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ORIGINAL RESEARCH

3D Neutronic Analysis in MHD Calculations at ARIES-ST Fusion Reactors Systems

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Abstract In this study, we developed new models for liquid wall (FW) state at ARIES-ST fusion reactor systems. ARIES-ST is a 1,000 MWe fusion reactor system based on a low aspect ratio ST plasma. In this article, we analyzed the characteristic properties of magnetohydrodynamics (MHD) and heat transfer conditions by using Monte-Carlo simulation methods (ARIES Team et al. in Fusion Eng Des 49–50:689–695, 2000; Tillack et al. in Fusion Eng Des 65:215–261, 2003) . In fusion applications, liquid metals are traditionally considered to be the best working fluids. The working liquid must be a lithium-containing medium in order to provide adequate tritium that the plasma is self-sustained and that the fusion is a renewable energy source. As for Flibe free surface flows, the MHD effects caused by interaction with the mean flow is negligible, while a fairly uniform flow of thick can be maintained throughout the reactor based on 3-D MHD calculations. In this study, neutronic parameters, that is to say, energy multiplication factor radiation, heat flux and fissile fuel breeding were researched for fusion reactor with various thorium and uranium molten salts. Sufficient tritium amount is needed for the reactor to work itself. In the tritium breeding ratio (TBR) >1.05 ARIES-ST fusion model TBR is >1.1 so that tritium self-sufficiency is maintained for DT fusion systems (Starke et al. in Fusion Energ Des 84:1794–1798, 2009; Najmabadi et al. in Fusion Energ Des 80:3–23, 2006).

Keywords MHD · ARIES-ST · Navier–Stokes equations · Fusion reactor

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Introduction

The ARIWS-ST search is a national US endeavor to investigate the potential of the spherical tokamak concept as fusion reactor and a system for advanced fusion reactor technology. Theoretical and experimental investigate shows that the magnetohydrodynamics (MHD) performance of a tokamak plasma is substantially improved with decreasing aspect ratio [1]. This analysis determined the definition of the ARIES-ST design point. The ARIES-ST investigated as a national US effort to survey the potential of the spherical tokamak concept as a fusion power plant and as a vehicle for fusion development. The 1,000 MW ARIES-ST power plant has an aspect ratio of 1.6, a major radius of 3.2 m, a plasma elongation at 95 % flux surface of 3.4 and triangularity of 0.64 [1, 2]. While the plasma current is 31 MA,the almost perfect configuration of bootstrap and equilibrium current density profiles results in a current-drive power of only 31 MW. The on-axis toroidal field is 2.1 T and the peak field at the TF coil is 7.6 T, which leads to 288 MW of joule losses in the normal-conducting.

TF system. Figure 1 shows a cross section of the reactor core in its standard working state within the vacuum vessel [1, 2]. A modeling of ARIES-ST of power plant is investigated by using molten salt containing ThF4 the procedure of obtaining electric energy from nuclear energy is supplied by light water or heavy water reactors. The primary objective of ARIES-RS is to identify and explore novel, possibly revolutionary, concepts for the Chamber. Technology that can substantially improve the attractiveness of fusion energy systems. In this study, two-layer model has been developed by the way of using fusion technology. The superiority of fusion technology from the other fusion technologies is that a fluid wall was used in reactor, which

