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1. Plasma technology.

Plasma state is the most abundant matter in the nature. However, the real study of this state counts no more than 70 years. During these 70 years have been researched not only fundamental properties of plasma, but also quite real applications, which are indispensable for daily life and for discovery of fancy possibilities for future applications. Most bright examples of such applications are:

- Electrical rocket space engines (ERE),
- Obtaining new materials at microgravitational conditions.
- Use of plasma technology for obtaining thermonuclear energy.

1.1 Ion Thrusters

The designed and now in use electrical rocket engines can be separated on three classes: electrothermal, plasma and ion. The main peculiarity of all ERE is the high specific impulse at very limited values of thrust.

In space, electrothermal engines working with ammonia or hydrazine have little application. They are intended for keeping artificial satellite in orbit or to transfer it into another orbit, differing by simplicity and cheapness. Designers of such ERE are Keldysh Research Center (working fluid NH_3, power 400 W, thrust 50-300mN, specific impulse 500 s, a total impulse 5*10 5 N.s) and Design Bureau "Fakel" (working fluid mass N_2H_4, power 0.6-2 kW, thrust 100-300 mN, specific impulse 500 s) [1,2,3].

The indisputable leader in design of stationary plasma engine (SPD) is Design Bureau "Fakel". Great number of developments of SPD was also carried out in other organizations: Central Research Institute for Machine Building (TsNIIMASH), Keldysh Research Centre, Institute of the Atomic Energy named I.V. Kurchatov, MAI, NIIPME MAI, etc. [3].

SPD-50, SPD-60, SPD-70 ensured keeping 8 low orbit Earth satellites, as well SPD-70 and SPD-100 worked on 20 geostationary satellites.

The modern requirements to SPD stipulate:

1. Increase of specific impulse (2000-3000 s) and Efficiencies (η = 0.3-05),
2. Increase of lifetime for continuous operation up to 10.000-30.000 hours,
3. Decrease of jet divergence to reduce effect on construction of aircraft.

Electrostatic engines were employed for the first time as cruising engines of spacecrafts at automatic interplanetary probe SMART-1 (the probe was launched on September of 2003 and remained working at Lunar orbit until September of 2006). The engine was developed jointly by Snecma Moteurs and Design Bureau "Fakel", which delivered thrust up to 70mN during flight to moon, power consumption 1350 W, efficiency η =51%, working gas xenon (60 liters), specific impulse 16400 m/s, worked for 3648 hours in space. [6].

Next 3-5 years will be continued design and implementation of SPD on wide range of power consumption, for higher powers (10-50 kW) in a single-unit, as well for small powers (50-500 W) for small spacecrafts.

Also perspective engines with anode layer are those developed by TsNIIMASH (D-100-1 and D-100-2 with power consumption of 1.3-15 kW) and Keldysh Centre (KM-32 and KM-45 with power consumption of 0.12-0.45 kW).

Pulsing Plasma Thrusters (PPT) developed by NIIPME MAI offers interest for missions with total impulse up to 80 kN.s. They have thrust efficiency η □ 0.25, outflow velocity 10-14 km/s and with energy accumulation at discharge ~100 J.There are reports [7] about tests of a new perspective ion thruster called Dual-Stage 4-Grid (DS4G), designed and built by specialists of the Australian University together with ESA. The acceleration system of ions of this engine contains four accelerating grids that allow to achieve voltage difference as high as 30 kV without breakdown. That, in turn, has allowed to obtain a flow of ions with velocity 210.000 m/s, which exceeds more than four times the velocity of particles on existing ERE. The diverging angle of exhaust plume was only 3˚, which is five times narrower than present systems.

However, the experience has shown that the development time from experimental engines up to flight version, at favorable conditions, can take about 2-3 years.

For the sake of justice, it is necessary to remember about two-lens thruster of hydrogen, developed by Institute of Atomic Energy in 1979, which had power 5 MW and ion exhaust plume velocity at 1.000 km/s.

<u>The ablation pulsing plasma thuster.</u>

The active use of Small Space Vehicles (SSV) contributes to design of cheap and reliable ERE with low power (10-100 W) to control orbital motion of such vehicles. For SSV with mass 50-400 kg, it is most reasonable to use propulsion systems based on Ablation Pulsing Plasma Thruster (APPT). In the range of total impulse of thrust up to $I_\Sigma = 70$ kN.s, APPT with Teflon is lighter in comparison with other types of ERE devices. Use of polymers with low molecular mass expands the range of I_Σ up to 200 kN.s.

Designs of ERE with APPT in Russia is carried out by Keldysh Research Center together with Scientific Research Institute of Applied Mechanics and Electrodynamics, as well by Institute of Nuclear Energy named I.V Kurchatov. Designs are directed to solve the following problems:

- use of alternative working materials - polymers with low molecular mass,
- decrease mass and dimensions of ERE with APPT,
- improvement of energy characteristics of APPT at cost of optimization of circuit discharge parameters (charging voltage of capacitive accumulator, geometrical dimensions of duct, etc.).

In near next years, the level of thrust efficiency will be 0.35 and single impulse of APPT 3 mN.s for energy in accumulator of 100 J, accordingly to dry mass of ERE device 8 kg.

1.3 High-temperature plasma for application to alternative power sources.

The confinement of high-temperature plasma is the key problem of Controlled Thermonuclear Synthesis (CTS). Now, it is been considered two methods of confinement. First - inertial method, for example, with initiation of reaction by means of laser, the second - confinement by magnetic field. In systems with magnetic confinement of plasma the main problem is the suppression of convective instability. The ratio of plasma pressure to magnetic field pressure, containing plasma, can be considered as the efficiency of magnetic confinement. For this reason plasma systems with high efficiency will be certainly demanded in CTS.

The majority of modern researchers' problems of CTS assume that the most probable candidates for the role of ideal traps of plasma are magnetic cylinders-galatea in which plasma is surrounded by a magnetic barrier in all directions [8].

The main advantage of magnetic cylinders is the automatic suppression of convective instability, which exists in all other traditional traps (tokamaks, stellarators, etc.). The necessity and actuality to analyze traps is also important, because the costs of construction and exploitation of thermonuclear reactor with this scheme is significantly lower than costs of traditional reactors. Investigations of toroidal multipolar galateas, carried out by Moscow State Institute of Radiotechnics, Electronics and Automation (MIREA), confirm the realizability of given conditions and classical character of transportations.

For filling trap by plasma, at MIREA was created and adjusted an injection system, consisting from gun and plasma injector. The basic physical principles and features of process of plasma capture and confinement in traps were revealed – galatea "Trimix" by slow bunches of hydrogen plasma [9, 10]. Capture is realized by bunch of hydrogen plasma with energy of ions equal to 100 eV. Increase of plasma parameters in trap is realized up to following values: temperature of electrons and ions Te=Ti = 20 eV, concentration of electrons 10^{14} [1/cm^3], plasma energy content 110 J. The confinement time of plasma on trap is t =300 s for quantity of field barrier $B_{бар}$ = 0.1 tesla.

At present time, it is not seen physical limitation for obtaining higher holding times t at significantly higher temperatures of ions and electrons Te=Ti.

On 30th Anniversary Academic symposium of Cosmonautics (Moscow, Russia, on 25-27th January, 2006), academician E.M. Galimov, director of Institute of Geochemistry and Analytical Chemistry V.I. Vernadskogo, has reported that «…one ton of He-3 has energy equivalent to $20*10^6$ t of petroleum, i.e. costs approximately 10^{10} \$. The transportation expenses to delivery 1 t of He-3 is (20-40)10^6… Moon should be involved in the economical sphere of the Earth, because He-3 is the unique modern alternative of energy source, ensuring ecological future of planet. »

On the same symposium, President of Russian Space Corporation "Energia", Chief designer N.N. Sevastjanov has declared, that Russia plans to construct a fixed base on moon and complete transportation to Earth of isotope He-3. First Russian manned flight to moon can be realized by 2012-2014, using technology of spacecraft type "Soyuz", and by 2020 we can construct industrial transport system for regular flights to moon and production of minerals over there.

