International Journal of
Applied Mathematics,
Electronics and Computers

IJAMEC

ISSN: 2147-8228 www.atscience.org/IJAMEC

Advanced Technology and Science

Original Research Paper

Calculation of energy deposited and stopping range through deuterium ignition beam and dynamical studies on the energy gain in D-^{3}He mixtures

S. N. Hosseinimotlagh[*1], M.Jahedi [2], S.Kianafraz[3] ,S.Ghaderi [4]

Accepted 15th August 2014

Abstract: The fast ignition approach to ICF consists in first compressing the fuel to high density by a suitable driver and then creating the hot spot required for ignition by means of a second external pulse. If the ignition beam is composed of deuterons, an additional energy is delivered to the target with increased energy gain. Therefore ,in this innovative suggestion ,we consider deuterium beams for fast ignition in D+^{3}He mixture and solve the dynamical balance equations under the available physical conditions by considering a new average reactivity formula ,then we compute the energy gain in this mixture .Our computational results show that we can get energy gain value larger than 1000 at resonant temperature (380keV)of D+^{3}He mixture. We select D+^{3}He fuel, because D+^{3}He reaction is very attractive from a theoretical point of view since it does not produced neutrons. The D+^{3}He benefits include full-lifetime materials, reduced radiation damage, less activation, absence of tritium breeding blankets, highly efficient direct energy conversion, easier maintenance, proliferation resistance. The deposited energy can reduce laser driver energy. Our calculations show that at 380 Kev (resonant temperature) the maximum numbers of fusion reactions are performed and the energy gain is maximized.

Keywords: *Fast Ignition, Deuteron Beam, Energy, Dynamics.*

1. Introduction

There is no doubt that one of the most difficult problems that a peaceful world will face in the 21th century will be to secure an adequate ,safe ,clean and economical source of energy. Fusion energy which is the energy source that powers the stars has its origin in nuclear fusion reactions. Inertial confined fusion (ICF) is the major alternative to magnetic confined fusion. The indirect and direct drive approaches to ICF have been reviewed respectively by Lindl et al. (1995 and 2004) [1] and Bodner (1998)[2]. Both rely on implosion of a spherical shell of deuterium –tritium ice with a central core of D+T gas to compress and ignite the fuel at a central hot spot. Fast ignition (FI) is a newer approach to ICF proposed in outline by Basov et al (1992)[3] and in much fuller detail by Tabak et al. (1994)[4]. Fuel compression and ignition are separated in FI by using a shell of fuel at solid density which is compressed by long pulse beams, together with short duration localized heating and ignition of the compressed fuel by a short pulse laser . The original concept of Tabak et al. assumed that short pulse laser beam would penetrate close to the dense fuel through a laser formed channel in the plasma and that laser generated relativistic electrons would ignite the fuel. Over the past year, there have been several observations of multi-MeV ion beams generated by high-intensity ultrashort laser pulses in the interaction with solid targets [5]. Light ions, similar to electrons, can be generated due to laser–plasma interaction in a target, while a heavy ion beam must be produced by an external driver and transported to the target. In summary, the fast ignition (FI) mechanism [4], in which a pellet containing the thermonuclear fuel is first compressed by a nanosecond laser pulse, and then irradiated by an intense "ignition" beam, initiated by a high power picosecond laser pulse, is one of the promising approaches to the There is no doubt that one of the most difficult problems that a peaceful world will face in the 21th century will be to secure an adequate ,safe ,clean and economical source of energy. Fusion energy which is the energy source that powers the stars has its origin in nuclear fusion reactions. Inertial confined fusion (ICF) is the major alternative to magnetic confined fusion. The indirect and direct drive approaches to ICF have been reviewed respectively by Lindl et al. (1995 and 2004) [1] and Bodner (1998)[2]. Both rely on implosion of a spherical shell of deuterium –tritium ice with a central core of D+T gas to compress and ignite the fuel at a central hot spot. Fast ignition (FI) is a newer approach to ICF proposed in outline by Basov et al (1992)[3] and in much fuller detail by Tabak et al. (1994)[4]. Fuel compression and ignition are separated in FI by using a shell of fuel at solid density which is compressed by long pulse beams, together with short duration localized heating and ignition of the compressed fuel by a short pulse laser . The original concept of Tabak et al. assumed that short pulse laser beam would penetrate close to the dense fuel through a laser formed channel in the plasma and that laser generated relativistic electrons would ignite the fuel. Over the past year, there have been several observations of multi-MeV ion beams generated by high-intensity ultrashort laser pulses in the interaction with solid targets [5]. Light ions, similar to electrons, can be generated due to laser–plasma interaction in a target, while a heavy ion beam must be produced by an external driver and transported to the target. In summary, the fast ignition (FI) mechanism [4], in which a pellet containing the thermonuclear fuel is first compressed by a nanosecond laser pulse, and then irradiated by an intense "ignition" beam, initiated by a high power picosecond laser pulse, is one of the promising approaches to the realization of the inertial confinement fusion (ICF). The ignition beam could consist of laser-accelerated electrons, protons, heavier ions, or could consist of the laser beam itself. It had been predicted that the FI mechanism would require much smaller overall laser energies to achieve ignition than the