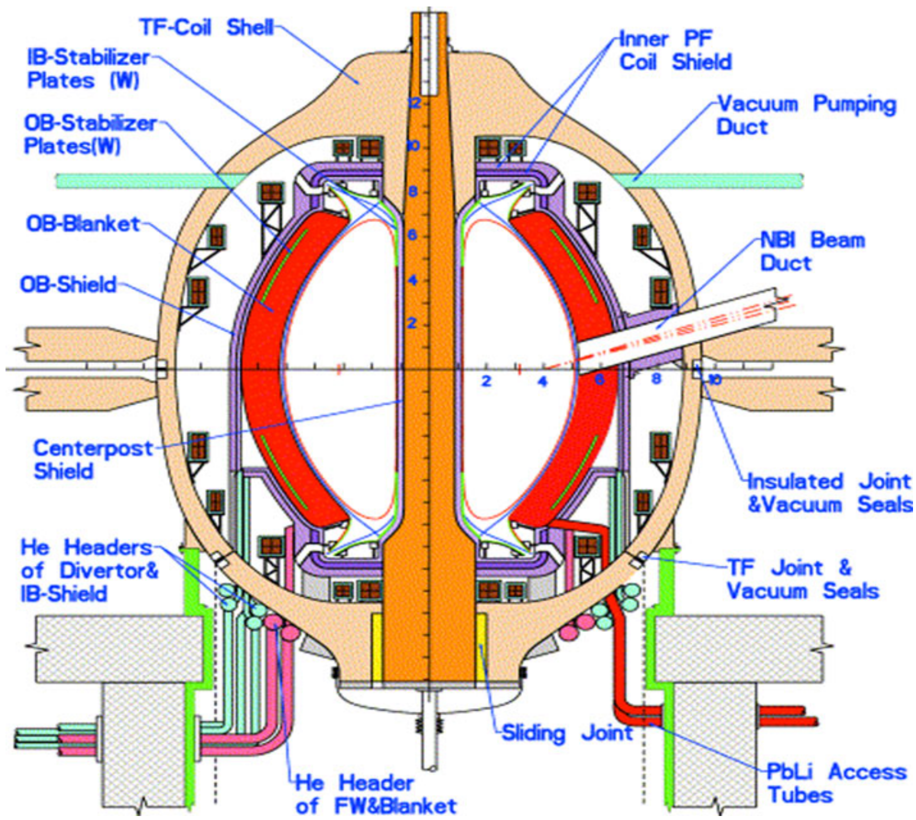


Fig. 1 ARIES-ST fusion reactor sysems [1]

flows instead the first solid wall [1–3]. The advantage of this fluid wall is to extend the life the structural material of the reactor by reducing the rate of damage on the structrual material. It also allows high neutron wall loads. The measures for this model has been taken from the ARIE-RS reactor design which was made in the framework of studies. Liquid wall has a large potential to enhance the vision of fusion, because, liquid wall usage can increase life time of the structure to that of the reactor by decreasing failures on the structural materials, and also allows for high neutron wall load. MHD covers phenomena in electrically conducting fluids, where the velocity U, and the magnetic field B are coupled. Any movement of a conducting material in a magnetic field generates electric currents j, which in turn induces a magnetic field. Each unit volume of liquid having j and B experiences MHD force $j \times B$, known as the "Lorentz force". In this study, two-layer model has been developed by the way of using fusion technology Molten salt Flibe (F, Li, Be) was taken as liquid wall. In liquid first wall concept, the use of flibe was found to be advantageous. A high Pr fluid flow, such as Flibe, has less heat transports capability due to low thermal conductivity and very thin thermal boundary layer [4–6]. A brief parameter

Table 1 ARIES-ST fusion reactors of physical parameters [2, 19, 20]

Parameter	Value
Plasma major toroidal radius, R_T (m)	5.52
Plasma minor radius, α_p (m)	1.38
Plasma aspect ratio	4.00
Plasma current	11.2
Plasma-edge safety factor, q	3.50
Troyon coefficient, C_T (Tm/MA)	0.05
Plasma beta, β	0.05
Peak-to-average density, n_0/n	1.45
Peak-to-average temperature, T_0/T	1.50
Normalized edge density	0.29
Ion temperature	18.00
Electron temperature, T_e (keV)	18.72
Ion density, n_i ($10^{20}/m^3$)	1.72
Electron density, n_e ($10^{20}/m^3$)	2.11
Particle-to-energy confinement time, τ_p/τ_E	1.00
Ion-to-electron energy confinement time, τ_{Ei}/τ_{Ee}	1.00
Lawson parameter, $n_i\tau_E$ ($10^{20}/s^1/m^3$)	2.40
On-axis toroidal field, $B_{\varphi 0}$ (T)	7.98
Radiation fraction, f_{RAD}	0.18

Table 2 General parameter of ARIES-ST at high temperature [2, 19]

Structural modification	AREA (m^2)	Nuclear heating (MW)	Surface heating (MW)	Total power (MW)
Outboard first wall	421	100	195	295
Inboard first wall	67	18	52	70
Inboard shells	54	71	73	144
Inboard shield	–	199	0	199
Divertor	128	201 (hts)	250	451
Outboard ferritic steel	–	~340	–	330
Outboard PbLi	–	~1,600	–	1,614
Total	–	~2,533	570	3,103

Table 3 Structural dimensions of ARIES-RS, APEX and ITER reactor [5, 6]

Structural modification	ITER reactor	APEX reactor	ARIES-RS reactor
Major radius (m)	6,62	5,52	3,02
Minor radius (m)	2,0	1,38	2,0
Plasma aspect ratio	3,31	4	1,61
Number of sectors	15	16	16
Fusion power (MW)	500	~4,000	2,859
Neutron power (MW)	700	~3,400	1,736
Alpha power (MW)	530	~600	433
Fusion power density (MW/m^3)	14	~12	6,38
Average neutron load (MW/m^3)	10	7	4, 3
Peak neutron load (MW/m^2)	14	10	6,0
Average fw surface heat flux (MW/m^2)	0.8	1,5	0,4
Peak fw surface heat	0.8	2	0,47

of ARIES-ST reactor is given Tables (1, 2, 3, 4). Laminar models based on Navier–Stokes—Maxwell equations are applied to be calculated simultaneously with other flow quantities [7, 8].

