Computer Design Technology of the Small Thrust Rocket Engines Using CAE / CAD Systems

V Ryzhkov[1] and E Lapshin[1]

[1]Researcher, Samara National Research University, Samara, Russia

E-mail:ke_src@ssau.ru

Abstract. The paper presents an algorithm for designing liquid small thrust rocket engine, the process of which consists of five aggregated stages with feedback. Three stages of the algorithm provide engineering support for design, and two stages - the actual engine design. A distinctive feature of the proposed approach is a deep study of the main technical solutions at the stage of engineering analysis and interaction with the created knowledge (data) base, which accelerates the process and provides enhanced design quality. The using multifunctional graphic package Siemens NX allows to obtain the final product –rocket engine and a set of design documentation in a fairly short time; the engine design does not require a long experimental development.

1. Introduction

Modern graphic packages are used to solve design tasks, production of design documentation, preparation of complex products production of rocket and space technology at the present time. The graphic packages are designed not only to automate the traditionally existing technological links, but also to fundamentally change the approach to designing and producing products.

At the heart of the computer technology for the design of technical devices, the creation of a complete electronic product layout lies in. The creation of three-dimensional models of adequately designed construction, opens opportunities for creating high-quality products (especially complex and science-intensive) in a short time. Ideally, the process of designing and manufacturing multicomponent products requires the creation of spatial electronic models of parts, assemblies, units, systems and the entire product

At the same time, it is necessary to simultaneously solve the tasks of conceptual design, various types of computational and analytical research, modeling of possible dangerous operating modes, as well as the layout of the product and the formation of its design appearance. The data obtained during the design must be used for technological preparation and for production.

In addition, it is required to manage all the created elements of the electronic model (product structure) and of the product creation process.

To implement computer technology design and production the systems of computer-aided design, engineering analysis and technological preparation of high-level production (CAE / CAD / CAM), as well as management systems (PDM) are currently used.

At the same time, the system provides the entire cycle of product creation from the conceptual idea to implementation, also a project-technological environment is created for simultaneous work of project executors with a single virtual electronic product model.

The system should be structured in a certain way and have several special opportunities to implement this approach to development. The main features are full parameterization, communication both within the model and with its applications, as well as the ability to manage the assembly (build components).

The concept of low-thrust liquid-fueled rocket engines development presupposes the availability of a developed knowledge base in the field of small thrust rocket engines and its wide use in the design (at the initial stages), for solving the main problematic issues at this stage of creating the engine.

2. Process of creating a new small thrust LRE

Conceptually, the process of creating a new small thrust LRE can be represented in the form of the following algorithm (Figure 1), which shows the sequence (technology) of the formation of the design image of thesmall thrust LRE.

This process is presented here in the form of five stages with feedback

The first stage is the preparation of the initial data for the engine being designed.

The second stage is the estimation of the main parameters based on known (classical) ideal methods using thermodynamic, gas dynamic calculations and calculation of heat transfer with access to the main geometric and integral parameters of the engine [1-5]; determination of the design appearance of the engine based on ideal workflow models.
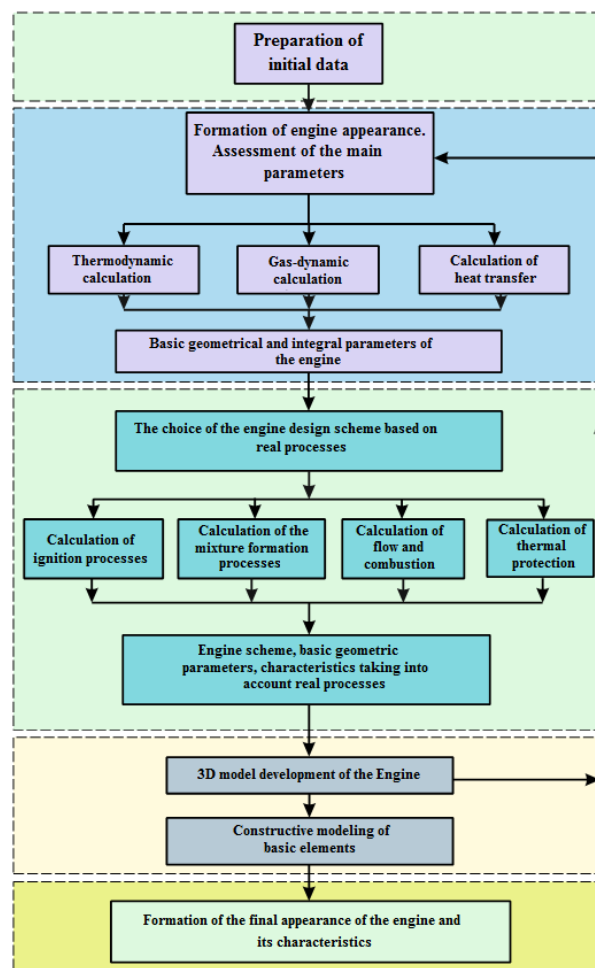

