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DEVELOPMENT OF THE NEW LNE 5 kN.m DEADWEIGHT TORQUE STANDARD MACHINE

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Abstract: This paper describes the new LNE 5 kN.m deadweight torque standard bench. Information on the design, development, and commissioning of this standard are given. Its design is described focusing on mechanical and metrological characteristics. In particular, three components, developed by LNE, are described: First, the double arm lever, one for deadweight force transmission and the other for localization of this force Then, the air bearing based on used of porous material. Finally, the system should enable us to avoid the wrinkling of the tape related to the positioning of the force at the extremity of the lever arm. The attention given to these elements enables to consider uncertainties compatible with the primary national reference function.

Keywords: calibration measurement torque standard.

1. INTRODUCTION

The development of the torque standard machine of 5 kN.m is part of a wider scheme which aims at updating French metrological references in torque metrology. Indeed, the design of the current calibration benches is outdated and these do not meet calibration needs of the standards used by the mechanical engineering, aeronautics, defence and energy industries. The *Laboratoire national de métrologie et d'essais* is conducting this project which involves the development of several machines: 5; 50; 500 and 5000 N.m. The latter will make the link with the LNE high capacity 200 kN.m. torque standard machine.

So as to gain sufficient experience in designing the new machines, we first developed the 50 N.m one, presented in articles [1] and [2]. This enabled us to validate the selected concepts to be used for the developement of the other machines. The manufacturing of the 5 kN.m (fig 1) was launched afterwards.

After a general description of the bench, the next sections introduce the different steps taken to develop this 5 kN.m machine: the deadweights, the lever arm, the air bearing and the anti-wrinkling system.

2. PRESENTATION OF THE MACHINE

This machine is based on the same principle than the 50 N.m machine [1] which was used as a validation base for the solutions. Therefore, this is a deadweights and lever arm type of machine. Forces are generated by the action of gravity on weights and are applied to the extremity of a rotating mobile lever arm. The lever arm is supported in its centre part by an air bearing.

The torque measuring device to be calibrated is located between the arm supported by the air bearing and the reduction gear used to compensate the torsion angle of the torque transducer and activate loading.

The general structure of the machine was designed with large dimensions to ensure rigidity and limit deformations. The aim is to minimize the interfering efforts applied to the torque transducer to calibrate. Thus, the structure enables to ensure a concentricity of ± 0.05 mm between the rotation axis of the lever arm and the rotation axis of the drive system. This tolerance is kept for all adjustments of the workshop, for which the maximum dimension is important : diameter of 1 m x length of 1 m.

Fig 1 : The new LNE 5 kN.m deadweight torque standard machine

3. THE WEIGHTSTACK

Two weightstack were manufactured and placed on both extremities of the lever arm to apply torques either on the left or the right side.

These stacks are strictly identical to the ones developed for the LNE deadweight torque standard bench of 5 kN [3]. They are made of a series of amagnetic stainless steel disks that are sequentially hanged to each other depending on the height of the weight carrier (fig 2).

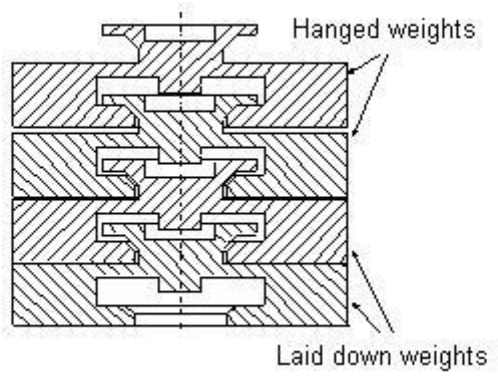

Fig 2 : Weights of 5 kN.m bench

Each stack is composed of the same series of the following 22 disks:

- 10 disks each creating 100 N ;
- 2 disks each creating 200 N ;
- 2 disks each creating 100 N ;
- 2 disks each creating 200 N ;
- 6 disks each creating 500 N.

This particular lay out enables to conduct loadings with intervals of 100, 200 or 500 N.m, by increasing or decreasing load values over approximately ten bearings with only one motorization. This allows us to respect the international practices regarding calibration of torque transducers with a capacity of 1 kN.m ; 2 kN.m and 5 kN.m.

The loading platforms are mounted with triggers stop. Their functioning is detailed in the article [1] for the presentation of the 50 N.m bench. The advantage of these triggers is that they ensure a progressive load without surges with improved loading times.