MHD Flow Modeling for Liquid Wall

The MHD model is the extension of fluid dynamics to electrically conducting fluids such as plasmas, with the inclusion of the effects of electromagnetic forces. The mhd equations consist of macroscopic transport equations and magnetic induction equation. In this study, turbulence model extended to an incompressible MHD flows and Monte Carlo simulation (MCS) and homotopy analysis are used for modeling of low-conductivity fluids. Turbulent models based on Navier–Stokes–Maxwell equations are applied to be calculated simultaneously with other flow quantities [8, 9]. The MHD model treats the plasma as a single, quasi-neutral, magnetized fluid and it solves the following set of MHD equations in non-conservative form. For many MHD flows at high Hartmann numbers currents j in Ohm's law (1) are small in comparison with $\nabla\emptyset$ *or* v $\times$ B. In fully developed flows the magnitude of j is usually of the order of c, where $c = t_G\sigma_G/L\sigma$ stands for the wall conductance ratio.

Table 4 Tritium parameters of ARIES-ST blanket [1, 2, 19]

Tritium state	Amount and dimension
In Pb	
Pb	47,450 kg/s
Pb–Li flow rate	2.5×10^5 mol/s
Sievert's constant at 700 °C	2×10^{-8} atom fraction per $Pa^{0.5}$
Tritium source term	1.8×10^{-3} mol/s
Tritium concentration increase per coolant pass	7.2 appb
Tritium concentration in ARIES-ST	0.72 appm
Tritium partial pressure over Pb–Li	7,400 Pa
Estimated Pb–Li inventory	150 m^3
Total tritium inventory in Pb–Li	16 g
In He	
He flow rate	1,444 kg/s
He density at 500 °C	7.6 kg/m^3
He volumetric flow rate	190 m^3/s
Tritium source term	1.5×10^{-5} mol/s
Tritium pressure increase per coolant pass	0.005 Pa
Tritium pressure in He	5 Pa
Estimated He volume	200 m^3
Tritium inventory in He	1 g

This fact is of particular importance since it allows determining the flow rates (mean velocities) in subchannels formed by cooling plates and grid plates if potential sensor are placed at the positions of those internal walls. The mean velocity between two potential sensor at positions y_1 and y_2 is then obtained as $\tilde{u} = -\frac{\emptyset 2-\emptyset 1}{y2-y1}$, moreover, since for Ha $\gg$ 1 the electric potential is constant along magnetic field lines. There are many modeling approaches used to study fusion system plasma interactions. The three most common are MHD, test-particle/Monte-Carlo and hybrid simulations. Each approach can be used to study ion motions but only the test particle/Monte-Carlo method can be applied to electron motion. However there is no feed-back MHD simulations treat the plasma as a charge neutral fluid Information about the kinetic nature of the ions is lost in this approach. The test-particle/Monte-Carlo approach traces the ion or electron motion through a background magnetic and electric field. The background fields can be from an analytic solution or taken from MHD or hybrid simulations. This approach includes some of the kinetic aspects of the plasma and can easily treat multiple species between the charged particles and the fields or between the individual particles. This can lead to significant differences in the results when compared to more self-consistent hybrid simulations. Hybrid simulations treat the ions as kinetic particles and the electrons as a charge neutralizing massless fluid. The ion motion and the fields are solved self-consistently. Since the electrons are treated as a fluid, electron kinetic effects are absent. Each modeling approach has its implicit assumptions, region of applicability, advantages and disadvantages.

In addition several possible numerical methods can be used for each approach, each with their own assumptions, advantages and disadvantages. It is the goal Modeling and Simulating Flowing Plasmas and Related Phenomena of this paper to provide the reader with a feel for each simulation method, their implicit assumptions and the issues associated with the choice of algorithm. One cannot cover every aspect of each modeling approach or every possible numerical scheme in this work. In fact to do so would probably fill a small library. The interested reader is encouraged to follow up these ideas using the cited references as a starting point. Traditionally cgs units were used in both space and plasma physics properties of the plasma, but low enough that the force due to near neighbor ions is much less than the long range Coulomb force exerted by many distant ions. The motion of an individual ion is governed by the equation of motion.