Figure 1. Algorithm for the design image formation of small thrust LRE

The third stage is the choice of the engine design scheme based on real processes, including the formation, considering knowledge bases for circuits, ignition devices, mixing elements, means of providing thermal protection for the engine. Moreover, knowledge bases created in electronic form have an independent value and in the process of selecting a constructive scheme of the engine, information exchange must be established with them not only in the form of enumeration of the base elements, but also in the form of searching for constructive execution in accordance with a certain algorithm.

The choice of the design of the engine, considering the geometry of the gas dynamic path, determined at the previous stage, allows us to form the calculation area for the computational procedures of the mathematical model of the high-level working process of the high-level liquid-fuel rocket engine, which allows to consider the actual processes of mixture formation, combustion, product flow, combustion and thermal protection. At the output of the third stage, the following is to be obtained: the motor circuit, the main geometric parameters and the characteristics of the small thrust LRE.

At the fourth stage, a 3D engine model is being developed. As a computer development environment, one of the graphic packages is used, which makes it possible to obtain a spatial electronic model based on the basic technologies and techniques of 3D electronic modeling of the complex technical devices, the element base of structural blocks, engine components. 3D model can be used as a basis for the release of design documentation for the development, and as part of the PLM-system, for example, propulsion system.

At the fifth stage of the technology of forming the design image of the engine, its final version is determined, verification calculations are carried out, the output parameters and characteristics of the small thrust LRE are determined.

As a computer environment for the development of the small thrust LRE, after the analysis of existing high-level systems, the graphic package Siemens NX (formerly UNIGRAPHICS) [6] was chosen, to the greatest extent, according to the authors, meeting the requirements of the computer technology for designing and manufacturing high-tech and science-intensive products of rocket and space technology.

Among the merits of the package we mention only a few:
- modules of the engineering analysis, based on the built-in solvers, allow to evaluate various scenarios of the working process of the structures being developed;
- the open programming interface allows you to develop your own software, which is integrated into Siemens NX;
- unification of the design processes and elements of the knowledge base accumulated in various fields in the unified system (the technology of design using the knowledge base).

According to the proposed algorithm, before starting the computer design of the small thrust RE (on fuel oxygen-hydrogen), it is necessary to specify the initial data for the development, which must correspond to the calculation results for models that take into account the actual processes in the combustion chamber and nozzle, the parameters of the chosen engine design, Taking into account the provision of the permissible thermal state of the structure and the construction material intended for use. These issues are solved at the initial stages of design - stages 2 and 3 of the algorithm for creating the small thrust LRE (Figure 1).
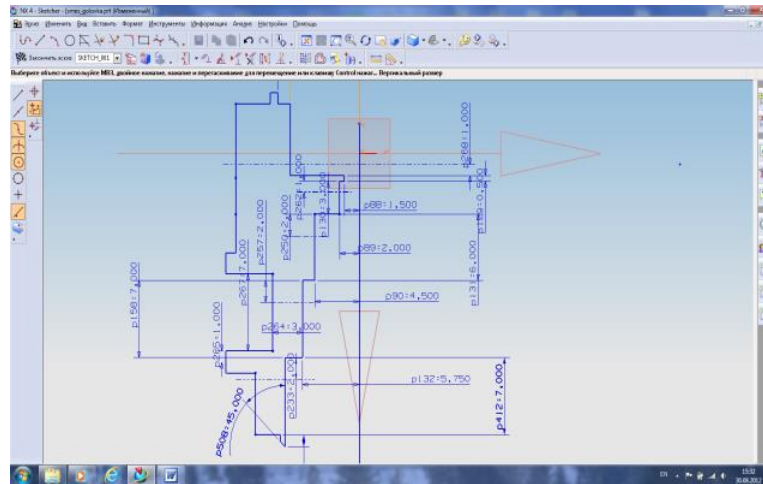
After receiving all the initial information about the engine, you can proceed directly to the process of developing a three-dimensional electronic model of the small thrust RE. The model is created in the environment of the Siemens NX graphic package.