4. THE LEVER ARM

The arm must fulfil two essential roles with regard to the vertical forces generated by the weights: transfer them to the torque transducer and position them at a controlled distance of the rotation axis.

The solution adopted consists in uncoupling these two functions by doubling the arm: one being used for transferring the effort and the other being used for keeping the distance. This solution, considered for the 50 N.m bench (cf. [1]), is particularly relevant for substantial efforts, as it is the case for the 5 kN.m bench.

Indeed, for optimal mobility and sensitiveness qualities, the arm must be as light as possible with a gravity centre close to the rotation axis. It should also be rigid to ensure the positioning of the force even when loaded at full capacity. This search for rigidity has a tendency to increase the weight of the arm and therefore to deteriorate its mobility and sensitivity. The doubling of the arm is a solution to this incompatibility.

The weight of an Invar arm (cf. figure 3) is lightened because it cannot withstand effort. It allows the right positioning at a meter from the rotation axis of a tape through which the efforts generated by the standard weights propagate. This tape is held by a second arm in aluminum alloy (cf. figure 3). This second arm is also lightened and its bending, even when it is significant, do not impact on the positioning of the tape held by the Invar arm.

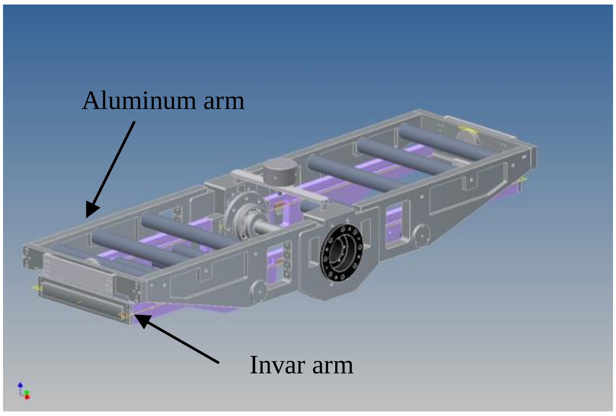

Fig 3 : Double arm of 5 kN.m bench

The double arm is 2 meter long and is supported in its centre by an air bearing presented in next section.

5. THE AIR BEARING

The use of an air bearing enables to reduce friction a a minimum. This bearing was manufactured from a pad in porous material made from carbon (cf. figure 4). The advantage that it has over media air bearings is that the air pressure is more homogenous over the whole surface with a limited air flow. The maximum radial load is 11 kN, which mean 7 kN more than the weight of the arm. Additional pads enables to rectify radial efforts (up to 1 kN). Tests allowed us to estimate the mobility : it is inferior to 2 mN.m.

The main difficulty during the manufacturing of the bearing was the machining of the rotor. The functioning operation between the rotor and the pads constitutive of the stator is in the order of 0,01 mm. To adapt to the diameter of the pads, the diameter of the rotor was adjusted to a target value of 500 mm with a tolerance of ± 10 µm. This lead to measuring it during the machining with an inferior uncertainty. To do so, a benchmark rule of 500 mm was used. It was associated to a specific mechanical installation implementing contactless displacement pick-up. This installation enabled to control the rotor without taking apart the machining bench.

A protection for the surface of the rotor was created by hard anodizing which added a machining oversize of important thickness (20 μm). It allows a greater resistance to abrasion.

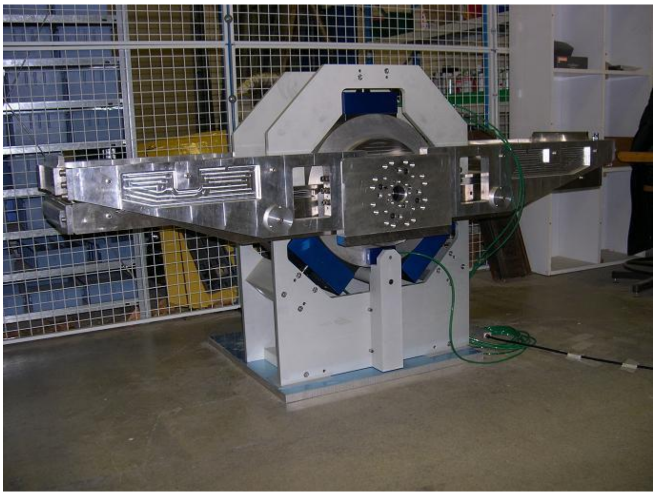

Fig 4 : Double arm mounted on the air bearing

6. THE ANTI-WRINKLING SYSTEM

As mentioned above, a tape is attached to each extremity of the aluminum arm. It is placed at 1 meter of the rotation axis by the Invar arm which is not sensitive to temperature variations.

