отдельных элементов дорог, необходимо учитывать неравномерность движения АТС в течение суток, а также неравномерность движения по различным направлениям в пределах перекрестков.

Сокращение время простоя машин при проезде перекрестка решается уменьшением интенсивности движения в заданном направлении, в частности, перенаправлением транспортного потока на прилегающие дороги.

Модель перекрестка может быть использована в различных работах по оценке простоя автомобилей в очередях. Преимуществами данного подхода к моделированию и исследованию транспортных сетей в пакете AnyLogic является простота и наглядность построения сети, возможность расширения и усовершенствования модели пользователем. Однако данная модель не учитывает индивидуальные особенности поведения водителей, дорожно-транспортные происшествия и ряд других характеристик автотранспортного потока в реальных условиях. Поэтому построение более детальных моделей требует использования дополнительных методов, например, метода клеточных автоматов. Для апробации модели необходимо провести анализ ее адекватности реальному процессу дорожного движения.

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Tests of liquid rocket thrusters

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Аннотация

В статье рассматриваются проблемы при проведении наземных испытаний жидкостных ракетных двигателей малой тяги и требования к их испытаниям.

Ключевые слова: двигатель малой тяги, система управления и измерения.

Abstract

The article deals with problems when conducting ground tests of liquid rocket thrusters and requirements for their testing.

Keywords: thruster, control and measurement system.

Low-thrust liquid-propellant jet engines are widely used as the executive bodies of a spacecraft's jet control system with respect to the center of mass or as autonomous auxiliary engines for maneuvering, accelerating or decelerating a spacecraft. They are also used in propulsion systems for stabilizing, orienting, and ensuring the launch of upper stages of various rockets.

There are both single-component engines and two-component liquid fuels.

Single-component liquid fuel reactive systems have several advantages compared to dual-component fuel systems: micromotors require only one tank with one feeding device

and, accordingly, fewer automation units; the design of one-component engines is much simpler; regarding [1].

low temperature of the working fluid ($t < 1200^{\circ}\text{C}$). Obtaining “clean” and “radiotransparent” decomposition products of carbon-free fuels plays a particularly significant role when optical devices are installed on board spacecraft, which have an increased sensitivity to pollution, and also to ensure reliable radio communications, especially for interplanetary flights.

Conducting bench fire tests for engines that simulate operating conditions is a rather complicated task. When developing stands for testing engines, the main tasks should be solved: imitation of high-altitude operating conditions and measurement of parameters that evaluate the quality of engines. Pulse modes of operation determine the nature of transients with high rates of change of engine parameters [2].

Measurement of thrust engines when tested in high vacuum is carried out by several methods. One of them is based on systems for measuring rapidly-changing pressures using inductive or strain gauge transducers widely used in engine testing. At the same time, load-bearing devices are used in which, under the action of thrust, a fluid pressure is generated in a closed volume, which is recorded by a pressure measurement system.

From the point of view of bench management systems and measurements, the features of engine tests are their short duration, which practically excludes the possibility of the operator carrying out any analysis and adjustment of the mode of operation during the test. In this regard, test control processes and parameter measurements should be as automated as possible.

The used high-speed automatic control systems provide a predetermined sequence of operating modes, allow you to simulate a variety of conditions for starting and stationary operation of the engine. The short duration of the engine and the need to automate measurements required the development and use of special measuring systems and equipment. Moreover, these systems are subject to two fundamental requirements - high accuracy of measurement of parameters in steady-state modes and minimal inertia in measuring a number of physical quantities in transient modes, including start-up and shutdown modes.

The second feature is the increased risk of engine testing. It is associated mainly with the use of highly active fuels and, above all, oxidizing agents. Their use predetermines a high level of temperature in the combustion chamber, and also contributes to the rapid development of defects, which in some cases may end in an explosion. The third feature is the high cost of testing, which is largely due to the high consumption of fuel components and, very often, the uniqueness of the test equipment. In this regard, there are requirements of high informativeness of tests and their rational planning, allowing you to get, perhaps, more complete data on the engine in the shortest time, and hence with minimal fuel consumption.

Information-measuring and control system of fire tests of engines, taking into account the noted features of their tests and allowing to reduce the costs of these tests, should provide:

- high accuracy and increased reliability of measuring instruments;
- remoteness and specified measurement algorithm;
- automation control equipment;
- the possibility of visual control of the parameters of the engine and bench systems at the choice of the test operator;
- high noise immunity of measuring instruments and channels for collecting and transmitting information;
- the possibility of selective processing of information in the process of testing, the operation of measuring instruments and the processing of the information obtained in the single-time mode;
- protection of the engine when critical parameters are reached [3].

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