50kNm TORQUE STANDARD MACHINE

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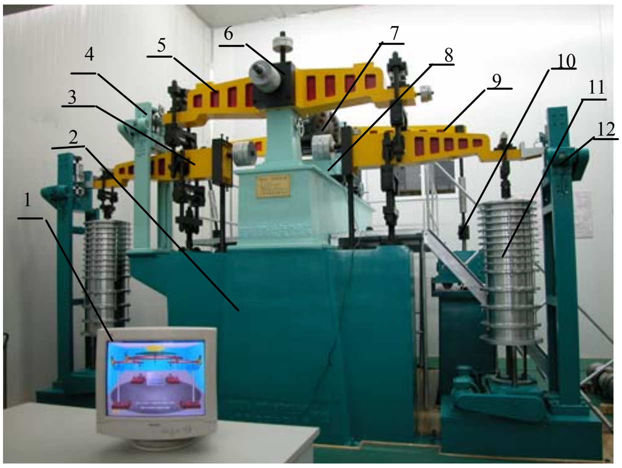
ABSTRACT

The paper introduces the working principle of dead-weight balance type 50kNm torque standard machine , which was developed recently. The paper describes in detail the key technique , etc. such as the knife edge supporting technique with high load , the force magnifing technique , the alignment technique and the computer control automatic loading technique , etc. The paper analyses the uncertainty of the machine and the compared and verifyed data with LNE . The uncertainty of the 50kNm torque standard machine arrives at 0.023%(tp=3.1) .

KeyWords: Torque standard machine, force magnification, couple balance , alignment

1.PRINCIPLE AND CONSTRUCTION

The structure of the machine is given in figure 1.



1-PC 2-Base
3-magnified arm of force
4-displacement transducer
5-standard arm of force
6-knife Edge support
7-calibrated transducer
8-three-dimension working
9-balance arm of force
10-stretch mechanism
11-weight group
12-clamping mechanism

Figure 1: 50kNm torque standard machine

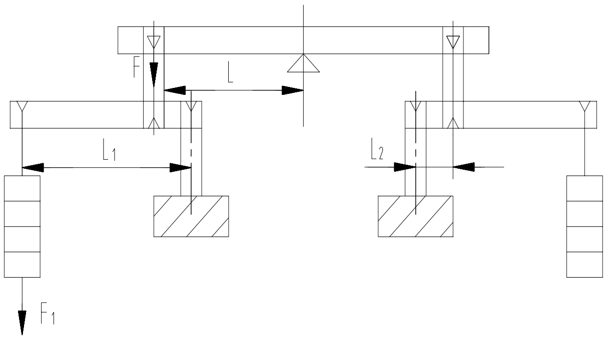
The machine consists of loading mechanism , balance mechanism , alignment adjusting mechanism ,control system and base . It can generate standard torque according to the dead-weight balance weight loading principle , and can apply standard torque to the calibrated torque transducer .The loading mechanism consists of the standard arm of force(5) , the magnified arm of force(3)The weight group and the loading mechanism(11).It can generate the standard torque . The magnified arm of force and the loading mechanism of weight group can magnify the weight force to 10 times , and apply it to the standard arm of force . The balance mechanism consists of balance arm of force(9) and the stretch mechanism for deceleration(10).It can generate the balance torque and pull back the standard arm of force to the horizontal position.

The loading mechanism and balance mechanism can form a standard torque and the latter can be applied to the calibrated transducer . The alignment adjusting mechanism consists of the axis adjusting mechanism , flexible coupling and the three-dimension working platform of transducer(8),and it can make the supporting centre of the standard arm of force knife edge(6),the centre of calibrated transducer (7) and the bearing centre of balance arm of force on the same line . Above mentioned mechanisms are installed on the rigid base (2) .The calibration process is controlled by PC(1),and the mechanism work is controlled automatically according to the order of PLC soft ware.

2. KEY TECHNIQUE

The standard arm of force and the balance arm of force are the symmetrical couple mechanisms The pulling force of balance arm of force is not applied to the base , but to the ground , thereby the uncertainty influence , which is brought from the base deformation due to the balance torque and it is applied to the torque transducer , is eliminated.