Navier–Stokes Equations and Free-Surface Flow

The movement of the electrically conducting fluid through the plasma-confining strong magnetic field induces an electric field and drives electric currents inside the liquid metal.

The current density is determined by Ohm's law as $j = \nabla\emptyset + v \times B$. The interaction of currents with the magnetic field give rise to electromagnetic Lorents forces that have to be considered in the momentum balance [7, 8, 10, 11].

$$\frac{1}{2}\left[\frac{\partial v}{\partial t} + (v\nabla)v\right] = -\nabla p + \frac{1}{Ha^2}\nabla^2 v + \mathrm{j} \times \mathrm{B}$$

In these equations the vectors v, B, and j stand for velocity, magnetic flux density and current density, scaled by the reference values ϑ, B, and $\sigma v B$, respectively [7, 11, 12].

The pressure scaled by $\sigma v L B^2$ is denoted as p and the electric potential normalized with ϑ LB is written as $\emptyset$. A typical length scale of the problem is L, the half distance beeter and between Hartmann walls and ρ, σ and ϑ stand for density, electric conductivity and kinematic viscosity of the fluid. The flow is governed by the interaction parameter and the Hartman number,

$$\mathrm{N} = \frac{\sigma L B^2}{\rho v}, \quad \mathrm{Ha} = \mathrm{LB}\sqrt[1]{\frac{\sigma}{\rho v}}$$

The interaction parameter gives the ratio of electromagnetic forces to inertia forces, while the square of the Hartmann number stands for the ratio of electromagnetic forces to viscous forces. The hydrodynamic Reynolds number is given in terms of these groups as $Re = \mathrm{Ha}^2/\mathrm{N}$. The incompressible Navier–Stokes and continuity equations described in Cartesian coordinate are numerically integrated in time by using the fractional-step method by Dukowics and Divinsky. A modified third order Runge–Kutta scheme is used for other terms impicity. The MCcode is combined with the following energy equation. Free surface of the open channel flow as shown in Fig. 2 is received the uniform heat flux from the plasma and the bottom wall of the channel. The liquid has an average U velocity in the x-directions consider an incompressible conducting fluid enclosed between two plates, separated by a distance L, under the influence of a pressure gradient and a magnetic field B_0, normal to the walls as shown in Fig. 2 [11, 13, 14].

The energy equation is described as; $\partial uE/\partial x + \partial vE/\partial y + \partial wE/\partial z + \partial E/\partial t = 1/Re_\tau\left[\frac{\partial^2 E}{\partial^2 X^2} + \frac{\partial^2 E}{\partial^2 Y^2} + \frac{\partial^2 E}{\partial^2 Z^2}\right]$. This is followed by liquid wall, coat, steel wall, armor, stainless steel, vacuum vessel and stainless steel areas consequently. The constant heat flux on the free surface $C = (-\Gamma\partial E/\partial y)_{\mathrm{surface}}$. The non-dimensional temperature is defined as,

$$\mathrm{T(x,y,z,t)} = \left\{<E_w>_{X,Z} - E(x, y, z, t)\right\}/E_\tau$$

where E_W and E_τ and are wall temperature and friction temperature, respectively, and $<>_{X,\ Z}$ express the average with respect to x and z. This method adopted channel flow and annulus flow. The gradient of the bulk temperature temperature $T_m = <T>_{X,\ Y,\ Z}$ is expressed by $\frac{dT_m}{dx} = \frac{2C}{\rho\varepsilon Uh}$, where U is the mean bulk velocity.

