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A boost for MYRRHA

MYRRHA switches to phased development

150 engineers, scientists, technicians and administrative assistants from 27 different countries are working on MYRRHA, the Multi-purpose Hybrid Research Reactor for High-tech Applications. What stage is the financing and development of this successor to BR2 at? Project Director Hamid Aït Abderrahim takes stock of the situation.

In 2009, investment in MYRRHA was estimated at 960 million euros. What are the figures today?

Hamid Aït Abderrahim: 'The slow but steady inflation of the euro caused the figure to increase by 112 million euros. In 2011, the nuclear accident in Fukushima also happened. As a result, although our project was still only on paper at that stage, additional security requirements were imposed on us by the Federal Agency for Nuclear Control, FANC. This resulted in almost 150 million euros of additional investments. Finally, the design of MYRRHA evolved, and that brought with it an additional cost of 250 million euros. Together, this meant a total figure of 1.6 billion euros. That was at the end of 2014, and we are still on track to reach that amount today.'

Is MYRRHA still a profitable project to carry out?

In 2015, we looked into this question together with external experts. The answer was unanimously positive. The portfolio of the analyses remains valid and necessary.

And what about the planning?

The Board of Directors asked us to examine closely the implementation strategy of the MYRRHA project. A step-by-step strategy must enable risks to be reduced and investments to be spread out.

What does this strategy involve?

We are dividing our work into three phases, of which phase 1 is currently the most concrete. In this phase, we plan to build the accelerator to be capable of 100 MeV (Megaelectron-volts), as well as one or two research stations: one to produce radioisotopes and one to carry out material research. We are doing that in phase 1 in order to demonstrate the reliability of our accelerator. Normally, such a large accelerator stops frequently, for example 2,000 times per year. In MYRRHA, we want to reduce the number of stops lasting more than three seconds to ten per quarter. The accelerator therefore needs to be extremely reliable. That will be possible thanks to a fault-tolerant design in which cavities can take over from each other, and also to injector redundancy.

How long will the development of the accelerator take?

We will be building the 100 MeV accelerator at actual size between 2019 and 2022. After that, we will spend two years testing reliability in real life situations, which will take us to 2024. Our simulations indicate that we will achieve the desired level of reliability, now it's up to us to demonstrate that in reality. At the same time, the development of stations for the production of radioisotopes and the material research will be taking place. As a result, the research stations will prove their value from the outset.

"During construction of the whole project, almost 1,000 people will be involved over a three-year period; during operation, between 300 and 400 people will be permanently employed for MYRRHA. And all these jobs will in turn generate another three jobs indirectly."

What will happen in the following two phases?
Phase 2 serves for the further development of the accelerator up to and including 600 MeV. Phase 3 is the construction of the reactor, i.e. the complete construction and finalisation of MYRRHA. We anticipate phases 2 and 3 will cost 1.25 billion euros. By building MYRRHA over an 11-year period, we are able to spread out the investment and have more time to bring all the funding together.

Where will the finances come from?
From a range of different sources. The Belgian government has already awarded us 40 million euros for 2016-2017 in order to develop the project with the new phased process. By the end of 2017, we need to provide the government with eleven large reports so that they can make a decision for the building activities in phase 1. But there's even more. At the start of January 2015, the government decided to include MYRRHA in the list of Belgian projects for the new investment plan of the European Commission, the Juncker Plan or EFSI, for an amount of 1.5 billion euros. And in the new Horizon 2020 programme from EURATOM, more than 11 million euros will be invested in MYRRHA via the H2020 MYRTE project, 9 million of which will come from the European Commission. Furthermore, MYRRHA has been chosen by the European Investment Bank as a potential project for financing via the InnovFin programme. That could generate a loan of between 120 and 240 million euros with a redemption-free period of 10 years and a long repayment period with a low interest rate. All sorts of negotiations are under way.

By when does the investment in MYRRHA need to be repaid?
We are starting a building period of 11 years, between now and 2030. After that, MYRRHA will be used for 35 years, until 2065. The repayment itself needs to be completed within 26 years. That doesn't take account of the impact of employment. During construction, almost 1,000 people will be involved over a three-year period; during operation, between 300 and 400 people will be permanently employed for MYRRHA. And all these jobs will in turn generate another three jobs indirectly.

What income will MYRRHA generate?
The world is awaiting new techniques for the management of radioactive waste. If we are able to develop and patent this, this will create opportunities. MYRRHA is also important for the building of future lead-cooled GEN IV reactors and SMRs (small modular reactors). Our expertise in terms of developing a new type of reactor that can use the same core for ten years without having to reload, with a lower production of waste and improved safety... that's something we can all make use of.