[1-4] *Department of Physics, Shiraz Branch, Islamic Azad University, Shiraz, Iran*
** Corresponding Author Email: hoseinimotlagh@ hotmail.com*
Note: This paper has been presented at the International Conference on Advanced Technology&Sciences (ICAT'14) held in Antalya (Turkey), August 12-15, 2014.

more conventional central hot spot approach, and that it could deliver a much higher fusion gain, due to peculiarities of the pressure and density distributions during the ignition. If the ignition beam is composed of deuterons, an additional energy is delivered to the target and increase target energy gain. Therefore, in this work we choose the D+^{3}He fuel with a deuteron ignition beam, under optimum conditions for the first time we compute the total energy deposited in the target and dynamically we determine energy gain. We must notice that D+^{3}He has different advantages: they include full-lifetime materials, reduced radiation damage, less activation, absence of tritium breeding blankets, highly efficient direct energy conversion, easier maintenance, proliferation resistance.

2. Physics of Fusion Reactions

The main fusion reactions are:

$$D + T \to {}_2^4He(3.5MeV) + n(14.1MeV) \qquad (a)$$
$$D + {}_2^3He \to {}_2^4He(3.6MeV) + p(14.7MeV) \qquad (b)$$
$$D + D \to {}_2^3He(0.82MeV) + n(2.45MeV) \qquad \%50 \qquad (c-1)$$
$$D + D \to T(1.01MeV) + p(3.03MeV) \qquad \%50 \qquad (c-2)$$

D+^{3}He reaction is very attractive from a theoretical point of view since it does not produced neutrons. A D+^{3}He fuelled fusion reactor would also possess substantial safety and environmental advantages over D+T. Efficient D+^{3}He fusion energy would be beneficial to terrestrial electricity, space power, and space propulsion. Fusion using D+^{3}He fuel requires significant physics development particularly of plasma confinement in high performance alternate fusion concept. Economically accessible ^{3}He on earth exists in sufficient quantities (a few hundred kg, equivalent to few thousand MW-years of fusion power) for an engineering test. In a D+T and D+^{3}He fuel mixture D+D reaction fusion also occurs. The main difficulties for D+3He reaction are the high temperature conditions and the scarceness of 3He on earth. The formula of fusion cross section for all these fusion reactions is given by: [6]

$$\sigma(E_{lab}) = -16389C_3\left(1+\frac{m_a}{m_b}\right)^2 \times\left[m_aE_{lab}\left[Exp\left(31.40\,Z_1Z_2\sqrt{\frac{m_a}{E_{lab}}}\right)-1\right]\left\{(C_1+C_2E_{lab})^2+\left(C_3-\frac{2\pi}{[Exp(31.40Z_1Z_2\sqrt{m_a/E_{lab}})-1]}\right)^2\right\}\right]^{-1} \qquad (1)$$