Finally, the non-dimensional form of Eq. 1 is rewritten as

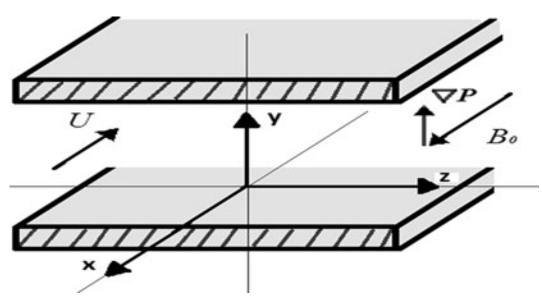


Fig. 2 Velocity Profile and MHD Flow [11, 13]

$$\partial E/\partial x + \partial E/\partial y \; + \partial E/\partial z + \partial E/\partial t = 1/\mathrm{Pe}_\tau\left[\frac{\partial^2 E}{\partial^2 X^2} + \frac{\partial^2 E}{\partial^2 Y^2} + \frac{\partial^2 E}{\partial^2 Z^2}\right] + 2\frac{u_Z}{U}$$

The zero-fluctuation boundary conditions for both velocity and temperature at the free surface are usually applied. However, this condition is not correct for the actual free surface because the free surface can deform and allow the fluctuations of them. In the present study, it is focused on the relatively low Reynolds number flow. Therefore, a high Pr fluid flow has less heat transport capability because of low thermal conductivity and very thin thermal boundary layer. Until today, turbulent flow and heat transfer feature of high Pr fluid, especially b as for a free-surface flow configuration, is not so clear because of the difficulties of velocity and temperature measurements in such a very thin boundary layer. On the other hand, the Navier–Stokes equation can be numerically solved and directly applied to turbulent flows via a current high performance supercomputing technology. This numerical approach is the so-called as a "monte carlo simulation. The temperature of the free liquid surface facing the plasma is the crucial parameter governing the amount of liquid that evaporates into the plasma chamber A molten salt metal wall has highly laminar and stable by magnetic field, the heat transfer at the free surface wall is indicated by laminar convection and conduction.

The liquid wall concept holds a central position in the fusion study prior to the upcoming ARIES-ST free-surface concept. The fusion design idea includes both thin liquid films flowing with very high velocity over the first wall solid surface, and thick liquid layers acting as both the first wall and blanket flow. In this concept, the working fluid is lithium-containing liquid metal or molten salt, such as Flibe. In spite of a very strong magnetic field inside the reactor chamber, Flibe flows do not undergo complete suppression of turbulence, since electrical conductivity of Flibe is relatively low, about 30 times greater than that of seawater, similar to strong electrolytes, but 10^4 times less than that of liquid metals. This feature is preferable to increase the heat transfer from the free-surface if the turbulence would work. In order to grasp the turbulent feature of free-surface flows, Monte Carlo simulation has been carried out in this study.

Numerical Calculations

Monte Carlo Simulasion of ARIES-ST Reactor

In recently,montecarlo method are used to obtain analytical solution of the governing differential equations. Mcnp is a generel-purpose monte carlo n-particle code that can be used for neutron,photon,electron for, or coupled neutron/photonelectron transport. Mcnp computer software provides instruments to solve nuclear problems by simulating the neutron activities cross-sectional view of ARIES-ST designed by using mcnp-4b computer code [3, 15, 16]. The numerical computations in the ARIES-ST fusion blanket have been performed in 3D torus with the aid of the mcnp-4b code and by using from (Endf/b-IV, VI) computer library. The inner region is consisting of plasma and vacuum. Following this, first liquid wall, blanket, ferritic steel, shield, stainless steel and ferritic steel zone take place. In the present study, the ARIES-ST fusion reactor used in this study has been designed in 3D torus shape by using the mc computer software that uses the Monte Carlo technique, using the ARIES-ST reactor model which has been realized in the scope of fusion studies. The cross section of the ARIES-ST which has been modeled by the computer software mc can be seen in Fig. 3. The 1000-MW ARIES-ST power plant has an aspect ratio of 1.6, a major radius of 3.2 m, a plasma extension of 3.4 and triangularity of 0.64 [1, 3, 5, 6, 10]. Mcnp technique is randomly number selection technique from one or more probabilistic distribution in a special trial or simulation study. The complexity in the nature of the industrial problems unfortunately makes analytical solution impossible diffusion problems. Monte-Carlo technique is randomly number selection technique from one or more probabilistic distribution in a special trial or simulation study [3, 5, 6, 15]. The method was then adopted easily for solution of much more complicated and non-statistical problems such as Integra-differential evaluation problems. It is possible to calculate the multiple integrals on phase transitions by Monte Carlo method When the integral of an f(x) function between [a, b]. It becomes $I = \int_a^b f(x)dx \rightarrow I = (b-a)\langle f\rangle$. In this case, its integral is calculated by multiplication of $\langle f\rangle$ average value with (b−a). If the arithmetical average of the function on N pcs points, chosen arbitrarily between [a, b] is calculated, it becomes $\langle f\rangle = \frac{1}{N}\sum_{i=1}^{N} f(x_i)$therefore Monte Carlo reaches the integration formula $I = \frac{b-a}{N}\sum_{i=1}^{N} f(x_i)$. We can benefit from the analyses described in the programme for flux distribution with MCNP method. On the geometrical surface and cells of the reactor, we study on, the code requirement is stated with Fn and Fn* analyses. The above seven tally categories represent the basic MCNP tally types. To have many tallies of a given type, add multiples of 10 to the tally number. Such as,the F_1 surface current.

