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DESIGN AND CALIBRATION OF A SIX-COMPONENT DYNAMOMETER USED IN AN AERODYNAMIC TUNNEL

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IN MEMORIAM (instead of an abstract)

The present paper is dedicated to the memory of our former colleague Liviu Crudu, who recently passed away, leaving behind many projects he enthusiastically designed. Doubtlessly, Liviu has always been among the most intellectually gifted people, curious and enthusiastic to acquire up-to-date information related to this profession. Since the first working day of his professional career, he proved to be not only a very hard working person but also a very inventive one. His collaboration and leadership skills were always truly impressive, and his capstone project on designing the six-component dynamometer described in the present paper won glowing reviews not only from his peers but also from the other faculty members.

Keywords: force dynamometer, moment dynamometer, naval aerodynamic tunnel, six-component dynamometer

1. INTRODUCTION

The aerodynamic tunnel is one of the essential equipment for naval, aviation and also civil engineering research. Basically, this equipment consists of a rectangular section of measurement where the specimen subjected to experiments is placed at the ends where there is an input section and an output section and where the fan is mounted to create the air flow. This air stream, depending on the type of experiment, may vary its flow rate.

The paper presents one of the main elements of such an aerodynamic tunnel, namely the System for Measuring the Forces and Moments (SMFM) that arise from the flow of air at various speeds around the test specimen.

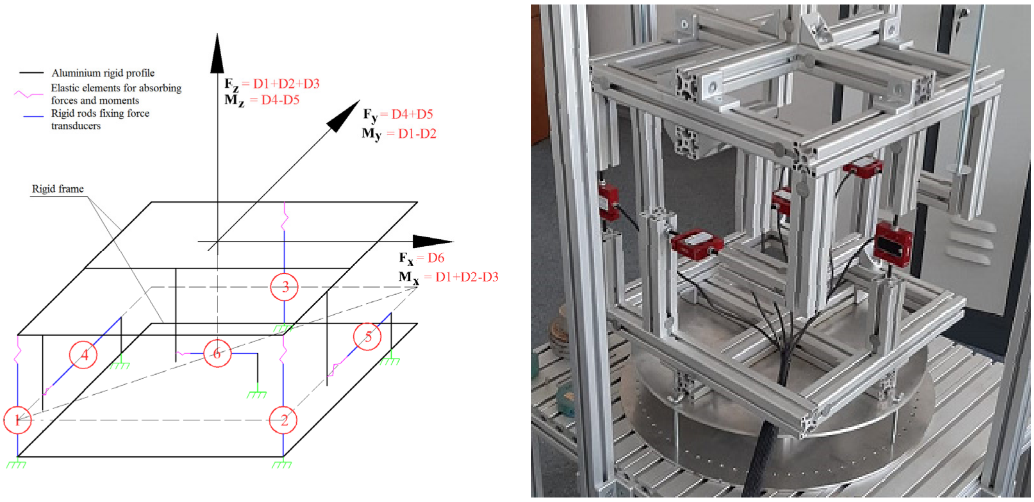
These forces and moments that arise as reactions in the SMFM are needed especially for architects and builders to have knowledge of the type and size of the foundation of the de-signed structures. The need for optimal ships, aviation and civil structures design is an open competitive field that has conducted many companies and research institutes to everlasting investments into new, better, cost-effective and improved equipment for laboratories worldwide.

In order to measure the loads (forces and moments) that arise when a fluid circulates around a structure, it is necessary to have a SMFM with six components in each aerodynamic tunnel [1]. The components to be measured are forces and moments on the axes of coordinates. This SMFM structure must be designed so that the measurement of a load in one direction is not influenced by the values of the components in the other directions. This involves minimizing the influence of the stress applied to the system in one direction of the components after the other directions. Influences should be eliminated as much as possible from the design and execution phase of the system because in the calibration phase this operation is impossible to achieve.

