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Research Article

Neutronic Performance Calculations by Using Suitable Molten Salt in Advanced Fusion Reactor to Produce Electric Energy

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ABSTRACT:

In this study,ARIES-RS fusion type reactor has been designed by using (MCNPX) code. The ARIES-RS study is investigating the use of free flowing liquid surfaces to form the inner surface of the chamber around a fusion plasma. Liquid wall concept has these important advantages compared to the traditional solid wall concept; with its feature of renewable wall it provides possibility for high power density. MHD equations consist of macroscopic transport equations and magnetic induction equation. Turbulent models based on NSM equations are suitable for two types of liquids, working fluid, molten salts operations are required. In this study, MHD balance is discussed in terms of radiation heat transfer conditions, current driving and nuclear performance. ARIES-RS reactor is essentially designed as ferritic steel and V - 4Cr - 4Ti alloy, self-cooled mild steel as the building material.

KEYWORDS: Advanced Reactor, Fusion, Mhd, Liquid Wall, Molten Salt

1. INTRODUCTION

For the last 25 years, the ARIES team has conducted research for various advanced fusion knockers and non-knock models and has investigated the operating performance and DT supply. The design could be based on the reverse knockout mode of the plasma cutting and using moderately advanced engineering concepts such as lithium, the average plasma with a large radius of 5,52m and a small plasma diameter of 1.38m, with a total thermal power of 2620 MW and a fusion power of 2170 MW, with a net output electrical power of 1000 MW. It is conceptualized [1,3]. It has emerged as a fusion power plant using the DT mix as the fuel type. Candidate liquid (LiBeF4, Li17Pb83, LiSn) solutions are used in various regions of the reactor, which are mild molten salts with various chemical properties that provide stable operation of the reactor.The torus type Aries-RS reactor seems to provide the best economic performance in terms of engineering and meeting the future energy demand with refrigerated vanadium alloy plasma surface components and steady state reversed truss buckle.It emphasized that the ARIES-RS engineering design process, in collaboration with the ARIES team, is reaching the high-level task requirements developed at the beginning of the study [1,4-7].Figure -1 show that the fusion power core-cross section 3D and table -1 summarizes the basic parameters for the design of the ARIES-RS moderate aspect ratio is the moderate aspect ratio is used in its design.

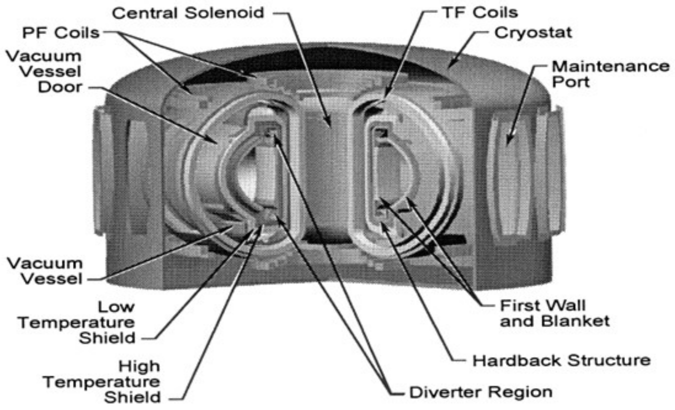

Figure 1. The ARIES-RS fusion power reactor segments [1,4-7].

ARIES-RS reactors are a hybrid model where fusion and fission reactions take place together. This reactor is a new fusion reactor design that uses a liquid wall between the fusion plasma and the solid first wall for tritium production or energy transfer. High-quality fissile fuel can be obtained by using the fast, energetic neutrons 238U and 232Th as a result of the reaction. In terms of these problems that can arise, the concept of liquid first wall (FW) in fusion reactors is a more appropriate choice. Neutrons emitted as a result of fusion reactions occurring in the plasma are captured by thorium and uranium in the blanket, resulting in fragmented fuel production. As with previous ARIES designs, the MCNP5X code is included for various simulations of this reactor.

The segments and plasma structure of the Aries-RS fusion power reactor are illustrated in Figure-1 by the Arıes team. Aries-RS reactor design, advanced commercial fusion power created by using liquids (LiBeF4, Li17Pb83, LiSn and LiNaBeF4) solutions for various candidate melt coolers with steel structure for both internal and external used The vapour pressure of the Li17-Pb83 and natural Li %, mole composition was calculated for the temperature range (200-1000K) containing a representative operating temperature range of the Aries-RS reactor. Li17-Pb83, LiNaBeF4 and pure Li phase diagram measured by Aries-RS suite [4-7]. Molten salts are used as high-temperature heat transfer medium in many industries. Table-1 shows the various physical properties and ARIES-RS parameters used in the design of the ARIES-RS fusion reactor It is the salt that is solid in the liquid phase at standard temperature and pressure due to the high temperature. The coolant pressure of the first wall is 12MPa and has a total surface area of 542 m2.The FW (First wall) has an average neutron wall load (NWL) 4.1Mw / m2 and an average heat flux of about 0.48Mw / m2.