The compound arm of force structure is used for arm of force magnification (see figure 2), so the produced force by weight can be amplified to 10 times.



$$F=F_1\times L_1/L_2$$

Where:

F—the force applied to the standard arm

F_1—the force applied to the amplified arm

L_1—the length of amplified arm

L_2—the length of proportional arm

Figure 2 : Compound arm of force

During using the arm of force amplification technique, it must be ensured that the plane of standard arm of force should be paralled to and coin sided with the plane of amplified arm of force.

The knife edge with high strength and large load is used to support the standard arm of force to reduce the frictional moment and raise the sensitivity. It is made of special tool steel. The supporting force of knife edge is 11.5 T, the radius of edge is R=0.3mm. In the case of full load, when 20g weight is put, the standard arm of force starts to swing.

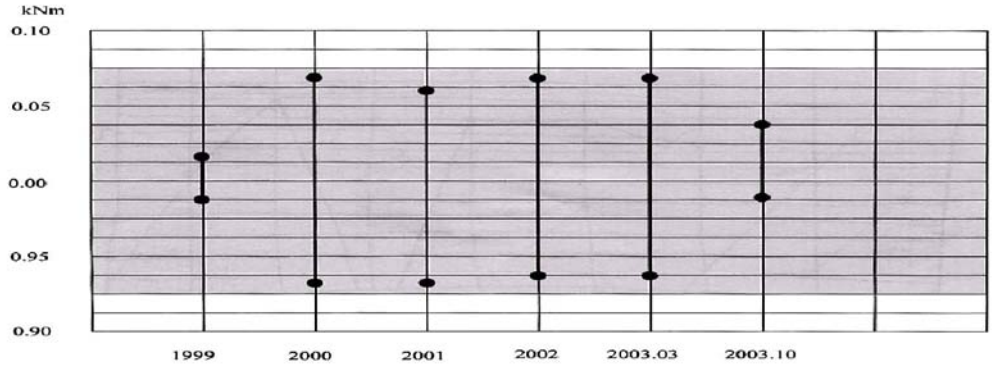
The coaxial requirement of torque transducer, the plane of standard arm of force and the plane of balance arm of force is met. The three-dimension installation platform, the standard arm of force and the balance arm of force are installed on the base with enough rigidity. The installation platform and balance arm of force can be moved on the straight line rolling bearing without clearance. The flexible coupling is used to connect the standard arm of force and the calibrated transducer to eliminate the error ,introduced by the uncoaxiality between the standard machine and the transducer to apply all of the standard torque to the calibrated transducer to make the uncertainty component caused by uncoaxiality arrive at <5×10^{-5}.

The whole process is controlled by PC and PLC. The special software was programmed to display all the structures and working steps on the screen of PC to make the operation become easy. The speed of automatic loading is treated by frequency conversion and the slowest speed is 40mm/min.Therefore, there are not shock and oscillation during loading process.

3. TEST DATA

After adjusting and testing of 50kNm torque standard machine, the HBM 25kNm torque transducer was calibrated on the machine. The result showed that the performance of the transducer was stable. And it was used for checking the transducer for a long time and there are a lot of records for many years.

The error zone of 25kNm (G05218) torque transducer



Note: The allowed error of HBM 30FN torque transducer is ±0.2％;the allowed error of MGC measuring and testing meter is 0.1％.The composed error is taken as 0.3％.The error gone is ±0.075kNm.

The data are as follows:

The tested transducer: T30FN 25kNm (No.G05218) the measuring meter: MGC (No.202675A)

The test date: Oct.31,2003 The temperature: 21℃ The humidity: 60％

Table 1: The loading direction: clockwise (CW)

nominal value （Nm）	Display Value（Nm）									
	loading					unloading				
	1	2	3	average	deviation	1	2	3	average	deviation
0	0	-12	0	-4	-4.0	-12	-7	-7	-8.7	-8.7
5000	5014	5006	5005	5008.3	8.3	5013	5013	5019	5015.0	15.0
10000	10022	10016	10014	10017.3	17.3	10006	10024	10031	10020.3	20.3
15000	15030	15013	15035	15026.0	26.0	15010	15015	15036	15020.3	20.3
20000	20038	20036	20042	20038.7	38.7	20015	20019	20044	20026.0	26.0
25000	25019	25043	25050	25037.3	37.3					

