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INVESTIGATION THE CREEP AND CREEP RECOVERY BEHAVIOR OF BUILD-UP SYSTEMS

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Abstract: The creep and creep recovery are important characteristics of Build-up system (BU-system). So, this paper is focused on the creep and creep recovery of several BU-systems. The creep and creep recovery of two different types of force transducers, including RTN and column type, are measured when applied 20%, 40%, 60%, 80%, and 100% of the rated loads and after unloading, respectively. Afterward built-up by these transducers, BU-systems with different structures and capacities are measured in order to investigate the creep and creep recovery behaviors of them and the differences between the BU-systems and single transducers.

Keywords: creep, creep recovery, force transducer, Build-up system, meganewton range

1. INTRODUCTION

Nowadays, there are more and more force measurements in the higher MN range within the fields of aerospace, safety engineering, energy and building industries. Some of them have excessed 20 MN, and reached up to 60 MN even. Many calibration machines and transfer standards have been set up in order to meet the existing and anticipated demands from the calibrations of testing facilities. With high precision and low cost, the BU-system, composed by several force transducers, is preferably chosen as the reference standard of the calibration machine or the transfer standard over 20 MN. The CRISS designed a 30 MN BU-system in which three force transducers of each having 10 MN capacity. Using the knowledge of the EMRP SIB 63 project, a 50 MN BU-system was design by PTB with five 10 MN transducers. A Build-up Force Standard Machine (BUFSM) up to 60 MN has been built up at Fujian Metrology Institute (FJIM) in China. As the reference standard, a 60 MN BU-system was designed by three 20 MN column type transducers. [1] Also another two 60 MN BU-systems were designed by FJIM, using three HBM and three GTM 20 MN column type force transducers, respectively. The six transducers were calibrated by NIM 20 MN Hydraulic Force Standard Machine (HFSM) and then assembled into two BU-systems extrapolated up to 60 MN. They would be compared with each other. As the transfer standards, they were used to calibrate the 60 MN machine finally.

The creep and creep recovery are very import characteristics for the BU-system. When the applied force acting upon a BU-system, the force transducers in it respond change rapidly to a new level. With various connection and boundary conditions, the creep and creep recovery of a transducer in a BU-system seems different from those when it calibrated singly in the force standard machine. So in the paper, BU-systems with different build-up structures, different capacities, and different types of the force transducers will be tested to investigated the creep and creep recovery characteristics of them.

2. EXPERIMENTAL DESIGN

2.1 BU-systems design

In order to investigate the creep and creep recovery behaviour, seven BU-systems of different capacities are designed, as showed in Table 1. The RTN and column type transducers of different capacities are used in the BU-systems. And the transducers are structured differently, as showed in Fig.1, so as to study the effects of the build-up structures on the creep and creep recovery behaviour. The so called "pendulum balance structure" is a special build-up structure commonly applied by FJIM. It is verified as stable structure especially for its outstanding specification of repeatability and reproducibility. As showed in Fig. 1, the balance plate connecting the pendulums could be used to uniform the rotations of the pendulums when they suffered nonuniform loads for the cross force or additional moment. The BU-systems are showed in Fig.2.

2-2. Experiment Procedure

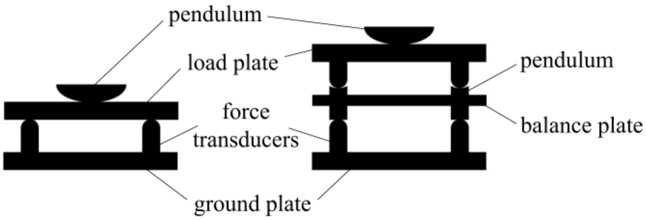
(1) Single force transducer test

The force transducers with the capacities of 100 kN and 300 kN were tested by a 300 kN Dead Weight Force Standard Machine (DWFSM) with a relative expanded uncertainty of 0.005% (k=2) at FJIM. These single transducers were loaded following the loading scheme showed in Fig. 3. Specially, the force step of 40% FS was changed into 100 kN when the transducers with capacities of 300 kN were measured. A DMP 41 was used as the amplifier, and a special software was developed to record the data every 0.2 s.