2. DYNAMOMETER STRUCTURE

In order to achieve the desired goal, a constructive scheme for the SMFM was conceived [1]. Structurally, this is shown in Figure 1 a). Figure 1 b) shows the system realized. It is built of euro aluminum profiles with special grips between the constructive elements. In the composition neutral system, there are 6 force transducers. They are inductive and can be operated in one direction, so they can measure a force. The arrangement of these transducers in the measuring system, which constitutes the body of the 6-component system, was made in such a way that if a load is applied in a certain direction, the request would be made only in one direction.

As shown in Figure 1 b), the transducers are those colored in dark red.



a) 6-component system design **b)** system with 6-components realized

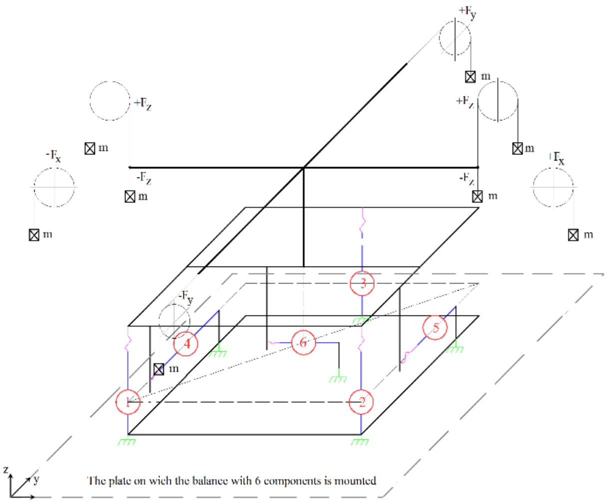
Figure 1. The structure of the system with 6 components

The connection between the transducer body and the rigid frame of the swing is made by means of M6 screws fixed to the system body by means of special parts that are used to join the euro profiles. M6 bolts are of such lengths that measurement errors due to their own elasticity are as small as possible.

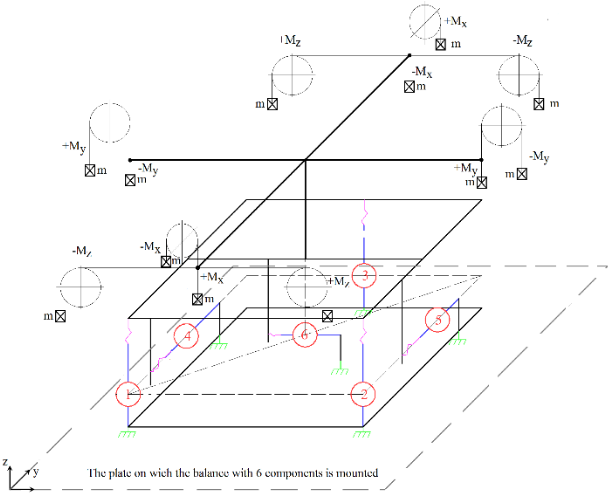
3. LOADING SCHEMES

Before using the 6-component system for any category of experiments, it should be calibrated. This calibration is done by successively charging in various directions and reading the records from the measurement transducers. The recorded signals are in V (volts). In Figure 3, where the calibration graphs for the six components of the system are represented, the load is given in the units of measurement of the transducers (volts).

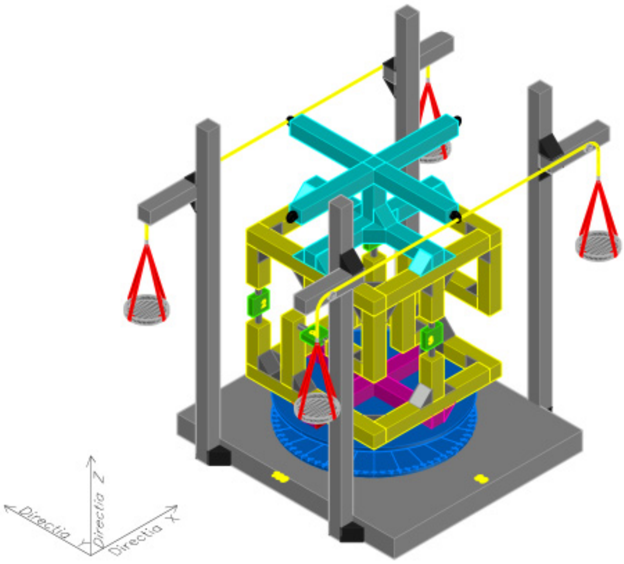
The constructive scheme of the 6-component system, in principle, consists of the existence of two rigid frames coupled together by means of elastic lines [1], [3] (Figure 1 b). The elastic connecting lines between the two rigid frames consist of force transducers (dynamometers) (Figure 1 b). The diagrams shown in Figure 2 are used to perform the calibration tasks.