With 3 adjustable parameters (C_1, C_2 and C_3) only. In equation (1), m_a and m_b are the mass number for the incident and target nucleus, respectively (e.g. m_a= 2 for incident deuteron); E_{lab} (deuteron energy in lab system) is in units of Kev and σ is in units of barn. The numerical values of C_1, C_2 and C_3 are given inRef.10.From this formula, we calculated and plotted the variations of fusion cross sections for these reactions in terms of E_{lab}. Also by comparing our calculated numerical values with available experimental results as are shown in [9], we concluded that this formula is very exact. Another important quantity is the reactivity, defined as the probability of reaction per unit time per unit density of target nuclei. In the present simple case, it is just given by the product $<\sigma v>$. In general, target nuclei move, so that the relative velocity v is different for each pair of interacting nuclei. In this case, we compute an averaged reactivity $<\sigma v>= \int_0^\infty \sigma(v)vf(v)dv$ where $f(v)$ is the distribution functioning of the relative velocities, normalized in such a way that $\int_0^\infty f(v)dv = 1$ .As we have seen earlier, the effectiveness of a fusion fuel is characterized by its reactivity $<\sigma v>$. Both in controlled fusion and in astrophysics we usually deal with mixtures of nuclei of different species, in thermal equilibrium, characterized by Maxwellian velocity distributions $f_j(v_j) = \left(\frac{m_j}{2\pi k_BT}\right)^{\frac{3}{2}} exp\left(-\frac{m_jv_j^2}{2\,k_BT}\right)$ where the subscript j labels the species, T is the temperature and k_B is Boltzmann constant. The expression for the average reactivity $<\sigma v>$ can now be written as: $<\sigma v> = \iint d\,v_1dv_2\sigma_{1,2}(v)vf_1(v_1)$ where $v = |v_1-v_2|$ and the integrals are taken over the three-dimensional velocity space. In order to put $<\sigma v>$ in a form suitable for integration, we express the velocities v_1 and v_2 by means of the relative velocity and of the center-of-mass velocity $v_c = \frac{m_1v_1+m_2v_2}{m_1+m_2}$: $v_1 = v_c + \frac{vm_2}{m_1+m_2}$ and $v_2 = v_c - \frac{vm_1}{m_1+m_2}$ then becomes:

$$<\sigma v>= \frac{(m_1m_2)^{\frac{3}{2}}}{(2\pi k_BT)^3}\iint d\,v_1dv_2\,exp\left(-\frac{(m_1+m_2)v_c^2}{2\pi k_BT}-\frac{m_rv^2}{2k_BT}\right)\sigma(v)v \qquad (2)$$

Where m_r is the reduced mass defined by $m_r = \frac{m_1m_2}{m_1+m_2}$, and the subscripts '1, 2'have been omitted. It can be shown that the integral over dv_1dv_2 can be replaced by an integral over dv_cdv , so that we can write:

$$<\sigma v> = \left[\left(\frac{m_1+m_2}{2\pi k_BT}\right)^{\frac{3}{2}}\int dv_c\,exp\left(-\frac{(m_1+m_2)v_c^2}{2\pi k_BT}\right) \times\left(\frac{m_rv^2}{2k_BT}\right)^{\frac{3}{2}}\int dv\,exp\left(-\frac{m_rv^2}{2k_BT}\right)\sigma(v)v\right] \qquad (3)$$

The term in square brackets is unity, being the integral of a normalized Maxwellian, and we are left with the integral over the relative velocity. By writing the volume element in velocity space as $dV = 4\pi v^2dv$, and using the definition $\varepsilon = \frac{1}{2}m_rv^2$ of center-of-mass energy ε, we finally get: $<\sigma v>= \frac{4\pi}{(2\pi m_r)^{\frac{1}{2}}}\frac{1}{(k_BT)^{\frac{3}{2}}}\int_0^\infty \sigma(\varepsilon)\,\varepsilon\,exp\left(-\frac{\varepsilon}{k_BT}\right)d\varepsilon$ We must notice that the resonance temperature ,where we have maximum probability for occurring fusion. From Figure 1 we see clearly that resonant temperature for both D+^{3}He and D+D fusion reactions are approximately 100 and 380 keV, respectively.

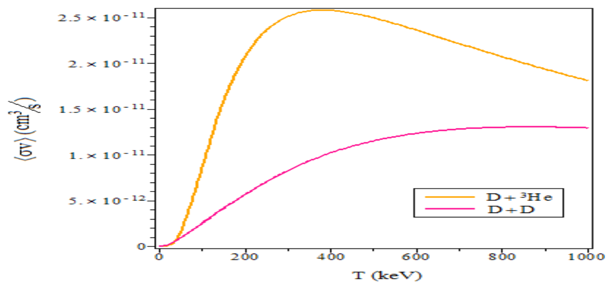


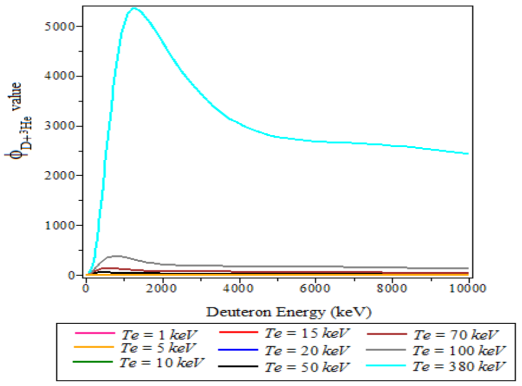
Fig 1:Variations of the averaged reactivity in terms of temperature for $<\sigma v>_{D+\,^3He}$ and $<\sigma v>_{D+D}$