3. Development of electronic models
Modeling should begin with the development of electronic models of the main components of RDMT with their subsequent virtual assembly at the final stage.

The plane of the exhausing of the outer and inner contours of the mixing head of the engine, as the most crucial element, is punished in Figure 2). The inner contour of the head is a part of the gas

dynamic path of the product, and the outer contour is formed taking into account the length of the fuel supply channels to the mixing head. Having set the sizes of the inner and outer contours of the head, by the "rotation" operation, turn the sketch around the central axis, getting the body of rotation - the workpiece of the solid model of the mixing head of the engine. The blank cut is shown in Figure 3.

Figure 2. The plane for sketching the contours of the mixing head of the engine

Figure 3. Cross-section of the mixing head of the engine

To create holes and channels in the mixing head, we form a new sketch and using the "subtraction" operation, using the "circular array" operation, setting the angle, diameters and number of holes, we obtain the solid model of the mixing head of the engine in its final form. Note that, depending on the location of the plane on which the sketch is depicted, it is possible to obtain a different version of the holes: tangential, radial and under different preset angles channels (see Figure 3).

The solid model of the mixing head of the projected rocket engine allows, if necessary, on the monitor screen to obtain the types and cross-sections of the future design.

In addition to the control functions that the developer of the electronic model pursues (checking the number, relative position in space, size, coordinates, etc.), visualization of the butt elements with other parts and nodes is possible at this development stage.

The main advantages of the generated virtual spatial solid model, in this case the mixing head of the engine, is the possibility to start preparing its production, after the model is transferred to other participants in the engine making process, meaning that subsequent possible changes will not be

fundamental, and the fact that the model can with success to be used in its production on machines with numerical program control.

Similarly, a combustion chamber and a rocket engine nozzle are simulated, which constitute a single unit and other elements of the product.

To create a design flare of the developed rocket engine, a part of the components is taken from the data bank of the LRE components.

The development of electronic models of the main engine parts allows us to proceed to the virtual assembly of the engine. Elements are assembled by conjugating the corresponding faces and axes.

After joining all the components and elements of the rocket engine, we obtain a complete solid-state electronic model of the product, which can be viewed from all the views of interest, including longitudinal sections (Figure 4) and use this model for further work. For example, it is possible to complete an electronic model of a propulsion system, if one is being developed.

4. Create design documentation
The presence of solid models of the components of the rocket engine and subsequent virtual assembly of all components allows to go to the drawing module and create design documentation for both the assembly (assembly drawing) and each part separately, preparing their subsequent manufacturing.

In the Siemens NX environment, parametric models are created and then used, if necessary, at the stages of improvement and modernization.

Figure 5 shows an assembly drawing of the developed rocket engine operating on oxygen-hydrogen fuel.

It is obvious that with the help of the spatial electronic model of the rocket engine, technical issues are simply solved simply technical issues, and technological issues, including selection of tolerances and landings, in accordance with the current GOST. Technical conditions, including leakproofness and strength tests, quality control of welded joints, reconciliation of alignment requirements and a few others, must be included in the design documentation additionally in accordance with the normative acts adopted in the manufacturer of the product.

A set of design documentation released with the help of a computer, responds (can be brought to the state) with all the requirements for design documentation that operate in the relevant industries in the Russian Federation.

