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FORCE COMPARISON BETWEEN FJIM AND PTB UP TO 16.5 MN

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Abstract: The paper describes a force comparison at forces steps of 10 MN and 16.5 MN between the FJIM 60 MN force standard machine and the PTB 16.5 MN force standard machine. The comparison was carried out corresponding to the ISO 376. A HBM 20 MN force transducer is used as the transfer standard. The comparison results showed that the relative deviation of the two machines was within ±0.048% up to 16.5 MN with an expanded uncertainty less than 0.115% (k=2).

Keywords: force standard machine, force comparison, transfer standard

1. INTRODUCTION

A build-up force standard machine up to 60 MN was built by Fujian Metrology Institute (FJIM) in 2014, as showed in Fig. 1 and Fig. 2. Two sets of build-up system, 60 MN one composed of three 20 MN transducers and 20 MN one composed of three 7.5 MN transducers, were used as the reference standard of the machine [1]. So with a special tracking unit used to transfer the reference standards, as showed in Fig.3, the machine could be used as two force standard machines actually. In this case, the machine covers the ranges from 2 MN to 20 MN and from 6 MN to 60 MN with the expanded uncertainty of 0.05% (k=2) and 0.1% (k=2) respectively. The general function principle of the machine was described within the paper [1]. A comparison was carried out in 2014 between the 60 MN machine with the range from 6 MN to 60 MN and 30 MN force standard machine at NPL. It was demonstrated that the agreement between the two machines was better than ±0.06% at each compared force point [2].

In order to investigate the agreement between the 60 MN machine with the range from 2 MN to 20 MN and 16.5 MN hydraulic force standard machine at PTB, the force comparison was carried out during April to June 2016. Also, it would be meaningful for the future comparison up to 50 MN between the 60 MN machine and the 50 MN build-up system of PTB, using the knowledge of the EMRP SIB 63 project. The present paper describes the method and results of the comparison up to 16.5 MN.

Fig.1 Photo of 60 MN force standard machine

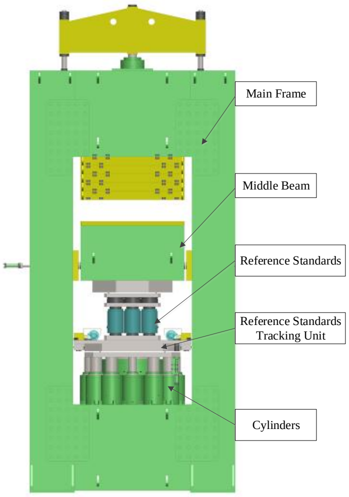

Fig.2 Schematic diagram of 60 MN force standard machine

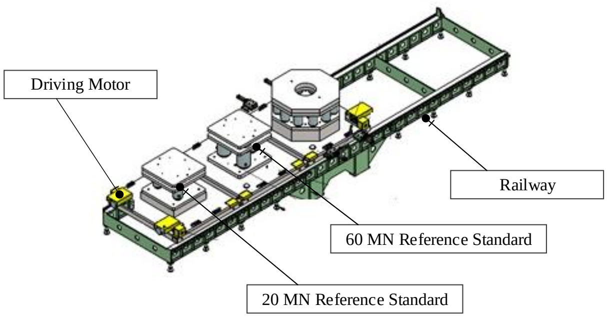

Fig.3 Schematic diagram of reference standard tracking unit

2. COMPARISON METHOD

2.1 Transfer standard

A 20 MN column-type transducer manufactured by HBM was used as the transfer standard, as showed in Fig.4. And a DMP 40 and a DMP 41 were used when the measurement carried out at FJIM and PTB respectively. The amplifiers were calibrated by BN 100 before and after the measurements.

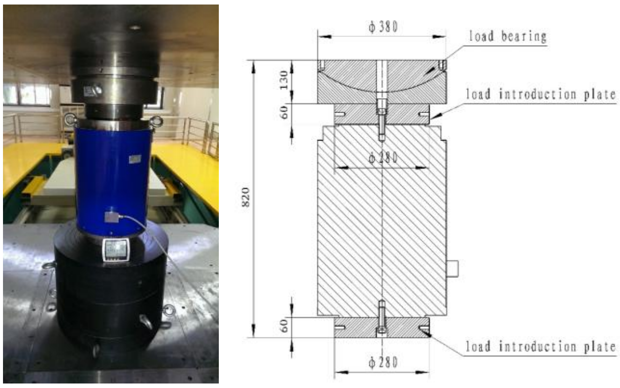

Fig. 4 20 MN transducer as transfer standard

2.2 Measurement Procedure

The measurements were carried out by FJIM (Series A1), then PTB (Series B), and finally FJIM (Series A2).

According to the ISO 376[3], two series of increasing forces were applied to transducer measurements, after three-time preloading in 0°position following the time profile of the measurement, as showed in Fig. 5.

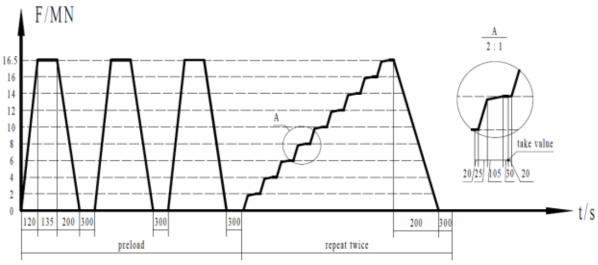

Fig.5. Time profile of measurement up to 16.5 MN in the 0°position

Afterwards, one series of incremental and decremental measurement was made after one-time preloading in 120°and 240°position respectively following the time profile of the measurement, as showed in Fig.6.

