1. INTRODUCTION

OAO “Mashinostroitelny Zavod” is one of the major companies in the world manufacturing fuel for the nuclear power reactors of various types. OAO MSZ manufactures fuel for VVER-440, VVER-1000, VK-50, RBMK-1500, BN-600, EGP-6, CM-3 reactors and fleet reactors.

OAO MSZ supplies Fuel Assemblies to the NPPs located in Russia, Ukraine, Armenia, Lithuania, Czechia, Hungary, Slovakia, Finland, Germany and other countries of the Western Europe.

OAO MSZ was the first enterprise that set up the production of VVER-1000 Fuel Assemblies in the period from 1975 to 1978. The first VVER-1000 reactor core was manufactured by OAO MSZ for Unit 5 of Novovoronezh NPP. Later on OAO “NZXK” (Novosibirsk) proceeded with the production of VVER-1000 Fuel Assemblies.

However, in 1995 the Russian Ministry of Atomic Energy taking into account the need to have another competitive supplier of nuclear fuel for the operating NPPs decided to resume the VVER-1000 fuel production at OAO MSZ.

Considering the current demand of the nuclear fuel market as well as the customers’ requirements the engineering departments of OAO MSZ in cooperation with the scientific research institutes and designing bureaus of the industry sector have brought about a number of improvements on increasing the life time and enhancing reliability and safety of Fuel Assemblies, in particular fuel rods.

The present paper represents the main ways to improve the fuel quality and VVER-1000 fuel rod design.

2. DEVELOPING DESIGN AND FABRICATION METHODS

2.1 Design

The fuel rod design applies the following:

– butt-resistance welding (KCC-2);
– a spring catch and a spacer to space fuel pellets apart;
– an advanced cladding tube;
– a lower plug that serves as a collet connector between a fuel rod and a lower lattice of FA and allows FA to be dismantled on the inspection jig to replace defective fuel rods if any;
– a fuel pellet with a reduced diameter of the inner opening to increase the fuel charging;
– a fuel column with an extended length to increase the duration of the fuel campaign as well as the rated power of the generating Units while maintaining the required level of thermotechnical core reliability;
– an increased enrichment of fuel pellets being up to 5% as to U-235;
– a burnable absorber integrated into fuel pellets;
– pellets from reprocessed uranium.

2.2 Fabrication methods

OAO MSZ operates the complete cycle of the nuclear fuel production – starting with conversion of uranium hexafluoride to uranium dioxide powder and completing with FA manufacture.

The methods for manufacturing fuel have been developed for years and have accumulated a wide experience. The most perspective trends to assure high quality of products are to continuously improve the existing techniques and to develop new promising technologies. At that, if the technology is highly automated, this eliminates the human interference on the production and results in increasing its stability and quality level. To follow the above trend OAO MSZ carries out a large scope of activities to upgrade the methods for manufacturing FA and its components. The high degree of the production automation and mechanization, application of the most efficient and reliable flow charts and controlling instruments as well as availability of its own highly - developed tooling manufacture continuously ensure high quality of products.

I would like to bring up details of some aspects for improving the fuel rod fabrication methods.

2.2.1 Over many years the leak test operation was a main obstacle for building up a completely automated line for the fuel rod production.

Automating a leak test with a pre-drying operation is a challenging task and raises a number of problems:

– it is necessary to properly carry out the pre-drying operation for at least 40 min at the temperature of 300...400°C prior to the leak test and to keep pace with the production line speed (the throughput is not less than 1 item per min);
not only the weld junctions but the fuel rod claddings are supposed to undergo the leak test (the test is carried out in a high vacuum).

To solve the above task we have looked for non-standard engineering solutions for developing the fundamentally new generation of the mechanized leak testing equipment for fuel rods. This new equipment ensures the completely automated production of fuel rods with the cladding tubes made of zirconium alloys and enhances the reliability of the leak test. At that, the leak test equipment detects wall-through defects, takes less production area, reduces the energy consumption by dozens of time, completely eliminates the rejects caused by the mechanical damage to the fuel rods.