2. Thick Liquid of Wall Concepts

In the ARIES-RS fusion reactor, we offer many advantages such as replacing the first liquid wall with thick liquids, high fusion power density, high control reliability and usability, and low failure reduced radioactive waste quantities and increased build a life [15-17].It contains structurally vanadium alloy self-cooling lithium design material. It by the ARIES team that was decided this blanket has the potential to perform better. Facility requirements with a moderate extrapolation of today's technology. V-alloy has low activation, low temperature, high temperature capability and can handle the high heat flux. In addition, this blanket provides excellent performance. At Figure-2 show that the ARIES-RS of view core 2D sector [12-15, 16-18].

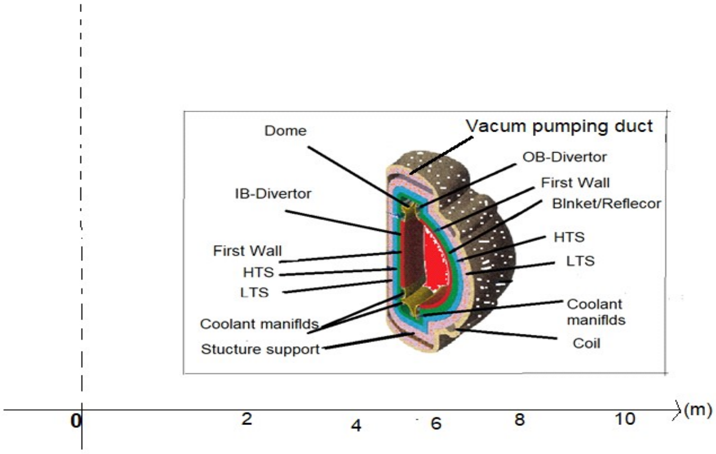

Figure 2. The ARIES-RS of view core 2D sector. [1,4-7].

In the ARIES-RS reference balance, the boot current fraction is 0.88 using density and temperature profiles characteristic of inverted shear plasmas. External non-inductive techniques are often required to drive off-axis currents in the plasma centre and near the axial cutting zone. A series of non-inductive current drive techniques have been considered for the inverted shear power plant. Depending on the reference balance, a combination of these techniques is required to drive currents in different parts of the plasma. Due to the tendency to radiate radially towards the plasma centre, the ICRF fastest waves are best suited for current propulsion on the magnetic axis. On the other hand, with a suitable launch spectrum, the low-hybrid wave can be made to move currents off-axis in the cutting reverse region. Scans of the plasma triangularity of 0,2 to 0,6 showed that a high over 0,4 was required for high β and β increased with increasing For ARIES-RS, internal deflector requirements (mainly adequate neutron protection for space requirements), is limited to 0,5. Plasma elongation improves b, but makes the plasma unstable to vertical movement. Maximum elongation is limited by passive stabilization conductive structure and feedback control system. Neutral rays can provide such plasma rotation rates. On the other hand, ARIES-RS only uses RF current drive [6, 9;15-19].

Table 1. ARIES-RS Reactors of Physical Scale Parameters [1,4-7]

Parameters	Scale
Major radius (m)	*5.52*
Minor plasma radius (m)	*1.38*
Aspect ratio	*4.00*
Plasma vertical elongation (x-point)	*1.70*
Plasma current (MA)	*11.32*
Bootstrap current fraction	*0.88*
Current-drive power (MW)	*81*
Toroidal field on axis (T)	*7.98*
Peak field at the TF coils (T)	*16*
Toroidal b	*0.05*
Average neutron wall load (MW/m^2)	*3.96*
Coolant inlet temperature (°C)	*330*
Coolant outlet temperature (°C)	*610*
Fusion power (MW)	*2170*
Total thermal power (MW)	*2620*
Net electric power (MW)	*1000*
thermal efficiency	*0.46*
Reactor Net efficiency	*0.38*
Recirculating power fraction	*0.17*
Cost of electricity (KWh/cent)	*75.79*
Plasma current, Ip (MA)	*11.3*
On-axis toroidal field (T)	*7.98*
Triangularity	*0.50*
Poloidal β	*2.28*
Toroidal β	*4.96*
Bootstrap current (MA)	*10.0*
Driven current, I_{CD} (MA)	*1.2*

