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VALIDATION OF THE 5 kN FORCE STANDARDS MACHINE OF THE AEROSPACE TECHNICAL CENTRE OF BRAZIL – FIRST PHASE

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Abstract: This paper presents the methodology and results of an interlaboratory comparison currently in progress for the validation of forces generated by the 5 kN force standards machine (MCCC) designed and manufactured for the Low Force Laboratory (LBF) of the Aerospace Technical Centre (CTA), Brazil. Reference forces were generated by the 5,2 kN force standards machine of the Isaac Newton Laboratory of the Technological Centre Foundation in the State of Minas Gerais (CETEC). Results obtained in the first phase of the intercomparison have shown that the errors and the best measurement capability are larger than expected. Further investigation in the MCCC initial nominal range is to be carried out in the second phase of the comparison.

Keywords: force, intercomparison, standards

1. INTRODUCTION

The Low Force Laboratory (LBF) of the Brazilian Aerospace Technical Centre (CTA) is responsible for the calibration of force transducers used in aerodynamic testing. The force transducers are coupled to the aerodynamic external six-component balance of the wind tunnel no. 2 - TA-2 (Fig. 1). The external balance supplies the aerodynamic forces and moments that act on the model being tested (Fig. 2).

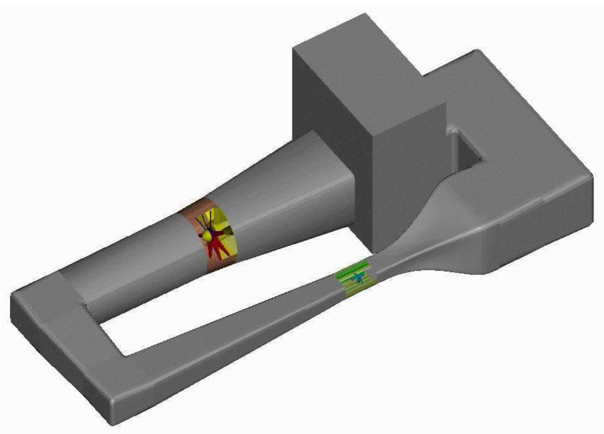

Fig. 1: The TA-2 wind tunnel.

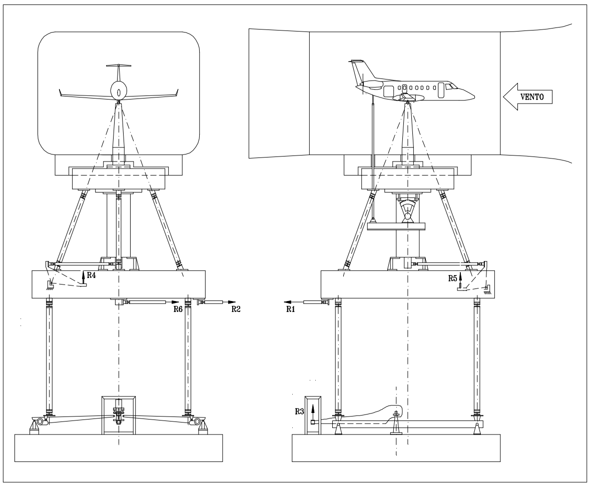

Fig. 2 - TA-2 external balance. $R_1,\ldots,R_6$ represent load cells.

The information supplied by ground testing is employed in aeronautical projects for several proposals, including the optimization of designs, the determination of the stability characteristics and the setting of the aerodynamic data base to be used in flight simulation. The quality of data derived from the force transducers used in the external balance exerts a direct influence on the accuracy and uncertainty associated to the wind tunnel tests, therefore it is fundamental that they are reliable and that the uncertainties in their calibration are suitably assessed. In addition to data reliability, transducer calibration time is important in order to keep research projects within budget and schedule limits. These performance demands were considered by the LBF engineers and a Load Cell Calibration Machine (MCCC) was designed (Fig. 3) in order to readily obtain load cell calibration. An interlaboratory comparison between LBF and the Isaac Newton Laboratory of the Technological Centre Foundation in the State of Minas Gerais (CETEC) is in progress with the aim of validating forces generated by the machine.