2.2.2 Over the last years a series of examinations have been carried out to analyze the factors that influence the moisture content in the finished fuel rods. The examinations have proved the following:

1. The main source of humidity in the finished fuel rods is moisture sorbed by the fuel pellets. At that, the limit for maximum open porosity of the fuel pellets allows reducing the moisture content in the finished fuel rods to a minimum.

2. The ingress of moisture under a fuel rod cladding in quantity substantially exceeding the allowable limits is possible only in the event that there is:
   – a gross violation of the manufacturing process;
   – an emergency situation when water may come into contact with the parts of the manufacturing equipment.

Using automated production lines and carrying out the continuous inspection of the manufacturing process and products quality allowed us to sort out this problem.

2.2.3 OAO MSZ has developed the methods for manufacturing fuel rods of various types the active part of which consists of several zones with different U235 content both with gadolinium doping and without it.

The production is carried out using the automated modular lines.

For the multi-zone fuel rod production the following tasks have been solved:

1. The operation of the whole complex for loading the multi-zone fuel rods has been co-ordinated.

2. The following requirements peculiar for the multi-zone fuel rods have been fulfilled:
   – length of fuel column zones;
   – length of total fuel column;
   – weight of fuel column zones;
   – weight of total fuel column;
3. MODIFICATIONS OF VVER-1000 FA-A FUEL RODS WHICH ARE INTENDED FOR THE TRIAL AND COMMERCIAL OPERATION IN GENERATING UNIT NO 1 OF KALININ NPP

The up-to-date nuclear fuel market features the strong competition that demands to supply the consumers with various fuel types capable of assuring maximum reliability, safety and efficiency. To increase the competitive ability a series of fuel rod modifications has been developed. Some of them as a part of FAs have been successfully installed and are being operated in Unit No 1 of Kalininskay NPP and some of them are being prepared for the operation.

3.1 FA-A-Y fuel rods

The overall length has been increased by 150 mm in comparison with a standard fuel rod by adding two blanket zones (lower zone – 90 mm and upper zone – 60 mm) that are collected with fuel pellets of 0,5% enrichment. The fuel rod contains a lower plug with a click. This will allow the FA to be dismantled. In the future it is planned to replace the low-enriched pellets with the pellets of typical enrichment. This will allow increasing the rated power of the VVER-1000 Units while maintaining the thermotechnical reliability of the pilot core. At that, the capacity of the Unit can be increased by 103% - 105%.

Increasing the height of the fuel rod active part results in reducing the specific energy release in the core, decreasing the linear load (- 4%) and increasing the margin to the critical heat flux while maintaining the capacity of the Unit.

3.2 FA-A-T fuel rod

The overall length has been increased by 17 mm in comparison with the standard fuel rod by using the elongated spacer. This change in design will allow the fuel rods to be used at the Czech Nuclear Power Plant “Temelin”. The fuel rod uses a lower plug with a click, this allows the FA to be dismantled.

3.3 FA-A-5

This design uses fuel with the enrichment of 5% as to U-235. The fuel pellets with the inner opening diameter of 1,2 mm will allow increasing the UO2 charging up to 500,6 kg per FA. The FAs consisting of FA-A-5 fuel rods are supposed to be operated under reactor conditions for 5 years.

Besides, for the next fuel reload it is planned to install pilot FA-A containing 18 fuel rods with the central opening - free pellets. In the future UO2 charge per FA that has
fuel columns of all 312 fuel rods loaded with the opening-free pellets will make up 546 kg.

4. CONCLUSION

Improving the design and fabrication methods as well as developing new modifications of fuel rods for alternative VVER-1000 FAs will allow us to reach such parameters as:

– 4 - 5 year fuel cycle;
– increase in fuel burn-up;
– enhancement of performance characteristics of fuel cycle.

Without doubt this will improve the competitive ability of VVER-1000 fuel being manufactured by OAO Mashinostroitelny Zavod.