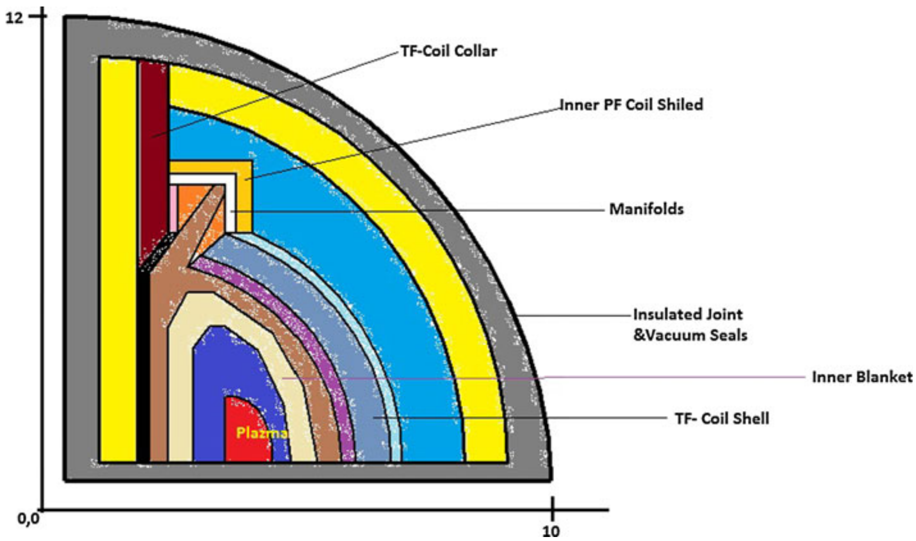


Fig. 3 Cross-sectional view of RIES-ST reactor designed in Mcnp-4b [3, 15]

$$F1 = \int_A \int_\mu \int_t \int_E J(\vec{r}, E, t, \mu) dE\, dt\, d\mu\, dA$$

$$*F1 = \int_A \int_\mu \int_t \int_E E * J(\vec{r}, E, t, \mu) dE\, dt\, d\mu\, dA$$

This tally is the number of particles (quantity of energy for *F_1) crossing a surface. The scalar current is related to the flux as $J(\vec{r}, E, t, \mu) = |\mu|\Phi(\vec{r}, E, t)A$. the range of integration over area, energy, time, and angle (A, E, t, μ) can be controlled by FS, E, T, and C cards, respectively. This is definition of flux also follows directly from the relation between flux and current, $J(\vec{r}, E, t, \mu) = |\mu|\Phi(\vec{r}, E, t)A$. Mcnp sets $|\mu| < 1$. The F_2 tally is essential for stochastic calculation of surface areas when the normal analytic procedure fails.

Tritium Breeding

Tritium breeding ratio (TBR) is defined as the ratio of the rate of tritium production in the system to the rate of tritium burned in plasma. In order to provide adequate tritium breeding, the flowing liquid must be a lithium containing medium. It is one of the most important design parameters in fusion reactor and it should be higher than 1.1 for tritium self-sufficiency is maintained for the DT fusion driver. Then the only practical liquids for first wall and blanket are lithium, lead–lithium, Flibe, and Sn–Li. Flowing liquid metals may require the use of electrical insulators to overcome the MHD drag, while for Flibe free surface flows, MHD effects caused by the interaction with the mean flow are less significant. Figure 4 shows tritium production ratio (TBR) values for the investigated salts according to their PuF_4 contents of the salts at operate of the Arıes-ST reactor. TBR increases with an increase in the

