Numerical simulation of waveguide elements of an experimental microwave setup to determine the burning rate of energy condensed systems

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Condensed energetic materials (CEMs) are widely used as an energy source in modern propulsion systems of various applications. The CEM burning rate is one of the most vital parameters for the propulsion systems design. Its value is determined only experimentally, since combustion processes have not yet been fully studied. There are many experimental methods for determining the burning rate [1], but one of the most promising methods is microwave, because it has the highest measurement accuracy in time and space. At the same time, this method has a number of disadvantages, including necessity for the high accuracy of manufacturing structural elements of the experimental setup [2].

The voltage standing wave rate (VSWR) is one of the parameters by which the quality of a wave-guide line is determined. For ideal systems it is equal to 1, for real devices it is in the range of 1.02-2. The occurrence of ghost reflections from local irregularities leads to an increase in VSWR, which negatively affects the accuracy of combustion rate measurements. Most commonly, ghost reflections occur at the wave-guides junctions, as well as in the transition region of the air-filled wave-guide to the CEM sample. Transition devices, such as dielectric antennas, are designed for removal of such disadvantages.

Dielectric permittivity is the main parameter of a dielectric material. The antenna itself is located in a tapered metal circular cross-section wave-guide and transmits an electromagnetic wave into the CEM sample with minimal ghost reflections. In this case, the dielectric permittivity of the antenna material and the sample under study should be close in value. For this reason, PLA plastic is used as the antenna material in this work. It also allows the possibility of antenna 3D printing [3].

This study includes the dielectric antenna outer surface profiling with further wave-guide section numerical modeling. Based on the simulations results, VSWR is determined in the frequency range 9-11 GHz, which are the operating frequencies of the electromagnetic wave generator. Additionally, the VSWR experimental determination for the experimental setup wave-guide section is carried out.

As a result of the current research, an antenna profile was obtained that ensures electromagnetic waves high-quality transmission in the wave-guide section with minimal ghost reflections. This technique made it possible to obtain high accuracy in determining the CEM burning rate. Dependence diagrams of VSWR in a given frequency range were obtained during numerical simulation, as well as for the experimental setup. The burning rate curves are shown with and without the use of a profiled antenna.

References

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