

A NEW TYPE OF WIDE MEASUREMENT RANGE BUILD-UP FORCE STANDARD MACHINE

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Abstract: The build-up force standard machine is widely used in large scale force measurement. The force measurement range of the standard machine depends on a reference force transducer, and it is usually from 10% to 100% rated force in a measurement process.

In order to perform continuous calibrations, it should be avoided two measurement processes by changing reference force transducer. This paper describes a new type of wide range standard machine, which is based on exchanging two reference force transducers in operation process. It can measure up to 10 MN, and its range is extended from 3% to 100% rated force in one measurement process. In addition, the repeatability and the relative reproducibility error with rotation of the new machine are calculated.

Keywords: force standard machine, reference force, wide range

1. INTRODUCTION

With the development of science and technology, large force value sensor is more and more widely used in the development of bridge construction, large hoisting machinery, high-speed railway construction and other aspects. Therefore, the accuracy of calibrating large force value sensor is particularly important. Today the build-up force standard machine is widely used in large force value measurement. The force measurement range of this type of the machine depends on a reference force transducer, and it is usually from 10% to 100% rated force in a measurement process. A new type of wide range build-up force standard machine was developed, which is based on exchanging two reference force transducers in operation process. It can measure up to 10 MN, and its range is extended from 3% to 100% rated force in one measurement process.

2. THE STRUCTURE AND WORKING PRINCIPLE OF WIDE MEASURE RANGE BUILD-UP FORCE STANDARD MACHINE

10 MN force standard machine adopts the build-up type. The machine consists mainly of an oil cylinder, reference sensors, a servo motor, a hydraulic loading system, and a pedestal part. The mechanical structure of 10 MN force standard machine is shown in Fig.1.

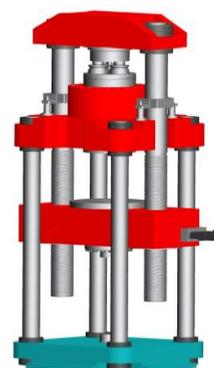


Fig.1

In order to perform continuous calibrations, changing reference force transducer should be avoided during measurement. Some new and optimized design features have been incorporated in the machine. The force standard machine adopts a special mechanical structure, which is shown in fig.2. The driving hydraulic cylinder is composed of two hydraulic cylinders, one is the inner cylinder, the other is the outer cylinder, and they are independently controlled. The reference force sensor is made up of two different capacity reference force sensors which are respectively installed on the two cylinders. The large reference sensor consists of three sensors adopting the build-up type. It is on the top of the small reference sensor and the two reference sensors are coaxial. The force standard machine consists of one part with 3 MN capacity and another part with 10 MN capacity. Its range is extended from 300 kN up to 10MN, which is the 3% to 100% rated force of the standard machine.

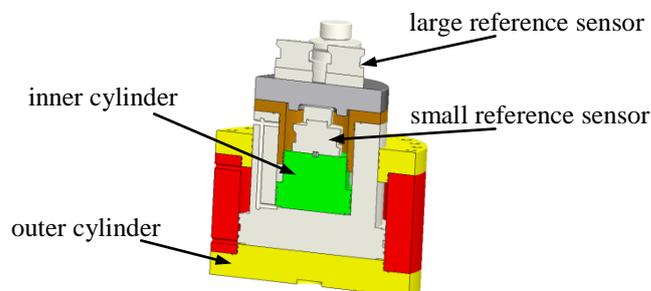


Fig.2

The wide measure range build-up force standard machine has been designed and developed by Innovative Testing Technology associate with Beijing Institute of

Metrology, PR China. It has been installed at Sunmoon instrument technology, Bengbu, PR China in 2016 which is shown in Fig.3.



Fig 3

3. ELECTRIC CONTROL SYSTEM

The control system of force standard machine consists of data acquisition and hydraulic control part. An industrial control computer is used as the controller to realize the centralized control and management of the machine. The load of standard machine is measured by the double reference force sensors. The measuring amplifier which is used to measure the output of the force transducer is communicated with the computer via the serial interface.

Hydraulic control system adopts pump control, including servo motor, hydraulic cylinder, gear pump, micro oil supplement by electric cylinder and so on. The output of the reference sensor is used as the feedback signal. The control system adjusts the speed of the servo motor to control the hydraulic pressure of the inner and outer ring oil cylinder so that it can control of the force value smoothly. PID control algorithm is applied to load control system. By designing the complex program, the machine realizes a closed-loop control. When the force standard machine starts to load, at first the inner cylinder rise double reference sensors together and record the value of small reference sensor values. Secondly the force reaching the rated load force of small sensor, the inner cylinder remains the load unchanged, then the outer cylinder starts to load until reaching rated load of the large sensors, and record its value. When the standard machine is unloading, the outer cylinder continues to unload, the force value reaching the rated load force of small sensor, the inner cylinder is unloading.

