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Calculation of fusion condition Hydrogen –Boron by I.C.F. Method

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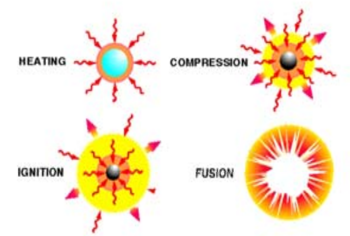
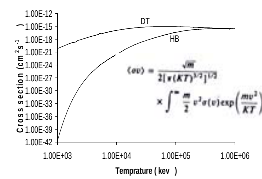
In order to obtain a clean and energy efficient fusion, the advantages of using advanced fuels for fusion have been recognized for a number of years, safety and environmental issues are two important problems. in order to avoid the radioactive tritium and the undesired radioactivity induced by the generated neutrons, the clean nuclear fusion reaction is Hydrogen – Boron. In suggested paper D-T fusion and H-B fusion theoretically are studied by computer simulation based on ICF method, the results are comparable with the experiment. In these computations the following causes are considered: primary ionization heating by laser, secondary heating and compressing by laser and α – particles. Calculations have two parts: calculation of optimum gain vs. input energy and calculation of plasma temperature vs. the confinement time. In this work it is shown that the necessary input energy for H-B fusion is very much the results indicate we can use the output energy provided by D-T fusion for H-B fusion by adding a D-T core inside the H-B fuel structure.



The calculation of cross section shows that H-B cross section is lower than D-T SCHEFFEL [4], therefore H-B fusion would be more difficult than D-T fusion. However because of the lack of technical abilities at the present fusion based on advanced H-B fuel pellets is impractical PIERUSCHKA [2]. Dependence of the cross section on temperature is calculated using the Maxwell distribution function this is shown in Fig . 1 .



n_0 x $[n_s]$	v_0(cm³)	E_0(MJ)	Gain HB	Depletion[%]
	10^{-8}	1.1×10^{1}	2.19	37.3
	10^{-7}	4.32×10^{1}	6.95	46.22
	10^{-6}	2.54×10^{2}	16.3	63.79
10^{5}	10^{-5}	1.93×10^{3}	25.4	75.512
	10^{-4}	1.59×10^{4}	35.9	87.65
	10^{-3}	1.3×10^{5}	46.9	93.84
	10^{-9}	2.25	1.95	33.91
	10^{-8}	7.9	7.56	46.02
	10^{-7}	5×10^{1}	16.2	62.48
2×10^{5}	10^{-6}	3.96×10^{2}	15.5	77.60
	10^{-5}	3.62×10^{3}	32.7	91.27
	10^{-4}	3.44×10^{4}	35.8	94.82
	10^{-9}	1.5	4.64	35.78
	10^{-8}	9.16	12.4	58.48
	10^{-7}	8.09×10^{1}	18.6	77.33
3×10^{5}	10^{-6}	7.98×10^{2}	21.6	88.29
	10^{-5}	7.31×10^{3}	24.2	90.79
	10^{-4}	6.9×10^{4}	26.5	94.93
	10^{-9}	2.25	8.53	59.24
	10^{-8}	2.22×10^{1}	10.9	74.92
	10^{-7}	2.19×10^{2}	12.8	86.23
5×10^{5}	10^{-6}	1.93×10^{3}	14.7	87.87
	10^{-5}	1.84×10^{4}	16.3	92.88
	10^{-4}	1.81×10^{5}	17.2	96.80
	10^{-9}	8.83	5.56	75.96
	10^{-8}	8.39×10^{1}	6.49	84.49
	10^{-7}	8.59×10^{2}	6.96	93.25
10^{6}	10^{-6}	5.86×10^{3}	7.60	69.51
	10^{-5}	4.8×10^{4}	9.49	71.19
	10^{-4}	3.94×10^{5}	11.7	72.08
	10^{-3}	3.35×10^{6}	14.3	74.82

Table 1

Calculations

The spherical plasma parameters with initial temperature To , radius Ro and ion density n0 are assumed. we begin from the first law of thermodynamics

$$\frac{dE}{dt} = -p\frac{dV}{dt} + \frac{dQ}{dt}$$

The second term is related to the laser interaction with plasma and the first term is

$$V = \frac{4}{3}\pi R^3 \rightarrow \frac{dV}{dt} = 4\pi R^2 \frac{dR}{dt} \qquad pV = nKT \rightarrow p = \frac{3(N_e+N_i)}{4\pi R^3}KT \qquad E = \frac{3}{2}(N_e+N_i)KT$$

$$\rightarrow \frac{3}{2}(N_e+N_i)K\frac{dT}{dt} = -4\pi \times 3(N_e+N_i)\frac{KT}{4\pi R^3} \times R^2 \frac{dR}{dt} \qquad \rightarrow T = T_0(\frac{R_0}{R})^2$$

Therefore the plasma expands and moves outward and It radius increases , the plasma temperature decreases.