3. Total deposited energy due to deuteron beam fast ignition in target fuel

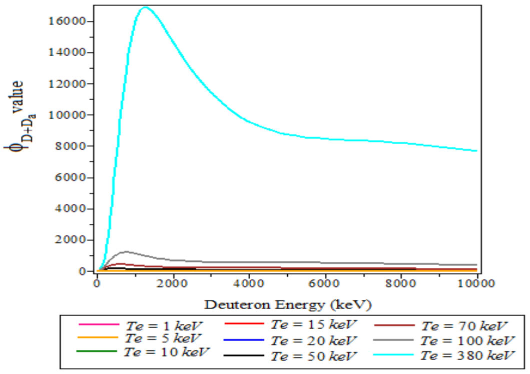
Deuterons have been considered for fast ignition as well. Bychenkov et al., considered an accelerated deuteron beam, but decided that deuterons would have too high an energy (7–8 MeV) to form the desired hot spot [7] .However, the recent proton acceleration experiments [8] suggest that the laser and converter foil parameters can be adjusted to achieve ion beams within the desired range of initial energies and spectra with low $\frac{\Delta E}{E}$ for maximum use of the beam. This reopens the door to a consideration of deuteron driven FI. Deuterons would not only provide proven ballistic focusing, but also fuse with the target fuel (both D and ^{3}He) as they slow down [9] , providing a "bonus" energy gain. Depending on the target plasma conditions, this added fusion gain can provide a significant contribution. We must notice that idea of bonus energy for first time is presented by Xiaoling Yang and et.al at low temperatures. In this work we elaborate on this idea , to compute the added energy released as the energetic deuterons interact with the target fuel ions of D+^{3}He in range of temperatures including resonant ones (380 keV). This added energy increases the total energy gain .We use a modified energy multiplication factor φ to estimate the bonus energy in terms of the added "hot spot" heating by beam-target fusion reaction for D+^{3}He [9] . The deuteron beam energy deposition range and time are also calculated for this reaction. The F value is the ratio between the fusion energy E_f produced and the ion energy input E_I to the plasma and for D+^{3}He reaction is given by [9] : $F_{D+{}^3He} = n_{{}^3He}\frac{\int_{E_{th}}^{E_I} S(E)dE}{E_I}$ where E_I and E_{th} are, respectively, the average initial energy and the asymptotic thermalized energy of the injected single ion for this reactions.[18,21,22].So, we consider $S(E) \equiv \sum_k K_k[<\sigma v(E)>_b]_{Ik}(E_f)_{Ik}/\left(\frac{dE}{dt}\right)$ where:

$$\frac{1}{n_{{}^3He}}\left(\frac{dE}{dt}\right) = -\frac{Z_I^2 e^4 m_e^{1/2} E \ln\Lambda_{D+{}^3He}}{3\pi(2\pi)^{1/2}\varepsilon_0^2 m_I (kT_e)^{3/2}}\left[1+\frac{3\sqrt{\pi} m_I^{3/2}(kT_e)^{3/2}}{4 m_k m_e^{1/2} E^{3/2}}\right] \quad (4)$$

