DEVELOPMENT OF ANTI-DEBRIS FILTER FOR VVER-440 WORKING FUEL ASSEMBLY

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Abstract

Mechanical damaging of the fuel rod claddings caused by debris is one of the main reasons for fuel assembly failures.

The paper focuses on the program and results of experimental and design activities carried out by Russian organizations relating to the development and investigation of operational characteristics of anti-debris filters for VVER-440 working fuel assemblies.

Lead working fuel assemblies equipped with anti-debris filters have been loaded in the core of Kola-2 NPP.

The results obtained can be used for making the decision concerning the application of anti-debris filter for VVER-440 working fuel assemblies with the purpose of enhancing their debris-resistance properties.

INTRODUCTION.

Operational experience of VVER-440 reactors over many years has shown high fuel reliability. However, fuel assembly (FA) damages are still observed and a fuel supplier should constantly take measures aimed at enhancing fuel reliability.

The damages of the fuel claddings in the pressurized water reactors to which VVER-440 belongs caused by foreign particles (debris) being transferred by the coolant, contributes to a great degree to the failure statistics. According to the Russian and foreign investigations of failed fuel assemblies it is the cladding-debris interaction that is the reason of failures in more than a half of cases.

One of the remedies to reduce fuel assembly failures due to the cladding damages caused by debris is to insert special devices – anti-debris filters (ADF), which protect against debris of a certain geometry entering the fuel assemblies during operation.

The main requirements for anti-debris filters are as follows:

- ADF should capture debris of more than 2-mm size;
- ADF should not become clogged;
- ADF should have an appropriate hydraulic resistance;
- ADF should not “deteriorate” a velocity field at the inlet of the fuel rod bundle;
- ADF should be robust enough;
- ADF should be installed into a fuel assembly in such a way as to assure optimal compatibility with the FA design.

In 1999 OAO TVEL adopted a modernization program for the VVER-440 fuel assemblies that provided for the anti-debris filters development.

In 2003 on the basis of the design offered by OAO Mashinostroitelny zavod and OKB Gidropress a R&D program (a development program) was launched to develop and license an anti-debris filter for the VVER-440 working fuel assemblies. The program is currently running.

The present paper describes an anti-debris filter design and basic steps provided by the development program as well as some results achieved.

ANTI-DEBRIS FILTER DESIGN.

Fig. 1 shows a cone-shaped ring filter design with a clear dimension of 2 mm that was accepted as the basic design.

Fig. 1. Anti-debris filter

ADF should be mounted in the FA tailpiece in such a way as to provide for safe fixing and to minimize an attachment point influence on the FA parameters. As a result of the comparative tests performed according to the program to be described further, a fixing area was selected in the expanding conical part of the tailpiece. ADF is attached with the cone point opposite to the flow direction. Fig. 2 shows the tailpiece of the working FA equipped with ADF.