The expanding velocity is obtained for the equation of conservation of energy

$$P\frac{dV}{dt} = \frac{d}{dt}(\bar{M}\frac{R^{o^2}}{2})$$

If one assumes that the plasma has to increase radialy from the center to the boundary one has $\bar{M} = \frac{3}{5}M$ where M is the total mass of plasma and $\bar{M}$ is the average mass for the plasma and V the Volume of the plasma at time t

$$\rightarrow p\frac{dV}{dt} = \frac{1}{2} \times \frac{3}{5}M\frac{d}{dt}(R^{o2}) \qquad \rightarrow 3(N_e+N_i)\frac{K}{4\pi R^3}T_0(\frac{R_0}{R})^2 \times 4\pi R^2 \frac{dR}{dt} = \frac{1}{2} \times \frac{3}{5}M\frac{d}{dt}(R^{o2})$$

We assumes that the plasma is quasi – neutral . and mi»me then the total

mass of the plasma is miNi and the number of electrons is $\bar{Z}N_i$

$$\rightarrow R^{o^2} = R^{o^2}{}_0 + \frac{5KT_0(1+\bar{Z})}{m_i}\left[1-\left(\frac{R_0}{R}\right)^2\right] \qquad dt = \frac{dR}{R^o} = \frac{dR}{\sqrt{1-(\frac{R_0}{R})^2}}\sqrt{\frac{m_i}{5KT_0(1+\bar{Z})}}$$

Numerical Results

In this work we aim to carry out qualitative numerical calculations of optimum gain vs input energy as well as plasma temperature vs. confinement time. In the confinement time. Numerical results based on volume ignition code are given in Table 1 for HB plasma and are compared with that of the DT plasma. Numerical results for DT plasma fusion in Table 1 of Khoda – Bakhsh [5] are recalculated in our work. The results are comparable with The experiment on laser compression of pellets at the Institute of laser Engineering (ILE) at Osaka university Naki [6]. It is obvious for DT plasma fusion that the necessary energy are within the MJ range. We calculated that for different densities and volumes of DT pellets the gains are of the order of 10^3, for example for density of 10^4 times solid state density and 10^{-5} cm³ volume the necessary laser energy is 3.289 MJ and the gain obtained is 1829. For HB pellets in table1 of our paper the necessary energy are within the GJ range. For example density of 10^5 times solid state and 10^{-5} cm³ volume the necessary laser energy is 1.93×10^3 MJ and the gain obtained is 25.4. The results of our computations of fusion gain G for HB pellets are summarized in Table 1. An example of the computations of the gain as a fusion of the input energy E_0, for an initial compression of 10^5 times the solid state density for varying initial volume, V_0, is shown in Fig. 2.

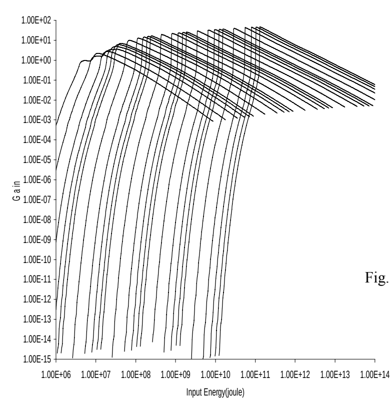
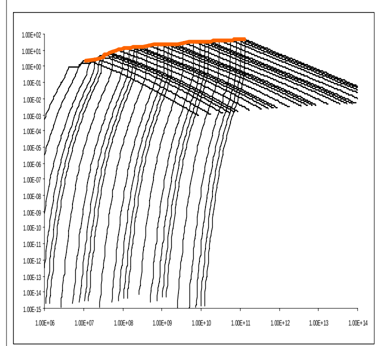


Fig. 2

The second step is to joint of the Max Gains.



