. Y. F. Hu, Research Assistant Professor of CNERC is recently awarded a project by **Chinese National Natural Science Foundation** under the scheme of *Young Scientists Fund*. The project title is “Structural behaviour and modelling of weld-induced residual stresses in high strength steel tubular joints for the maritime environment”. The funding of this 36-month project is RMB$300,000, and its commencement date is 1 January 2024.

NEWS

Board Meeting of Cold-Formed Steel Branch of China Steel Construction Society

Dr. H. C. Ho, Deputy Executive Secretary of CNERC attended the Board Meeting of the Cold-Formed Steel Branch of China Steel Construction Society from 2 to 3 August 2023 in Guangzhou. The meeting was well attended by many experts, industrialists and senior engineers, and they discussed and exchanged extensively on latest development of the industry. Dr. Ho was invited to share key research and development activities at CNERC to all the delegates.

VISITS

Ir Michael Kwok, Chairman Asia Pacific Council of ARUP visited CNERC on 1 June 2023.

Prof. Y. J. Shi, Vice President of China Steel Construction Society, and Professor at Tsinghua University visited CNERC on 8 June 2023.

Dr. Robin Sham, Director of Global Long Span and Specialty Bridges, AECOM visited CNERC on 23 June 2023.

Engineers from Civil Engineering and Development Department and Highways Department visited CNERC on 1 August 2023.

Mr. J. Xin, Chairman of Shenzhen Metro Group Co. Ltd. visited CNERC on 17 August 2023.

CNERC RESEARCH

The CNERC Newsletter incorporates research articles from our researchers in aim to share the latest findings in their research work. Should there be any question or comment in these research works, you may send an email to: cnerc.steel@polyu.edu.hk or contact the researchers directly.

The researchers' contact information is available right at the end of each article.

RESEARCH

Research on Structural Behaviour of Stainless-Clad Bi-Metallic Steel Welded Connections and Joints under Monotonic and Cyclic Actions

Stainless-clad (SC) bi-metallic steel is an advanced high-performance steel (HPS) that consists of two different types of metals, typically i) S235, S355 and S460 carbon-steels, and ii) S316L stainless-steel, being bonded together at metallurgic level through explosive welding. Use of the SC bi-metallic steel sections in maritime structures is highly desirable in terms of structural performance, corrosion resistance, and cost efficiency. While their use is highly beneficial in achieving both structural adequacy and life cycle costs, there is a concern on the structural performance of welded sections and joints among these steel sections under both monotonic and cyclic actions, in particular, integrity along bonding interfaces of the two component metals under seismic actions. In order to promote wide applications of these SC bi-metallic steel sections in construction, it is essential to demonstrate structural integrity of these metallurgically bonded interfaces in the vicinity of welded sections and joints. Scientific understanding and engineering data on the mechanical properties of the interfaces under large deformations will release concern of structural engineers, and facilitate structural design of these SC bi-metallic steel sections in construction.

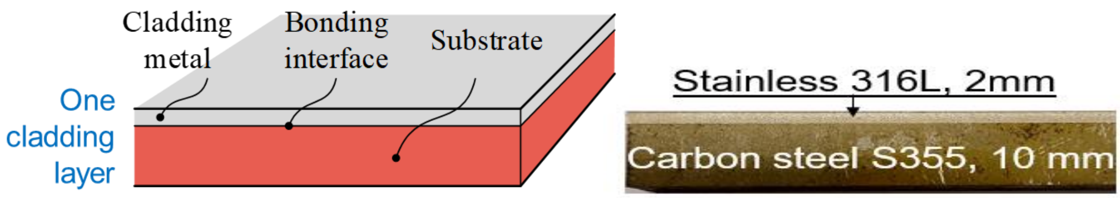

Figure 1 Cross-section of one cladding layer bi-metallic stainless clad steel

The mechanical properties of the bi-metallic steel together with their stress-strain curves are shown in Figure 2. It should be noted that the mechanical properties of the stainless steel are superior to those of the carbon steel in terms of strength and ductility. The yield and the tensile strengths of both the stainless steel and the carbon steel are readily mobilized as the corresponding strains $\leq 20\%$. As the deformation reaches ≈ 28 to 30%, carbon steel tends to fracture first, and then, debonding takes place.