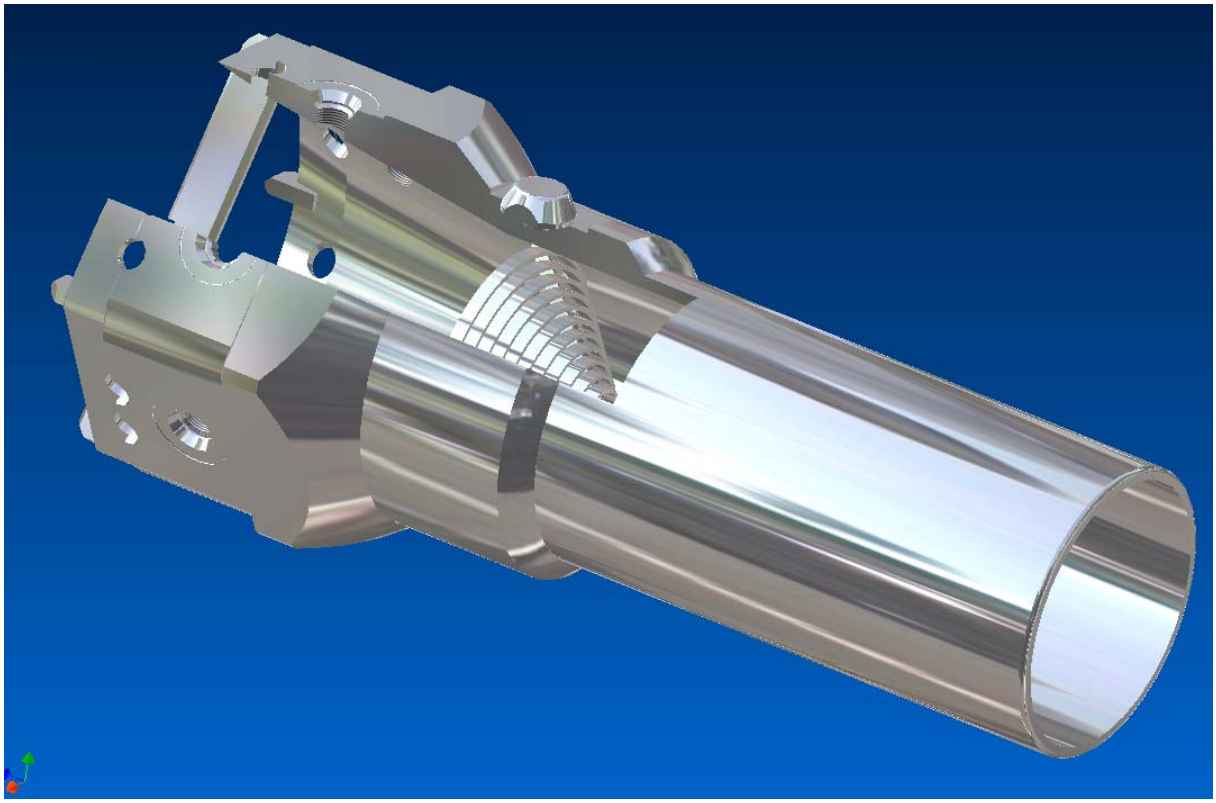

Fig.2. Tailpiece of the working FA equipped with ADF.

ADF is made of corrosion-resistant steel of X18H10T grade that is used for manufacturing of other components of the fuel assembly.

THE DEVELOPMENT PROGRAM

R&D program (the development program) was developed to justify the selected design of ADF and to define the characteristics of the FA to be equipped with ADF.

The development program included:

- Hydraulic testing of a dummy;
- Testing of ADF efficiency;
- Evaluation of the robustness of ADF design;
- Evaluation of ADF effect on the coolant velocity field;
- Licensing of pilot FA operation;
- Manufacturing of pilot FAs to be inserted in the reactor;
- On-line inspection of the pilot FAs.

Fig.3 presents the development program schedule.