Table 1. BU-systems

Series Number	Capaci ty	Component Force Transducer	Build-up Structure

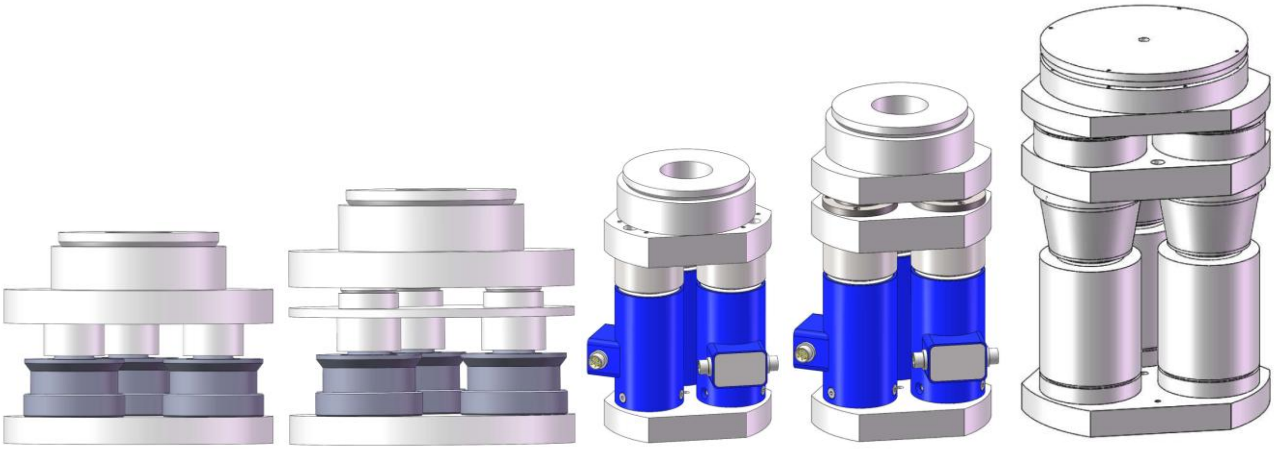
		Capacity	Type	
BU 1	300 kN	100 kN	RTN	ordinary
BU 2	300 kN	100 kN	RTN	pendulum balance
BU 3	300 kN	100 kN	Column	ordinary
BU 4	300 kN	100 kN	Column	pendulum balance
BU 5	900 kN	300 kN	Column	ordinary
BU 6	900 kN	300 kN	Column	pendulum balance
BU 7	60 MN	20 MN	Column	pendulum balance



(a) (b)

Fig.1 Build-up structures of different types

(a) Ordinary structure (b) Pendulum balance structure



(a) (b) (c) (d) (e)

Fig.2 BU-systems used in the experiments

(a) BU 1 (b) BU 2 (c) BU 3 and BU5 (d) BU 4 and BU 6 (e) BU 7

And the three 20 MN column type force transducers were tested up to 16.5 MN according to the ISO 376-2011 [2] in the 16.5 MN HFSM at PTB. The creep and creep recovery of them were measured at the force of 16.5 MN and after the force removal.

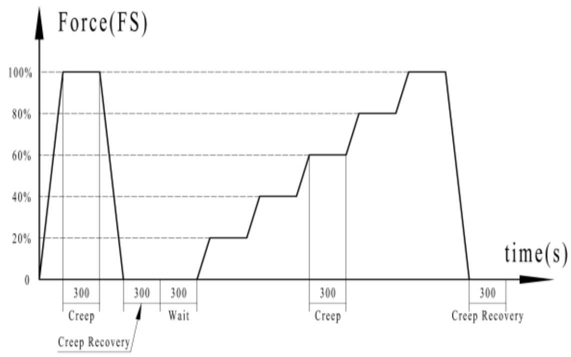


Fig. 3 Loading scheme of the creep and creep recovery measurements

(2) Build-up system test

The BU-systems with the capacities of 300 kN (BU 1, BU 2, BU 3 and BU 4) were tested by the same 300 kN DWFSM at FJIM, as showed in Fig. 4. And the measurements of creep and creep recovery were carried out following the same loading scheme showed in Fig. 3.

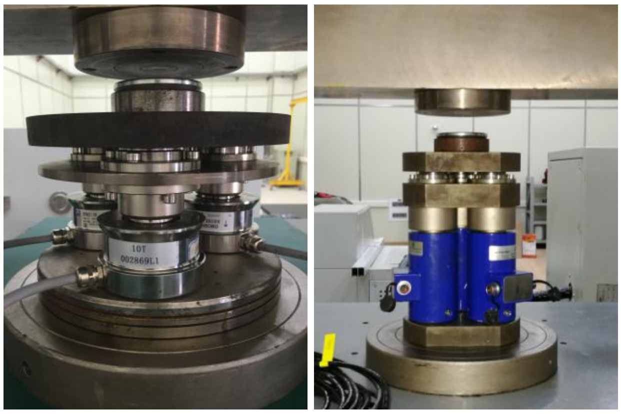


Fig. 4 BU 2 and BU 4 were tested in the 300 kN DWFSM

The BU 5 and the BU 6 were tested following the loading scheme, as showed in Fig.5. The creep were measured at the force steps of 180 kN and 300 kN in the 300 kN DWFSM. Afterwards, the creep recovery was performed at zero force in a 1 MN BUFSM with a relative expanded uncertainty of 0.05% (k=2) at FJIM.

