RGC Ref.: N_HKUST617/14 NSFC Ref.: 11461161008
(please insert ref. above)

The Research Grants Council of Hong Kong
NSFC/RGC Joint Research Scheme
Joint Completion Report

(Please attach a copy of the completion report submitted to the NSFC by the Mainland researcher)

Part A: The Project and Investigator(s)

1. Project Title

Thermo-mechanical coupling and spatiotemporal effects in phase transitions of shape memory materials

2. Investigator(s) and Academic Department/Units Involved

	Hong Kong Team	Mainland Team
Name of Principal Investigator *(with title)*	Prof. Qingping Sun	Prof. Yongzhong Huo
Post	Professor	Professor
Unit / Department / Institution	Department of Mechanical and Aerospace Engineering, Hong Kong University of Science and Technology	Department of Mechanics and Engineering Science, Fudan University
Contact Information	meqpsun@ust.hk	yzhuo@fudan.edu.cn
Co-investigator(s) *(with title and institution)*		

3. Project Duration

	Original	Revised	Date of RGC/ Institution Approval *(must be quoted*)
Project Start date	1 Jan. 2015	N/A	
Project Completion date	31 Dec. 2018	N/A	
Duration *(in month)*	48	N/A	
Deadline for Submission of Completion Report	31 Dec. 2019	N/A	

Part B: The Completion Report

5. Project Objectives

5.1 Objectives as per original application

1. Design and fabrication of a cyclic tensile loading testing platform which is capable of: (a) providing displacement- and force-controlled cyclic loading of SMA specimen over the frequency range of 0.0001 to 20 Hz; (b) providing well-controlled heat transfer boundary conditions; (c) synchronizing the measurements of spatiotemporal variations in deformation patterns, temperature field and stress-strain curves.

2. Fabrication of nano-grained NiTi polycrystalline thin sheet samples with well controlled grain size (from 10nm to 100 nm) by severe plastic deformation (SPD) and characterization of the nano-structures and thermomechanical properties of the fabricated samples.

3. Conduct cyclic tests on NiTi SMA specimens of different grain sizes over wide frequency range to acquired systematic data of the evolution dynamics and fatigue behavior of the material (stress-strain relation, surface morphology and temperature field of the specimen). The grain size dependent spatiotemporal oscillations of the thermal and mechanical fields will be quantified.

4. To achieve an in-depth understanding of the observed spatiotemporal responses of the material through theoretical analysis of the measured data. Scaling laws among the response, the external and internal governing parameters (such as the grain size, loading frequency and amplitude, heat transfer condition, heat sources) will be established, especially the roles of grain size in the fatigue performance of the material will be identified and verified through comparison between the analysis and experiments.

5.2 Revised Objectives

Date of approval from the RGC: N/A

Reasons for the change: _____

_____

1.
2.
3. ....

6. Research Outcome

Major findings and research outcome
(maximum 1 page; please make reference to Part C where necessary)

The major findings and research outcome of the project are the following:

1. For the topic of the effects of important material internal length scale, grain size, on the thermomechanical responses and temporal oscillation of the NiTi SMA material, we have published 5 journal papers in international journals (*J. Mech. Phys. Solids, Acta Mater., Scripta Mater., Mater. Letters, Smart Mater. Structures*), Please refer to Part C for more details.

2. For the fabrication of nano-grained NiTi and characterization of the nano-structures, material properties, fatigue life, nonlinear vibration, and the theoretical derivation of the scaling law of the spatiotemporal domain patterns, we have published 3 journal papers in international journals (*Int. J. of Solid Structures, Scripta Mater.)* and submitted 1 manuscript (under view) to *Int. J. of Solid Structures*. Please refer to Part C for more details.

7. Potential for further development of the research and the proposed course of action
(maximum half a page)

The research outcome of this project laid a solid foundation for the future development of novel nanostructured NiTi SMA for ultrahigh performance and durability.

8. The Layman's Summary
(describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

Spatiotemporal variations, thermomechanical coupling and deformation patterns are widely observed in nature and in various kind of materials. In this research project, we focused on the phenomena in the NiTi shape memory alloys that have wide and important

applications in medical and aerospace industries. We overcame many difficulties in establish the test platforms and in performing the experiment (to capture the spatiotemporal variation of thermomechanically-coupled quantities under cyclic loading) and theoretical modelling (to quantify the effects of external and internal time and length scales on the thermomechanical responses and domain patterns). We have achieved the project objectives and have published 8 papers in international journals and submitted one manuscript to international journal (under review). The research outcome of this project have received international visibility and citation by the research community, and have laid a solid foundation for the future development of novel nanostructured NiTi SMA for ultrahigh performance and durability.

