DEVELOPMENT OF MULTICOMPONENT FORCE TRANSFER STANDARDS BY ONERA FOR FRENCH BNM

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SUMMARY
This paper describes three force transfer standards built for the comparison of the various force standard machines developed in France by ONERA for BNM (National Bureau of Metrologie).

The first one measures the compression axial force up to 300 kN and three moments. The second one, of same capacity in traction, measures the six components, and the third measures only the axial force up to 50 kN in traction but is unsensitive to the other components.

Their sensitivity makes it possible to appreciate variations of axial force of a few $10^{-5}$ of their maximum value and for the two 300 kN dynamometers, force, off-centering of about 0.3 micron for the first one and 0.02 micron for the second.

1. INTRODUCTION
Since the recommendations given by the Technical Committee IMEKO "Measurement of force and mass" in The Hague in september 1971, one component strain gauge dynamometers have been generally used as force transfer standard in many countries, to qualify and compare various force standard machines and material testing machines [1 to 6]. But some defects in construction, machine assembly or connection between bench and dynamometer (off-centering, inclinations, faulty planeity, insufficient stiffness, backlash...) can generate, under the action of the applied force, parasitic components and erroneous measurements. To quantify errors and bring corrections on axial force, it is necessary to measure simultaneously the main component and the eventual parasitic components (fig. 1).

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<th>DETECTING AND ELIMINATING OF THE INTERACTIONS</th>
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<td>H. Wieringa (ed.), Mechanical Problems in Measuring Force and Mass</td>
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<td>© Martinus Nijhoff Publishers, Dordrecht 1986</td>
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That is the reason why, as early as 1975 the French National Bureau of Metrology (BNM) decided to develop multicomponent force transfer standards to qualify and compare the French force standard machines in order to increase the national level of quality. Their qualities (linearity, repeatability, stability vs. temperature) have to be such as the accuracy of the axial force measurement is better than $1 \times 10^{-4}$ of the capacity. The experience acquired by ONERA in the field of dynamometry and the qualities of the various force machines operating at the Modane center [7 to 9], have led the BNM to entrust it with the study, equipment and qualification of a first then two others force transfer standards of different shapes and capacities.

The first dynamometer, studied and manufactured in 1976-1977 works in compression up to 300 kN and measures four components: the main axial force and the three moments. It was presented at the IMEKO.TC 3 conference at ODESSA in 1977 [10] [11]. It has been used in 1979 to compare the three French force standard machines, of capacities 250-300 kN approved by the BNM, belonging to the Laboratoire National d'Essai (LNE), Etablissement Technique Central de l'Armement (ETCA) and ONERA Modane. The results of this comparison were given at the 8th IMEKO.TC 3 at KRAKOW in 1980 [13]. Among the very interesting results, it was demonstrated that it would be better to use a dynamometer measuring six components in order to determine, completely, all parasitic efforts acting on the transfer standard and to obtain the best precision in the main force measurement.

Taking advantage of this experience, a second 300 kN transfer standard was studied in 1981. It works in traction and can measure the six components of efforts.

The third force transfer standard is defined by BNM to be used by manufacturers to calibrate their material testing machines. It is more simple and cheaper. It measures only the axial force up to 50 kN in traction and includes elastic flexures so that parasitic components do not affect the measurement. It was realised in 1980.

These three standard dynamometers are characterized by a structure designed by ONERA PARIS by means of the finite elements calculation. The architecture is realised by electro-erosion in a single block of metal. It is rigid along the longitudinal axis for the main component and well uncoupled in regard to the other components. The central part measuring the main force, works in shear that give the advantage of high rigidity, better sensitivity and linearity in regard to the other means of working (tension, flexion).

Experimental studies undertaken by ONERA several years ago [7, 8] had shown that the Z.85 WD V6 fast steel was the best material on creep and hysteresis point of view. But this alloy is very expensive and difficult to elaborate for great size dynamometers. That is the reason why the three force transfer standards were manufactured in the V.300 carbon steel (45 S.CD 6) well known by ONERA. According to the fact that transfer standards should be used only in one sense (traction or compression) the elastic defects are so tolerably reduced. The V.300 steel used was, vacuum cast, forged, then thermally treated so that ultimate strength be $1600$ M.Pa.