3. MATERIALS AND METHODS

3.1. Numerical Calculations

The design and calculations of Aries-RS were carried out as a 3D torus by using the MCNPX code / Endf / VI library. The parameters of the first wall (FW) of the reactor examined different blankets and molten salt mixtures at Table-2 are shown valid driver requirements for ARIES-RS balance. Specially; tritium production rate, energy multiplication factor, fissile fuel breeding, radiation damage amount, initial installation cost (COS) and heat deposition rate, neutron wall loading (NWL) investigated. The compatibility between high- temperature materials is the transfer of fluid dynamics such as plasmas to the MHD model, including the effects of electromagnetic forces inside and inside the blanket.

Table 2. Valid Driver Requirements for ARIES-RS Balance[1,4-7].

System	Frequency (GHz)	N	Power (MW)	Launcher Position
ICRF Fastwave	*0,091*	*2.0*	*5.4*	*15*
High-frequency wave	*1,000*	*2.1*	*21.4*	*0*
Lower hybrid wave	*4,600*	*1.9*	*9.5*	*-15*

3.2. The ARIES-RS of Engineering Concept

The ARIES-RS design process due to the need and generally operates with an inverted plasma. Sufficient power needed to make a viable diver solution in the SOL and submersible areas. In this case, the sum of the particle and radiation heat flow does not exceed 6 MW/m^2. As a function of fuel density and temperature, the contours of the auxiliary power required for steady-state plasma power balance are displayed [2,20;23-28,31].9 ≤ I ≤15 KeV and fuel densities n≥2 x10^{20}/m^3. Transport and radiation losses in areas outside the ignition zone exceed fusion power and assist steady-state operation requires a medium aspect ratio (α = 4.0) and plasma current is relatively low (IP = 11.32 MA) and a preload current ratio (f = 0.88) is quite high. As a result, the auxiliary power required for the RF current driver is relatively low (80 MW). At the same time, the average beta (β = 5%) is high, which provides power densities close to practical engineering limits (peak neutron wall 5.7 MW/m2 High capacity such that the inlet temperature of the refrigerant into the reactor's heart is approximately 330°C and the coolant outlet melt salt temperature from the reactor is approximately 610 °C It is designed as a vanadium alloy at the Table 4 shown that dimensionless some parameter flow in ARIES-RS reactors.

3.3.Tritium Breeding Rate (TBR) and Energy Multiplication Factor (M)

Tritium growth rate (TBR) is defined as the ratio of tritium production rate in the system to the burnt tritium ratio in plasma. To provide adequate tritium cultivation, there must be a medium containing liquid lithium flowing. By using MCNP5X simulation, the tritium production rates (TBR) resulting from the natural lithium 7.56 6Li and 92.44 7Li isotopes for various blanket layer thicknesses (15, 20, 25, 30 and 50 cm) of the ARIES-RS reactor [1-3,23-27,30-33]. In order for DT fusion reactor should be TBR ≥ 1,05 self-sufficient tritium. The amount of tritium was taken from the reproduction reaction of 6Li and 7Li isotopes in the blanket. Thermal neutrons with 6Li (n, α) T reaction and fast neutrons tritium produced with the help of 7Li (n, α, 'n). Exothermic and Endothermic neutron capture reactions of 6Li and 7Li, respectively, also affect M values. These reactions are given as follows,

$$^{6}Li + n \rightarrow {}^{4}He + T + Q(4.784)\ MeV$$

$$^{7}Li + n \rightarrow {}^{4}He + T + n + Q\ (-2.467\ )\ MeV$$

The overall TBR and M depend on the neutron coverage fractions (NCF) of regions surrounding the plasma and the blanket thickness in each region. The relative NCF for the inboard and outboard regions varies significantly with the aspect ratio. The Tritium breeding ratio (TBR) would be given, TBR =Tbr6 +Tbr7; where, respectively; Tbr- 6 and Tbr- 7 on Li_6 and Li_7 depended. The Tritium breeding ratio (TBR) can be given as follows;

$$Tbr_6 = \iint \emptyset.\sum n,\alpha)T\, dE\,.dV \quad and \quad Tbr_7 = \iint \emptyset.\sum (n,n',\alpha)T\, dE\,.dV$$

Another important neutronic parameter is the energy impact factor M. It is defined ratio of the ratio total energy deposited in the systems to the incident neutron kinetic energy. The energy produced in (D, T) reactor should be as high as possible than this energy produced by plasma Multiplication coefficient can be obtained by increasing the fusion neutron energy, mainly in the blanket with ^{233}U and ^{232}Th fission. In addition to the kinetic energy transfer of 14.1 Mev Fusion-induced neutrons resulting from the Fusion DT reaction also Li hopes to generate neutrons in the additional doped fission energy from a blanket of melt salts. In the Figure-3 per source neutron, local tritium breeding ratio TBR (atoms /Sec) and M (MeV) states of energy multiplication coefficient change versus % 6Li can be seen. In Figure 3, it is clear that enriching the Li result in a significant decrease in the TBR and a negligible increase M.