a) loads for forces calibration



b) loads for moments calibration



c) load applied

Figure 2. Loads design

These loading schemes lead, through the conceptual system of the 6-component SMFM, to obtaining important "reactions" in size compared to the others only in the directions of interest (the coordinate axes of the system).

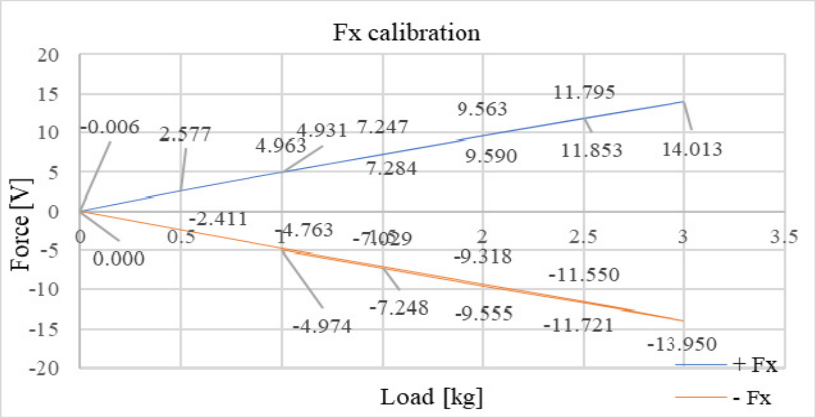
As can be seen from the load diagrams in Figure 2 a), the loading mode for the forces on the coordinate axes is shown [2]. Figure 2 b) shows how to load the moments on the coordinate axes. Special attention was paid to the installation of force transducers in the 6-component SMFM. It is imperative that these transducers indicate positive values when requested to extend it or negative values when requested to compress.

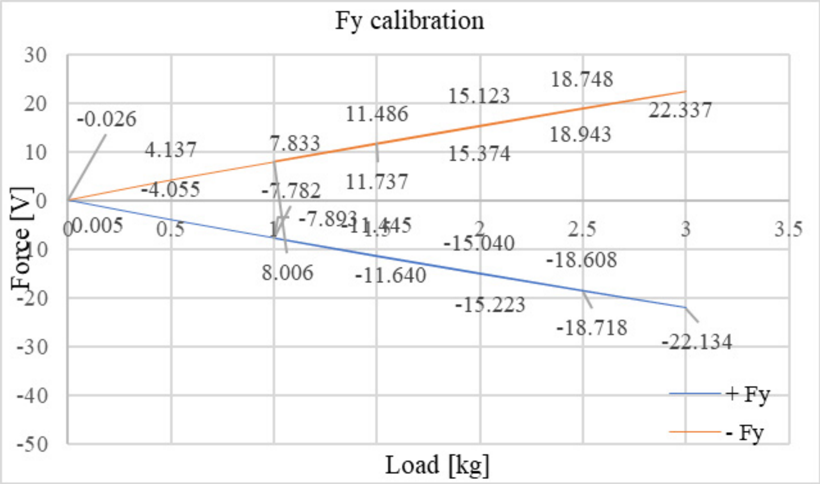
The signs of these values are very important in determining the interdependence matrix. This is a 6x6 component matrix that will indicate, in the calibration phase, the correctness of the SMFM execution and the inherent errors that will have to be taken into account when converting the signals recorded using a specially designed program. Loading with increasing loads from 5 to 5 N recorded the signals received from the transducers.