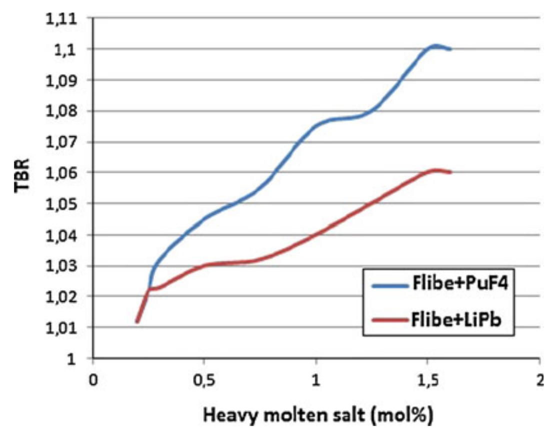


Fig. 4 The variation of TBR value the heavy molten salt

plutonium content for both cases [4, 16–18]. Tritium fuel, required to be burnt in the DT fusion driver, can be subtract by lithium inclusive coolants since the isotopes; Li-6 and Li-7 have dramatically tritium production cross-sections with minimum and maximum energetic neutrons, respectively. In ARIES-ST fusion reactor, the coolant of LiPb is considered to be used as both energy carrier and tritium breeder.

Required Thickness for Liquid Blanket

A primary motivation for considering a thick ıiquid blanket is to prodect the structure behind it from radiation damage and from becoming highly activated. This situation is very important to evaluate the neutronics response of the structural material as a function of the thickness of the liquid blanket protecting. The impact of increasing the liquid thickness on the DPA, and helium production rates in the structure behind the liquid. With thickness t_G and conductivity σ_G we find typical values of $c = 0.014 \ll 1$ for the present experiment. For such conditions it is possible to solve (1) for velocity and we find for a magnetic field $B = \tilde{Z}$ the components $u = -(\partial\varnothing)/\partial y$, $v = -(\partial\varnothing)/\partial x$, the electric potential represents an approximate hydrodynamic stream function for the flow. Recently, one of the authors has proposed a new thermal boundary treatment for free surface, that is, a thin fictitious cell outside the free surface is imposed as an unsteady heat conduction slab [7, 8, 11].

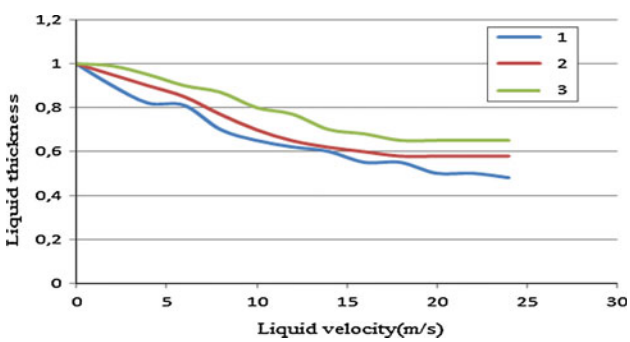


Fig. 5 Distribution of velocity in different types liquid thickness

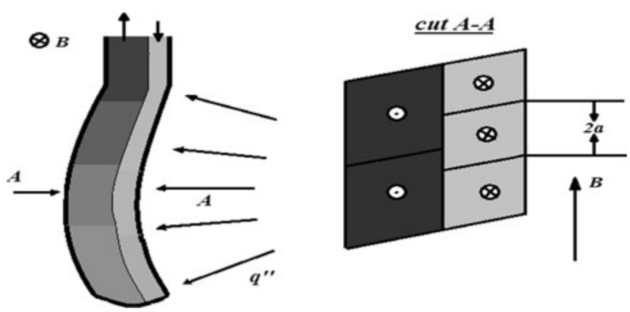


Fig. 6 Liquid cooled poloidal blanket confining magnetic field

This concept stands on the independent boundary treatment of velocity and temperature. In general, a high Prandtl number (Pr = v/a, here v is the viscosity) fluid like Flibe Pr = 28 (600 °C) has less thermal diffusivity. Figure 5 is film thickness evolution as a function of dimensionless cross-sectional velocity profile at the bottom of reactor, and flow proceeds downstream. Figure 5 as shown, indicate that is different thick lithium layer (1, 2, 3). The film thickness increases while the velocity decreases as the flow proceeds downstream due to MHD drag [8, 14].