The above-stated deadlines can be considered approximately as baseline for developing programs of CTS, satisfying pollution-free energy needs of the Earth with support of this project by international community.

1.4. Plasma technology for development of materials for space application.

Plasma technology comprehends a long list of technological processes allowing to:

- apply both interior and exterior superficial treatment of metallic and nonmetallic coating for different purposes (thermal-protective, anticorrosive, abrasive resistant, dielectric and current-conducting, etc.),

- implant high-energy particles into superficial layer of material with purpose to change its properties,

- obtain in plasma reactors with different types of nanomaterials (10-200 nm) and metals and non-metals powders (1-50 μm),

- modify surface properties of materials (improving adhesion, obtaining of thin oxide semiconductor layers, oxides of metals, decrease of friction, etc.).

-implantation of ions in semi-conductors (creating p-n and n-p junctions in Si, Ge, InSb, protection p-n junctions by ionic bombardment of oxygen, creating ohmic contacts, etc.).

Ecological cleanness of the listed techniques, high controllability and, as a rule, absence of negative collateral effects has supplied continuous widening of area its application and high-quality perfection.

Now electron-ion-plasma technology tends to be improved in all developed countries, in hundreds of research and industrial organizations in the following directions:

- creation of compact, relatively cheap, efficient and combined sources of plasma (plasmatrons) [11, 12],

- creation of plants for complex processing of material and items,

- scientific research on different kinds of electron-ion-vacuum technology.

It is difficult to find objects in space-rocket techniques that do not use plasma technology in their constructions. First of all, propulsion systems, which uses plasma technology for deposition of heat-resistant and antioxidant coating on interior surfaces of gas channels and blades of turbines. For example, the most powerful present-day Liquid Rocket Engines (LRE) of Design Bureau ENERGOMASH (RD-170, RD-180, RD-191- operating on oxygen-kerosene propellants at closed scheme with oxidizer-rich gas generator), are protected by antioxidant layer on oxidizer channels. The covering by method of plasma spraying, work reliably in oxidizing medium at pressure 250 atm and temperature 800 K during one hour.

Production of electronic equipments on semi-conductors and integrated circuits use technology of ion-implantation.

Protective screens against collision of particles of space debris (International Space Station and other space vehicles) have a surface treatment by ion-implantation method for strengthening.

Among the numerous organizations that are developing methods of plasma technology, it is necessary to mention:

-Institute of Theoretical and applied Mechanics SB RAS (Russia),

-Institute of Nuclear Energy named Kurtchatov (Moscow, Russia),

-Moscow Institute of Physics and Technology (Dolgoprudny, Moscow reg., Russia),

-Moscow Aviation Institute (State Technical University (Moscow, Russia),

-Archimedes Technology Group Inc. (San Diego, USA),

-Lockheed Martin Space Plasmas Group - The Space Physics Laboratory (LMSPL).

1.5 Influence of operation of electrical rocket engines on not hermetic compartments of space vehicles.

During the use of electrical rocket engines, the equipments of not hermetic compartments and surfaces of spacecraft are exposed to "bubble" plasma effect and to own atmosphere, organized around of spacecraft. As result, it is established conditions for electrical breakdowns and interferences on electronic equipments, erosion of surfaces and formation of pelliculate impurity on optical sensors, solar batteries, port lights and on any other component and aggregates [15].

As result of theoretical analysis and experimental investigations [13,14], models of plasma permeation (penetration) were developed for not hermetic compartments of space vehicles, allowing to recommend at stage of design work and finishing the placement of ERE and compartments of equipments, to evaluate dynamics of out gassing of surfaces. The obtained procedures are already demanded by organizations when designing a space vehicle.

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2. Sensors and materials

2.1 Solar batteries and panels.

The modern space vehicles require substantial sources of electrical energy for normal operation of own subsystems and for scientific research equipments. The sources of energy can be solar batteries (SB), fuel cells (FC), radioisotope sources of electrical energy use. The primary source of electrical energy of a spacecraft today is SB.

Thus, the International Space Station (ISS) for total deployment consumes 115 kW from SB, working completely with electrochemical batteries. Total area of SB for all modules of ISS is equal to 2500 m^2.

As basis for materials for photoelectric transformers (PET) now is in use gallium arsenide (GaAs) and silicium (Si). Arsenide-gallic Hetero-Photo-Transformer (HPT) has the highest theoretical efficiency even at depth (5-6) microns, at the same time the thickness of silicic elements cannot be less than (50-100) microns without their visible decrease of efficiency. This advantage allows obtaining **light sheet and miniature of HPT** (especially whether for base plate does not use GaAs and synthetic sapphire Al_2O_3.) Other relevant advantage of HPT from GaAs is capability to not sink boiler efficiency at temperatures GaAs up to 150-180˚C (on matching with silicic PEM for which one already at the temperature of 60-70˚C efficiency decrease twice).

Finally, the third important advantage of HPT from GaAs is its greater durability in flow of protons and electrons with high energy. It is proved experimentally, that the radiation defects in HPT, based on GaAs, disappear after their heating up to temperatures of the same order (150-180˚C).

Silicic photo-electrical solar batteries are well finished in production and are much cheaper. Production of silicium in the world is being incremented continuously in connection with construction of ground solar power stations, cost of silic photoelectric batteries now is 2,5 $/watt and tends to be cheaper.

In a spacecraft where mass, dimensions and efficiency of SB are determined parameters, gallium arsenide is the main material for PET. The Russian satellites "Yamal-100" (December 1999) and "Yamal-200" (November 2003) contain arsenide-gallium SB with an output power of 3.58 kW and lifetime of 12 years. By specific mass characteristics (2.91 kg/m^2), they are the best in the world [1] . Nickel-hydrogen electrochemical batteries with output energy of 2000 W.h each and specific energy output of 59 W.h/kg also have no similar in the world.

Within next years will be continued the increase of efficiency for space SB and improving their mass performances both due to application nanotechnology for PET, and due to decrease of thickness of base plate.

On May, 25th 2006, scientists of laboratories of Information Technologies at Joint Institute of Nuclear Research (JINR, Dubna - Moscow) have demonstrated a very unique design, so-called «Star-shaped batteries». New matter on the substrate of nano-particles gold and argentum (heteroeletric or heteroeletric photo element) "packs" the sunlight (consisting of different wave lengths) at one frequency, increasing thereby efficiency of the battery.

The source of feeding consists of 2 main elements: hetero-electric photo element, converting visible and infrared light in electricity, and hetero-electric condenser which is accumulating energy (capacity is 10^4 times bigger than common battery).

Thus, this device has unique capability to work not only during the day, but also at night, using visible and infrared flows. Efficiency of conversion from visible spectrum into electrical power is ~54 %, and from infrared into electrical power is ~31 %. Besides, photocurrent of hetero-electric-photo-element is four times bigger than for solar battery.

Hetero-electric represents the heterogeneous substance, consisting of carrier and active agent from nanoparticles which has distinct matter from the carrier. For such sizes of nano-particles and distance between them is lesser than a wave length acting electromagnetic field, hetero-electric-photo-element has mass of semiconductor matter on 1 watt of energy in 1000 times smaller, than for photoelectric cells of modern SB.

Calculation shows that cost price of hetero-electric-photo-element will be lower than cost price of a photoelectric cell of modern SB.

2.5 Micro Electro Mechanical Systems (MEMS).

The major tendency in the field of developing modern space technique is the miniaturization of its all components and systems.

The miniaturization allows to create space vehicle (SV) by mass in hundreds and tens kilograms, which are capable to fulfill of tasks, which 20 years ago were possible only with multiton satellites. The miniaturization of items rocket space technique foresee fabricate nano-sattellites with mass up to 10 kg, micro satellites with mass up to 100 kg and small satellites with mass from 100 up to 500 kg.