For the 16.5 MN machine, 20 s was taken to change the mass combination, then 25 s to reach 95% of the load, and 105 s to reach the exact force step. So the loading and unloading procedures of 60 MN machine were set the same to it. And after a wait of 30 s, the value was taken at each force step.

There was a wait of 300 s between each measurement series.

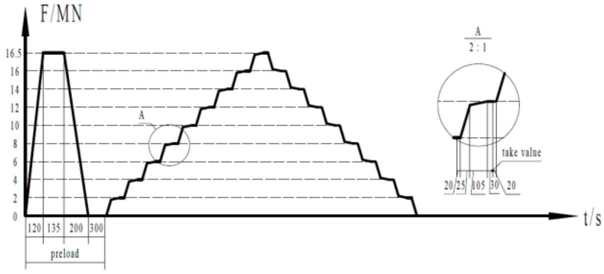

Fig.6. Time profile of measurement up to 16.5 MN in the 120°and 240°position

2.3 Date processing

The two force standard machine were compared at the force steps of 10 MN and 16.5 MN. The relative deviations of the forces were calculated by eq. (1),

$$\delta = \frac{\overline{X}_{\mathrm{r,B}} - \left(\overline{X}_{\mathrm{r,A1}} + \overline{X}_{\mathrm{r,A2}}\right)/2}{\left(\overline{X}_{\mathrm{r,A1}} + \overline{X}_{\mathrm{r,A2}}\right)/2} \qquad (1)$$

The uncertainty was estimated according to the ISO 376. The E_n value could be gotten by eq. (2),

$$E_n = \frac{\delta}{2\sqrt{\left(\frac{w_{\mathrm{c,A1}} + w_{\mathrm{c,A2}}}{2}\right)^2 + \left(w_{\mathrm{c,B}}\right)^2}} \qquad (2)$$

3. MEASUREMENT RESULTS

The measurement dates were listed in the Table.1, while the corresponding relative uncertainties were presented in the Table.2.

The relative deviation was showed in Fig. 7. It is obviously that the relative deviation were less than 0.048% up to 16.5 MN. And E_n value was 0.4 for both force steps of 10 MN and 16.5 MN.

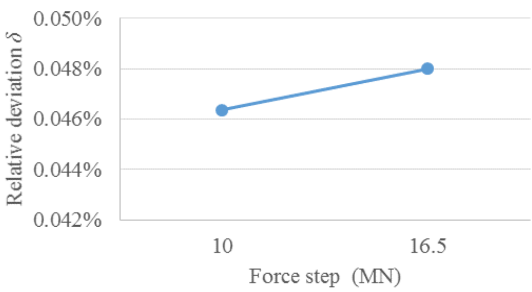

Fig. 7. Relative deviation

Table 1 Measurement Results of Series A1、B and A2

Series	Force Step (MN)	X_1	X_2	X_3	X'_4	X_5	X'_6	$\overline{X}_r$	b'	b
		(mV/V)								
A1	0	0.00000	0.00000	0.00000	-0.00006	0.00000	-0.00006			
	10	1.21377	1.21373	1.21369	1.21257	1.21371	1.21252	1.21372	0.003%	0.007%
	16.5	2.00156	2.00159	2.00142		2.00144		2.00147	0.001%	0.007%
	0	-0.00028	-0.00027							
B	0	0.00000	0.00000	0.00000	-0.00007	0.00000	-0.00007			
	10	1.21431	1.21436	1.21435	1.21389	1.21443	1.21400	1.21436	0.004%	0.010%
	16.5	2.00247	2.00255	2.00256		2.00265		2.00256	0.004%	0.009%
	0	-0.00037	-0.00032							
A2	0	0.00000	0.00000	0.00000	-0.00007	0.00000	-0.00004			
	10	1.21391	1.21397	1.21397	1.21285	1.21374	1.21263	1.21387	0.005%	0.019%
	16.5	2.00173	2.00180	2.00184		2.00159		2.00172	0.003%	0.012%
	0	-0.00020	-0.00017							

Table 2 Measurement Uncertainty of Series A1、B and A2

Series	Force Step (MN)	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_c
A1	10	0.050%	0.002%	0.002%	0.000%	0.006%	0.014%	0.001%	0.002%	0.053%
	16.5	0.050%	0.002%	0.001%	0.000%	0.006%	0.014%	0.001%	0.001%	0.053%
B	10	0.005%	0.003%	0.003%	0.000%	0.010%	0.018%	0.000%	0.002%	0.022%
	16.5	0.005%	0.003%	0.002%	0.000%	0.010%	0.018%	0.000%	0.000%	0.022%
A2	10	0.050%	0.006%	0.003%	0.000%	0.007%	0.010%	0.000%	0.004%	0.052%
	16.5	0.050%	0.004%	0.002%	0.000%	0.007%	0.010%	0.000%	0.002%	0.052%

4. CONCLUSIONS

A force comparison between the FJIM 60 MN force standard machine and the PTB 16.5 MN force standard machine has been carried out using a 20 MN force transducer. Especially the creep behaviour and time dependency of the load profile was carefully taken to account. The degrees of equivalence demonstrate that the relative deviation of the two machines was within ±0.048% up to 16.5 MN with an expanded uncertainty less than 0.115% (k=2).

5. ACKNOWLEDGMENTS

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6. REFERENCES

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