Fig. 3 - View of MCCC

1.1. MCCC characteristics

MCCC is capable of generating tension and compression forces up to 5.5 kN in steps of 10 N, by manual addition of up to 50 weights of nominal masses 1 kg (5 pieces), 2 kg (5), 5 kg (10), 10 kg (10), and 20 kg (20).

One of the MCCC design features is the possibility to receive the transducer for calibration mounted on its own case, to assure mechanical alignment when coupling to the aerodynamic balance.

Figure 4 shows a schematic diagram of MCCC. Tension forces are generated by transferring weights directly to the force application shaft of the machine, whereas compressive forces are generated with the aid of a multiplication lever.

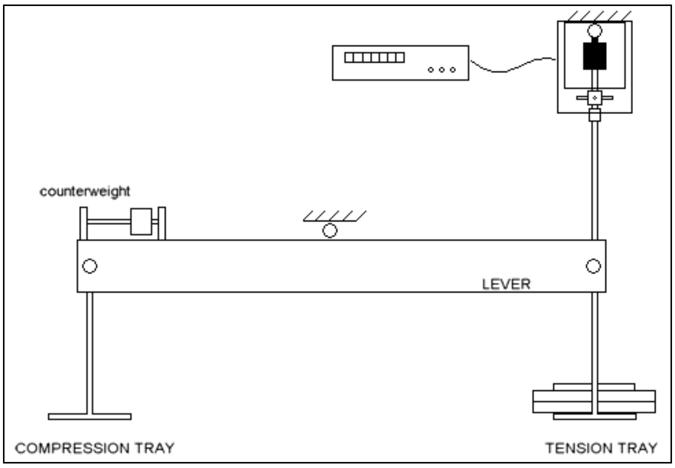

Fig. 4 - MCCC schematic diagram

Table 1 presents the nominal forces object of the first phase of the intercomparison.

Table 1 – Intercompared Forces

Nominal	Number of weights – (nominal mass / kg)				
force / N	1	2	5	10	20
50			1		
100			2		
150			3		
250			5		
550		1	1	5	
600		1	2	5	
650		1	3	5	
750		1	3	5	
950		1	3	6	
2000				1	10
2500				2	12
3000				3	14
3500				4	16
4000				5	18
4500				6	20

1.2. Forces realised by the Isaac Newton Laboratory

Isaac Newton Laboratory realises forces up to 50 kN by means of dead-weight standards machines. Forces above this value, up to 1 MN, are realised with reference force transducers and Morehouse universal calibration machines. The dead-weight machines are two Morehouse devices, of nominal ranges 5.2 kN (MGL) and 50 kN (MNZ), and a 110 N machine, developed by the Laboratory [1]. Reference force transducers are 42 HBM devices which are coupled to signal conditioners of the same make. In this case, forces are continuously realised in the range 10 N to 10^6 N. Forces are traceable to the Brazilian reference standards maintained by INMETRO. Declared best measurement capabilities are 100 ppm and 200 ppm, respectively.

2. METHODOLOGY

The interlaboratary comparison was originally conceived as a one phase study. It aimed at the evaluation of the MCCC errors and best measurement capability [5]. Due to deviation from the reference values in the initial range of the machine, a second phase will be conducted in order to finally characterize the machine.

In each phase, MCCC and MGL compressive and tensile forces up to 5 kN are compared in three measurement cycles, as described in literature [2]. In the first cycle, reference HBM transducers coupled to an HBM-DMP40 signal conditioner are calibrated by the Isaac Newton Laboratory against MGL, to act as transfer standards. The second cycle consists of the calibration using MCCC forces and the third cycle comprises the re-calibration of the transducers at the Isaac Newton Laboratory. All measurements are conducted by a same operator of the reference laboratory.

