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APPLICATION OF PARTIAL LEAST SQUARES REGRESSION METHOD FOR MATHEMATICAL MODELING OF ROCKET AERODYNAMIC DATA

Abstract

Partial Least Squares regression (PLS) is a new multi-variate data analysis method taking advantage of the Least Squares regression, Principal Component Analysis, and Canonical Correlation Analysis and it has now been widely used in the research fields of industrial and social sciences. In this paper, the PLS method is extended for the mathematical modeling of the aerodynamic data of the rockets. The basic idea is that at a given incidence and Mach number the aerodynamic forces of the rockets can be written as a trigonometric series function of the roll angle and the control surface deflection angles, so the terms in the series can be treated as independent variables and the regression of aerodynamic forces on these terms can be carried out by PLS method. In the PLS, the cross-validation technique is utilized to determine the best number of the principal components and the resultant model could exhibit a good generalization capability. Two examples are further investigated as follows. In the first case, the normal force data of a rocket with four control surfaces deflecting identically are modeled with both PLS and the prevailing Orthogonal Least Squares regression (OLS) method. The data of totally 63 states with a combination of 7 control surface deflections and 9 roll angles are present. 21 states are sampled to build the OLS and PLS models, and the other states are used for prediction. It can be seen that the modeling results of PLS model with component number of 7 is much better than the OLS model. In the second case, the axial force data of a rocket with all four control surfaces deflecting respectively are studied. By selecting 54 samples from 1728 states with 216 control surface combinations multiplied by 8 rolling angles to carry out the PLS and OLS modeling, it can be seen from the results that the PLS model with 10 components is also more general and better than the OLS model. So the reasoning goes, for OLS, some terms in the trigonometric series of the aerodynamic force model with insignificant contribution are truncated to preserve the stability of the model, so some useful modes in these truncated terms may be deleted. However, in PLS, all the series' terms are retained but some latent insignificant modes are ignored, so generally more useful information are kept in PLS model rather than OLS. These results show that the PLS is another effective method for aerodynamic modeling of rockets.