What does collaboration with other countries look like now?
We are currently in discussions with a number of countries regarding their participation in MYRRHA. We are preparing a cooperation agreement with the French CNRS (*Centre national de la recherche scientifique*), Sweden is prepared to participate, Japan is going to decide about its possible participation and the German government is again examining a cooperation report. More news will be revealed in the course of 2017!

Archimedes gives a boost to MYRRHA

A closer look at fuel bundles and control rods

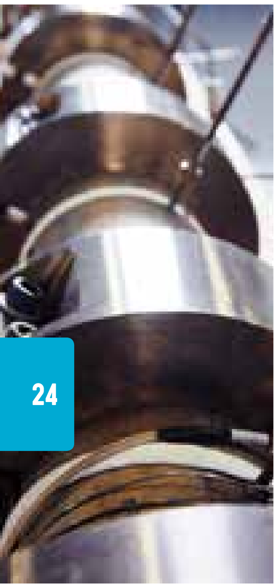
Our scientists are using the lead-bismuth loop COMPLOT to investigate the thermal hydraulic and hydrodynamic behaviour of full scale reactor components intended for MYRRHA. They have focused on pressure drops in nuclear fuel assemblies and have also built and tested a prototype control rod.

The pressure drops in the fuel bundle determine the flow rate of the coolant through the reactor core. It is important to know whether there is always a sufficient flow rate of the coolant, especially when the reactor stops suddenly. This must then be able to remove the heat from the fuel in a passive way, that is to say without interfering with the pumps.

In COMPLOT, researchers Katrien Van Tichelen and Graham Kennedy investigated these pressure drops: 'We demonstrated that the data that we use for the reactor design for pressure drops in the fuel bundle are sufficiently precise.' Other environmental factors have an influence: 'The temperature changes the characteristics of the coolant and the material of the bundle. As a result, the walls of the bundle may become rougher, for example, resulting in an additional loss of pressure.'

In the near future, they want to conduct further research on the behaviour of the fuel bundle: 'How strong, for example, are the vibrations of the fuel rods that result from the flow of the coolant? We will also investigate whether the pressure drops vary over time if additional phenomena were to manifest themselves.'

> *For the first time, use is being made of Archimedes' principle for the insertion of control rods. And it's paying off!*



Thanks to Archimedes

A second research study in COMPLOT focused on the control rods: 'They form a complex component that is almost 10 metres long, with the same size, geometry and weight in the experiment as in MYRRHA. We are trying to demonstrate that it is possible to put them in the reactor core in less than one second. That's important for safety, because it must be possible to stop the reactor quickly. It is a big challenge to position the slender structure precisely so that it doesn't end up getting jammed or distorted when in motion.'

Moving the control rods takes place in lead-bismuth, a heavy liquid metal. That makes the conditions different to those of a traditional reactor, Katrien and Graham explain: 'In traditional reactors, the control rods go down thanks to gravity. In this case, the liquid is so heavy that standard materials continue to float in it.'

The solution? 'We place the control rods under the reactor core. If we release them, they move upwards. These proof-of-principle tests are unique within their field. For the first time, use is being made of Archimedes' principle for the insertion of control rods. And it's paying off.'

Following the demonstration of the principle, research is shifting to the behaviour of the control rods during repeated insertion. They need to last at least one reactor cycle of three months: 'We assume this will be longer, because we have made a very conservative estimate of the durability.'

The testing of other components is planned for the future. 'The majority of our time will be spent adjusting COMPLOT for testing the thermal hydraulic behaviour of the MYRRHA heat exchanger tubes. We want to supply proven basic information to our designers so that they can use this in the following design revision.'

Innovation

Unique experimental facilities are essential

SCK•CEN uses advanced and complex mathematical models in developing innovative nuclear systems. These models are validated through targeted experiments in specific experimental set-ups. This exclusive array of experimental facilities enhances the international character of SCK•CEN and adds to its unique allure.

Peter Baeten
Advanced Nuclear Systems Institute Director

Unique corrosion cycle for MYRRHA

Clear insight via correlations

Are you planning to use a heavy liquid metal as the coolant in a nuclear reactor? If so, remember that corrosion can occur with certain materials. That's not good for the temperature and durability of the components. For that reason, it's necessary to carefully examine the effects of corrosion when designing an installation such as MYRRHA. But how can you demonstrate that the materials will survive when MYRRHA doesn't even exist yet?