where m_e is the mass of electron and m_I is the mass of the injected ion, both of which are in atomic mass unit (amu). $<\sigma V>_{Ik}$ is the fusion reactivity for the injected ion *I* of species *k* having atomic fraction K_k in the target, $(E_f)_{Ik}$ is the corresponding energy released per fusion, and T_e is the target electron temperature. By inserting Eq.(3) inside $F_{D+{}^3He}$) we can see that the $n_{{}^3He}$ in Eq. (4) cancel that in $F_{D+{}^3He}$, thus $F_{D+{}^3He}$ is nearly independent of the target density $((n_{{}^3He})$. $\ln\Lambda_{D+{}^3He}$ is the Coulomb logarithm for D+^{3}He reaction. In the D+^{3}He fusion reaction the products are all energetic charged particles (14.7 MeV proton and 3.6 MeV alpha) based on the binary collision model, the Coulomb logarithm based slowing down process in the back ground plasma is usually defined as: $\ln\Lambda_{D+{}^3He} = 14.8\text{-}\ln\left(\sqrt{n_e}/T_e\right)$.The $(E_f)_{Ik}$ in $S(E)$ gives the energy released in the fusion reaction carried by the produced particles. For, D+^{3}He reaction in the target (see reaction (b)) only 20% of the fusion energy carried by the alphas is useful for heating while for the D+D reaction about 63% of the total is applicable (see reaction c) . Therefore, to prevent confusion, we introduce a new factor φ to represent the energy multiplication factor for the hot spot heating by the charged particles for D+^{3}He fusion reaction. We have $\varphi_{D+{}^3He} = 20\%\, F_{D+{}^3He}$ and for D+D fusion in D+^{3}He mixture $\varphi_{D+D} = 63\%\, F_{D+{}^3He}$. In summary, the total energy that could be deposited into the target due to combined deuteron ion heating and beam-target fusion for D+^{3}He and D+D respectively becomes: $\varepsilon_{D+{}^3He} = E_I\left(1+\varphi_{D+{}^3He}\right)$ and $\varepsilon_{D+D} = E_I(1+\varphi_{D+D})$ so it is seen that φ plays the role of a "bonus energy" for deuteron driven fast ignition. To avoid confusion, please note that the ε here is the total energy deposited by the ion beam plus any contribution from its beam-target fusion in the hot spot, but not the total input energy to the target which is often cited in energy studies and represents the total laser compression plus fast ignition energy delivered to the total target ,also the deuteron stopping range and stopping time can be calculated by following equations [9]: $R_S = \int_{E_{th}}^{E_I} v_D dE/\left(\frac{dE}{dt}\right)$ and $t_S = \int_{E_{th}}^{E_I} dE/\left(\frac{dE}{dt}\right)$ Where, $\left(\frac{dE}{dt}\right)$are calculated from Eq.(3) for D+^{3}He reactions ,the deuteron velocity is $v_D = \sqrt{\frac{2E}{m_D}}$ .For calculating the total energy deposited into the target of D+^{3}He mixture at first step we substitute : $\ln\Lambda_{D+{}^3He}$ into equation (3),then at second step the obtained result is replaced into $S(E)$ and at third step the result of second step is inserted into $F_{D+{}^3He}$ and we compute, $F_{D+{}^3He}$ and F_{D+D} in D+^{3}He reaction at step 4 we use these parameters for determining φ_{D+D} and $\varphi_{D+{}^3He}$ Finally, results are delivered by the last step inserted in $\sigma(E_{lab})$ and thus we have the numerical values of $\varepsilon_{D+{}^3He}$, ε_{D+D} in D+^{3}He for $10^{26} \le n_e(cm^{-3}) \le 10^{29}$, $0 \le T_e(keV) \le 380$ and deuteron energy E, with range of $0 \le E(MeV) \le 10$.(see Table1) Also under these conditions we can calculate the deuteron stopping range and stopping time using equationsR_S and t_S.For D+^{3}He mixture these parameters are shown respectively, by $t_{S_{D+{}^3He}}$, $R_{S_{D+{}^3He}}$.The numerical results about above discussion are given in Figs.2 to 4. Our calculations show that multiplication factors φ_{D+D} , $\varphi_{D+{}^3He}$ increases by increasing temperature from 1 to 380 keV (resonance temperature of D+^{3}He) and also by increasing energy from 0 to 10000keV increases slowly till at the deuteron energy in lab system maximized and after this energy slowly decreases. The value of total energy deposited in hot spot ($\varepsilon_{D+{}^3He}$ and ε_{D+D}) by increasing temperature from 1 to 380 keV increases such that these total energy deposited at temperature 380 KeV respect to lower temperatures highly increases. Also , total energy deposited by increasing deuteron energy in range of 0 to 10000keV for low temperatures (about approximately 10keV) increase approximately linearly. Also by increasing electron density from $n_e = 10^{26}$ to 10^{29} (cm^{-3}) the amount of total deposited energy of $\varepsilon_{D+{}^3He}$ and $\varepsilon_{D+{}^3He}$ and also the amount of multiplication factors $\varphi_{D+{}^3He}$ and φ_{D+D_a} are decreased. From comparing numerical values of multiplication factors $\varphi_{D+D_a}$and $\varphi_{D+{}^3He}$ we can say that φ_{D+D_a} is very higher than $\varphi_{D+{}^3He}$ .Therefore the total energy deposited $\varepsilon_{D+D_a}$is higher than $\varepsilon_{D+{}^3He}$. The difference between them is more sensitive at high temperature (see TABLE.1). Also, our results clearly show that the stopping time remarkable increases by increasing temperature from 1keV to 380 keV , also $t_{S_{D+{}^3He}}$ increases by increasing deuteron energy. We must notice that the values of $t_{S_{D+{}^3He}}$ is reduced by increasing electron density, n_e ,from 10^{26} to 10^{29}(cm^{-3}).In these three dimensional figures is obvious the dependency of $t_{S_{D+{}^3He}}$ to temperature. Numerical results of $t_{S_{D+{}^3He}}$ show that stopping time is increased by increasing temperature. The effect of helium-3 density ($\mathbf{n}_{{}^3\mathbf{He}}$) from 10^{22} to 10^{24}(cm^{-3}) is important on the value of $t_{S_{D+{}^3He}}$ and in this range this quantity is reduced (by factor O(10) to O(100)). Our calculations show that show that stopping range ($R_{S_{D+{}^3He}}$) is increased strongly by increasing temperature from 1keV to 380keV and also deuteron energy in lab system is an effective parameter on the stopping power such that by increasing this energy $R_{S_{D+{}^3He}}$ is increased. But the numerical values of $R_{S_{D+{}^3He}}$ are decreased by increasing electron density $\mathbf{n_e}$ from 10^{26} to 10^{29}(cm^{-3}) . The other parameter that effects on the numerical values of $R_{S_{D+{}^3He}}$ is target density (ρ). If ρ changes from 200 to 500 cm^{-3} , stopping range is increased. Also ,the other effective parameter that decreased stopping range , is $n_{{}^3He}$. Our calculation shows that by changing $n_{{}^3He}$ from 10^{22} to 10^{29}(cm^{-3}) , $R_{S_{D+{}^3He}}$ is decreased by the order of 10 and 100.