	E (kN/mm^2)	$R_{p,0.2}$ (N/mm^2)	R_m (N/mm^2)	$R_m/R_{p,0.2}$	A (%)
Bi-metallic 10 + 2 mm	199	423	595	1.34	33.2
Stainless steel 2 mm	*200*	*582*	*775*	*1.34*	*41.9*
Carbon steel 2 mm	*206*	*395*	*569*	*1.44*	*29.6*

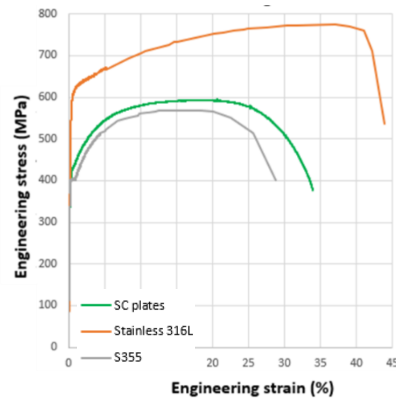

Figure 2 Engineering stress-strain curves and mechanical properties of bi-metallic steel

Figure 3 shows the stress-strain curves together with the test coupons of the welded sections with two different welding procedures after testing. It should be noted that the welding procedure Type S uses only one type of stainless welding wire, and the welding procedure Type D sues three types of welding wires. It is shown that the curves of all these test coupons are nearly the same. In addition, the fracture regions are all located in the parent metal, which means that the strengths of both the weld metal and the heat affected zones are superior to that of the parent metal.

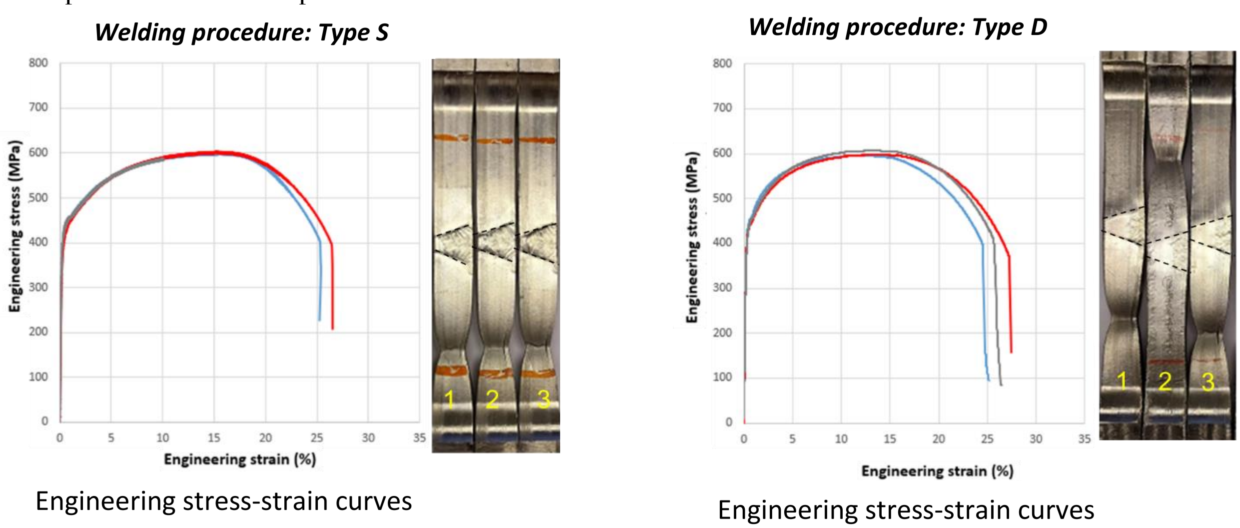

Figure 3 Engineering Stress-strain curves for welded sections of bi-metallic stainless clad steel

Experimental results have shown that both welding procedures are feasible for welding of stainless steel, and the choice of welding method depends on the welding efficiency and economy. In general, using one type of stainless welding wire (S-Type) is more efficient while using three types of welding wires (D-Type) are more economical.

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Self-centering dampers with multi-energy-dissipation mechanisms: Experimental studies and structural seismic demand performance

Previous research has highlighted that commonly used lateral resisting systems (e.g., moment resisting frames (MRFs) and braced frames) are satisfactory against earthquakes for the life-safety objective. However, earthquake-induced damages may inevitably result in large residual deformations, and cause much economic losses and long repair periods. It was found that if the residual drift of structures is larger than 0.5%, an anticipated repair plan may not be economical compared with reconstruction. Thus, residual deformation has become one of critical engineering demand parameters in performance-based designs or evaluations for emerging structures. Inspired by the damage-control mechanisms, self-centering energy-dissipative braces have been extensively examined and used in resilient braced frame systems. Based on the findings of existing investigations, an innovative self-centering brace characterized by a damper with multi-energy-dissipation mechanisms is proposed in this research study.