2.1. Loading and measurement cycles

Each cycle is made up of 10 measurement series in four positions of the transfer standard, relative to the machine. Forces are chosen to cover the 40-100% range of each transfer standard, in order to minimise the influence of parasite components derived from the transducer-machine interaction [3].

Figure 5 and Figure 6 are respectively a schematic representation of the loading positions and of the measurements carried out for each cycle. The latter represents the ideal situation in which a transducer is calibrated at every 10% step.

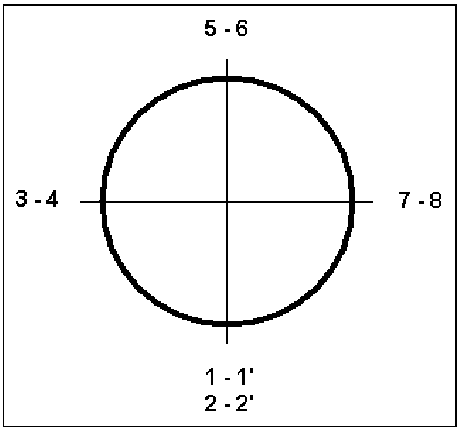

Fig. 5 - Loading scheme

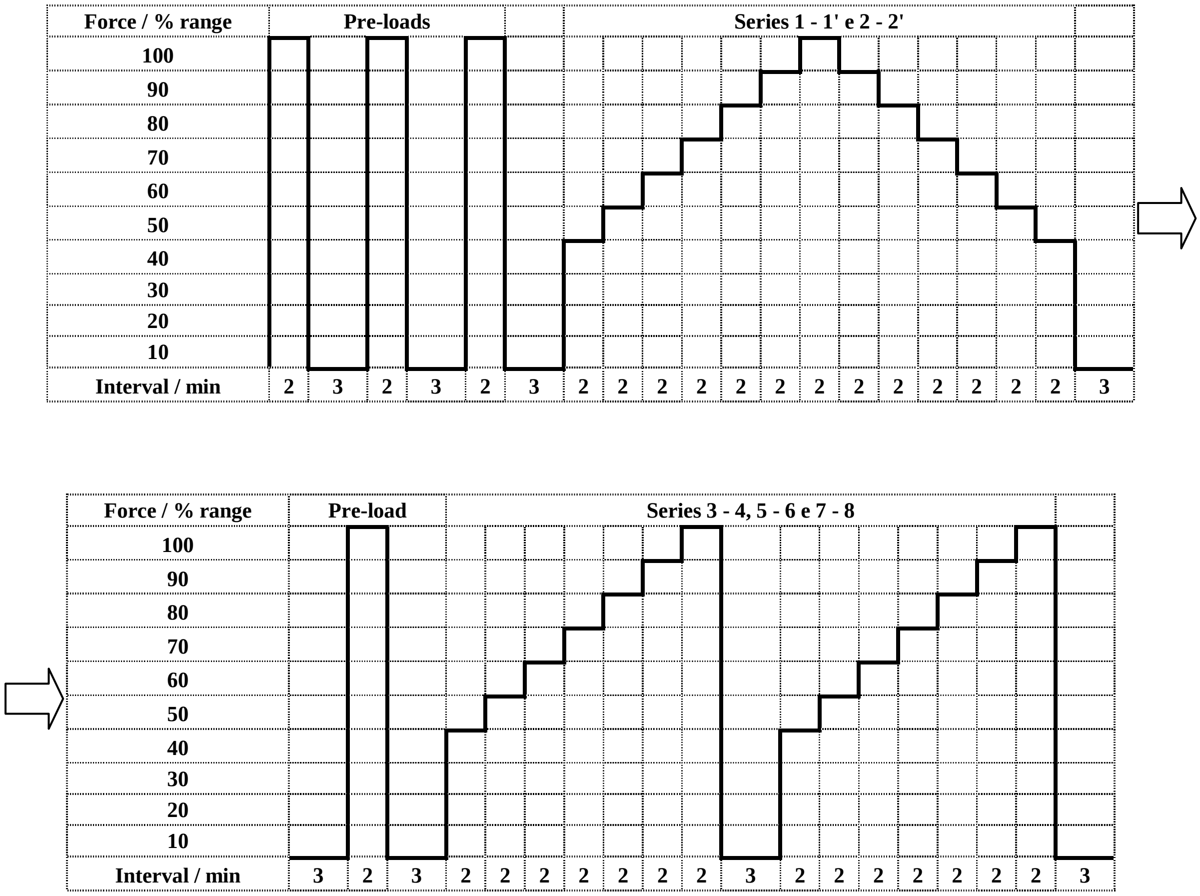

Fig.6 - Measurements

3. RESULTS

Measurement results were analysed using an established methodology, which consists of: (i) an estimation of the uncertainty of the reference values, based on the uncertainty of force values generated by the reference machine (MGL), and the repeatability and change of sensitivity presented by the transfer standards; and (ii) an assessment of the error of the forces produced by the validating machine plus an estimation of its best measurement capability [4, 5]. The latter takes into consideration the influences of the uncertainty of the reference forces, measurement error, lack of repeatability, and hysteresis.

Figures 7 through 12 present the results obtained in the first phase of the intercomparison.