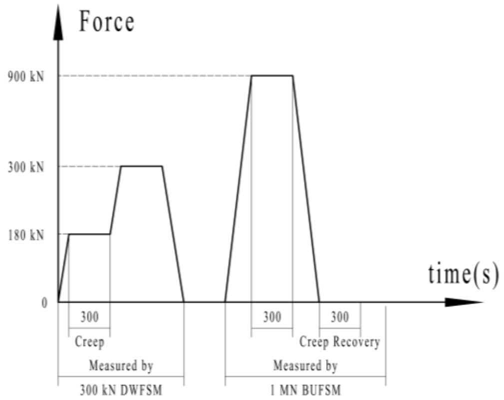


Fig. 5 Loading scheme of the creep and creep recovery measurements for the BU 5 and BU 6

The BU 7 was loaded up to 49.5 MN directly and maintained for 300 s by the 60 MN BUFSM at FJIM, as showed in Fig. 6. The creep recovery was measured after the force removal.

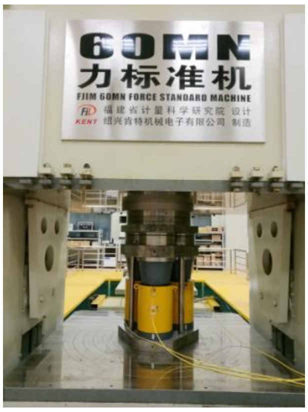


Fig.6 BU7 tested in FJIM 60 MN machine

The values of the three component force transducers in every BU-system were taken simultaneously every 0.2 s, as showed in the Fig. 7.

Fig. 7 Data were indicated by DMP 41 and taken by a software every 0.2 s

2.3 Data processing

The creep or the creep recovery of single transducer is calculated by the following equation,

$$c = \left| i_{300} - i_{30} \right| \quad (1)$$

Where, c is the creep or creep recovery of single transducer;

i_{300} is the output obtained at 300 s;

i_{30} is the output obtained at 30 s.

The creep or the creep recovery of BU-system is calculated by the following equation,

$$C = \sum_{n=1}^{3} \left| I_{n,300} - I_{n,30} \right| \quad (2)$$

Where, C is the creep or creep recovery of BU-system;

$I_{n,300}$ is output of the n th transducer in the BU-system obtained at 300 s, when the BU-system is tested;

$I_{n,30}$ is output of the n th transducer in the BU-system obtained at 30 s, when the BU-system is tested.

And in order to compare the creep or creep recovery behaviour between the single transducer and BU-system, a so called "calculated creep" of BU-system is calculated by equation (3),

$$C' = \sum_{n=1}^{3} \left| i_{n,300} - i_{n,30} \right| \quad (3)$$

Where, C' is the calculated creep of BU-system, which is the sum of the creep or creep recovery of the three component transducers in BU-system when the single transducers are measured;

$i_{n,300}$ is output of the n th transducer obtained at 300 s, when the single transducer is tested;

$i_{n,30}$ is output of the n th transducer obtained at 30 s, when the single transducer is tested.

3. RESULTS AND DISCUSSION

The table 2 shows the creep and creep recovery behaviour of single transducer under loading schemes. It is obvious that the creep of transducer loaded directly to full load is much higher than that when the transducer is loaded up to full load step by step.

Table 2 the creep and creep recovery of single transducer

Force step		RTN	Column	Column
		100 kN	100 kN	300 kN
Creep, direct loading		0.000195	0.000116	0.000117
Creep recovery		0.000036	0.000059	0.000067
Creep, several steps	20% FS	0.000008	0.000018	0.000024
	40% FS	0.000020	0.000029	0.000030
	60% FS	0.000024	0.000042	0.000047
	80% FS	0.000031	0.000046	0.000048
	100% FS	0.000037	0.000043	0.000054
Creep recovery		0.000029	0.000081	0.000076

The creep or the creep recovery measurement results of BU 1 to BU 6 are showed in Fig. 8, Fig. 9 and Fig. 10. Comparing the deviations between the creep from BU-systems testing and calculated creep from single transducer testing, it is obvious that the creep of BU-systems are effected by the build-up structure. And the deviations are small when the force are less than 30% FS, but they become more and more larger as the force increases. It might be caused by the parasitic component because of the deformation of the build-up structure. It is more objective to evaluate the creep behaviour of BU-system from the data of creep recovery. Because the creep recovery is measured after force removal, and not effected by the build-up structure anymore. The deviations of the creep recovery from the Fig. 8, Fig. 9 and Fig. 10 are quite small. And the same result also could be gotten from the testing of BU 7, as showed in Fig. 11.