The miniaturization of items produces a push to developing nanotechnology, first of all for elements of control systems, for example, micro-electro-mechanical systems (MEMS). These systems represent three-dimensional microscopic objects and micro machines: motors, pumps, turbines, micro robots, micro sensors or the full analytical micro labs, which have been executed at one chip.

The diminutiveness of MEMS items, being their characteristic peculiarity, causes such properties of items, as portability, long lifetime (extremely small masses of devices minimize vibrational and inertial overloads), low power consumption, simplicity in service and replacement.

Application of MEMS allows to decrease approximately by one order the sizes, mass and a power consumption of aerospace systems. As examples of successful application of MEMS in space technology, it is possible to mention silicon gyros, accelerometers, valves, pressure sensors, micro power sources, systems for chemical and biological analysis, high-frequency optical and mechanical filters, etc.

Directions in nanotechnology, applied to items rocket space techniques are increasing of productivity of base computers in control systems in millions times, due to application nano-eletronics, also making high-reflective systems (solar, laser radiation, mirrors of space telescopes).

The miniaturization of items rocket space technique rocket space techniques requires application of the new materials having nano-dimensions structures. These materials, using processes of self-organization and the self-assembly, guarantee the possibility to obtain items not by method «from up-down », but by method « from down-up».

Such materials may be 10 times stronger than steel, and have small mass. To such materials it is possible to refer fullerons - derivatives of graphite which have face-centered crystal cubic structure with molecules C60. Fullerons have unique properties - elasticity, plasticity and high hardness (diamond).

Unique constructive material which may be applied on small space vehicles is the "flexible" nano-phase ceramics, which includes oxigen and nitrogen components with quantity of grain smaller than 70 nanometers.

Micron typical dimensions of devices MEMS requires for their manufacture a modified base of technology operations traditionally applied in microelectronics. These technologies ensure the possibility of integration in one item of varied functions, because processes of sensors manufacturing, activators and a microelectronic control system may be combined in one technologic cycle.

Hundreds scientific research institute, designs bureaus, universities and the industrial companies are developing different application of MEMS for space-rocket technique. It is difficult to follow all news in this roughly advances field, however, the nearest perspective (5-7 years) are **perfecting materials nano-dimension structure, micro-activators, implants for space medicine, micro miniature space light modulators, etc.**

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2.7. Microgravity experiments for materials.

Experiments on effect of microgravity during formation of crystal and various different plasma structures have been started at 1976; at 1998 - in space station "Mir" (devices PK-1 and PK-2) and was continued until 2001 at International Space Station (ISS) (device PK-3). On the modified devices (PK-3 plus and PK-4) these experiments will be continue in 2007. The analysis of results of conducted experiments has allowed to advance on understanding of behavior of processes of diffusion, crystallization and gasification. New scientific directions -

physics of microgravity, hydromechanics and heat transfer in microgravity - new technological direction « space materials technology » [1] are created.

Among applied researches it is necessary to mention:

-studying of processes of crystallization of semiconductor materials,

-influence of technological conditions on properties magnetic and superconductors and requirements of thermodynamic stability of phases of alloys,

- influence of different conditions on properties of composite materials,

- methods to decrease the concentrations of different kinds of inserts in optical glasses, etc.

For study of processes of heat transfer, phase changes in liquid and gas environments, growth of semiconductor crystals was obtained by modern scientific equipments, working on autonomous regime and with the participation of cosmonauts.

To the present time, the conducted experiments have shown perspectives for the development of operations in microgravity for obtaining both new materials and fundamental data with the purpose of improving of ground technology.

The most perspective direction of these operations is the production in space high-clean biological matters, crystal, protein, semiconductor materials.

Especially, it is necessary to mention at space experiment «Plasma crystal», carried out jointly by the Russian Institute of Thermal Physics of the Russian Academy of Science and the German Institute of Extra-terrestrial Physics named M. Plank. Plasma in conditions of microgravity behaves unusually: in her ordered structure of strong charged particles are formed. Radioactive dust particles can produce an electric current (on this basis, it is possible to do new compact energy sources with big lifetime of operation). From parts of plasma crystal, it is possible to create new materials. It is possible to grow artificial diamonds in space. Results of experiments on devices «Plasma crystal» will allow to create "vacuum cleaner" for the directional removal of radioactive atmosphere emission at nuclear accidents.

Specialists «Russian Research Institute Synthesis of Mineral Materials » (Russia, Alexandrov) developed a method of crystal growth in conditions of axial heat flux near to front of crystallization (AHF method of crystallization). The method is based on calculation of feeble laminar flows of a melt and effect of perturbations on process of a crystallization and can be used with success as for organization of efficient production of crystal in space, and for "ground" technologies.

Within the next years the main task in the field of space materials technology will be conducted investigations with the purpose of obtaining of new fundamental knowledge of processes:

-crystallization of substances,

-phenomena of heat and mass transfers in them,

-conditions of formation of macro micro inhomogeneities of materials,

-composition, structure and electrophysical properties of growth crystal in conditions of microgravity,

-creation on the basis of obtained knowledge of experimental and industrial "space" production of materials with unique properties, not accessible in ground requirements, and also improvement of ground technologies.

There has occurred phase of complex application and developing of space resources, finishing of perspective technologies during 2007-2015. The phase of technological perfecting will be prolonged till 2025.

3. Combustion and Propulsion.

3.1. Propulsion system for orbit correction, attitude control, apogee motors and auxiliary propulsion.

Delivery of payloads to low Earth orbits is performed now exclusively on rockets and reusable vehicles («Space Shuttle» or "Buran"). Liquid or solid fuel engines of these transportation systems have achieved high efficiency (SSME, RD-0120, RD-170, RD-180, RD-191) and within next decades they will be, in general, only improved: increasing the **lifetime**, improving of **mass performances** due to usage of new structural materials and increasing **reliability**.

Transport operations in orbits of an artificial satellite, acceleration on departure paths and on maneuver operations in a deep space are fulfilled and will be fulfilled by propulsion systems of two types:

-Liquid Rocket Engines storage propellants for "prompt" maneuvers of spacecraft (ensuring the significant overloads $n_0 = P/G_0 = 5*10^{-2} - 5*10^{-4}$, here P - thrust of engine, G_0 - weight of SV),

- ERE of different type for "slow" maneuvers of spacecraft (the long-term overloads at a level $n_0 = 10^{-4}$-10^{-6}).

For "prompt" transfer from low Earth orbits (LEO) into Geostationary and Geo-polar (GSO and GPO) and also for acceleration of spacecraft of the significant mass during departure path, the accelerating blocks are used. Only three countries (Russia, the USA and India) have accelerating blocks.

The USA have accelerating block 'Centaur' on which oxygen-hydrogen engines RL-10A-3 with thrust 99,2 kN are installed, executed on without gas-generator scheme (expander cycle).

Russia has three accelerating blocks:

"Breeze-M" with cruising engine LRE 14D30 (thrust 2 tf, I_{sp} = 326s), four engines of correction 11D58 (thrust 40 kgf), 12 engines of stabilization 17D58E (thrust 1.36 kgf). All engines work on storable, self-ignited propellant N_2O_4 +$(CH_3)_2N_2H_2$. It is possible realize 8 actuations of cruising engine.

"Frigate" with cruising engine C5-92 (thrust 2 tf, I_{sp}=327s), propellant N_2O_4 +$(CH_3)_2N_2H_2$ and a engine of stabilization, attitude and ensuring of starting up on monopropellant (hydrazine): 12 engines with thrust 5 kgf (I_{sp}= 2250m/s).

Space hydrogenous accelerating block with cruising engine KVD-1M (thrust 7.5 tf, I_{sp}= 461s), propellant $O_{2\ liq}$+$H_{2\ liq}$, the engine of the closed scheme with two control chambers in gimbal joint, feeding from common turbo-pump unit. The engine of stabilization and attitude has two thruster blocks on propellant N_2O_4 +$(CH_3)_2N_2H_2$.