Maximum deviation: 38.7Nm

Table 2 : The loading direction: counter-clockwise (CCW)

nominal value （Nm）	Display Value（Nm）									
	loading					unloading				
	1	2	3	average	deviation	1	2	3	average	deviation
0	0	0	1	0.3	0.3	-1	-3	-2	-2.0	-2.0
5000	5011	5009	5008	5009.3	9.3	5013	5006	5005	5008.0	8.0
10000	10019	10014	10017	10016.7	16.7	10023	10017	10016	10018.7	18.7
15000	15025	15024	15023	15024.0	24.0	15028	15028	15027	15027.7	27.7
20000	20033	20032	20031	20032.0	32.0	20035	20031	20033	20033.0	33.0
25000	25039	25037	25037	25037.7	37.7					

Maximum deviation: 37.7Nm

Form the above two groups of data we may know that the maximum deviation of calibrated data of transducer on 50kNm torque standard machine is 38.7Nm,less then the error gone (75Nm).It is proved that the performance of 50kNm torque standard machine is good and it's all specifications are within the standard range.

4. UNCERTAINTY　EVALUATION

Calculation of uncertainty:The uncertainty component was analyzed according to the independent variable parameter of mathematical model. The A grade and B grade evaluation methods were used. From the mathematical model we know that each variable is independent and has no relation to each other. The sensitivity factor is Cj=1.

Table 3 : The relative uncertainty component of 50kNm torque standard machine

No		Influence quantity	component	grade	Distribution Factor	Uncertainly component	Degrees of Freedom
length	1-1	Length of arm of force Δl	Δl_l=0.01215mm	B	$\sqrt{3}$	$U_{l1}=7\times10^{-6}$	50
	1-2	Length of magnified arm of force $\Delta\eta$	$\Delta\eta$=0.0001	B	$\sqrt{3}$	$u_\eta=5.8\times10^{-5}$	50
	1-3	Full load flexibility of arm ΔL_1 and horizontal deviation ΔL_2	ΔL_1=15mm ΔL_2=0.02mm	B	$\sqrt{3}$	$u_{L12}=3.5\times10^{-7}$	50
	1-4	Change of temperatureΔL_T	$\Delta L_T=6\times10^{-5}$m		$\sqrt{3}$	$u_{LT}=3\times10^{-5}$	10
	1-5	Uncoaxiality of clamping head and knife edge ΔL_3	ΔL_3=0.05mm	B	$\sqrt{3}$	$u_{l1}=2.9\times10^{-5}$	20
force	2-1	Weight forceΔm	Δm=0.5mg	B	$\sqrt{3}$	$u_m=5.8\times10^{-7}$	50
	2-2	Acceleration of gravity Δg	$\Delta g=0.0001 m/S^2$	B	$\sqrt{3}$	$u_g=1.51\times10^{-5}$	6
	2-3	Temperature influence on material density and air density$\Delta\rho$	$\Delta\rho=2.61\times10^{-5}$	B	$\sqrt{3}$	$u_a=1.3\times10^{-7}$	6

	2-4	Swing of weightΔα	Δα=2.7×10^{-7}	B	$\sqrt{3}$	U_{11}=7×10^{-6}	10
friction	1	Influence of friction moment on idle load and full load Δf	idleload×10^{-3}Nm Fullload×10^{-1}Nm	B	$\sqrt{3}$	u_f=6×10^{-7}	10
Alignment degree	1	Uncoaxiality of arm plane centre and plane centre of arm force Δδ	Δδ=0.02mm	B	$\sqrt{3}$	u_δ=1.2×10^{-5}	10

$u_l=\sqrt{u_{L1}^2+u_n^2+u_{L12}^2+u_{L13}^2+u_{LT}^2}=0.65\times10^{-4}$ $u_f=\sqrt{u_m^2+u_g^2+u_f^2+u_d^2}=0.15\times10^{-4}$