Thus, in accordance with the proposed sequence, it is possible to organize the design of thesmall thrust LRE using modern computer technologies, software products and knowledge bases.
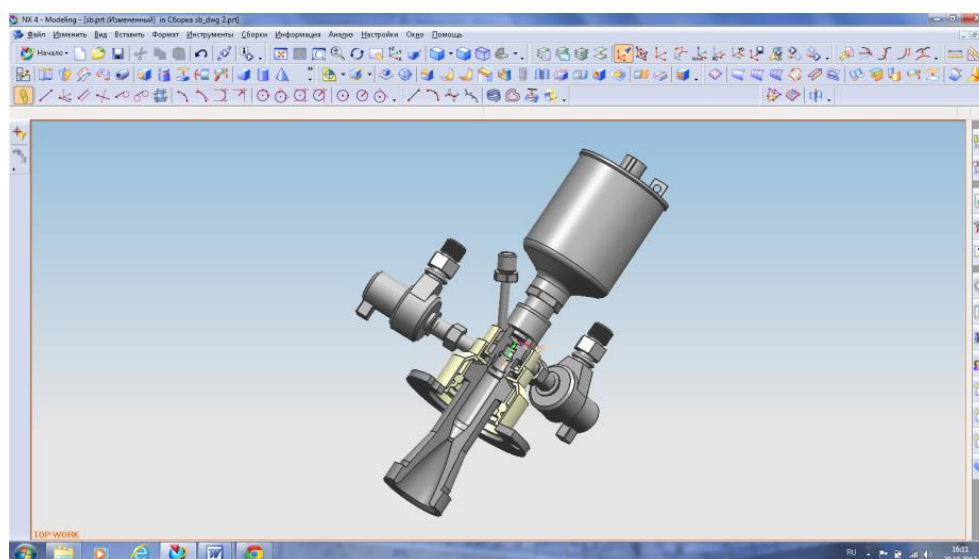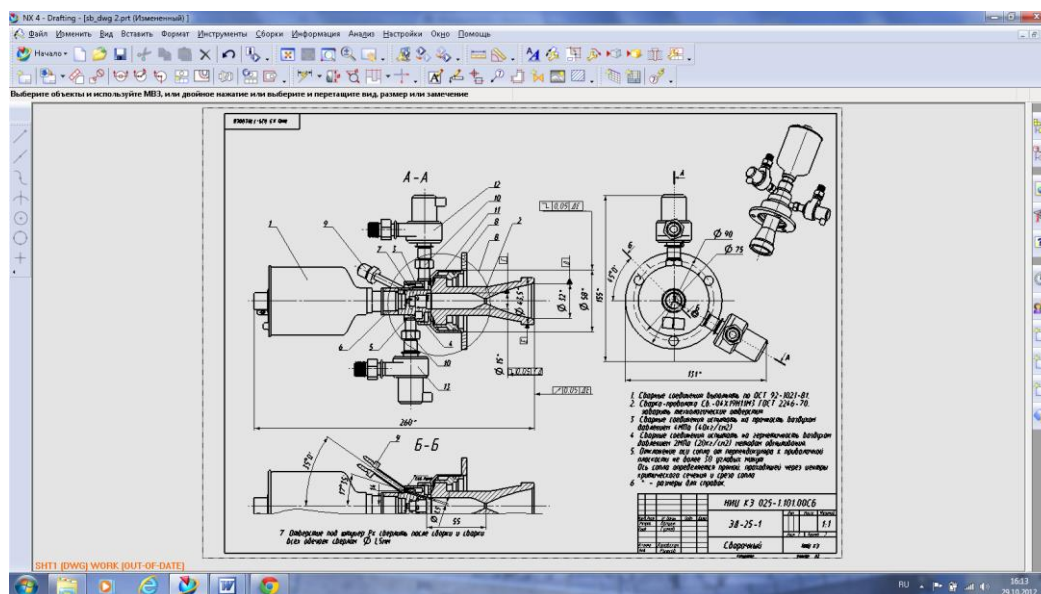

Figure 4. Engine section using a solid model

Figure 5. Engine assembly drawing executed using the solid model

References
[1]   Alemasov, V., Dergalin, A. and Tishin, A., 1989, The theory of rocket engines (Teorijaraketnyhdvigatelej)// Textbook for university students, Moscow: Mechanical Engineering, p. 464.
[2]   Dobrovolsky, M., 2005, Liquid rocket engines. Fundamentals of Design (Zhidkostnyeraketnyedvigateli. Osnovyproektirovanija) // Textbook for Universities, Moscow: Izdatelstvo MGTU named after Bauman, p. 448.
[3]   Kudryavtsev, V., 1983, Fundamentals of the theory and calculation of liquid rocket engines (Osnovyteoriiiraschjotazhidkostnyhraketnyhdvigatelej) // Moscow: Higher School, p. 704
[4]   Koshkin, V., 1975, Fundamentals of heat transfer in aviation and rocket engineering (Osnovyteploperedachi v aviacionnojiraketnojtehnike) // Moscow: Mechanical Engineering, p. 624.
[5]   Glushko, V., 1971-1979, Thermodynamic and Thermophysical Properties of Combustion Products (Termodinamicheskieiteplofizicheskiesvojstvaproduktovsgoranija) // Handbook in 10 volumes, Moscow: VINITI AS USSR.
[6]   Krasnov, M., Chigishev, Yu., 2004 Unigraphics for professionals // Moscow: Lori,p. 319.