a)



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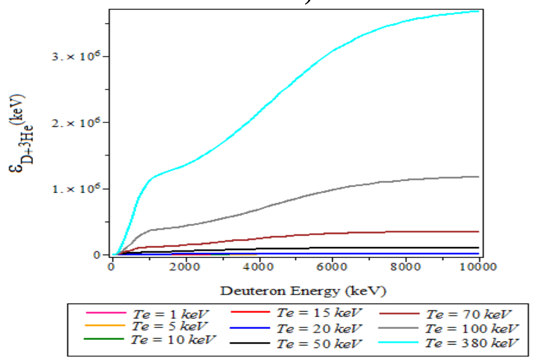

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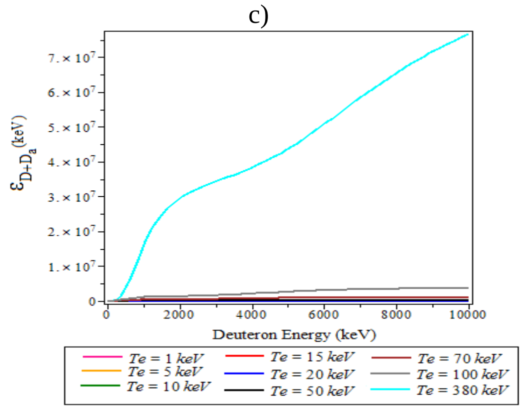

d)

Fig 2: The two dimensional variation of a) $\varphi_{D+{}^3He}$ b) φ_{D+D_a} c) $\varepsilon_{D+{}^3He}$ d) ε_{D+D_a} in terms of deuteron energy in different temperature in D+^{3}He mixture for $n_e = 10^{26}\mathrm{cm}^{-3}$.

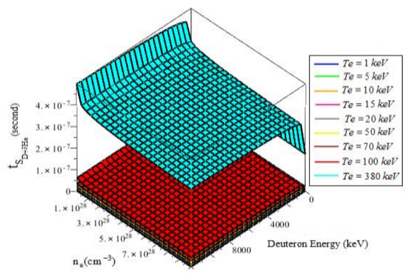

Fig 3: Three dimensional variations of stopping time versus electron density and deuteron energy in different temperatures in different density of ^{3}He $n_{^3He} = 10^{22}(\mathrm{cm}^{-3})$.

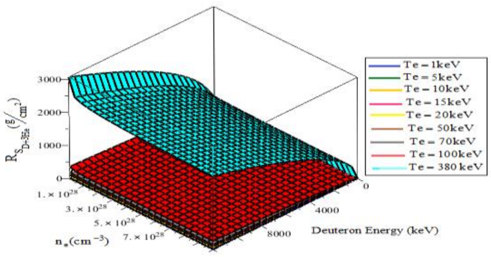

Fig 4: The three dimensional variations of stopping range versus electron density and deuteron energy in different temperatures in D+^{3}He mixture.at $\rho = 300\,(\mathrm{g/cm^3})$ and $n_{^3He} = 10^{23}(\mathrm{cm}^{-3})$