The initial thickness of the stainless steel tape is 0.07 mm but it is possible to conduct tests with different thickness and materials if needed.

This tape is compressed between two plates. Under the effect of the tensile strength generated by the weights in the gravity field, this tape is deformed and stretches vertically as it horizontally shrinks. Of course, the extent of this phenomenon depends on the elasticity characteristics of the material defined by its Young's modulus (in the same direction than the force) and by its Poisson's ratio (perpendicular).

This horizontal shrinking could lead to wrinkling (cf. examples in figure 5) which could hamper the contact with the positioning arm in Invar.

Fig 5 : Wrinkling observed on an other bench

An innovative system that allows to avoid the wrinkling of the tape was studied. This system consists in gripping the tape between two deformable pieces (cf. figure 6). This leaves a transversal freedom of movement to the tape, while allowing the transmission of vertical efforts.

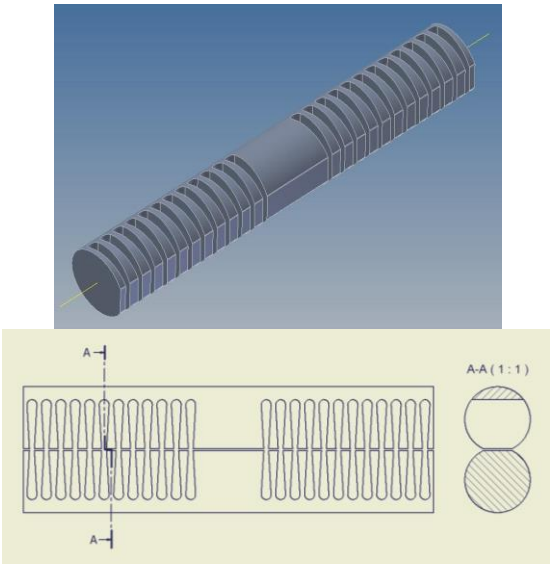

Fig 6 : Deformable grip

Furthermore, the clamping should be distributed evenly throughout the width of the tape. The system under consideration implements a double row of balls (cf. figure 7). It allows to equilibrate the effort through the optimization of the setting angle.

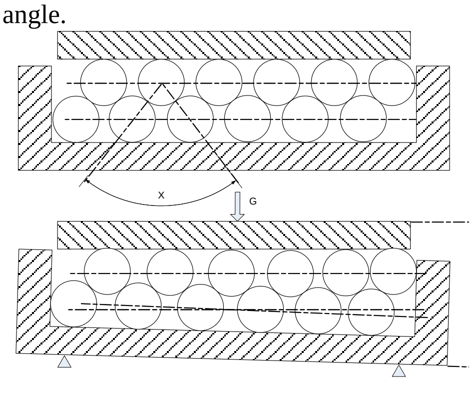

Fig 7 : Deformable grip

The entire system (deformable grip and rows of balls) will be manufactured is needed, depending on the estimation of the uncertainty components in relation to the wrinkling effect.

7. OPERATING THE TORQUE STANDARD MACHINE

The operation mode is that of the LNE force standard machines (500, 50, and 5 kN) as well as the mode of the couple machine 50 N.m.

For all basic functions, the machine is operated by a programmable automatic control. The latter is operated by a computer which acts as an interface with the user. A specially designed software makes the programming adjustable according to the type of calibration to perform.

Moreover, the automation of calibrations is possible with the recording of values for the sensor being calibrated through the use of a camera and a character recognition system.

8. CONCLUSION

The machine was assembled completely. Its metrological qualification is on its way with, first, internal comparisons with the LNE machines that it will replace. Comparisons on an international level are then scheduled. The geometrical quality of the machine and the functioning quality of the air bearing allowed us to think about making additions to the product range in which this 5 kN.m bench belongs. The manufacturing of 500 N.m weightstacks and of an exchange system for the weightstacks have already been launched.

With the 5 and 50 N.m machines [1 and 2], these new 500 and 5000 N.m machines will enable us to meet the connections needs with the best uncertainties required for the needs of manufacturers.

9. REFERENCES

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