Fig. 1 shows details of a proposed damper. The proposed damper consists of an interior core, an exterior tube, a number of interior/exterior friction plates, a preloaded disc system, and endplates. The assembling steps of the proposed damper are given in Fig. 2.

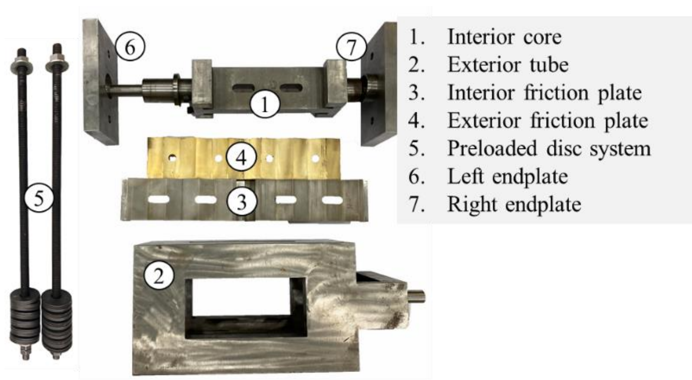

Fig. 1. Details of a proposed damper

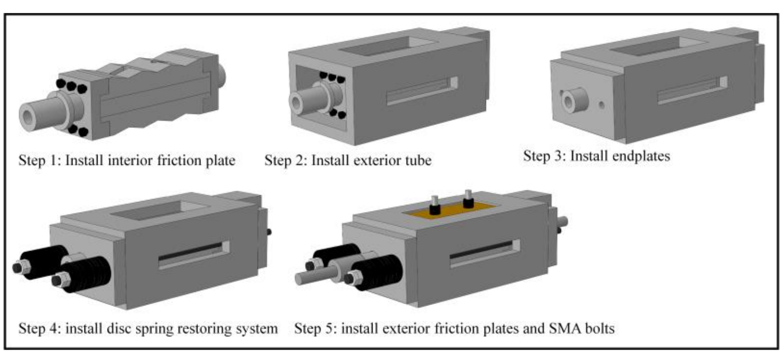

Fig. 2. Assembling steps of the proposed damper

In order to demonstrate the principles of the proposed damper, the sliding deformation modes and the expected force-displacement relationship of the proposed damper under cyclic loadings are illustrated in Fig. 3. It is shown that the idealised hysteretic curve of the damper exhibits a trilinear flag-shaped feature with enhanced energy-dissipation capacities.

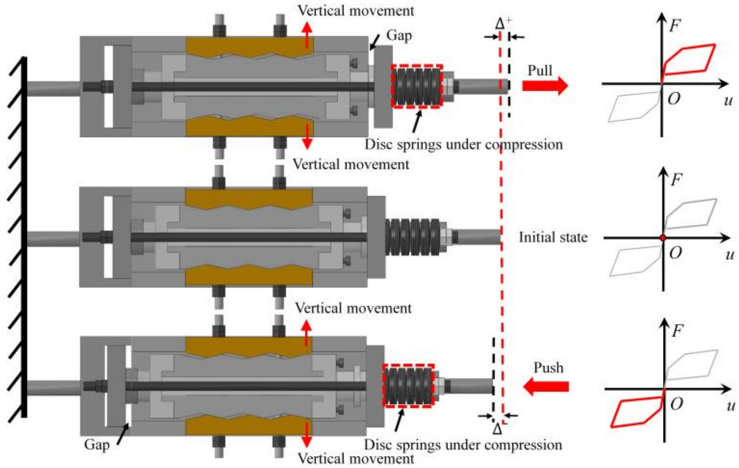

Fig. 3. Deformation vs force relationship of the proposed damper

In order to validate the mechanisms of the proposed damper, a series of tests are conducted. Fig. 4 shows typical cyclic test results of a specimen. A trilinear flag-shaped hysteretic curve of the proposed damper with effective hysteretic characteristics is observed, i.e. its stiffness and its strength are decoupled while its energy-dissipation capacities are enhanced.

