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PhD thesis abstract

„Noninvasive method for determination of aerodynamic loads basing on PIV measurements"

Main aim of the dissertation was to develop an experimental method for aerodynamic loads determination (lift and drag forces). It is based on velocity vector field results obtained by means of PIV (Particle Image Velocimetry). As PIV is an optical measurement technique, proposed method for load determination can be defined as non-invasive. It is possible to isolate an analysed body from experimental apparatus or test stand elements, and thus to avoid disturbing the flow which could influence significantly measured forces.

It can be shown that the only information needed for estimation of aerodynamic loads is the velocity distribution measured around the investigated object. Therefore, PIV results were assumed as a sufficient source of input experimental data to be used. Fundamental fluid mechanics theories was utilised for algorithms development. Lift force determination is based on velocity circulation calculation. It is obtained by integration of velocity field along a closed loop encircling the body. An essential achievement made is development of procedure for finding an optimal size of integration curve used for lift calculation. In case of drag force estimation, analysis of fluid momentum change has been used. Momentum deficit, within a given control volume containing the analysed aerofoil, is determined and related to a reaction drag force exerted on the body. Additionally, pressure field reconstruction basing on velocity data was introduced which allowed to use relatively small control volumes and keep drag estimation error at a satisfactory low level.

During the initial stage of study wind tunnel experimental stand was modernised. It included a test section adaptation for optical measurements as well as extensive process of flow quality evaluation (i.e. turbulence intensity and flow distribution measurements). Final PIV measurements were carried out for flow around NACA aerofoils. MATLAB script for velocity fields analysis was developed. In order to tune and verify mathematical models implemented in the code a reference CFD data was used. Flow around a NACA0012 aerofoil was simulated at conditions mimicking wind tunnel experiment carried out.

Finally, lift and drag coefficient characteristics as a function of angle of attack were obtained for two aerofoils tested. Two flow regimes was investigated (for Reynolds number $Re=0{,}7\cdot10^5$ and $Re=1{,}4\cdot10^5$). An exceptional agreement between experimental and reference numerical lift characteristics was achieved (relative errors no larger than 5%). In case of drag estimation an acceptable level of similarity was observed (max. discrepancies below 20%).