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Operation of the WEGA Stellarator with Vertical Field and Compensation Coils

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Introduction

The WEGA is a classical stellarator in a l=2 and m=5 configuration and is operated at the Greifswald branch of IPP. Since the start in July 2001 approximately 6600 discharges have been performed.

During a first campaign in 2002 magnetic flux surface mapping has been carried out scanning a wide range of iota ($0.1 \leq \iota_0/2\pi \leq 1$) at a constant toroidal field $B_0 = 87.5$mT [1]. As a result the existence of closed and nested flux surfaces could be verified. However, the flux surfaces were disturbed by non-natural islands caused by unwanted error fields. Using a compensation coil a significant decrease of the low order rational islands could be experimentally and theoretically verified. Additionally, we have determined the influence of a set of vertical field coils for different magnetic configurations.

Furthermore we have investigated the interrelation between the magnetic configuration with or without islands and the plasma parameters derived from Langmuir probe measurements.

Magnetic Flux Surface Measurements

As mentioned above a first campaign of vacuum magnetic flux surface measurements revealed the existence of non-natural islands of the order m=1 and m=2 caused by unwanted error fields. Although the origin of the magnetic errors fields can not be derived from flux surface measurements they can be used for a comparison with results of calculations including errors. In our calculations (Gourdon-code and LMAA field line tracing code [3]) it could be shown that a horizontal misalignment between the toroidal and the helical field coils results in the experimentally found islands [1]. As misalignment a horizontal shift of the vertical axis of the toroidal and helical field coils of ~3mm is used. The direction of the shift has been choosen to fit the islands in size and phase at given poloidal cross sections. Due to the high shear of the WEGA it is nearly impossible to find a region without low order rational islands.

After analysing different types of available coils an optimal position for a single planar field coil (Φ=34cm, 36 turns) was determined. The compensation coil is installed in the mid-plane and on a toroidal position derived from code results. The results of these calculations show that even the largest island obtained for low iota rational values can be significantly decreased in size.

In a second campaign the results from the code calculations have been compared with magnetic surface measurements including the compensation coil. The measurements have been performed for the same conditions as in the first campaign [1]. A first check showed no differences in the magnetic flux surfaces after a further year of operation (~4000 discharges). The size and the poloidal phase of the islands are unchanged.

In Fig. 1 the experimentally determined magnetic flux surfaces for B_0=87.5mT at the resonance $\iota/2\pi=1/4$ are shown. Fig. 1b presents the situation without using the compensation coil. For the same magnetic configuration the width of the island can be clearly decreased with the help of the compensation coil as shown in Fig. 1a. The size of the islands was decreased by a factor of ~2. However, by inverting the direction of the magnetic field the size of the island can be further increased as can be seen in Fig. 1c.

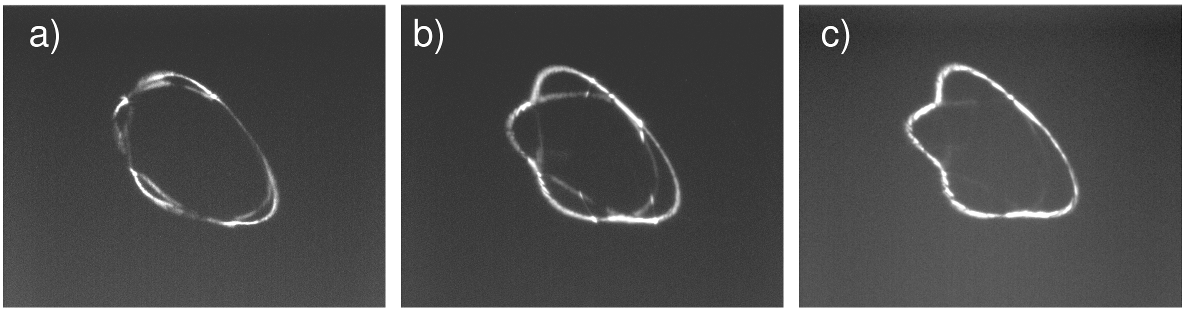

Fig. 1 Experimentally determined magnetic flux surface for a $\iota/2\pi=1/4$ configuration b) and influence of the compensation coil a) and c).

While the main purpose of the compensation coil is the suppression of non-natural islands it can also be used to turn the islands poloidally by tilting the coil. In the future it is planned to rotate an island structure from the X to the O point along the tip of a Langmuir probe to measure transport and fluctuations properties inside islands.

Additionally, during the second campaign the vertical field coils have been put in operation, which are used to shift the plasma radially in order to keep the plasma away from the vessel. Without a vertical field the magnetic axis in the WEGA is approximately 2cm inside the geometric axis. However, the vertical field coils have also an influence on the rotational transform and the shear of the magnetic configuration.