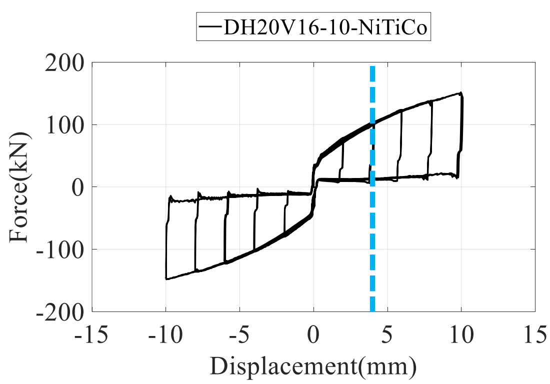

Fig. 4. Typical cyclic test result

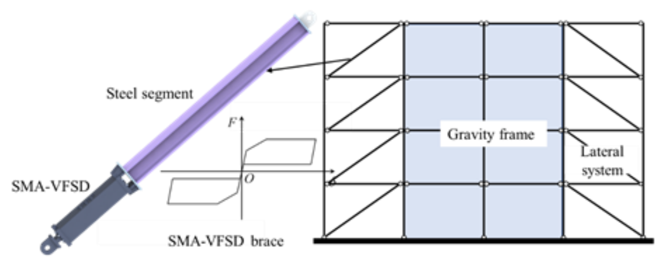

Fig. 5. A braced steel frame equipped with proposed dampers

Finally, in order to demonstrate the effectiveness of the proposed damper on mitigating structural seismic responses, a novel braced steel frame, shown in Fig. 5, is conceived. The inelastic seismic demand of the proposed braced frame is quantified by energy and acceleration demand of the equivalent SDOF systems using spectral analyses. To quantify the energy demand, the energy modification factor (γ) is used. For the acceleration demand, an acceleration factor (η) is adopted, and it is defined as the ratio of the maximum absolute acceleration of the equivalent SDOF system to that of the corresponding elastic SDOF system during an earthquake. The seismic demand of the proposed braced system is also compared with that of conventional braced systems with efficient hysteretic characteristic.

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New structural form of NiTi shape memory alloy – hot-rolled shape memory alloy angle

Conventional seismic design normally requires members and connections of a structure to develop unrecoverable inelastic deformations in order to dissipate seismic energy under earthquakes as a means to prevent the structure from collapse. Post-earthquake residual drifts and deformations in these members often require extensive retrofitting and strengthening, leading to enormous monetary loss for repair as well as prolonged occupancy suspension in damaged structures. In extreme cases, demolition as well as reconstruction are needed, which may result in demolition and construction waste and huge energy consumption, causing extensive carbon emissions. Hence, to be in line with the global trend of sustainability, earthquake-resilient structures are pursued which allow restoration of structural functions after an earthquake attack. Among various novel earthquake-resilient systems, self-centring structures has been attracting much attention owing to their ability to return to their initial configurations before earthquakes.

Shape memory alloys (SMAs) provide a promising solution to achieve self-centring behaviour for structural systems due to the superelastic (SE) and shape memory (SM) properties. As shown in Fig. 1, at temperatures above the austenitic finish temperature (A_f), SMAs will deform in the austenitic form exhibiting SE, and the deformation caused by the applied loading can be recovered upon unloading. SMAs are expected to exhibit SM in the martensitic form when the temperature is below martensitic finish temperature (M_f). In this case, the original deformation can be recovered through subsequent heating. The efficiency of utilising devices equipped with SMA components (i.e. SMA wires, cables, bars, and plates) in mitigating post-earthquake damages was well established experimentally and numerically in previous studies.

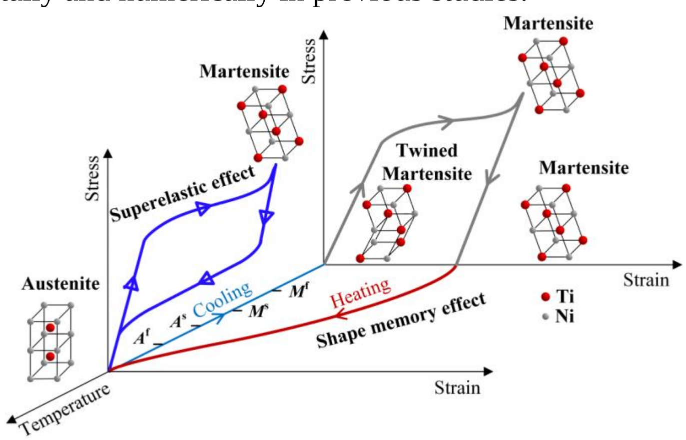

Fig. 1. Superelastic and shape memory properties of SMA

However, there are some limitations to the existing structural forms such as wires, cables, bars and plates of SMAs utilised for seismic application. For instance, gripping is a main challenge when using SMA wires and cables, and applying pre-strain/load process is necessary but complicated. For SMA bars, extensive machining of the threaded area is needed to eliminate potential fracture over the threaded area, which is costly and likely to be ineffective. In addition, the low flexural stiffness of SMA plate restricts its use to a tension system, and hence, the use of SMA plates in connections subject to cyclic loading is limited.