MYRRHA is a research installation that will contain fourth-generation nuclear reactor technology. The materials pose a difficulty for the development of MYRRHA. They need to be able to endure harsh conditions, such as high temperature, strong radiation and a corrosive environment.

High temperatures

Different conditions will apply in future reactors compared to traditional reactors. The temperature in MYRRHA can reach up to 400°C, for example; in fourth-generation nuclear reactors with liquid lead as coolant, temperatures can even reach up to 600°C. What is the corrosion resistance of the selected materials if they then come into contact with the coolant, liquid lead-bismuth metal?

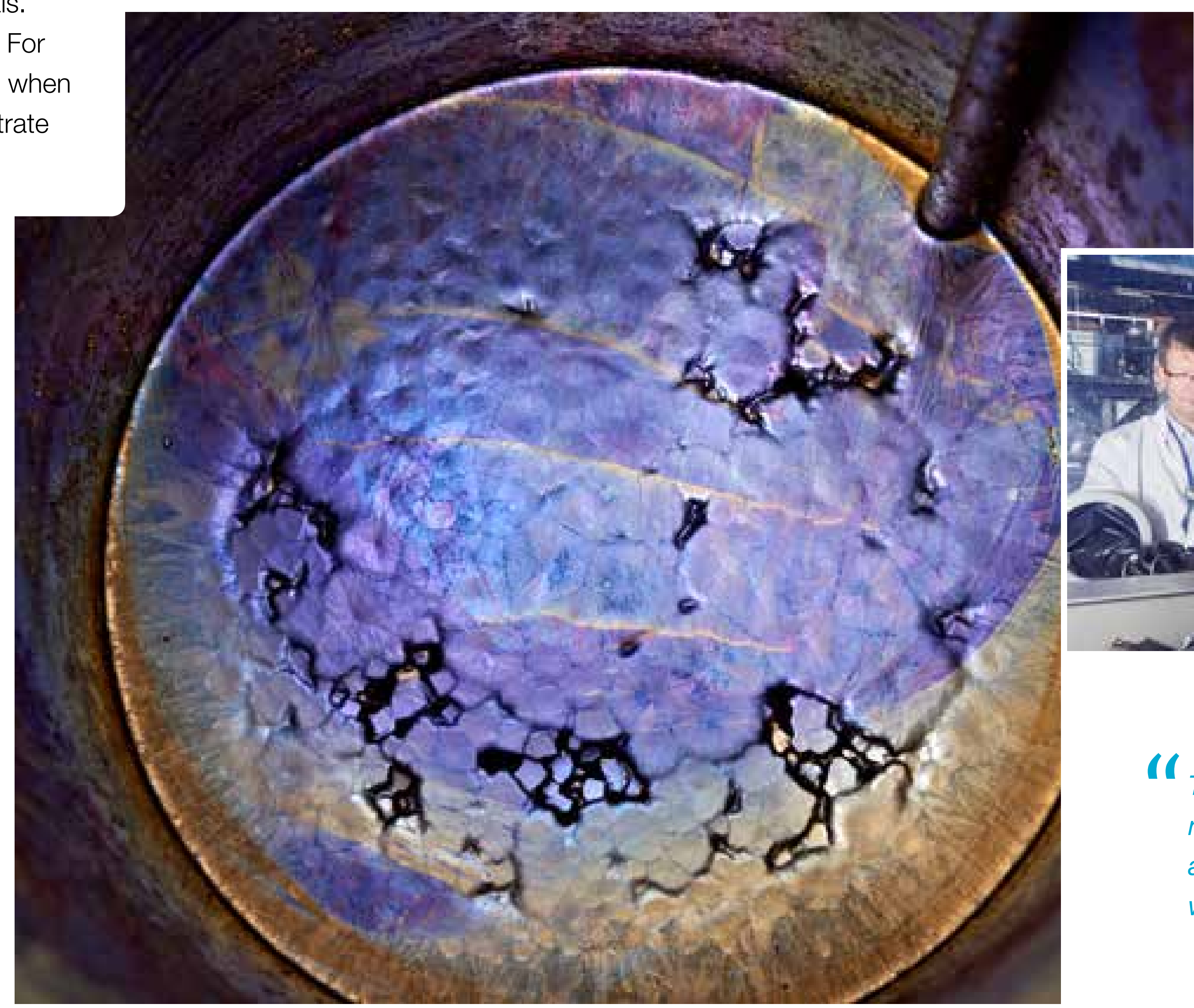
This is being investigated as part of the material programme for MYRRHA. The aim is to select and verify the candidate materials selected for structural and functional components of the primary circuit in MYRRHA.