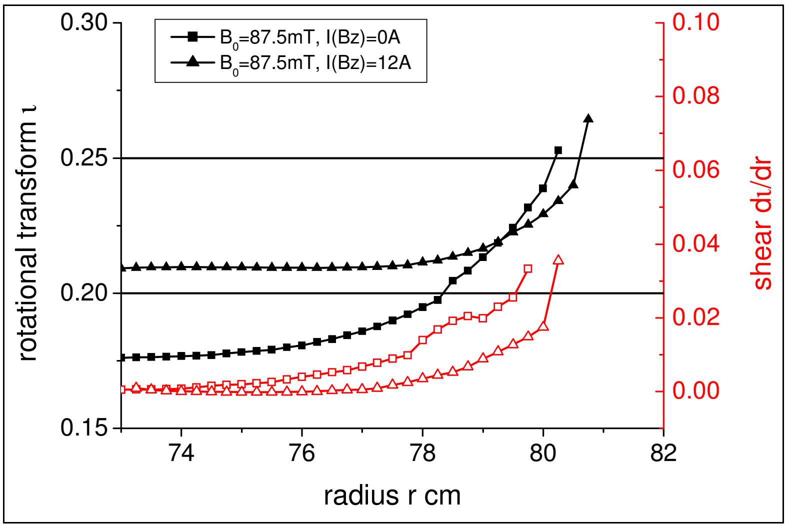

Fig. 2 Rotational transform and shear of a magnetic configuration with and without vertical field.

By increasing the vertical field the rotational transform is increased while the shear is lowered. With the help of the vertical field coils it is now possible to operate the WEGA in magnetic configurations avoiding low order rational resonances, even without any compensation. The experimentally determined flux surfaces are qualitatively in good agreement with results obtained from vacuum field line tracing codes.

Interrelation between plasma parameters and magnetic configuration

The different heating scenarios in the WEGA are discussed in a separate paper at this conference [2]. By applying an optimised heating scenario and using spatially resolved Langmuir probe measurements it was found that for all magnetic configurations the main part of deposited energy is located inside the LCFS. At the LCFS steep gradients were observed. Furthermore we did not found significant features in the Langmuir profiles at the radial position of islands. In Fig. 3 we show the profile of the electron current of a radially moveable Langmuir probe (a) and the Poincaré plot for the given magnetic configurations (b). The lack of specific features in the plasma profiles at the position of islands may be caused by a broad power deposition profile which includes the islands and by a rather high collisionality of the plasma.

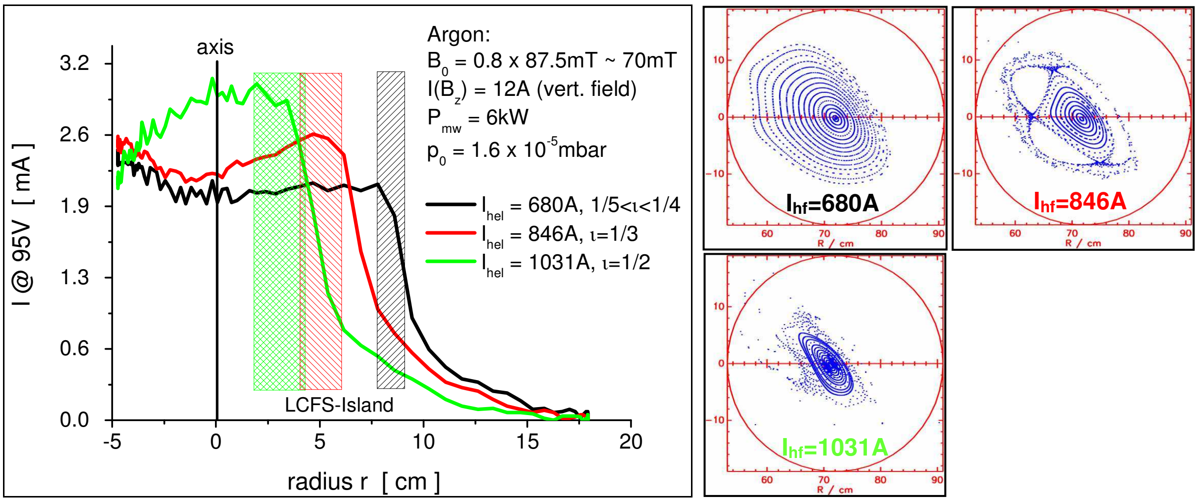

Fig. 3 Spatially resolved Langmuir probe measurements (a) and appropriate Poincaré plot (b) for the given magnetic configuration and position.

Conclusion

In order to suppress non-natural magnetic islands found in a first campaign of vacuum magnetic flux surface measurements in the WEGA stellarator a compensation coil has been installed in a second campaign. Using this coil the size of these islands could be significantly decreased. By tilting the compensation coil it is also possible to rotate the magnetic islands poloidally. Additionally, vertical field coils have been put in operation in order to shift the plasma radially avoiding contact with the vessel. The flux surface measurements are qualitatively in good agreement with results obtained from vacuum field line tracing codes.

Secondly we have investigated the interrelation between the plasma parameter and the magnetic configuration. Using an optimised heating scenario the main plasma energy for all magnetic configurations is contained within the LCFS. At configurations with magnetic islands we did not find significant changes in the profiles of Langmuir probe characteristics at the island positions.

References

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