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Abstract #
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Title

Rough Surface Calculation in Rarefied Gas Flow Applying the Solution of Inverse Problem

Authors

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Abstract

Aerodynamic parameters of surface roughness in rarefied gas flow are determined most effectively using the solution of the inverse problem, because applied in practical calculations profile diagrams show only the roughness of the largest scale. However, aerodynamic values of rough surface in rarefied gas are influenced mainly on the roughness of smaller scale [1]–[3], usually negligible on the profile diagram. Therefore, the best way to find the roughness parameters is to calculate them from aerodynamic measurements, solving the inverse problem. Based on this solution algorithm allows us applying the results of our previous investigations concerning the problem of accounting surface roughness in aerodynamic calculation [1]–[3].

Most exact model of surface roughness on micro-level is Gaussian or poly-Gaussian random field [1]–[4]. The possibility of precise approximation of real micro-reliefs in different technology processes by these random fields is confirmed. In particular, rough surfaces are simulated which have been modeled as well by ionic bombardment of the steel using nitrogen ions, as by chemical etching of the steel by alcohol solution of nitric acid. In both cases, very good agreement with experimental measurements is confirmed [4].

The scattering kernel on the smooth surface is supposed – either to be ray–diffuse or described by Cercignani–Lampis model. This approach gives the opportunity to solve the inverse problem if original experimental measurements of aerodynamic values (scattering function, momentum or energy exchange coefficients) are known on the same surface with different roughness parameters. The lack of rarefied gas experiments with measured surface roughness parameters limits the number of test examples for our algorithm. However, several computations based on experimental data from [5]–[8] and from other papers allows us to make following conclusion.

The value of the main roughness parameter obtained from the solution of inverse problem is substantially higher (at least 25–50%) than similar value of the same parameter measured from the profile diagrams. Thus, the effect of surface roughness in aerodynamic values of rough surface in rarefied gas flow is always significantly underestimated. First main reason of it is the low precision of roughness parameter measurements from the profile diagrams, and the second is based on usual lack of taking into account aerodynamic shadowing effect.

References

[1] O. A. Aksenova and I. A. Khalidov, “Inverse Problem of Finding Surface Roughness Parameters in Rarefied Gas Flow”, in *Rarefied Gas Dynamics*, AIP Conference Proceedings 2132(1), 170005 (2019), pp. 1700051–1700058; doi: https://doi.org/10.1063/1.5119658

[2] O. A. Aksenova and I. A. Khalidov, *Surface Roughness in Rarefied Gas Aerodynamics: Statistical and Fractal Models*, (St.-Petersburg, St.-Petersburg University Publishers, 2004, in Russian), pp. 1–120.
[3] O. A. Aksenova and I. A. Khalidov, "Analytic Model of the Effect of Poly-Gaussian Roughness on Rarefied Gas Flow near the Surface", in *Rarefied Gas Dynamics*, AIP Conference Proceedings 1786, 100007 (2016), pp. 1000071–1000078; doi: http://dx.doi.org/10.1063/1.4967618
[4] M. Litvak and V. Malyugin, Journal of Technical Physics **82**, No.4, pp. 99–107 (2012, in Russian).
[5] A. I. Erofeev, O. G. Friedlander *et al*., "The Influence of Roughness of the Surface on the Interchange of Momentum between Gas Flow and Solid Surface", in *Rarefied Gas Dynamics*, AIP Conference Proceedings 1501, edited by M. Mareschal, (Melville, NY, 2012), pp. 1168–1174.
[6] A.I. Erofeev, A.P. Nikiforov, S.B. Nesterov, R.A. Nezhmetdinova, in *TSAGI Journal*, **47**, 4, pp. 12–27 (2016).
[7] G. Markelov, , S. Stefanov, "Statistical simulation of gas flows through short rough microchannels" in *Rarefied Gas Dynamics*, AIP Conference Proceedings 1404, (Melville, NY, 2011).
[8] N. E. Gimelshein, T. C. Lilly, S. F. Gimelshein, A. D. Ketsdever and I. J. Wysong, "Surface Roughness Effects in Low Reynolds Number Nozzle Flows", in *Rarefied Gas Dynamics*, edited by M. S. Ivanov and A. K. Rebrov, (Novosibirsk: Siberian Branch of RAS, 2007), pp. 695–702.