The calculation of the fusion reaction gain G from Volume ignition of HB plasma by laser is

$$G = \frac{output \quad fusion \quad reaction \quad energy}{input \quad energy \quad Eo}$$

With the laser input energy Hora [1] .

$$E_0 = 2\pi(1+\bar{Z})n_0 R^3{}_0 T_0$$

$$G = \frac{E_f}{E_0}\int_0^{\infty} dt \int_{R_0}^{+\infty} \frac{n_i^2}{A} <\sigma v> dV$$

$$G = \frac{E_f}{E_0} \times \frac{4}{3}\pi \sqrt{\frac{m_i}{5KT_0(1+\bar{Z})}} \int_0^{\infty} R^3 \frac{n_i^2}{A} <\sigma v> \frac{dR}{\sqrt{1-\left(\frac{R_0}{R}\right)^2}}$$

In calculation it is assumed that A=4 for HB or DT plasmas and A=2 for DD or TT plasmas Hora [1]. Furthermore the Depletion is $D = \frac{n\tau<\sigma v>}{2+n\tau<\sigma v>}$ $\tau = \frac{R}{v_s}$

Conclusions

It is essential that we use HB fusion in ICF reactors because the output energy of HB fusion Is not only very clean but also more available, however the calculations in Figure 3 based on Table 1 shows that the necessary input energy for HB fusion are in the GJ range, the present technology is uncap able to provide this energy by laser however we can use the output energy provided by DT fusion fo HB fusion simply by adding a DT core inside a HB fuel structure. To compress this fuel the HB fuel is ignited by the output energy of DT fusion. In section 3 for example we showed that to ignite HB pellet with the density of 105times Solid state and 10^{-5}cm³ volume the necessary laser energy is 1.93×10^3MJ however we add a DT core with the density of 10^4 times solid state and 10^{-5}cm³ volume , because the output Energy of DT fusion in this cause is given by Gain x Ein =1829 x 3.289 MJ > 1.93×10^3 MJ ,and this is enough for HB fusion. We will consider the following cases: Calculation of the optimum gain for HB fuel by DT ignitor ,The neutrons interaction with DT plasma and The neutrons interaction with HB fuel by DT ignitor.

Therefore the curve of the optimum gains of HB plasma fusion for different densities is demonstrated in Fig. 3. The plot shows that in order to obtain the considerable gains the required energy are within the GJ range. Furthermore with to in crease density the gain decreases, there are two reasons for this. First when the density of plasma increases the necessary laser energy would also increase. However due to the inverse proportionality of gain to laser energy the gain decreases. The second reason is related to the Debye radius $\lambda_d = (KT/4\pi n_e e^2)^{1/2}$ and mean free path of the α-Particles. At high plasma densities, and therefore high electron densities, the Debye spheres become too small; therefore, there will not be enough energy loss of the alphas for the self-heating of the plasma therefore the gain decreases SCHEFFEL [4].

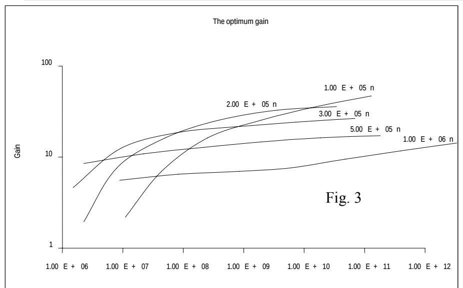


Fig. 3

In this computation the following effects are considered: primary ionization and heating by laser, secondary heating and compressing by laser and the reabsorbtion of Bremsstrahlung and α-Particles (the cause of self heating of the plasma) Hora [3]. These demonstrated in Fig. 4.

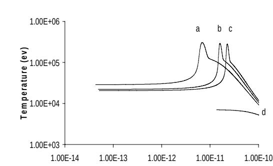


Fig. 4 Dependence of the temperature of a HB pellet on time at initial compression to 10^5 times The solid state and initial volume of 10^{-5}cm³ . The input energies E_0 were a :2.6x10³MJ,b:2.01x10³MJ, c:1.86x10³MJ , d:6.39x10² MJ and the fusion Gain were a : 20.1 , b : 25. C:25.2 ,d: 1.88×10^{-4} fuel depletion [%] were a: 80 :59 , b: 77.17 , c: 72.3, d: 0.06

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