Plasma physicist discusses the Wendelstein 7-X stellarator

February 5 2016, by Peter Hergersberg

Thomas Klinger, director at the Max Planck Institute for Plasma Physics in front of the 725-ton-heavy plasma container for the nuclear fusion experiment Wendelstein 7-X located in Greifswald. Credit: Stefan Sauer

Researchers from the Max Planck Institute for Plasma Physics (IPP) produced the first helium plasma in the Wendelstein 7-X stellarator last December. Since then, they have cleaned the plasma vessel with many more helium discharges. On 3 February they produced a hydrogen plasma in the world's biggest and most advanced stellarator-type nuclear fusion device for the first time. Thomas Klinger, Director at the IPP, talks about the special features of the Wendelstein 7-X stellarator and its structure, and the prospects for the construction of a fusion power plant.

Professor Klinger, will Federal Chancellor Angela Merkel launch the world's first fusion power plant on Wednesday?

No, the Wendelstein 7-X will not supply any energy yet. What we are aiming to demonstrate is that a stellarator is just as suitable a device for a power plant as a tokamak, and that it can bring its two advantages into play here: first, its plasma is fundamentally more stable and, second, it can operate in continuous mode without further intervention. In contrast, a tokamak requires pulsed operation, which is a considerable disadvantage for a power plant.

If the stellarator has such advantages to offer, why is the ITER, the world's biggest fusion device, being built as a tokamak?

A crash course in plasma physics is needed to understand this: for the plasma in a fusion device to reach the temperature of 100 million degrees Celsius required for nuclear fusion, it must make as little contact as possible with the walls of the plasma vessel. For this reason, its charged particles are captured in a ring-shaped magnetic field. And this magnetic field must be twisted into a spiral.

But this applies to both the tokamak and the stellarator…

Exactly. The crucial factor is how the magnetic field is twisted. For this purpose, in addition to the magnetic field of coils around the ring-shaped plasma vessel, in the tokamak, a component is generated through a current in the plasma, specifically through the current in a transformer coil inside the ring. Because the current must change over time in a transformer, it is regularly started and then switched off again. Then, the plasma is no longer enclosed and cools down again.

How do you avoid this in the stellarator?

We use only the geometry and arrangement of the coils in the plasma chamber to twist the magnetic field.

So that explains the strangely twisted form of the coils in the Wendelstein 7-X. How did you come up with this?

The geometric characteristics of the plasma in a conventional stellarator make it very difficult to achieve good plasma confinement. It's like having a limp: you can do as much training as you like, but you're never going to be a 100-metre sprinter. However, our former Director, Jürgen Nührenberg, discovered a hidden symmetry characteristic of plasmas in the 1980s which makes it possible to also confine a plasma without plasma current. The shape of the plasma and the magnetic field resulted from this. Using what were very powerful computers at the time, Jürgen Nührenberg calculated how the magnetic coils had to be shaped to generate this field.

So if the stellarator can also confine the plasma well and has crucial advantages to offer, what's the problem with it?

The technical realization of a stellarator is very difficult. Many colleagues said that the idea was nice but no one would be able to build it. Today they say: nice idea but only the Germans can build it. That's kind of them, but we of course had a lot of help, particularly from our European industry partners. Nevertheless, the attempt to build a comparative stellarator in Princeton was abandoned.

Why is it so difficult to build a stellarator?

There are many difficulties involved, but some of them were particularly challenging: the first was the manufacture of the superconducting coils which had never been built like this before. Despite having a diameter of 3.5 metres and weighing six tonnes, they must be built with millimetre precision. Second, it is very difficult to build the device in a way that ensures its mechanical stability. The magnetic coils are bolted to a central ring which acts as the supporting structure. During operation, the magnetic fields exert shear forces on the bolted connections which correspond to weights of up to 150 tonnes. Because the distribution of these forces is extremely unintuitive, we developed a computer model for the entire magnetic system and steel vessels, which is probably the most complex in the world. Experts from all over the EU and Russia worked on this model. One of the facts that emerged from the simulations is that the supporting structure can only withstand the forces if the interfaces between the ten individual segments of the central rings, which weighs several tonnes, are built with a level of precision of less than 100 millionths of a metre.

How did you achieve such extreme precision?

We had to search every corner of Europe to find a company that could mill the segments of the central ring with such accuracy. A watchmaker's precision is needed here, but in components that weigh six tonnes and stand several metres high. In the north of Italy we found CLP, a family business in a small village. Because the massive segments have to be re-chucked several times, the company developed special techniques to ensure the precise positioning of the steel components. This is just one example of the dozens of technical developments that made the Wendelstein 7-X possible.

Which other difficulty was encountered in the construction of the Wendelstein 7-X is worth mentioning?