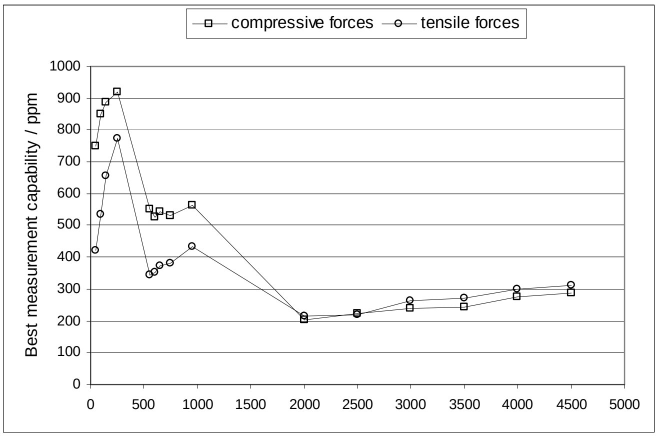

Fig. 7 - All forces - best measurement capability

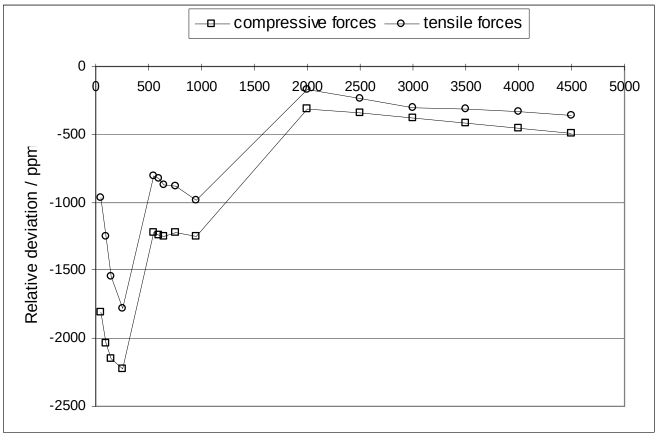

Fig. 8 - All forces - relative deviation

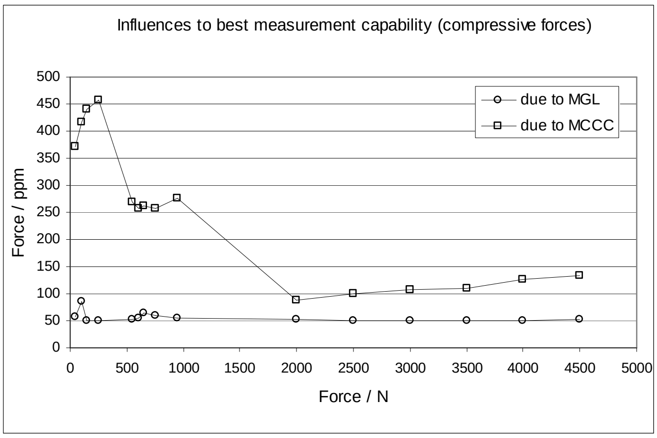

Fig. 9 - Compressive forces - influences to BMC

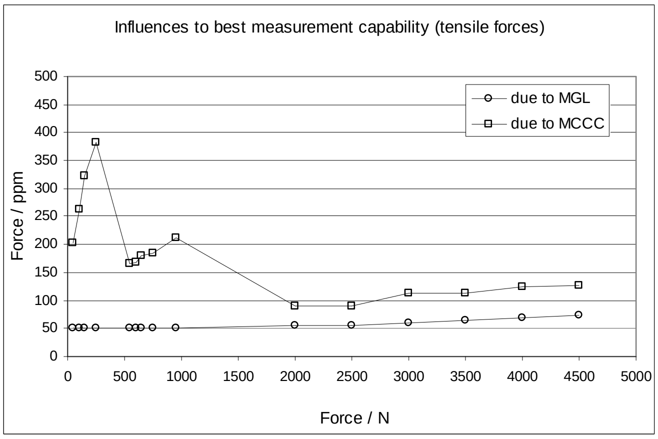

Fig. 10 - Tensile forces - influences to BMC

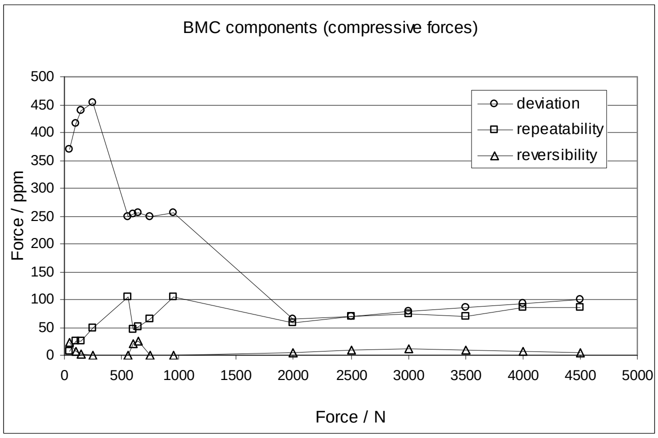

Fig. 11 - Compressive forces - influences to BMC

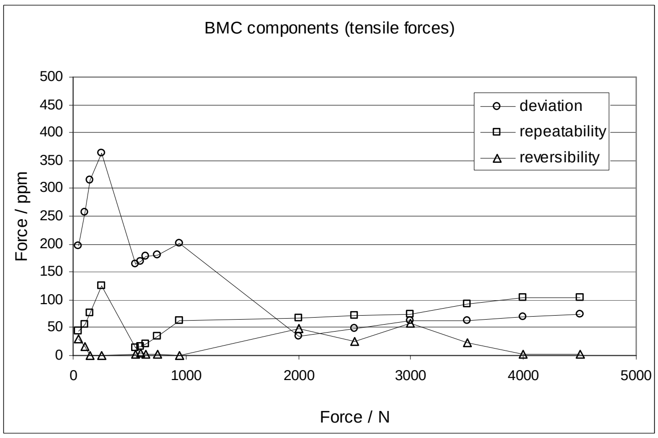

Fig. 12 - Tensile forces - influences to BMC

4. DISCUSSION

Figures 7 and 8 clearly show that MCCC present values for best measurement capability and relative deviations higher than expected, that is 100 to 500 ppm, typical of lever-amplification force standards machines [5]. Moreover, figures 9 and 12 show that high best measurement capability errors are mainly due to MCCC internal causes. Finally, figures 11 and 12 suggest that deviation errors are the main causes of higher values of best measurement capabilities.

5. CONCLUSIONS

Results obtained in the first phase of the intercomparison suggest a MCCC project revision in order to lower both the relative deviations and best measurement capability obtained by the machine. Nevertheless, a further investigation of the initial force range of the machine must be accomplished, to cover the scope of the second phase of the intercomparison, to be started in early 2006.

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