4. Balance equations of deuterium-helium3 mixture

The following system of equations is used to describe the temporal evolution of plasma parameters averaged over the volume (the density of deuterium ions n_D ,density of helllium-3 ions $n_{^3He}$, density of thermal alpha-particlesn_α , plasma energy E), for D+^{3}He nuclear fusion reaction :

$$\frac{dn_D}{dt} = -\frac{n_D}{\tau_P} - n_D n_{^3He}\langle\sigma v\rangle_{D+{}^3He} + S_D$$

$$\frac{dn_{^3He}}{dt} = -\frac{n_{^3He}}{\tau_P} - n_D n_{^3He}\langle\sigma v\rangle_{D+{}^3He} + S_{^3He}$$

$$\frac{dn_\alpha}{dt} = -\frac{n_\alpha}{\tau_\alpha} + n_D n_{^3He}\langle\sigma v\rangle_{D+{}^3He}$$

The energy balance is given by

$$\frac{dE}{dt} = -\frac{E}{\tau_E} + Q_\alpha n_D n_{^3He}\langle\sigma v\rangle_{D+{}^3He} - P_{rad}$$

S_D , *and* $S_{^3He}$ are the source terms which give us the fuel rates; τ_α, τ_P, and τ_E are the lifetimes of thermal alpha-particles, deuterium and hellium-3, and the energy confinement time, respectively, also the energy of the alpha particles is: $Q_\alpha = 3.52\mathrm{MeV} = 3.6\times10^6\times1.6\times10^{-19}\mathrm{J}$. The radiation loss P_{rad} is given by: $P_{rad} = P_{brem} = A_b Z_{eff} n_e^2\sqrt{T}$ Where $A_b = 5.35\times10^{-37}\frac{\mathrm{Wm^3}}{\sqrt{\mathrm{keV}}}$ is the bremsstrahlung radiation coefficient. No explicit evolution equation is provided for the electron density n_e since we can obtain it from the neutrality condition $n_e = n_D + n_{^3He} + 2n_\alpha$, whereas the effective atomic number, the total density and the energy are written as $Z_{eff} = \frac{\sum_i n_i Z_i^2}{n_e} = \frac{n_D + n_{^3He} + 4n_\alpha}{n_e}$ where , Z_i is the atomic number of the different ions. The fusion energy gain is defined as: $G(t) = \frac{E_f(t)}{E_{driver}}$. Where $E_f(t)$ is equal to the energy due to the number of occurred fusion reactions in target in terms of time and E_{driver} is the required energy for triggering fusion reactions in hot spot and is equal to 4MJ . Also the fusion power density for D+^{3}He reaction is given by $P_{D+ ^3He} = n_D(t) n_{^3He}(t) < \sigma v >_{D+ ^3He} Q_{D+ ^3He}$ where $Q_{D+ ^3He} = 18.3$MeV. We solve equations(4-1) , (4-2, (4-3)and (4-4)(in dynamical state (time-dependent density of atoms) with the use of computers under available physical conditions .Our computational obtained results are given in TABLE.2. we see clearly that ,by increasing temperature from 1 keV to 380 keV the variations of deuterium and helium-3 density in terms of time ($n_D(t), n_{^3He}(t)$) are decreased since that by increasing time the consumption rate of $n_D(t)$ and $n_{^3He}(t)$ are increased but the rate of this reduction at resonant temperature 380 keV is more than respect to the other temperatures. Thus, by increasing temperature 1keV to 380 keV the variations of alpha density ($n_\alpha(t)$) versus time at first by increasing time is increased and then decreased while the production rate of fusion plasma energy ($E_f(t)$) is increased until in resonant temperature 380 keV is maximized because in this temperature the highest number of D+^{3}He fusion reaction is occurred. The numerical values of these quantities ($n_\alpha(t)$ and $E_f(t)$) are decreased at temperature higher than 380keV since temperature 380 keV is resonant temperature for D+^{3}He mixture. Also, our calculations show that by increasing the injection rate of deuterium and hellium-3 (S_D and $S_{^3He}$) from 10^{22} to 10^{24}cm^{-3} the rate of variations of $n_D(t)$ and $n_{^3He}(t)$ in terms of time are increased while for $n_\alpha(t)$ and $E_f(t)$ are increased. We expect that in this temperature, energy gain and fusion power density are maximized .Therefore, for calculating these parameters we use of $S_D = S_{^3He} = 10^{24}$cm^{-3} (see TABLE3).

Table 1. Maximum numerical values of total energy deposited in D+^{3}He mixture at different temperature for $10^{26} \le n_e(\text{cm}^{-3}) \le 10^{29}$.