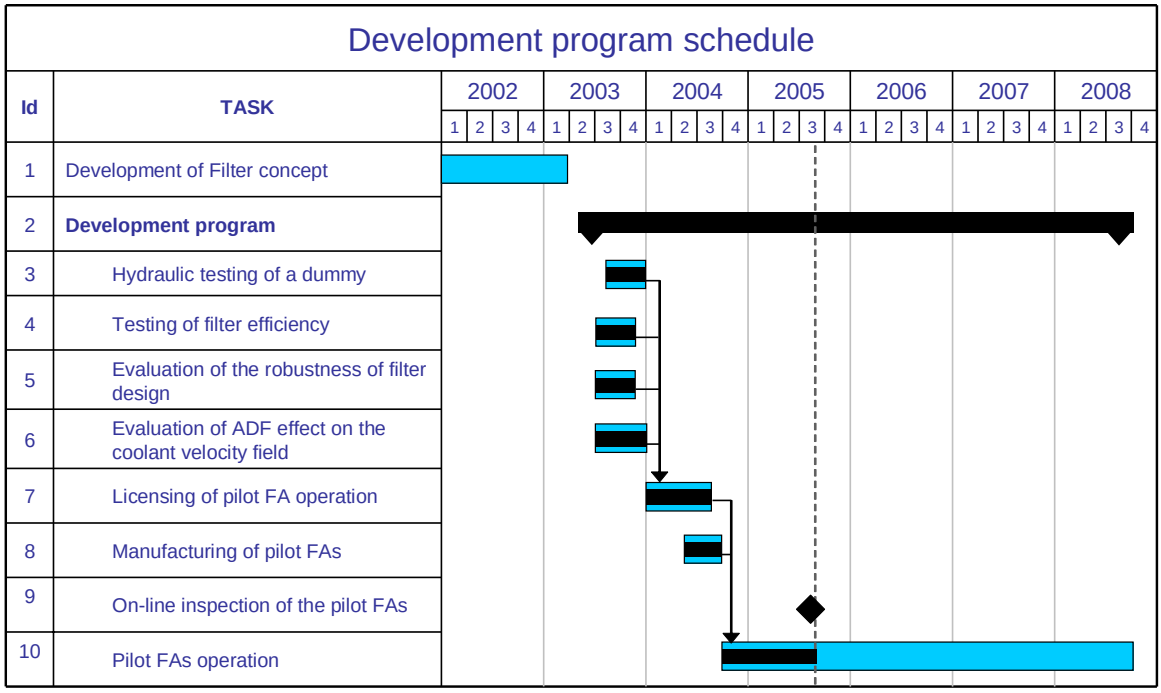

Fig. 3. Development program schedule

Hydraulic testing

The hydraulic tests were performed on a full-scale dummy of the working fuel assembly equipped with ADF. The OKB Gidropress's rig allows to make real tests with the coolant parameters meeting the VVER-440 reactor requirements.

Based on the test results a hydraulic resistance coefficient for ADF has been determined as well as optimal position and orientation of the ADF in tailpiece.

Testing of ADF efficiency

Testing of ADF efficiency was carried out on Elektrogorsk test rig specially designed to perform this kind of tests. The test rig is described in detail in the paper /1/.

The tests assumed that a certain quantity of debris in the form of wires, small balls and other things of different sizes were introduced into the coolant.

The tests show that:

- a sufficiently big amount of debris (with a dimension of less than 2,0 mm) pass through FA without being stuck;

- the biggest amount of debris is sticking in the FA not equipped with ADF;
- the smallest amount of debris sticks in the FA equipped with ADF;
- ADF of the selected design (i.e. a cone-shaped ring filter with a clear dimension of 2 mm) has not been clogged with debris nor prevented the coolant flow.

Evaluation of filter robustness.

For the purpose of testing of the filters an imitator of debris was used, its weight being in the range 0,05 – 300 g. The tests were made at the conditions of the increased coolant flow rate up to 150 m^3/h. No dents or damages caused by debris have been found on the filters. The endurance tests of the dummy working FA on the OKB Gidropress's rig have not shown any damages of the ADF as well.

Evaluation of ADF effect on the coolant velocity field.

The investigations of the coolant velocity field were carried out in the Bauman Moscow State Technical University on the rig described in detail in the paper /1/. As a result of the work performed it has been established that the ADF of the selected design (i.e. a cone-shaped ring filter with a clear dimension of 2 mm) is efficient in decreasing nonuniformity of average velocity in the inlet of the working FA support grid in the working FA of VVER-440 reactor.

Licensing of pilot FA operation.

Upon completion of the tests a decision was made and agreed upon with the operating organization to insert six pilot working FAs equipped with the ADF of the selected design into Kola-2 for a trial run. For licensing of the trial run the following work was performed:

- Estimated analysis of the thermal and hydraulic characteristics of the core;
- ADF strength analysis;
- Program and methods were developed for in-reactor testing of the pilot batch of the working FAs;
- Acceptance tests of the manufactured pilot working FAs;
- Operational documentation for the 27 reload of the Kola-2 NPP was corrected.

Based on the work performed a release was obtained from the Russian competent authority to change the license conditions for the Kola NPP.

Pilot working FA fabrication.

Six pilot working FAs equipped with ADF were manufactured by OAO Mashinostroitelny Zavod in June 2004. The plant developed working design documentation, manufactured process tooling for ADF and upgraded tailpieces for the working FAs. On the results of the acceptance tests the pilot working FAs were considered good to be loaded into the reactor.

Pilot working FA operation.

Six pilot working FAs equipped with ADF were loaded into the core of Kola-2 during scheduled refueling in 2004. They have been operating according to the trial run program mentioned above. This program stipulates that the inspection of the pilot working FAs should be carried out during refueling outage. The scheduled inspection date is August 2005.

CONCLUSION

The work performed by the Russian organizations enabled to develop the working FAs equipped with ADF and insert them into the reactor for the trial run. It will obviously enhance the reliability and safety of the VVER-440 FAs under severe operating conditions.

REFERENCES

1. V. Gashenko and others. Pilot study of various ADF designs for VVER-440 working FA. Conference on VVER-440 safety, 2005, Podolsk, Russia.