The Design Bureau of Chemical Automatics (DBCA, Russia, Voronezh) has developed new oxygen-hydrogen engine without gas generator scheme (expander cycle) RD-146 [3.1] thrust 10 tf. (I^v_{sp} = 4600 m/s with telescopic nozzle) with reference to space accelerating blocks of launching vehicle "Proton-M" and "Angara". Distinctive peculiarity of given engine is high pressure in combustion chamber (80.5 атм).

Design bureaus « DB CHIMMACH» and «DBCA» developed and tested the first liquefied natural gas - oxygen engines having the best energy and cooling properties [3.3, 3.4] (in comparison with oxygen-kerosene) and higher density of propellants comparing with oxygen-hydrogen engines).

Application of engines operating with propellants (natural gas-O_{2liq}) in Russia is restricted exclusively by financial and economic reasons.

The development of a big quantity of thrusters for orbit correction and stabilization of spacecraft, provision of starting up of cruising engine and other trajectory operations. The majority of them works on storable self-ignition propellants. However, there is a tendency to use ecologically clean propellants (O_2+H_2, O_2+kerosene, high-concentration hydrogen peroxide +kerosene) [3.2, 3.3]. It is considered as perspective the combined engine devices by LRE and ERE [3.5].

Immediate perspective for thrusters is the high-temperature, light design materials (high-temperature and heat resistant steels with silicide covering, composite materials with protective coatings, etc.).

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3.2. Modeling of combustion chambers.

In the combustion chambers of liquid rocket engines the transformation chemical energy of the propellant in the kinetic energy combustion products (expelled from the nozzle) takes place. This transformation contents complete complex hydrodynamic, physical-chemical and heat-mass exchanged processes, including process of combustion. From the analysis of these processes, which may be superimposed one on other, are selected usually:

- pulverization liquid components of the propellant,
- the mixing liquid drops and gaseous components,
- the evaporation of liquid drops and mixing vapors with gaseous products of combustion,
- diffusion combustion and combustion of liquid drops,
- the expelling combustion products from the nozzle,
- the convective and radiation heat-exchange takes place between combustion products and combustion chamber walls.

Enumerated processes take place in turbulent flows and limited volume at the high pressures (till 350 atm) and temperatures (2500-4000)K. The instability of the combustion process is appeared not seldom with oscillations of pressure and decrease of combustion efficiency.

Theoretical and experimental investigations of these processes during last 60 years let to create there mathematical models. Models of combustion became most difficult, because turbulence reacting flows include numerous chemical reactions, radiation. Temperature, concentrations of components and other parameters are changed as in result of chemical reactions and in result of different physical processes (diffusion, convection, radiation flow and others). In combustion chambers of LRE namely physical factors influence mainly at the condition of self ignition and combustion efficiency. For the correct description of these processes it is necessary to use different models of the turbulence. [1]

In spite of big quantity works at the models of the combustion, fulfilled in dozens of research institutes and laboratories, enough universal combustion models do not exist till this moment. Simplified models of combustion let to obtain positive results and to use it during the design work of combustion chambers. So, if the time of residence exceeds the time of chemical reactions $\tau_r > \tau_{ch.r.}$ (Equilibrium processes) the programmed complexes of thermo-dynamical processes give a good correlation with experimental investigations at composition and temperature of combustion products (NASA-SP 273, authors Gordon and MacBridde; "ASTRA-4M" -author B. Trusov-MSTU named N. Bauman).

Successes of computational and numerical methods of calculations let to create programmed complexes "Flow Vision", ANSYS CFX" and others, combined the possibilities of the analyze of hydrodynamic processes, multiphase flows, chemical kinetic, combustion, heat transfer and others. [3]

At presence these programmed complexes are finished permanently in the direction as physical model, its mathematical description and numerical methods of its solution. The results of together experimental investigations and computer technologies are necessary for the perfection of these models. [2]

Besides, it is necessary to member about the forming of the boundary conditions of the complete turbulence reacting flow. These boundary conditions are created by mixing head of combustion chamber (type of injectors, there quantity and distribution at the surface of head, distribution of liquid phase and so on).The structure of the programmed complex must be flexible for the taking into account real boundary conditions.

In spite of famous successes in the area modeling of the combustion, it is impossible to see the necessity of perfection own physical models, the examine these models in different experiments (including conditions of microgravity). One may to say with confidence, during nearest 5-10 years the modeling of inside chamber processes let jet at steady of design works to decide the questions of choice type of injectors, their design and regime parameters, placement at the surface of injector head.

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3.4 Scramjets.

The RAMJET engine is considered the most efficient for hypersonic atmospheric flights, called further SCRAMJET. This engine inherently has the high level of integration with construction of aircraft. Practically, whole fuselage of hypersonic aircraft considered as an engine device. Therefore, competence SCRAMJET should be confirmed only in requirements of real hypersonic flying of aircraft.

For development of SCRAMJET should be solved following complex technical problems:

- supplying effective combustion of fuel at supersonic speed of airflow (mixing, stabilization of combustion in high-velocity flows),

- supplying of cooling construction of combustion chamber (T=3300°K), allowing for stagnation temperature of an intake air (1300-1500) K,

- development of the optimum input device and nozzle in view of a lot of exterior dilatation that requires use of space technology of three-dimensional computer model operation and experiments on hypersonic stands and hypersonic flying labs.

Among designers of this complex problem in Russia, it is necessary to mention CIAM named P.I. Baranov, MAI, DB ChimAutomatics. In the USA, NASA has positive results with demonstrator **X-43A.** This aircraft is scramjet-power un-manned aircraft and was launched from a B-52 on the nose of a Pegasus rocket. The rocket powers the X-43 to near Mach 7 where the X-43A separates from the rocket and flies using the scramjet propulsion system. The X-43A successfully demonstrated scramjet propulsion for the first time in March, 2004.

On 31march 2006, The Pentagon (Defense Advanced Research Project Agency-DARPA) have tested hypersonic aircraft with SCRAMJET on kerosene. Launched} by means of a missile on an altitude 20 km, aircraft has detached and further made independent flying, having reached velocity of M = 5.5.

Australian University of Queensland also has prepared and has fulfilled flight tests of demonstrator SCRAMJET.

While in developing process engineering SCRAMJET put the significant amount only military departments.

Before occurring flight tests of SCRAMJET demonstrator, a lot of experimental investigation on ground facilities was executed.

However, today some critical technologies are not finished, which ensure the development of high-velocity SCRAMJET (M = 5-15) at level of modern reaching in viewed fields of science and technique. Among them:

- technology of design work of the flowing tract of the engine considers its integration with aircraft,
- technology of process control of combustion in view of velocity and flight altitudes of aircraft (H = 15-50 km),
- technology of cooling by fuel of a combustor, accounting the changes its phase state,
- technology realization of flight tests with SCRAMJET demonstrators deeply integrated with aircraft.

The nearest task (3-4 years) – on the basis of tests of SCRAMJET demonstrators to proved competence SCRAMJET as engine, i.e. – creating optimum input device and nozzle, considering a lot of external expansion, demonstrating effective thrust in conditions enough the long-time independent flying. Technical realization of aircraft with SCRAMJET is possible by integration numerical methods and test results, non-traditional design material and the newest technologies of production.

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4. Computational Modeling and High Performance Computing for Space and Environment Applications

4.1 Development of algorithms and Programs of Automatic Control for Rover System, landing systems and navigation using Artificial Intelligence

Now, virtual reality systems (VRS) are applied for education in different areas of knowledge and in professional training. It is especially important for operational training and education for new specialists of new areas of techniques and the industry.

Intended for training VRS represents the further development of class of training computer systems, but differ from the last by the presence of three-dimensional images of video information synthesized by computer, considerably higher program-algorithmic security, more perfect computer facilities and application of some new information subsystems (a subsystem of tactile sensation, speech dialogue, etc.)

The virtual reality is a technology of three-dimensional information interaction between person and computer which is realized with the help of complex multimedia - operational tools.

Virtual reality serves for creation, with the help computer graphics and other tools, realistic three-dimensional seen, tangible and sounding space in which the person can be shipped and where it can really cooperate with the three-dimensional objects created by a computer.

