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Trade-off analysis on the fusion reactor design using FUSAC
統合計算コードFUSACを用いた核融合設計におけるトレードオフ分析

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The nuclear fusion reactors including the element of many fields such as hydrodynamics and electromagnetism are very complicated systems, and there are many phenomena that are not yet elucidated. We are using a system design code FUSAC for fusion reactor design, in which various physical and engineering parameters are employed. We visualize those results with MATLAB so as to investigate a trade-off between various design parameters.

1. Introduction

The nuclear fusion reactors including the element of many fields such as hydrodynamics and electromagnetism are very complicated systems, and there are many phenomena that are not yet elucidated. If we overlook the perspective of the nuclear fusion reactor, a system design code is very important. In this paper, we use a system design code FUSAC[1], and a trade-off between various parameters is analyzed, so as to get the prospect of the nuclear fusion reactor design that stood on the future technical development. In addition the visualization of calculated results is quite important, as well. Here we introduced MATLAB so as to visualize [2] the relationship between various parameters.

2. Parameter Region

FUSAC employs a zero-dimensional plasma model base on ITER Physics Guidelines[3], and Generomak Model for economic analysis. Here we have carried out parameter survey for steady-state tokamak by changing several parameters[4]. The employed parameters and their parameter regions are listed in Table 1.

Table I Parameter region

Parameter	Region	Step size
a(m)	1.2~3	Δ a=0.2
A	2.5~4.9	ΔA=0.25
κ	1.5~2.1	Δκ =0.1
δ	0.2~0.5	Δδ=0.15
Te(=Ti)(keV)	10~19	ΔTe=3
qΨ	3.0~6.0	ΔqΨ=1
Btmax(T)	13~19	ΔBtmax=1.5
ηe(%)	30~40	Δηe=10
η NBI(%)	30~50	Δ η NBI=10

Here, the minor radius is changed from 1.2 m to 3.0 m, with a step size of 0.2 m, and the aspect ratio is changed from 2.5 to 4.9 with a step size of 0.3. While, the major radius is limited the parameter region between 5.5 m and 10 m. Step sizes of other parameters are listed in Table 1, as well. By using these parameter regions and their step sizes, we take database of 300,000 design points.

3. Result and discussion

The results obtained by system design code are showed Figs.1~4.

Figure 1(a) shows the relation between the confinement improvement factor HH and the net electric power Pe, in which layer indicates normalized beta value. From this figure, high β is necessary to attain a large net electric power. While, if the normalized beta value is limited to be low (e.g., $\beta_N < 2$), the net electric power larger than 1 GWe might be difficult.

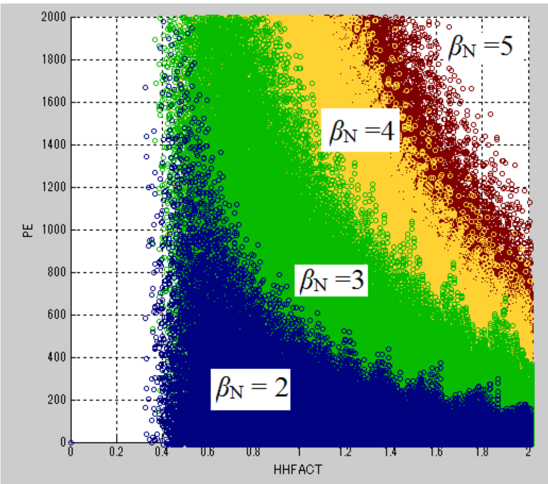

Fig.1(a) HH factor & PE
(layer: normalized beta value)

Here we pay attention to the relation between HH factor and the net electric power, and find a correlative expression of the HH factor and PE.

$$P_E \propto HH^{-0.86} \qquad (1)$$

Next, we considered the role of the magnetic field in Fig. 1(a). In Fig. 1(b), the each point is represented by the maximum magnetic field Bmax, in which the range of the Bmas is 13 ~ 19 T. When the magnetic field is restricted to be Bmax = 13T, the design point is limited at the relatively narrow region.