In order to reduce the load fluctuation of the force standard machine, the hydraulic control system uses a micro oil filling device, which consists of a filling-oil cylinder, a worm gear reducer, a lead screw and a servo motor. Details are shown in Fig.4. The servo motor drives the lead screw through the worm gear reducer, so as to control the front and back movement of the filling-oil cylinder's piston rod. When the servo motor receives the PID control signal, in one case, it pushes the piston rod of the oil cylinder so that the oil pressure inside and outside the cylinder is slight

increased; in another case, it pull back the piston rod of the oil cylinder, so as to reduce the pressure of cylinder slightly. The pump-control hydraulic system enhances the control precision and efficiency, but its dynamic response is not as good as the valve-control hydraulic system.

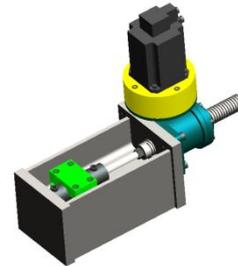


Fig 4

4. METROLOGICAL CHARACTERISTICS

The force repeatability and relative reproducibility error with rotation experiments were carried out by using the high precision force transducer and measuring amplifier. In general, the high precision force transducer meets its performance requirements between 10% and 100% of its nominal load, but cannot guarantee the accuracy when it is less than 10% of its nominal load. For this standard machine, the repeatability experiments were carried out in the range of 0.3 MN-10 MN, C18-4.5 MN transducer, MPZ1804007 transducer, and DMP40 measuring amplifier were used in the tests. The measurements were done in compression direction. The measurement sequence includes three preloading and three measurements at initial mounting position of force transducer (0°), one preloading and one measurement at each of other two rotational positions of force transducers (120° and 240°).

The result of force measure by the 10 MN force standard machine can be described as the following model.

$$\delta = \frac{X_s - X}{X} \times 100\% \quad (1)$$

Where, δ is the deviation of measurements, X_s is the output of the standard dynamometer which used as transfer standard, X is the output of the reference force sensors.

According to the model, the relative standard uncertainty of the force measure result can be calculated as follows:

$$u = \sqrt{u_1^2 + u_2^2 + u_3^2 + u_4^2} \quad (2)$$

Where, u_1 is the uncertainty component which come from the standard dynamometer contribution. u_2 is the uncertainty component which caused by the repeatability of standard machine. u_3 is the uncertainty component which caused by the relative reproducibility error of standard machine. u_4 is the uncertainty component which caused by the instability of standard machine.

The results of repeatability and relative reproducibility error with rotation test are shown in Table.1-Table.2 which are calibrated by NIM, China. The results indicate the repeatability of the machine is better than 2.2×10^{-4} in 3 MN force range segment, 4×10^{-5} in 10 MN force range segment. The relative reproducibility error with rotation of the

machine is not more than 1.3×10^{-3} in 3 MN force range segment, 1.2×10^{-3} in 10 MN force range segment.

Indicating value (kN)	Force repeatability (%)	Relative reproducibility error with	Expanded uncertainty(%) k=2
300	0.022	0.10	0.08
600	0.007	0.09	0.07
900	0.010	0.11	0.08
1200	0.011	0.13	0.08
1500	0.009	0.10	0.08
1800	0.011	0.09	0.07
2100	0.007	0.10	0.08
2400	0.006	0.10	0.08
2700	0.005	0.10	0.08
3000	0.008	0.11	0.08

Table.1 3 MN force range

indicating value (kN)	Force repeatability (%)	Relative reproducibility error with rotation(%)	Expanded uncertainty(%) k=2
1000	0.004	0.12	0.09
2000	0.002	0.09	0.07
3000	0.001	0.07	0.06
4000	0.001	0.06	0.05
5000	0.002	0.06	0.05
6000	0.001	0.05	0.05
7000	0.000	0.05	0.05
8000	0.002	0.04	0.05
9000	0.002	0.04	0.04
10000	0.004	0.04	0.04

Table.2 10 MN force range

5. CONCLUSIONS

This wide measure range build-up force standard machine has the following main features: The driving hydraulic cylinder is composed of two hydraulic cylinders, and they are independently controlled. The reference force sensor is made up of two different capacity reference force sensors, which are respectively install on the two cylinders. The hydraulic control system adopts micro oil supplement by electric cylinder in order to reduce load fluctuation of the force standard machine. 10 MN build-up force standard machine with this type has been established in 2016. It can achieve measure range from 300 kN up to 10 MN. Repeatability of the machine is better than 2.2×10^{-4} , and the load fluctuation less than 2×10^{-4} in 30 seconds.

6. REFERENCES

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