Being the human-machine interface of qualitatively new type modeling a three-dimensional realistic virtual environment (environment), VRS allow the person enter this environment and to cooperate with it. Actions of the person in a virtual reality are taken into account during its modeling. Position of a body, a direction of a sight, effort of muscles, and also results of activity of the person are fixed by various sensors and entered in a computer, closing a feedback of a control system by development of the reproduced virtual script.

Recently began possible to cooperate with models VRS in the different ways, including by tools of voice commands and a sign language.

For creation of the realistic image of the three-dimensional virtual environment it is used three-dimensional graphic with various receptions of toning and drawing of a structure. Three-dimensional modeling of virtual objects with realistic behavior is key property of VRS. Imitation of behavior of objects of the virtual environment is achieved by the realistic three-dimensional show of an environment accompanied with corresponding sound effects and even, in a number of the systems, specific movement of parts of object.

In VRS for display of the three-dimensional information the greatest distribution was received the stereotelevision systems: both two, and single-channel. In two-channel stereosystems two images - stereopairs - are displayed simultaneously on two kinescopes (or two flat television panels) and perceived simultaneously both left, and the right eye. Thus the observer has illusion of a three-dimensional scene. The given approach is realized in so-called stereoviewer (helmet-mounted stereodisplays). In single-channel stereosystems the consecutive principle of reproduction of two images of stereopair on one display with their subsequent division and a direction in the left and right eye of the observer is usually realized.

For division of images stereopairs use various glasses: color, polarizing, light-switching valves. Such glasses reduce seen brightness of the image. Besides necessity of use of special glasses causes in the observer the certain discomfort at perception of the three-dimensional information. Therefore the big attention is paid on system engineering of the three-dimensional display, possessing property of autostereoscopy, i.e. not demanding special stereo glasses. Raster and holographic systems, and also systems concern to autostereoscopy systems with mobile screens. Another type is digital electroholographic systems and systems with mobile screens. In such systems, owing to the principles of action incorporated in them, the three-dimensional image which can be seen in various foreshortenings, in any direction and in a wide range of corners is formed. For creation such displays in helmet stereosystem it is necessary to define with the help of special sensors changes of position of a head and a sight of the observer and, according to the received signals, to make in the computing way the necessary changes to the image of stereopair submitted in helmet stereodisplay. However such approach is enough complex and does not give high accuracy of display dynamically changing picture.

By development highly effective helmet displays for systems VR, there is a number of problems, basic of which is the following: maintenance of the necessary resolution, a required corner of sight and corresponding information productivity of the computing structures synthesizing the necessary video information.

One of ways of partial elimination of the named lacks can be creation special laser micro-scanner mini-display with resolution about 8000*6000 elements in the staff. Use of two such mini-displays in helmet stereosystem can considerably increase effect of visual occurrence of the person in a virtual reality.

For the best sensation of a reality at occurrence in a virtual reality it is necessary to increase considerably amount and speed of calculations at synthesis of television stereopairs. Productivity of modern computing systems yet does not provide for sight of the person of comfortable perception of the three-dimensional dynamically changing visual information on virtual space.

However application of the computing structures based on the newest neural technologies and having ramified parallel architecture, allows to expect, that efficient control the three-dimensional visual environment in virtual space will be possible and that comfortable enough conditions for visual perception SVR will be created in the near future . In some cases application autostereoscopy multiple-angle systems of display, such, as some raster systems (in multiple-angle realizations) and, especially, digital electroholographic systems of display is the most effective. They allow to create for the person natural conditions multiple-angle perception of the three-dimensional image. However use of modern holographic systems while is connected to the big computing expenses, and the level of the achieved characteristics leaves much to be desired.

Methodological and psychophysiological aspects of creation of virtual space and interaction with it are developed still poorly, here again there is a set of questions.

Obviously, technical development of VR-systems will go aside perfection of opportunities of graphic imagine, and simultaneously - gradual reduction in price of systems. Brothers Latipov develop "Virtual Sphere» which rotates, simulating movement of the person in the virtual world - thus, his movement demands real muscular efforts, instead of simple pressing buttons or joystick turn. There are the projects supposing saturation of a virtual reality by smells corresponding to conditions.

In Virtual Reality Applications Center in the Iowa State University modernization of the virtual reality most powerful and accomplished from all rooms in the world is completed: 100 million of pixels surrounding the visitor literally from different directions, even on a floor, the original three-dimensional image and a multichannel sound. It is a cube with the sides of 3 meters (the internal size of a room), all sides - walls, the floor and a ceiling - represent screens on which in the high resolution are reproduced a picture from the most powerful computers. The picture is 3-d. So the visitor of a room should put on special glasses. Speakers surrounding a room from different directions, and system of wireless "tracking" of the person inside, positions of his hands, legs, heads allow to create the unprecedented worlds for scientists.

Convenient tools of the image for many kinds of researches are not half of success. And in any cases is a unique way to understand details of process and to receive the necessary information.

Because of C6 scientists can wander among huge albuminous molecules, touch them, and turn.

Also in this room it is possible to simulate interiors of complex machines, and - to recover them, having made possible revealing of any weak places.

With C6 biologists (is more exact, programmers) have created recently new way of convenient image of the information at once about 22 thousand the genes, allowing to find new dependences between them.

C6 modernization cost for university is about $4 one million. For the resolution of the computer video shown on all sides of a room it was possible to increase without the slightest loss in speed of processing of the information, authors of the project have bought 96 powerful graphic processor Hewlett-Packard.

Besides 24 digital projectors Sony, and also new eight-channel sound system and new system of tracking of moving of the person inside a room have been bought.

One of the important directions in VRS - creation of three-dimensional model of city with all streets, houses, courtyard, with each window and a doorway.

Except for a traditional "manual" way new methods are developed. So, new technology of fast creation of 3D-model of the city environment (Fast 3D City Model Generation) have offered in laboratory of university of Berkeley (UC Berkeley Video and Image Processing Lab) by professor Avide Zahor (Avideh Zakhor) and Christian Frju (Christian Früh). For that laser scanners and the digital camera established, accordingly, by the plane and a ground vehicle are used. Time of creation of 3-d models of city quarter is reduced till 2-3 hours. With the help of the laser it is possible to fix distances, the sizes of objects and other "geometry", and a photo are necessary to pull "facades" on skeletons of these objects. The given work custom-made by armies the USA on behalf of research agency DARPA which financed the most part of research.

At the numerical decision of many of scientific and applied problems there is a task of evident representation of results of modeling. Especially the problem of visualization rises at carrying out of large-scale computing experiments in area of 3d modeling on multiprocessing computing systems of tasks of gas dynamics, burning, microelectronics and of some others. Now practically there are no comprehensible standard universal tools of visualization of the net multivariate data of great volume.

Development of the supercomputer centers giving the resources to remote users through slow Internet channels demands creation of interactive network tools of visualization. Because of limitation of capacity of global networks, transfer through them of results of calculations does not give an opportunity of their interactive studying. Even with fast local network, great volume of results of calculations does not allow to use directly for visualization uniprocessor computers at users workplaces. Thus, for today, absence of convenient interactive tools of representation 3d data of great volume is one of the major factors limiting an opportunity of an effective utilization of high-efficiency multiprocessing systems for studying of complex nonlinear problems. System of three-dimensional visualization of the scalar data of great volume, focused on support of the local and remote users of the supercomputer centers. Division of the program of visualization into two parts - server and client, allows to carry out the basic processing of the visualized data on computing resources of the supercomputer center, transferring on a workplace of the user a minimum of the information directly necessary for construction of the image. Such approach assumes, that the image is finally formed on a workplace of the user [1]

One of the major directions of development of computer graphics in VRS is physically accurate modeling distribution of light in various environments. This task is determined by the decision of a problem of global light exposure when it is taken into account not only direct light exposure of surfaces of a scene by the beams going directly from light sources, but also the secondary light exposure created by beams, reflected or refracted other surfaces. All physically proved methods of calculation of global light exposure are the approached decisions of the integrated equation of rendering. Difficulty of the decision of this equation is determined by its recursive character and complexity of area of integration; therefore in practice the approached methods of the numerical decision are applied.