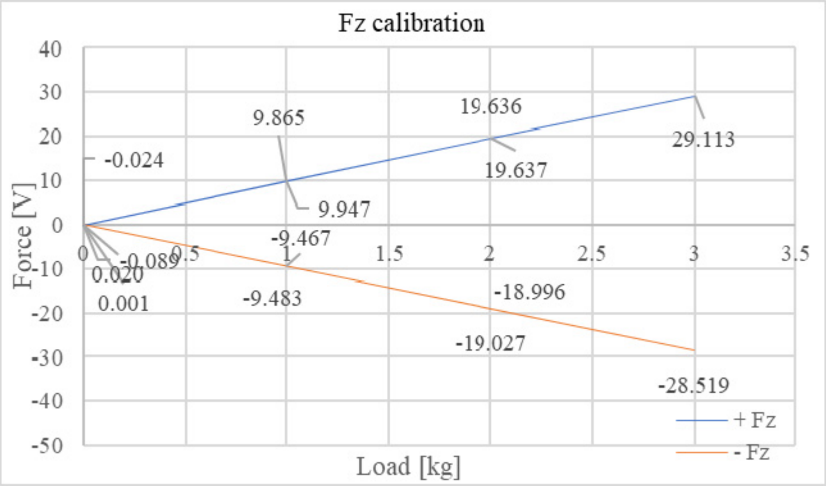
4. CALIBRATION

By loading in increments of 5 N (corresponding to a mass of 0.5 kg) up to the maximum value of 30 N (corresponding to the mass of 3 kg), the correct installation of the transducers in the 6-component SMFM was checked. The charts in Figure 3 show the calibration graphs on each of the 6-component to be measured using the designed system.

Calibration was performed by loading and then unloading with the same steps. As can be seen from the graphs in Figure 3 the loading and unloading took place on the same route (graphs for positive and negative forces). This shows that the transducers work correctly in the system. Another aspect to be reported is that the measurement errors on loading and unloading fall into the maximum permissible deviation in mechanical engineering of 10% [4]. For this system, it is intended that the measurement error does not exceed the percentage value of 2%.


Fx calibration
20
15
10
5
0
-5
-10
-15
-20
Force [V]
0
0.5
1
1.5
2
2.5
3
3.5
Load [kg]
-0.006
2.577
4.963
4.931
7.247
7.284
9.563
9.590
11.795
11.853
14.013
0.000
-2.411
-4.763
-4.974
-7.029
-7.248
-9.318
-9.555
-11.550
-11.721
-13.950
+ Fx
- Fx


Fy calibration
30
20
10
0
-10
-20
-30
-40
-50
Force [V]
0
0.5
1
1.5
2
2.5
3
3.5
Load [kg]
-0.026
4.137
7.833
11.486
11.737
15.123
15.374
18.748
18.943
22.337
0.005
-4.055
-7.782
-7.893
8.006
-11.445
-11.640
-15.040
-15.223
-18.608
-18.718
-22.134
+ Fy
- Fy


Fz calibration
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30
20
10
0
-10
-20
-30
-40
-50
Force [V]
0
0.5
1
1.5
2
2.5
3
3.5
Load [kg]
-0.024
9.865
9.947
19.636
19.637
29.113
-0.089
0.020
0.001
-9.467
-9.483
-18.996
-19.027
-28.519
+ Fz
- Fz

