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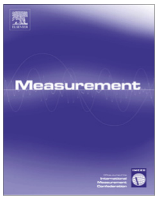

# Model sting support with hard metal core for measurement in the blowdown pressurized wind tunnel

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## ABSTRACT

The wind tunnel model, balance and sting are exposed to the large transient load in the blowdown wind tunnels. As part of the research, in order to improve wind tunnel testing, a new high stiffness sting for testing in the T-38 wind tunnel is developed. The existing steel sting, with modular construction, has been used for initial analysis. Its central cylindrical part is changed with core made of material of the high modulus of the elasticity. In this way geometrically the same sting is obtained, but stiffness of the sting is increased. Comparison between elastic characteristics of the combined sting and steel sting is made on the basis of the results obtained by load simulation and experimental verification. Load simulation results are obtained using NX Nastran software. Results of the experimental verification of the new sting are obtained in the T-38 wind tunnel test.

## 1. Introduction

The flexibility of the blowdown-type wind tunnels for various types of wind tunnel tests is far more important than the long running time of continuous wind tunnels. For the same values of Mach and Reynolds numbers in wind tunnel test section, the blowdown-type wind tunnels are more cheaper to be constructed and for operational work than continuous wind tunnels. The use of blowdown wind tunnels has pointed out the issue related to the transient phenomena i.e. large transient loads. Transient loads occur at the beginning and at the end of the wind tunnel run and under their influence the model, wind tunnel balance and sting are exposed to the effect of extremely large forces and moments. The model, wind tunnel balance and sting in the wind tunnel test section are shown in Fig. 1. The intensity of the transient loads is proportional to the model size and wind tunnel stagnation pressure. All these are reasons why in blowdown pressurized wind tunnels much attention is paid to the issue of transient phenomena [1–3]. In the 1.2 × 1.2 $m^2$ Trisonic Wind Tunnel (India) protective panels for model are used as solution of the problem of transient load. These protective panels are used in the beginning and in the end of the wind tunnel run. The panels protect model from the transient loads and enable optimal design for the model support system (mechanism for the change of the model angle of attack). This type of protection complicates usage and functionality of the wind tunnels test section. Therefore, the researchers and constructors in the majority of other wind tunnels have opted for design and manufacture of the model, sting and measurement equipment from steel alloys of high quality. Besides choosing alloys of high quality, the attention is focused on the determination of interference and deformation of the model and sting during wind tunnel tests, but also on the development of wind tunnel balances and stings for large load ranges. Much attention is also paid to increasing the stiffness of the assembly “balance–sting”. This increase in stiffness results in a reduction of unwanted oscillations and large deformations of the assembly “bal ance–sting” [4]. Also, this increase in stiffness leads to

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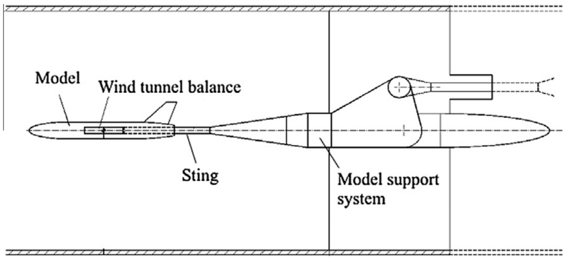

**Fig. 1.** Model, wind tunnel balance and sting in the wind tunnel test section.

increase in measuring accuracy. An example of the application of composite materials to increase the sting stiffness is presented in [5]. The sting configuration is based on combination of the stainless steel and four kinds of composite materials.

The T-38 wind tunnel of the Military Technical Institute (VTI) in Belgrade is a blowdown-type pressurized wind tunnel [6]. Mach number in the range 0.2–4.0 can be achieved in the $1.5 \times 1.5\ \text{m}^2$ square test section. In this wind tunnel the various models can be tested: standard wind tunnel calibration models, pressure distribution models, force models, powered models, stability derivatives models and models for testing air intakes. Due to the requirement for a low noise level in the environment noise silencers are installed in the wind tunnel nozzle. The silences reduced noise, but on the other hand they increased the minimum stagnation pressure at the time of establishing and stopping of the supersonic flow. This increase in the stagnation pressure has resulted in appearance of large transient loads [7,8]. An alternative design of high stiffness sting for testing in the T-38 wind tunnel is presented in this paper.

## 2. High stiffness sting

The design of appropriate sting during preparation of the T-38 wind tunnel tests in supersonic speed range is always connected to the strict requirements. The most important requirements are the maximum loads expected during the wind tunnel test (transient and stationary loads) and required stiffness of the each component in the assembly which is consisted of the model, wind tunnel balance and sting. Successful overcoming of the demanding conditions that lead to inaccurate measurement of aerodynamic loads and decreasing the area of model angle of attack in test is possible by making the sting of higher stiffness.

The sting dimensions are determined by size and geometry of the rear part of the model as well as by aerodynamic requirements for reducing the influence of sting on measurement of the aerodynamic load. In order to limit sting influence on the measurement of the aerodynamic load, it is necessary the diameter of the sting to be the half of the size of the model base diameter. Also, the length of the sting behind of the model base (the part of the sting before increasing of the diameter, Fig. 1) should be four times bigger than the model base diameter. Since the dimensions of the sting are limited by these conditions, the stiffness of the sting can be increased by utilizing the appropriate material having a sufficiently large modulus of elasticity.

The deflection of the sting and wind tunnel balance is proportional to the bending moment generated by a combination of aerodynamic forces and moments, and inversely proportional to the product of modulus of elasticity ($E$) and moment of inertia of the sting ($I$). The sting deformation is shown in Fig. 2, where $V_\infty$ is free stream velocity, $My$ is aerodynamic pitching moment, $R_z$ is aerodynamic normal force, $\alpha$ is angle of attack, $z$ is coordinate axis, $\Delta z$ is sting deflection and $\theta$ is sting slope.

The choice of material for fabricating the sting depends on:

- Sting geometry.
- Maximum values of the aerodynamic forces and moments generated on the model during the wind tunnel test.
- Allowable sting deflection and slope in the assembly "model–balance–sting".

In addition to the mechanical characteristics, a very important characteristic in selecting the material are also the technological capabilities of processing materials with available methods of machining. For material of every reasonable part installed in the T-38 wind tunnel it is adopted the high quality maraging stainless steel: Armco Ph 13.8 Mo [9]. The areas of application of this steel are: airplane parts, components of nuclear reactors, high performance shafts as well as application in the petrochemical industry where the corrosion resistance is demanded due to high strain combined with high tensile strength. The sting geometry and connection to wind tunnel balance requires great precision in making (or in proceedings of grinding, drilling in assembly, thread cutting, etc.). The use of materials with high values of the modulus of elasticity for making the stings usually implies high hardness of these materials, which leads to the possibility of machining. In order to overcome these technical challenges, and take advantage of the mechanical properties of certain materials, stings may be obtained by combining several materials. Sting model with core of hard metal represents a sting made just by combining two materials: Armco Ph 13.8-Mo steel and 90WC–10Co tungsten-carbide hard-alloy powder.

### *2.1. Description of the high stiffness sting configuration*

The existing sting of the diameter of 43 mm made of Armco Ph 13.8 Mo steel has been used for the initial load analysis. This sting is shown in Fig. 3. The main reason for choosing this sting is its modular construction. The steel sting is composed of two parts, the cylindrical part of the diameter of 43 mm and the conical part which is connected to the model support system in the wind tunnel test section. The connection of the cylindrical and conical part is realized by a close fit and two corresponding pins. By changing the cylindrical part of the sting it can be obtained geometrically the same sting. In this way, it is