Direct and return trace of beams

For the numerical decision of the equation of rendering the technology has been constructed on the basis of methods of Monte Carlo and trace of the beams, allowing with high accuracy to expect light exposure of real scene and to build realistic images of photographic quality [2]. The idea of a method of Monte Carlo of direct trace of beams will consist in statistical reproduction of the mechanism of distribution of light by modeling every possible trajectory of beams. Trajectories of light particles (photons) are traced at all scene of existence, from the moment of their generation by light sources before absorption or an exit from a scene. A direction in which the photon and a launching site of a light source are determined stochastically according to photometric distribution of energy. The trajectory of a photon is traced before crossing with a surface.

At interaction of a photon with a surface, it can be absorbed, is diffusely reflected (refracted) with uniform density of distribution on a hemisphere, reflected (refracted) in a mirror direction, or reflected (refracted) according to the set density of distribution. At a choice of the further behavior of a photon according to properties of a surface (for example, diffusive or mirror reflection) the principle of a roulette is used.

For the task of not trivial optical properties of a surface the bidirectional function describing density of distribution of reflections and refractions (BRDF/BTDF) can be used

After global light exposure of a scene is designed by a method of Monte Carlo, its photorealistic image can be constructed with the help deterministic algorithm of return trace of beams.

Another, modern, method of determining of natural illumination images with a wide dynamic range of brightness (High Dynamic Range Images - HDR images) real scene can serve. HDR the image represents spherical, indefinitely remote, a light source which with high accuracy describes light exposure of a real scene. Such images can be received by special processing several digital photos with a various exposition or results of panoramic videoscanning. HDR images allow to use earlier fixed illumination of a real scene (as the image with a wide dynamic range of brightness) as a light source for a modeled scene. In result there is an opportunity to integrate modeled objects with a real environment.

The complex task is rendering in real time of the volumetric data. The estimation of amount of the calculations required for rendering of high resolution volume in real time, makes hundreds TFLOPS. And, nevertheless, the requirement for such rendering constantly grows on the part of arising technologies, such, as virtual surgery and fast prototyping. There are five basic approaches to solve it: 1) reduction of amount given by construction of model; 2) development of the specialized hardware devices; 3) optimization existing and the invention of faster algorithms; 4) realization on parallel general purpose architecture, and 5) use of the modern graphic equipment.

The most simple way for construction of a visual image is to bypass all volume, considering everyone Voxel as 3D point which will be transformed on a matrix of specific transformation, then is projected in the Z-buffer and drawn on the screen. Such way of visualization name rendering in objective space (object-space rendering) or rendering of a direct course (forward rendering).

Other algorithm - BTF (back-to-front) to an essence coincides with a method of the Z-buffer, and differs only preliminary sorting of a Voxel array which allows to scan its components by way of reduction or increases in distance up to the observer. Using preliminary sorted Voxel arrays, in BTF-algorithm detour of volume is made by way of reduction of distance up to the observer, and the Z-buffer is not becomes necessary for elimination invisible Voxels. The algorithm of drawing mixes it with value of the screen.

Algorithm FTB (front-to-back) basically coincides with BTF, however Voxels distances manage in ascending order. It should be noted, meaning, that the pure method of the Z-buffer cannot provide rendering of translucent materials as Voxels are displayed on the screen in the any order. Mixture of light is based on the calculations modeling its passage through different materials. Thus, it is possible to realize easily translucency both in BTF, and in FTB as in these methods objects are displayed on the screen in the same order in which on a scene pass light beams.

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Automatic Control Systems

The devices controlled either distantly or automatically are necessary to research the Earth and space, such as Earth space satellites, spacecrafts and Interplanetary automatic stations with docking system, returned flight vehicles, and planet research vehicles, robots for carrying out every possible jobs and researches in dangerous conditions. The automatic control system is necessary for all of them.

Today, the most advanced methods for designing of automatic control systems are based on use of strict mathematical models of objects. However, for the overwhelming majority both artificial and natural control object (CO) construction of exact mathematical models is practically impossible in view of their bad formulation. Besides, these objects can operate in environments which properties may change or cannot be determined completely beforehand. Control of such objects is possible only with use of adaptive principles. In case of bad formulation of CO special interest is caused by the systems constructed on new, intelligence principles. These systems use such parts of an artificial intelligence (AI), as fuzzy logic, intelligent systems, genetic algorithms, artificial neural networks, etc.

Among all intelligent control systems, those systems designed not only with one control of AI, but joining some of them is especially effective.

Processing of the fuzzy information and fuzzy deduction are already applied in various intelligent systems, however most fuzzy systems have received a large widespread in the field of control systems.

The general scheme of fuzzy processing of information seems as it follows. The exact initial data from the sensors of supervising control process are translated into values of language variables in the special block. Then, used procedures of fuzzy conclusion on set of the rules making the knowledge base of a control system and resulting in making target linguistic values which are translated in exact values. On an output control influences for executive mechanisms are formed. This conceptual scheme used in the so-called fuzzy controller in intelligent systems of processing of the uncertain information, in particular, in intelligent control systems.

In classical fuzzy controllers there are no mechanisms of adaptation in real time to change characteristics of interaction of control object with an environment that does not allow applying fuzzy systems to control of objects with changing in time properties. However, there are a number of methods expanding possibilities of fuzzy controllers in this area.

Application of traditional fuzzy logic in modern systems is limited by the following factors:

- As a rule, complex control system has a lot of inputs, than the most ordinary fuzzy appendix;
- Addition of input variables increases the complexity of calculations;
- As consequence of the previous item, increases the base of rules;
- Operations in real-time demand some special equipment.

At the same time, the Neural Network (NN) for processing of information has the following pleasant properties:

1. Flexible model for nonlinear approximation of multivariate functions;

2. Means of forecasting in real-time those processes dependent on many variables;
3. The qualifier to many attributes, giving splitting of input space into areas;
4. Means of recognition of images;
5. The tool for search on correlations;
6. Model for search of regularities in data.

1. Learnability. Having selected one of the NN models, having created a network and having executed algorithm of tutoring, we can train a network to solve a problem.

2. Ability of abstraction. If to input to networks some deformed variants of an input image the network itself can create an ideal image which it never met.

The tasks successfully solved in NN at the given stage of their development concern:

- Visual Recognition, acoustical images;
- Text Recognition;
- Targets Recognition on radar screen;
- Systems of voice control;
- Associative information, search and creation of associative models; synthesis of speech; formation of natural language;
- Formation of models and many nonlinear systems difficult to describe mathematically, prediction the development of these systems in time: application on manufacture; forecasting of cyclones evolution and other natural processes, forecasting of fluctuations of exchange rates and other financial processes;
- Control systems and regulations with prediction; control of robots and other complex devices;
- Diverse ultimate automatic devices: systems of public service and commutation, telecommunication systems;
- Decision-making and diagnostics excluding a logical deduction; especially in areas, where there are no precise mathematical models: in medicine, criminalistics and financial field;

Recently, it is developed a large quantity of methods, allowing to produce high-quality control systems of dynamic objects with unknown or variable parameters. However, these systems as a rule are complicate, so it is required to measure or identify all their changing parameters.

Relating to this, it is appropriate to elaborate new approaches and methods based on new philosophy of control, including the neural networks (NN). Automatic control systems, constructed with use of NN, have appreciable advantages in comparison with traditional systems. In particular, they not require exact knowledge of control object (CO) mathematical models, they can work in conditions of parametrical uncertainty of these objects, are insensitive to changes of CO parameters (robustness), stable under noise, are easily realized with use of typical controllers and allow to use parallel calculations.