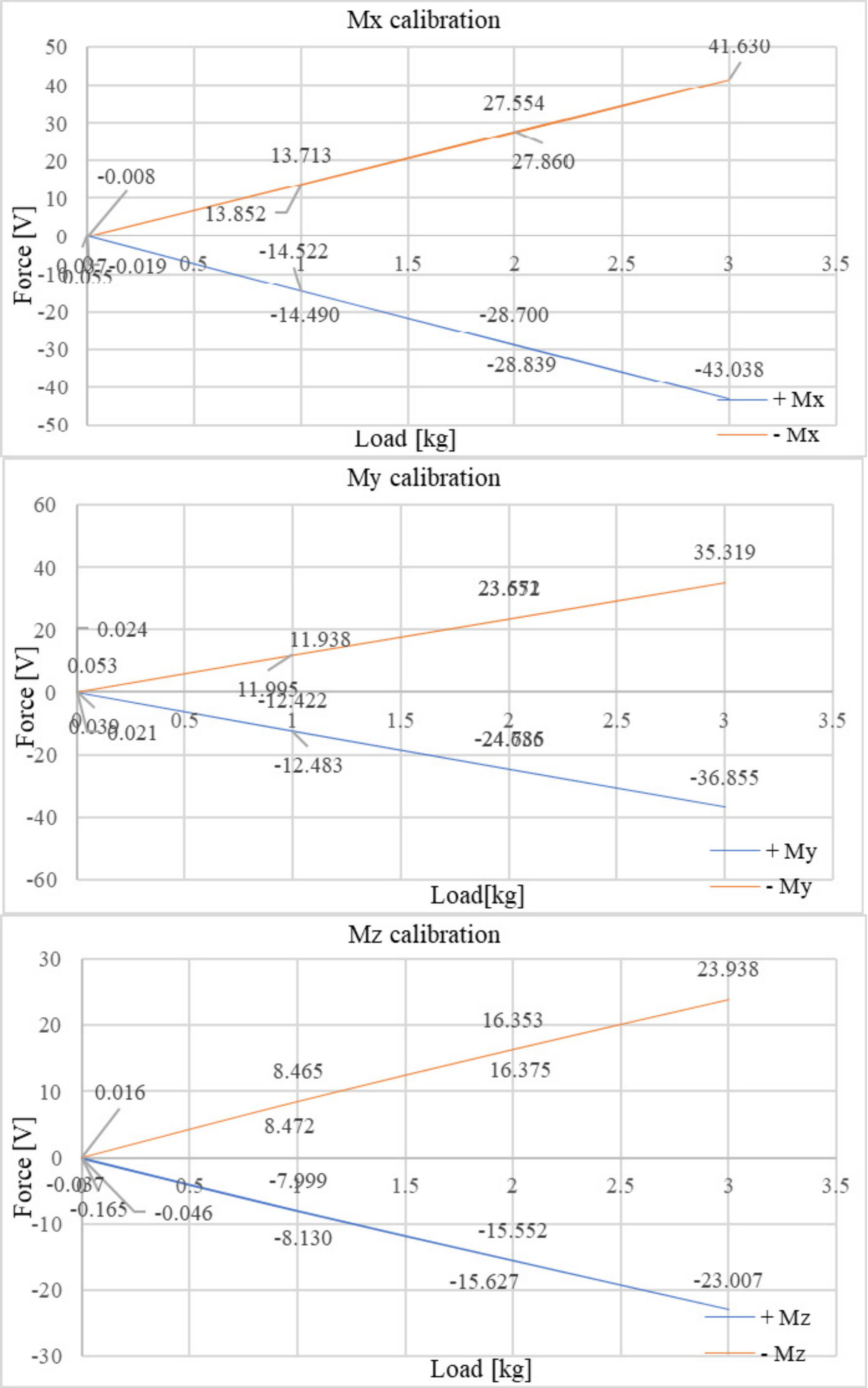

Figure 3 Calibration for the 6 components SMFM

5. CONCLUSION

Analyzing the variation form of signals received [4] during loading/unloading in the directions with the tasks used in calibration, it can be concluded that the 6-component system corresponds in terms of accuracy to the purpose of measuring forces and moments that occur in various loading situations to the aerodynamic of specimens tested in the aerodynamic tunnel.

With errors detected of up to 10% the measurements that will be made in the aerodynamic tunnel will have a high degree of veracity. Thus, the results obtained from the measurements performed in the aerodynamic tunnel can contain bases for checking the numerical models designed by the research teams.

Considering the complete facilities of the aerodynamic tunnel of "Dunarea de Jos" University of Galati, it can be used for air current testing of any category of naval, aviation or civil structures.

Acknowledgements

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