In order to overcome the abovementioned drawbacks and to enhance seismic application of SMAs, SMA angles are first developed, and they are manufactured with hot-rolling (Fig. 2). The SMA angles are hot-rolled from SMA plates prior to heat treatment to achieve various desirable SE properties. Micro-structural examination and mechanical testing are conducted on these SMA angles to determine their thermo-mechanical and structural properties. The DSC results (Fig. 3a) show that A_f of the samples is below 20℃, which means the hot-rolled SMA angles will deform in austenitic form, and exhibit SE at room temperature (20℃). Besides, good self-centring and energy-dissipation capacities can be observed in the results of tensile tests of the hot-rolled SMA angles, as shown in Fig. 3b. These results demonstrate that the hot-rolled SMA angles possess both good self-centring and energy dissipation capabilities, which can be readily utilised for seismic application. Further investigation on the use of these SMA angles in connections is in progress.

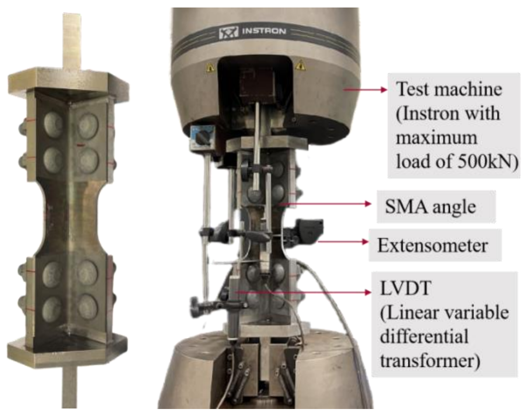

Fig. 2. Test set-up of tensile tests on hot-rolled SMA angles

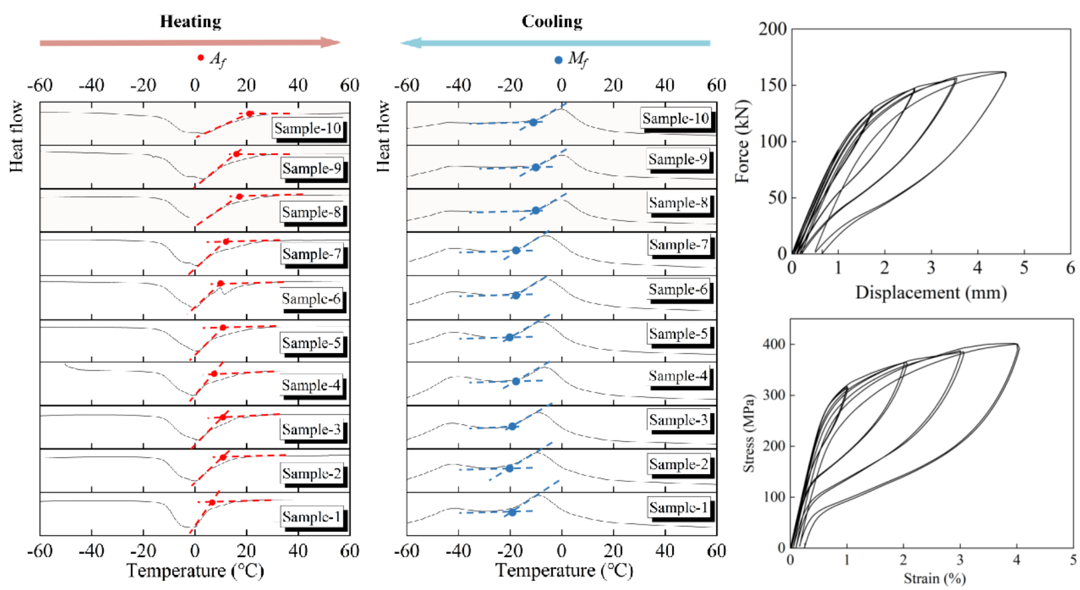

Fig. 3. Experimental data a) DSC results b) Tensile test results

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