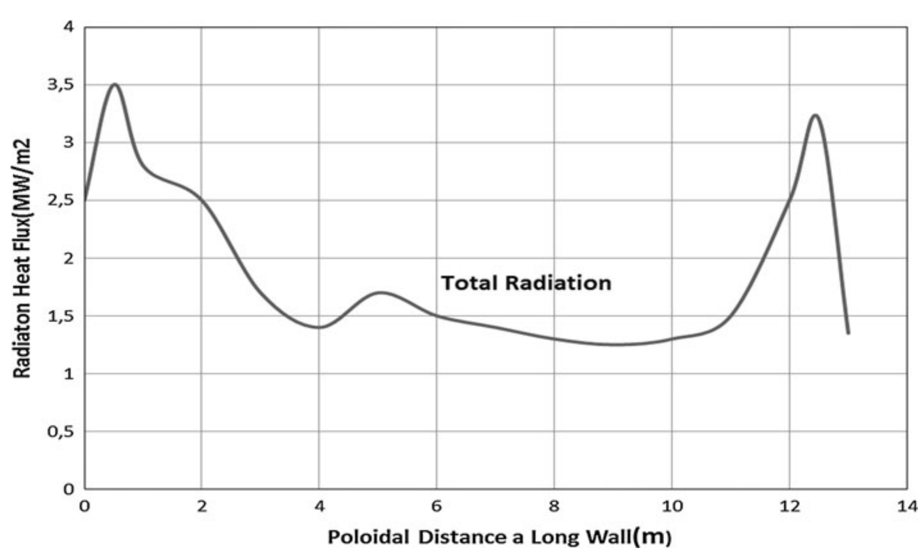
Fissile Fuel Breeding

Fissile fuel breeding and radion damage calculations are done for a NWL of 1o MeV/m^2. Fissile fuel breeding rates of ^{238}U(n,γ)^{239}Pu and ^{232}Th(n,γ)^{233}U increase almost linearly with increased heavy metal content. 3D Mcnp calculations yield a fissile fuel breeding rate of ^{238}U(n,γ)^{239}Pu, 1,20 per momentary fusion neuton number at employ conditions. It is comply with 5,789 kg ^{239}Pu per year. Utilization of nuclear fuel in the liquid coolant both causes in the development of energy multiplication factor and produces fissile fuel which can be used either in the external fission reactors. Fissile isotopes of ^{239}Pu and ^{240}Pu, may be produced by using (n,γ)reactions of fertile istopes; ^{238}Pu and ^{240}Pu, respectively.

Radiation Heat Flux

The influence of the magnetic field on liquid wall flow characteristics and heat transfer is crucial for both thick and thin liquid wall concepts. As two sorts of liquids are the candidates for the working fluid, the molten salt (flibe) and liquids metals (Li, Sn–Li), two separate treatments are needed. In contras with solid metallic walls in which the

Fig. 7 Total radiation heat flux depend of distance ARIES-ST model chamber



heat transfer only depends on conduction, the heat transfer for liquid walls is governed by several physical mechanisms including laminar and turbulent convection and conduction, and it is intimately connected to the motion of the liquid through the convection terms. Figure 6 is shown that, an electrically conducting fluid circulating in the strong magnetic field B of a fusion reactor experiences a body force opposing the fluid motion. Figure 7 shows radiation heat flux profile of the external driven blanket. Heat generation decreases exponentially from inner beginning of tritium breeding zone to other end of the molten salt region. There is a slight increase in heating at the other end of the tritium breeding zone due to the fact that increasing low energy neutronflux at the other [17].

Conclusions

The nuclear assessment proceeded interactively with the economic and safety analyses to determine how the various nuclear parameters influence the performance of ARIES-ST reactor model [1, 2, 19]. The nuclear analysis confirmed the necessity of shielding the center-post and considering all design aspect, particularly the safety and economics. Analysis of the new innovative ideas reveals a number of challenging science states that offer dramatically opportunities for exciting research in fusion technology. The basic conclusions i that the use of molten salt containing UF_4 guied a important value of 239 Pu, fissile fuel which is production in ARIES-ST fusion reactors [6, 12, 16–18]. It is necessary to provide the TBR $>$ 1,1 terms in order to maintain the continuity of the operation of the reactors. 3D Mcnp calculations yield a fissile fuel breeding rate of $^{238}U(n,\gamma)^{239}Pu$, 1,20 per momentary fusion neuton number at employ conditions. It is comply with 5,789 kg ^{239}Pu per year [1, 17]. Monte-Carlo method of turbulent free-surface flow of various pr fluids has been carried out with a constant heat flux from the free-surface and an adiabatic condition imposed on the wall from the Monte Carlo method. The main requirement is that the molten salts flow be free of drips, droplets and side spray and deliver a flow track so that multiple streams will coalesce on the first wall without scattering and to make last their impulse down the FW so that a flow is stabile toroidally in its thickness and velocity is established. As for Flibe free surface flows, the MHD effects caused by interaction with the mean flow is negligible, while a fairly uniform flow of thick can be maintained throughout the reactor based on 3-D hydrodynamics calculations.

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