The same transducers with different build-up structures, as showed in Fig. 8 and Fig. 9, the deviation between the BU 1 and BU 2 is larger than the deviation between the BU 3 and BU 4. It seems that the creep behaviour of the RTN transducer is more sensitive to the build-up structure than that of column type column transducer. But it may need more experiments to confirm it.

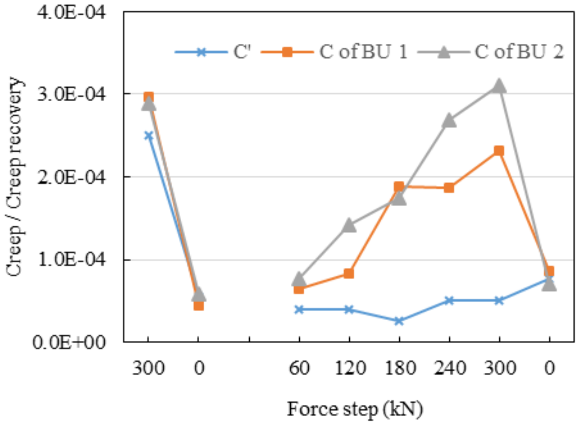


Fig. 8 The creep and the creep recovery of BU 1 and BU 2

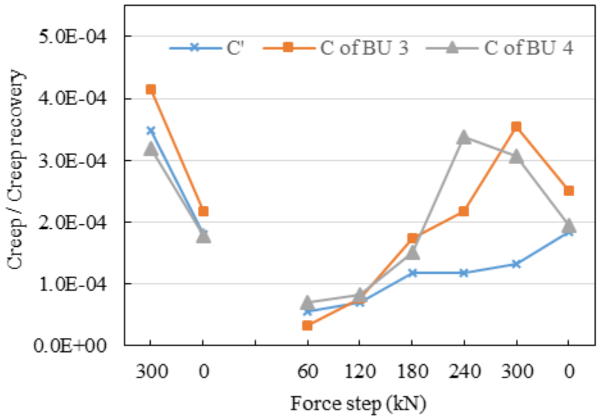


Fig. 9 The creep and the creep recovery of BU 3 and BU 4

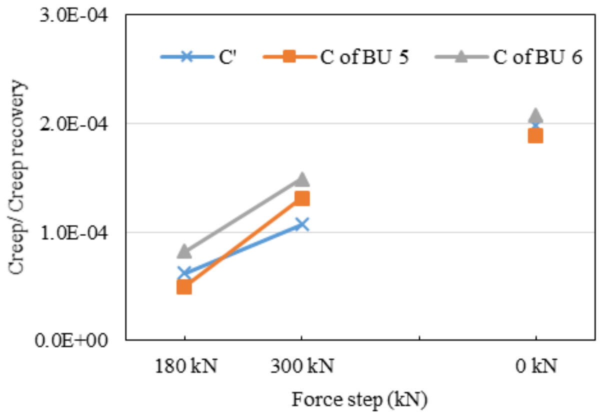


Fig. 10 The creep and the creep recovery of BU 5 and BU 6

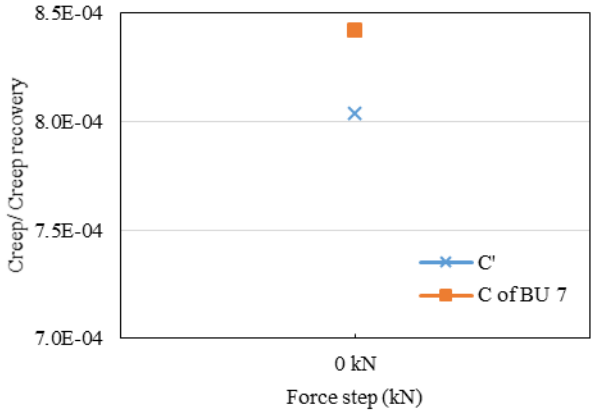


Fig. 11 The creep recovery of BU 7

4. CONLUSION

The paper focuses on the study of creep and creep recovery of BU-system, built-up by different structures and different transducers. From the experiments results, the conclusion could be gotten that the creep behavior of BU-system is sensitive to the build-up structure while the creep recovery is not effected the structure. And the effect of the structure on the creep would become more and more obvious with the increasing of the force applied on the BU-system. It is meaningful to enhance the stiffness of the build-up structure when it is designed.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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