The tests for this research are taking place in an environment that simulates real corrosion conditions. A realistic approach to researching corrosion in circumstances that are representative for MYRRHA would require much more expensive and sophisticated configurations, which would then have to run for many years in parallel.

Unique corrosion cycle

For that reason, the researchers at SCK•CEN developed a method that gives a clear insight into corrosion thanks to the principle of correlation: the possible interaction between two series of observations. The researchers didn't just use a number of small test set-ups, they also built a large corrosion cycle, which is unique in its field. This is necessary in order to prove that the correlations calculated from the small set-ups are conservative enough.

By analysing and comparing the test results, the researchers find solutions to counter the effects of corrosion. The calculations form a useful tool for the MYRRHA designers to define limitations, estimate operating parameters and to validate the permitted corrosion in components such as fuel elements, heat exchanger tubes, the reactor vessel etc.



Examining corrosion mechanisms

Right now the researchers are checking whether the correlations are able to predict corrosion damage accurately by comparing every experimental result obtained with the predictions. At this point, the predictive ability of the observed correlations has been very positive.

They are also examining corrosion mechanisms, by using modern techniques to describe the microstructure and microchemistry, as well as various types of electron microscopy. This insight into mechanisms is necessary in order to substantiate the correlations. Finally, the researchers also want to improve and update the correlations developed, especially for the welds in materials.

> *"The researchers didn't just use a number of small test set-ups, they also built a large corrosion cycle, which is unique in its field."*

Structural materials for Gen-IV reactors

Promising collaboration between SCK•CEN and KU Leuven

A pump impeller is used in the MYRRHA reactor. This is a rotating pump component, the role of which is to move the coolant Lead Bismuth Eutectic (LBE). With traditional structural materials such as stainless steel, there is a risk of erosion and dissolution. In order to prevent the pump impeller becoming a stumbling block for the reactor, SCK•CEN and KU Leuven have joined forces. Innovative structural materials based on MAX phases are the result.

Which materials retain their shape and characteristics if they come into contact with fast-flowing heavy liquid metals (HLM) such as LBE and lead? Thomas Lapauw, a PhD student at KU Leuven, is researching the potential of MAX phases: 'This class of ternary carbides and nitrides exhibits a unique combination of features: some have the characteristics of ceramics and others have the characteristics of metals.'

Superior resistance

MAX phases are robust. They have a superior resistance against corrosion if they come into contact with liquid metals and are characterised by a high damage tolerance. As a result, MAX phases have a high potential for use in HLM-cooled nuclear systems. Konstantza Lambrinou from SCK•CEN is supervising the research and is extremely enthusiastic about MAX phases: 'You can use them to produce components with a complex geometry. Even if the durability of high-performance MAX phases doesn't suffice when exposed to fast-flowing HLMs, it is possible to form durable phases such as binary carbides and nitrides on the impeller surface.'

MAX phases are also relevant for pump impellers in fourth-generation lead-cooled fast reactors (Gen-IV LFRs). The impeller must be reliable in MYRRHA at temperatures up to 270°C, but with LFRs the temperature increases to 480°C. Of course, this requires thorough investigation. Thomas Lapauw explains how he is approaching this: 'First of all, I prepare MAX phase-based monoliths and their composites, for example cermets (composite material made of ceramic parts in a metal matrix), by means of powder metallurgy. After that, I carry out a micro-structural characterisation of the materials produced and I assess the strength and fracture toughness. Finally, I evaluate the resistance against corrosion and erosion in liquid metals.'

MAX phases form a material with which it is possible to make complex shapes. Conventional milling can also work perfectly.

Discovery of new MAX phases

What is the highlight of this project? Konstantza Lambrinou leaves us in no doubt: 'The powder metallurgical synthesis of MAX phase materials that are difficult to make. Thomas discovered promising new MAX phases, such as Zr_2AlC, Zr_3AlC_2, Hf_2AlC and Hf_3AlC_2, ideal for applications in HLM-cooled systems and high-temperature applications. It is logical that SCK•CEN and KU Leuven have submitted a joint patent application.'

Cermets for even better performance

Is it possible to produce cermets on the basis of MAX phases? This is a question that will be answered in the near future. These composites are able to maintain the benefits of these ternary carbides and improve the fracture toughness. Thomas Lapauw has prepared a first generation of these materials in order to evaluate their mechanical characteristics.