$u_c=\sqrt{u_L^2+u_F^2+u_f^2+u_\delta^2}=0.74\times10^{-4}$

The effective degrees of freedom is $V_{eff}=u_c^4/\sum(\frac{u_i^4}{V_i})=86.43$ p=0.9973 tp(86)=3.1

The expanded uncertainty is $U=3.1\times0.74\times10^{-4}=2.3\times10^{-4}$

Conclusion:The expanded uncertainty of 50kNm torque standard machine is

U=2.3x10^{-4} tp=(8.6)=3.1

5. INTERNATIONAL TEST AND VERIFICATION

In order to test and verify the technical data, we have developed the companion transducer (No.95020), the torque measurement meter (No.3.2) and the comparison shaft (No.4.1 Φ=130mm) for testing and verifying 50kNm torque standard machine. The machine was verified in the LNE national mechanics laboratory of France in 2003.And it was verified with the same transducer, torque measuring meter and the shaft for comparison in 2004.The comparison of the data got from each comparing showed that the performance of 50kNm torque standard machine was stable. The concrete data are as follows:

Table 4 : The loading direction:clockwise (CW)

Nominal value （kNm）	LNE (kHz)	SMERI (kHz)	$\Delta_{SMERI-LNE}$ (%)	LNE U_{LNE}	SMERI U_{SMERI}	W_{ILC}	E_n
10	3.480	3.480	0.02	0.00370	0.00057	0.00749	0.03
20	6.961	6.956	-0.06	0.00360	0.00036	0.00724	0.08
30	10.443	10.435	-0.08	0.00367	0.00030	0.00736	0.10
40	13.923	13.906	-0.12	0.00350	0.00026	0.00702	0.17
50	17.404	17.377	-0.15	0.00360	0.00029	0.00722	0.21

Table 5: The loading direction:counter-clockwise (CCW)

Nominal value （kNm）	LNE (kHz)	SMERI (kHz)	$\Delta_{SMERI-LNE}$ (%)	LNE U_{LNE}	SMERI U_{SMERI}	W_{ILC}	E_n

10	3.477	3.466	-0.29	0.00370	0.00042	0.00745	0.39
20	6.950	6.929	-0.31	0.00360	0.00030	0.00723	0.42
30	10.423	10.393	-0.29	0.00367	0.00028	0.00735	0.40
40	13.892	13.856	-0.26	0.00350	0.00026	0.00702	0.37
50	17.363	17.317	-0.26	0.00360	0.00030	0.00723	0.37

Above mentioned comparison procedure and data treatment and analysis all were carried out in accordance with the “Europe International Comparison Draft” and the : EA10/14 “Calibration guide for the static torque measurement device”. According to the stipulations, when the comparison criterion is En≤1, that means the standard machine

on which the comparison was carried out, has arrived at the specified technical index. And from the comparison result we could see that Enmax=0.45≤1, therefore, the comparison result of 50kNm torque standard machine could meet the technical requirements, i.e.

$U=2.3\times10^{-4}$ tp=3.1

Note: $En=\frac{|\Delta_{SMERI-LNE}|}{W_{ILC}}$

6. CONCLUSION

The uncertainty of 50kNm torque standard machine has arrived at U=0.023 %(tp=3.1). And the practices also indicate that its performance is stable and the operation is convenient.

The new ideas used in the machine are : The compound arm loading device is uesd. So, the weights have been reduced to 1/10 of original numbers, the cost has been saved and the volume of machine has been shortened. The key techniques, such as the parallelism, verticality, the swing and the sensibility of main and secondary arms all attained the design goal.

The couple balance type used in the machine makes the support point of balance force falls on the ground, but not on the base of machine, so the machine can bear only positive pressure without any torsion deformation and the stability of the machine has been increased during the loading process.

The alignment technique i.e the alignment of the arm plane axis and the balance arm plane axis requires the six degrees of freedom of axis should be the same .Thinking of this problem , the precise guide track was used during the design and process to limit the error , therefore , the produced errors were within 5×10^{-5} .

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