Among NN, the neural fuzzy networks offer the greatest interest. Algorithm of formation of these networks is built on the basis of system of a fuzzy deduction, which is required manual adjustment of parameters. That is the main obstacle of application of fuzzy regulators in adaptive systems. However, in the system of a fuzzy derivation such as neural network, it is possible to apply a method of the inverse error propagation with the purpose to find optimum coefficients of fuzzy system, satisfying to the condition of adequate display training data. It is significant facilitate the practical decision of a task of formulating the specified regulators. Application of algorithms of automatic adjusting of parameters of neural fuzzy network on the basis of opposite error propagation allows to avoid process manual adjustment. But, in this case, for adjusting parameters of given network is demanded a long time. Since computing complexity of algorithms of adjusting NN is proportional to amount of the used training data, at introduction of local optimization it is possible to decrease substantially volume of these constantly updated training data and by that essentially reducing capacity used computing means, solving a task of tuning of a network in real time

Since neural fuzzy systems are rather easily adjusted and possess property robustness (it especially important if these systems are intended for job with noised signals in conditions of parametrical uncertainty) these properties presume to provide their effective utilization for management of complex nonlinear dynamic objects with uncertain and (is essentially unpredictable) in changing parameters. Such systems can be used, in particular, for designing high-precision control of submarines (underwater vehicles).

Example of application of such system is the task of synthesis of control system can serve as nonlinear non-stationary dynamic object on the basis of the NN adjusted in real time. [1]. In the given job it is applied NN ANFIS (Adaptive Neural Fuzzy Inference System).

Proposed new approach to synthesis of neural systems control in conditions of uncertainty does not suppose the direct use of model of control object. From the point of view of techniques of synthesis this closes to inverse neural control, but functionally the system has properties of predicting control. It is obvious, that attempts of deeper calculation of increasing number of factors at synthesis of systems of automatic control create qualitatively new situation, then it seems more productive the solution of problems with positions of functioning of system in conditions of full or partial uncertainty. It is possible, that in such tasks the classical methods of control theory be ineffective, and essentially new results can be expected in the field of intelligent control systems which are based on neural networks. Taking into account ability of NN to learn, it is possible to realize a paradigm of control with prediction (Predictive Control).

The most widespread is recognized as "Model-Based Predictive Control (MPC) ", being as a variant of the optimum control generated in real-time on each step of discrete control system. Essentially, this techniques demands existence of model of direct dynamics of controlled object, with the help of this model the prediction is carried out. Interesting attempt to realize technique without direct use of model of control object is the Model-free Predictive Control. The results of comparison of this approach with classical and modern systems the PID-controls received on the basis of mathematical modeling and real control by complex objects [2].

The NN is widely applied to analysis of the geophysical information. Huge interest causes application of intelligent systems in tasks of processing of geo-information system. For example, at reference [3] are examined the problems surging at treatment of experimental data tables. Neural network methods of information processing are used for tasks of classification and construction of regression dependences. With the help of neural network, the transposed linear regression, neural network nonlinear regression and neural network qualifiers tasks to predict unknown values of climatic parameters, classifications of landscape zones and global modeling of consequences of change of climate are solved on the basis of the table of the data collected from meteorological stations of Siberia and Far East.

Processing of images

It is necessary to develop methods of presentation and analysis of images (compression, coding by transfer with use of various reports, processing of biometric images, pictures from satellites), reproduction independent of equidevices, for optimization of color image on the screen and at printing, the distributed methods of reception of images.

The further development should receive search engines, indexing and the analysis of sense of images, the coordination of contents of help catalogues at automatic cataloguing, the organization of copy protection, and also machine vision, algorithms of recognition and classification of images. The development of neurocomputer for control of mobile engine of the hyper sound plane is perspective. For the decision with the help neurocomputer the task of training of a neural network to manufacturing of exact maneuver of a fighter, a task of robots control: direct, return kinematic and dynamic tasks, planning of a traffic road of robot. Transition to neurocomputer is connected first of all to limitation of volumes of computing systems, and also with necessity of realization of efficient control in real time.

For a task of synthesis of neurocontroller (NC) for control of movement of multimode flying device may be used the concept of ensemble of NC. Designing of control systems for multimode objects, in particular, for planes with high flight performances, still represents very uneasy problem, despite of the significant successes achieved both in the theory of management, and in increase of capacity of the onboard computing means realizing corresponding control laws . Such state of affairs is caused by a wide range of conditions in which such plane (speeds and heights of flight, loading on a wing, flight weight, etc.) is used; presence of the big number of modes of flight with variable dynamics, proceeding from the requirement in the best way to solve those or other tasks ("usual" flight, vigorous maneuvering, refueling in air, etc.).[4]

One of important direction of development - search of effective methods of synchronization of job of neural networks on parallel devices.

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4.2 The brief review of 3D modeling of gasdynamics processes in Gas Turbine Engines.

By present time, a number of different approaches to decide the set of individual problems within the scope of this problem are found. Actually, there is a wide choice of tools with various combinations which allow solving the majority of gas dynamic problems of engineering practice. The advent of supercomputers and parallel programming only expands options of methods, but the choice of correct tools for specific aims is becoming more difficult and depends entirely on engineer. The problem of the analysis of decision also falls on him

The most typical equations and tasks are solved by means of commercial CFD packages. There are also many programs, which are used in large companies and research centers. In this review; there is no comparison of existing products, but the most typical approaches which are considered to solve gas dynamics problems.

First of all, there is the problem of choice of equations for describing the dynamics of fluid. It can be Boltzmann equation (it is applied, for example, to describe the movement of rarefied gases), Euler (it describes the behavior of non-viscous liquid), Navier-Stokes (taking into account the viscosity of medium) in various forms (for example, averaged on Reynolds, Favr, in approximation of boundary layer, etc.).

These equations are complemented with those ones describing physical processes, occurring in flow. Here, it is necessary to introduce models of turbulence, model of chemical reactions and multiphase models, which are being developed intensively now, but still do not satisfy researchers (for example, there are problems of the correct description of boundary layer transition, modeling of burning). It is possible to mention the models of Londer (k - ε), Menter (SST), Spallart-Allmaras, turbulent viscosity (nu_t-92, CIAM). So-called momentary hydrodynamics in which there are taken into account the internal moment of momentum of medium, asymmetry of turbulent and viscous tension developed recently. Multiphase flow is described within the framework of Euler's approaches (interpenetrating continuums, unique models in this direction are developed in JIHT, MAI) and Lagrangian (evolution of coherent area of each phase). This variety of equations introduces different types of name (differential, integral), different variables (for example, physical variables, a rotor of speed, potential, etc.), different systems of coordinates (1D, 2D, 3D, special curvilinear, etc.) applicable to real classes of flow and geometries of calculated areas.

Let us notice that the overwhelming majority of mathematical models used for solving the problems of engineering practice concerns to the category of so-called empirical models, when the system includes equations obtained by the basis of processing of experimental data.

After researcher decision about equations, the next task is the choice of the solving method. It is possible to use: analytical, asymptotic methods (very narrow class of tasks), variational, spectral methods, at last, differential methods (the widest spectrum of tasks). It is necessary to note that in connection with development of artificial intelligence, analytical and asymptotic solving methods have received new push, allowing obtaining real estimations of errors of solution and revealing characteristic of interrelations.

More detail shall be given to differential methods. Here, the tasks are: splitting of settlement area (grid generation), approximations of mesh functions, methods to account physical processes, tasks boundary and initial conditions. It is noticed, that, with use of non-stationary equations, it is possible to obtain various stationary solutions at different initial distribution of parameters. The decision of this problem depends on researcher; it is possible to recommend only that initial distribution of parameters corresponded to physically real flow. As to the task of boundary conditions, one side of a problem - the task of the conditions as much as possible corresponding to a reality (it is usual in commercial packages CFD of a variety of these conditions does not suffice), on the other side – boundary conditions should not bring spurious disturbances in solution (for example, for open borders are designed special nonreflecting conditions). Circuits of splitting (are most perspective for modeling multicomponent multiphase reacting streams) are applied to modeling various physical processes or global iterations (occupy many resources of the computer), or. We shall note, that commercial packages CFD give big freedom in a choice of models (sets of the equations) and ways of approximation, but practically do not give exact instructions, in what case what to use.