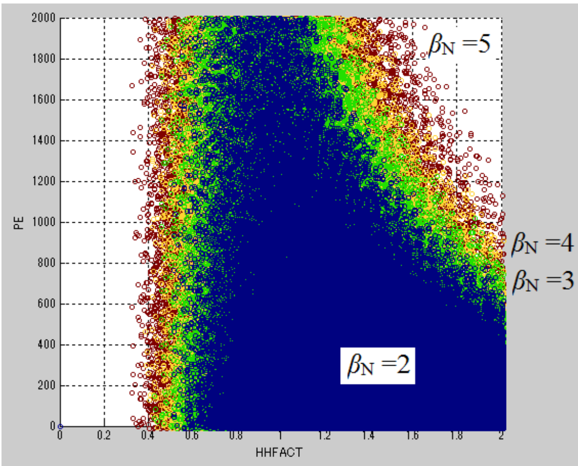

Fig.1(b) HH factor & PE(layer: Max Magnetic field)

Figure 2 shows the relation between the confinement improvement factor HH and the bootstrap fraction f_{bs}, in which a layer indicates normalized beta value. We can see that the bootstrap current fraction is not so sensitive to the HH factor, and seems to be monotonically increased as the normalized beta value is increased.

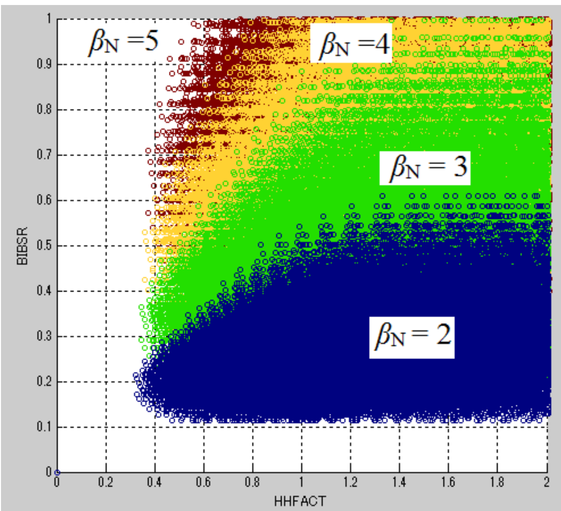

Fig.2 HH factor & BC rate
(layer: normalized beta value)

Finally, we considered the current drive power. Figure 3 shows the relation between the current drive power and the net electric power, in which layer indicates a normalized beta value, as well. If the normalized beta value is low (e.g., . $\beta_N = 2$), the net electric power might be limited to be less than 300 MW, even if the current drive power is increased up to more than 100 MW. At the moderate current drive power (e.g., PCD=100 MW), the net electric power might increases as the beta value is increased.

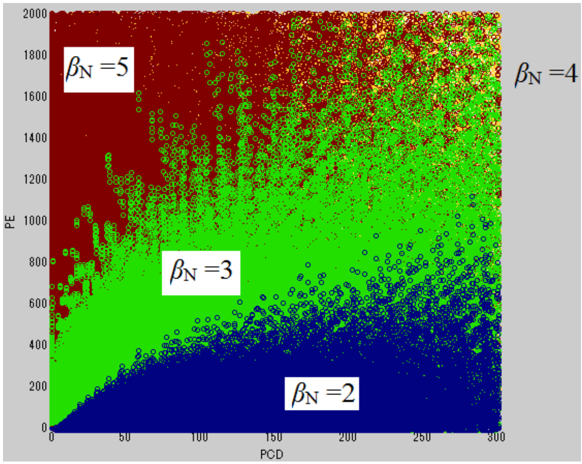

Fig.3 PE & PCD (layer: normalized beta value)

We have developed the visualization technique with MATLAB so as to study the trade-off analysis between various design parameters in fusion reactor design. At present, we have found that the normalized beta value is playing an important role for an attractive fusion reactor design.

References

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