Part C: Research Output

9. Peer-reviewed journal publication(s) arising directly from this research project

(Please attach a copy of each publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) ***(bold** the authors belonging to the project teams and denote the corresponding author with an asterisk*)*	Title and Journal/ Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this Joint Research Scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
Year of publication	Year of Acceptance *(For paper accepted but not yet published)*	Under Review	Under Preparation *(optional)*						
2017				*Xia, Minglu; Sun, Qingping**	*Thermomechanical Responses of Nonlinear Torsional Vibration with NiTi Shape Memory Alloy – Alternative Stable States and Their Jumps, Journal of the Mechanics and Physics of Solids, v. 102, May 2017, p. 257-276.*	*2019*	*Yes*	*Yes*	*Yes*
2017				*Xia, Minglu; Sun, Qingping**	*Grain Size Effects On Stability Of Nonlinear Vibration With Nanocrystalline Niti Shape Memory Alloy, Smart Materials and Structures, v. 26, (10), October 2017, article number 105033.*	*2019*	*Yes*	*Yes*	*Yes*
2017				*Ahadi, Aslan; Matsushita, Y.; Sawaguchi, Takahiro; Sun, Qingping; Tsuchiya, K.*	*Origin of zero and negative thermal expansion in severely-deformed superelastic NiTi alloy, Acta Materialia, v. 124, February 2017, p. 79-92.*	*2019*	*Yes*	*Yes*	*Yes*

2018				*Kabirifar, Parham; Chu, Kangjie; Ren, Fuzeng; Sun, Qingping**	*Effects of Grain Size on Compressive Behavior of NiTi Polycrystalline Superelastic Macro- and Micropillars, Materials Letters, v. 214, March 2018, p. 53-55.*	*2019*	*Yes*	*Yes*	*Yes*
2108				*Xia, Minglu; Liu, Pan; Sun, Qingping**	*Grain Size Dependence of Young's Modulus and Hardness for Nanocrystalline NiTi Shape Memory Alloy, Materials Letters, v. 211, January 2018, p. 352-355.*	*2019*	*Yes*	*Yes*	*Yes*
2019				*Zhuo, Mingzhao; Xia, Minglu; Sun, Qingping**	*Analytical Solution of a Mass-spring System Containing Shape Memory Alloys: Effects of Nonlinearity and Hysteresis, International Journal of Solids and Structures, v. 171, October 2019, p. 189-200.*	*2019*	*Yes*	*Yes*	*Yes*
2019				*Zhang, Kuo; Kang, Guozheng; Sun, Qingping**	*High fatigue life and cooling efficiency of NiTi shape memory alloy under cyclic compression, SCRIPTA MATERIALIA, v. 159, January 2019, p. 62-67.*	*2019*	*Yes*	*Yes*	*Yes*
2019				*Kabirifar, Parham; Li, Mingpeng; Sun, Qingping**	*Non-monotonic Grain Size Dependence of Phase Transformation Behavior in NiTi Microscale Samples, Scripta Materialia, v. 165, May 2019, p. 50-54*	*2019*	*Yes*	*Yes*	*Yes*
		2020		*Li, Mingpeng; Mingxiang Chen; Sun, Qingping**	*Non-local modelling and analysis of spatiotemporal patterns in NiTi thin strips during non-isothermal phase transformation, submitted to Int. J. Solids and Structure*	*2019*	*Yes*	*Yes*	*No*

10. Recognized international conference(s) in which paper(s) related to this research project was/were delivered

(Please attach a copy of each delivered paper. All listed papers must acknowledge RGC's funding support by quoting the specific grant reference.)

Month/Year/ Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this Joint Research Scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*

11. Student(s) trained *(Please attach a copy of the title page of the thesis.)*

Name	Degree registered for	Date of registration	Date of thesis submission/ graduation
LANG Meng	MPhil	Sept. 2013	Apr. 2016
CHEN Tongheng	MPhil	Sept. 2013	Jan. 2016
Kuo Zhang	PHD	Jan. 2016	Jan. 2019

12. Other impact *(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, etc.)*

Research collaborations with Fudan University and Wuhan University of mainland China have been established.