Putting the 20 million parts of the puzzle together also presented us with quite a challenge. To do this, we had to develop special processes and tools with our industry partners, which include MAN Diesel & Turbo. These processes and tools are so precise that, in the end, the device deviates from the planned design by a maximum of two millimetres. The welding techniques had to be refined to achieve this: the standard deviation usually accepted by industry for such welding work is five millimetres, however in our case it had to be between one and two millimetres at most. The participating companies developed a considerable amount of expertise and skill here. What's more, we also had to work to very tight deadlines and cost constraints. This was only possible because we invested over one million assembly hours in the device over ten years by working two daily shifts on six days most weeks. At the same time, of course, we had to ensure that we stayed on top of things from a scientific perspective. This was only possible thanks to the great spirit at the Institute.

There were delays despite this – how did they arise?

The manufacture and testing of the superconducting coils took far longer than we thought – six years in total – and the device itself was supposed to commence operation after six years. The assembly process also proved far more complicated than expected. If we had known how difficult it would be to build, we might not have embarked on it in the first place. Of course, we are delighted now that a powerful machine like the Wendelstein 7-X is available for research. From that point of view, it is probably not such a bad thing that we embarked on this project so idealistically. However, we also had to completely re-invent ourselves as an Institute so that we could meet the different challenges.

In what way?

We had to familiarize ourselves with industrial standards and processes, and we learned how to operate like a good medium-sized industrial operation.

Which means?

For example, it is no good moaning when you have a crisis on your hands. What you need is an immediate plan specifying who must do what. We also needed professional risk management. In other words, we had to identify risks in advance, reduce them and try to overcome them. There were many situations in which we had to weigh up risks and in which we asked ourselves whether we should continue testing or if we could assume that things worked well as they were. Sometimes we simply accepted the risks. And we were right about all the main risks, so everything works now.

Which scientific issues will you now investigate using the Wendelstein 7-X?

We will study the three crucial performance factors, namely the temperature and density of the plasma and the quality of the plasma confinement, which depends on the insulation. However, we will not reach the so-called triple point here – that is the threshold value for the product of the three parameters, after which a fusion device becomes a power plant. But we want to become as good as possible, at least as good as a comparably sized tokamak. We also want to produce clean contact between the plasma and the wall.

But the plasma is not supposed to touch the wall at all?

That's the ideal. In reality, however, it always comes into contact with the wall. The heat and particles from the plasma collide with the wall, particularly in the so-called diverter. This is a kind of ash pit, in which cooled particles and, above all, impurities from the wall and, later in a power plant, the helium as a product of the nuclear fusion collect. We want to be able to predict how the plasma behaves at the diverter. This is all quite complicated.

Can you give us another example?

The physics of the transport process will also be a major topic. How do heat, particles and impurities get into the plasma and out again. This occurs through diffusion, on the one hand, and through turbulent transport, on the other. Irrespective of the plasma research, a lot of questions relating to turbulence in physics remain unanswered. We are already doing the best calculations in the world here to provide numerical predictions of turbulent processes. Ideally, of course, we would like to find out how turbulence can be controlled.

According to the predictions made in the 1960s, the first fusion power plant should already exist. So when

will we reach this point?

We've reached a really advanced stage in plasma research. ITER also contributes to this.

Despite the difficulties that repeatedly arise there?

This does not detract from the fact that ITER is a good machine, with which a major advance in the direction of a power plant was achieved. However, it is very difficult to get such a big international project off the ground. But I think that many of the problems associated with it have now been resolved. So we will need just one more generation of researchers until we have a basis for deciding whether we want to build a fusion power plant.

And do we?

I firmly believe that we will be grateful for the option of nuclear fusion. The supply of fossil fuels will inevitably dwindle, perhaps much sooner than the low oil price would have us believe. Moreover, we want to stop climate change. Nuclear fusion offers us the possibility of building climate-friendly power stations that are capable of providing a consistent energy supply, are far less risky than nuclear power plants and do not pose any problems in relation to final waste disposal.

And will the first fusion power plant be a tokamak or a stellarator?

It's not a race. In the end they do not represent two different worlds; the two branches of research provide mutual inspiration for each other. Insights from stellarator research have been incorporated into the development of the tokamak and vice versa. They are two pillars of a large edifice. The exact form the edifice will ultimately take is something we do not yet know. It is even conceivable today that a fusion power plant will be built one day as a hybrid of the two types.

Provided by Max Planck Society

Citation: Plasma physicist discusses the Wendelstein 7-X stellarator (2016, February 5) retrieved 19 April 2024 from
https://phys.org/news/2016-02-plasma-physicist-discusses-wendelstein-x.html