$n_e(cm^{-3})$	T_e (keV)	$\varepsilon_{D+ ^3He_{max}}$ (keV)	$\varepsilon_{D+D_{a max}}$ (keV)
10^{26}	15	10590.79627	11861.00824
10^{26}	50	101366.0808	297803.1545
10^{26}	100	1173268.091	3674294.486
10^{26}	380	3674294.486	7.673686266E7
10^{27}	15	10540.6978	11703.19806
10^{27}	50	92864.49313	271023.1533
10^{27}	100	1058602.594	3313098.17
10^{27}	380	3313098.17	6.819772378E7
10^{28}	15	10498.43168	11570.05979
10^{28}	50	85810.36076	248802.6364
10^{28}	100	964514.3416	3016720.176
10^{28}	380	3016720.176	6.136892405E7
10^{29}	15	10462.29433	11456.22713
10^{29}	50	79863.0243	230068.5265
10^{29}	100	885920.3924	2769149.236
10^{29}	380	2769149.236	5.578338395E7

Table 2. Time dependent optimum numerical values of deuterium, helium-3, alpha particles densities and fusion plasma energy in different temperatures.

T_e (keV)	T (s)	$P_{D+ ^3He}(t)$ $(\frac{W}{cm^3})$	$G_{D+ ^3He}(t)$
15	10^{-20}	491.94E19	5.72E-25
15	10^{-22}	218.51E15	0.57248E-16
15	60	196.78E-4	2.7776E-8
15	100	196.78E-4	1.71496E-2
50	10^{-20}	555.35E21	435.799E-22
50	10^{-22}	391.77E16	2.378E-12
50	60	222.14E-2	1.1536E-3
50	100	222.14E-2	0.7124E3
100	10^{-20}	3144.01E21	2467.212E-22
100	10^{-22}	4678.90E13	0.40904E-11
100	60	1257.60E-2	1.98452E-3
100	100	943.20E-2	1.22532E3
380	10^{-20}	954.43E22	7489.8807E-22
380	10^{-22}	1195.97E8	0.44372E-11
380	60	381.77E-1	2.15276E-3
380	100	381.77E-1	1.3292E3

Table 3. Time dependent numerical values of fusion power density and target energy gain at $S_D = 0.63 \times 10^{24}$ (cm^{-3}) , $S_{^3He} = 0.20 \times 10^{24}$ (cm^{-3})

T_e (keV)	t (s)	$n_D(t)$ (cm^{-3})	$n_{^3He}(t)$ (cm^{-3})	$n_\alpha(t)$ (cm^{-3})	$E_f(t)$ (keV)
15	10^{-20}	6.2E23	1.9E23	1.6E13	0.014
15	10^{-11}	4.2E21	1.3E21	2.2E19	1.43E6
15	60	1.2E12	3.9E11	0.01	6.94E14
15	100	1.2E12	3.9E11	0.01	4.28E20
50	10^{-20}	6.2E23	1.9E23	1.8E15	1089.49
50	10^{-11}	3.1E21	2.7E20	1.0E21	5.94E10
50	60	1.2E12	3.9E11	1.5	2.88E19
50	100	1.2E12	3.9E11	1.5	1.78E25
100	10^{-20}	6.2E23	1.9E23	1.0E16	6168.03
100	10^{-11}	2.8E21	6.4E17	1.3E21	1.02E11
100	60	1.2E12	3.9E11	8.5	4.96E19
100	100	1.2E12	3.0E11	8.5	3.06E25
380	10^{-20}	6.2E23	1.9E23	3.2E16	18724.7
380	10^{-11}	2.8E21	5.4E11	1.3E21	1.10E11
380	60	1.2E12	3.9E11	26.0	5.38E19
380	100	1.2E12	3.9E11	26.0	3.32E25

5. Conclusion

The advantages of $D+^3He$ over D+T appear as full-lifetime materials, reduced radiation damage, less activation, absence of tritium breeding blankets, highly efficient direct energy conversion, easier maintenance, proliferation resistance. $D+^3He$ reaction is very attractive from a theoretical point of view since it does not produced neutrons. A $D+^3He$ fuel fusion reactor would also possess substantial safety and environmental advantages over D+T. Efficient $D+^3He$ fusion energy would benefit terrestrial electricity ,space power , and space propulsion. Fusion using $D+^3He$ fuel requires significant physics development particularly of plasma confinement in high performance alternate fusion concept. Economically accessible ^3He on earth exists in sufficient quantities for an engineering . In a $D+^3He$ fuel mixture D+D reaction fusion also is occurred. The main difficulties for $D+^3He$ reaction are the high temperature conditions and the scarceness of ^3He on earth.

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