Let us give more attention to the problem of computing grid generation. Essentially, there are two different approaches: or the grid is motionless, for given absolute system of coordinates (the stream flows through borders of settlement cell); or the grid is moving with the flow (there is no overflowing between cells; borders are deformed according to deformation of lines of current). The classical representation of the last approach is the method of finite elements with all variety of its updating. Use of such moving grids when the border of moving grid is connected to physical border also is possible, and inside a corresponding subarea movement of borders of cells is set any way. The form of cells can be various and is connected to, whether approximate sides of settlement cells geometrical and others (for example, shock-wave) borders, whether or not. In connection with limitation of resources of the computer always there is a problem of generation of optimum grid, which is having the minimal number of cells at the set accuracy of the decision. Here adaptive grids when the size (density) of cells is connected to geometry of calculated area or with structure of a stream (for example, the wall or in a zone of the big gradient of parameter of a cell has less). However application of this or that grid demands its account of isotropy, since the decision can vary essentially at change of orientation of a grid and-or the form of cells.

Another problem is the definition of computational time step when solving non-stationary equations. Explicit methods are used, when the step is defined from Curant's condition and can be rather small, that increases time of calculation, or implicit methods, when there are no formal restrictions on step, but the solution can be far enough from real physical process. As probable compromise is the use of local steps for separate physical processes (equations).

Another part of solving methods is the paralleling method. Probably so-called block paralleling when the area of calculation is broken into sub-areas, flows in each of which calculated on different processor, and then there is a coordination of solving on the borders of sub-areas. Another approach will consist in paralleling operations, i.e., independent actions on each calculational step and performance of these actions on separate processors.

As a result, it is possible to verify that today there is no unequivocal approach to modeling complex flow in Gas-turbine engines and especially in scramjets. As the most perspective general approach, it is possible to allocate direct numerical modeling of Navier-Stokes equations with undergrid models (LES, DES), technology of use of the switch of models (Spallart) and anisotropic tensor of turbulent tension. Experience of calculations and interactions with 3D designing systems allows recommending grids in which sides of cells approximate real physical borders (for example, tetrahedral grids with a triangulation Delon). Created codes of calculation of parameters of a stream should carry or very narrow character (for example, models of acoustics, aerosols of various density with the account or without taking into account burning drops of fuel), that will allow to use corresponding economic methods of calculation, exact boundary conditions, or to contain the big set of the equations and boundary conditions, that is to have a research orientation (recommendations on use of those or other combinations of the equations, boundary conditions, approximations, grids, etc.

should be formed by community of users and be present at the accompanying documentation). Each code even specialized, inevitably should pass stages of a choice of models for physical processes of researched current and testing on authentic experimental data.

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Prof. Ph.D. A.A. Kozlov

Moscow, 07th December, 2006

Answers at the questions to the final Report of AST.

Prof. Kozlov A.A.

1. Although we recognize the importance of the Russian references cited in the document, why did you not mention other sources such as American and European bibliographies?

Answer - We use usually analytical reviews about foreign developments (including USA and ESA) of different Russian organizations:

- VINITI www.viniti.ru
- Keldysh Research Center http://kerc.msk.ru
- CIAM www.ciam.ru
- Journal "News of Cosmonautics"

We support also directly communications with many firms and organizations (European Apogee Motor, Royal Ordnance (now Lockheed Martin), AMPAC-ISP, Shanghai Institute of Space Propulsion and others).

You may see last short reviews about thrusters at my cite (as example) http://www.mai.ru/dep/k202/

2. Could you, please, explain the lack in the document of the research prospect on detectors and instruments for scientific satellites as required?

Answer - All instruments and sensors at satellites, spacecrafts and Space Stations may be separated in accordance with its role:

-for fundamental research investigations (astronomical, biological, medical, investigation of combustion and others),

-for applied research investigations (navigation, distance probation of the Earth,...),

-for development new technologies (the obtaining new materials, telecommunication…),

-for own subsystems of satellites (control system, thermo control system…).For example:

The "Cassini" spacecraft with European "Huygens probe" have 12instruments (magnetograph, 2 photo cameras, 3 spectrometers…) and accordingly 6 (spectrum radiometer, gas-chromatograph, mass-spectrograph, different analyzers …).

Abundance of this instruments and sensors and organizations for its development requires, at my opinion, the special analysis. Even short investigation of this direction will require a lot of time and 30-40 pages of report

3. Have you considered in the final document all kinds of electric propulsion under development around the world?

Answer - There are a lot of different kinds and design electric engines. I analyzed main electric propulsion, witch may by perspective in nearest future (10-15years).

4. What are the catalysts used in the Russian space program (monopropellant thrusters)?

Answer - Next catalysts are used in Russian monopropellant thrusters:

For hydrazine (N_2H_4) – on the base iridium, heated till 620˚K,

For high concentration hydrogen peroxide – $KMnO_4$ (with special treatment).

5. Could you provide more details of the combustion chamber (shape and materials) of bipropellant thrusters?

Answer - The typical calculation of the thrusters shape you may find in my publication:"Kozlov A.A., Abashev V.M. Calculation and design work of thruster (in Russian).Moscow, MAI, 2004. In principle, I may send by E-mail copy of this work.

There are several directions in the development materials of thrusters:

5.1. The use high temperature materials for combustion chamber and nozzle like niobium alloys, platinum alloys, composite materials with different coverings. It gives a possibility increase specific impulse of thrusters. But the use of these materials led to the increase the cost of engine and some difficulties in the technology of fabrication and connection metallic head with composite combustion chamber.

5.2. The use high temperature stainless steels with organization of inner protection of combustion chamber walls from high temperature combustion products. In this case we have more simple technology of fabrication, more low cost of the engine. The temperatures of the fire wall don't increase 1500˚K and necessary to organize enough reliable curtain.

6. Could you provide more details of injector heads in bipropellant, medium thrust (up to 400 N) thrusters?

Answer - All developers of liquid rocket engines (and different thrusters also) don't like to show the design of the mixing head and peculiarities of combustion chamber because these design are "know-how" usually. You may see some design of mixing head at may cite http://www.mai.ru/dep/k202/ and in INPE also (please, ask Mr. Nivaldo Hinckel).

7. What are the perspectives for low thrust (up to 400-500N) bipropellant thrusters?

Answer - Bipropellant thrusters with thrust up 400N are used and will be used very wide in space industry as apogee engine or main engine on spacecrafts. For examples:

КТДУ-80(developer NII MASH –DB NII CHIMMASH), P^v=6190N, propellant N_2O_4 + $(CH_3)_2N_2H_2$ .Used on spacecraft "Progress" and other modifications of "Progress", on spacecraft " Soyuz-TM" and other modifications of "Soyuz";

EAM (European Apogee Motor), P = 480-520N, propellant $CH_3N_2H_3$+

MON-1+MON-3, used for spacecraft bus;

TR-308(Company Northern Grumman), P = 470N, propellant N_2O_4 + N_2H_4, used for spacecraft bus;

SPPS- project of the Solar thermal propulsion system (Keldysh Research Center), H_2 +O_2, I_{sp} =810s, Pv = 780N.

8. What are the perspectives for test benches with altitude simulation in the nearly future? Will computers take their place? How does the Russian space program handle with this matter? And in other countries?

Answer - At presence, the tendency increase of role PC in the fire tests of thrusters is developed. Measure-calculated complexes of the firms Kontron, Grayhill and Dataforh let not only measure the thrust, pressure, mass flow rate and temperature of propellant and design, but to control regime work of the engine (including pulse regimes). Besides, developed models of the heat state thruster let to simulate heat condition of the engine work and, therefore, to decrease the volume of the fire tests.

Next perspective direction – for the decrease high cost of fire tests in vacuum chamber (very expensive tests) – the use of gas injectors for guarantee altitude conditions of pressure at the exit section of the engine nozzle. In this case only short fire tests are fulfilled in the vacuum chamber for the finishing start characteristics of the thruster. Total cost of the fire tests is decreased significantly.