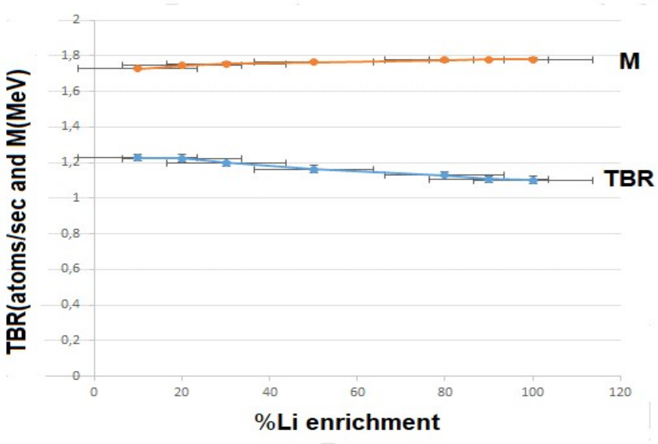

Figure 3. Local TBR and M exchange versus of % Li7+% Li6

3. RESULT AND DISCUSSION

For the full assessment of neutron wall loading, it is primarily necessary to determine the amount of radiation that interacts with the structural material of the ARIES-RS reactor. It is vital to design the various components of the neutron wall charge and fusion power core and evaluate the radiation environment and intensity around the torus geometry. Neutron wall loading, with the change of vertical distance from the middle plane, tritium production depends on the blanket structure. Plasma systems make up 10-20% of the first wall. In Figure-9 show the NWL of ARIES-RS reactor versus distance from the midpoint. ARIES-RS of diverter structure depending on the outboard (OB) and inboard (IB) NWL values are 5.67MW /m^2 and 4.03 Mw /m^2, respectively. Due to its asymmetric geometry, the upper half of the first wall and the diverter are modelled with the code MCNPX to create the poloidal distribution. The ARIES-RS forward power fusion reactor creates a maximum fusion power of 2,170 MW. The total surface area of the fire wall and resulting in the machine's average peak (4.1MW/m^2). The NWL value reaches a peak in the midpoint of the outboard FW with the outboard and the diverter plate and exchange outboard. In Figure-4 show the NWL of ARIES-RS reactor versus distance from the midpoint. ARIES-RS of diverter structure depending on the outboard (OB) and inboard (IB) NWL values are 5.67MW / m^2 and 4.03 MW /m^2, respectively.

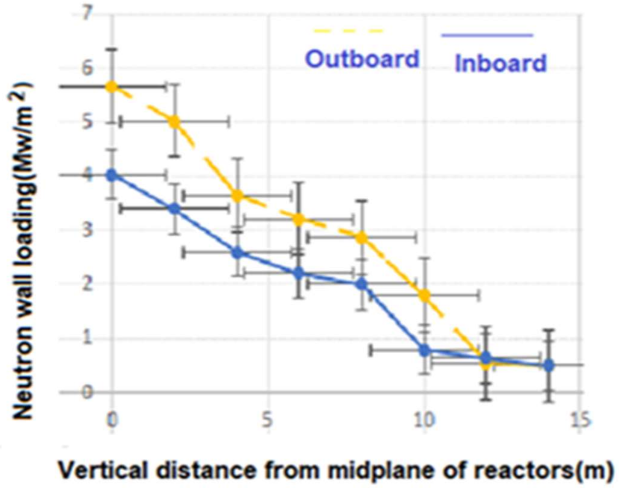

Figure 4. NWL of ARIES-RS reactor versus distance from midpoint

4. CONCLUSIONS

In this study, an advanced ARIES-RS fusion reactor demonstrated the advantages of using it in mixed mode by adding a fission zone to the system. In addition, the emergence of various energies arising from the plasma and the initial setup cost (COS) of the rector allowed the use of candidate solution salts of different thicknesses and spontaneous tritium capable of forming tritium [1-3,8-10]. The design and calculations of ARIES-RS were carried out as a 3D ball torus using the MCNP5X simulation code/ Endf -5B/VI library. In order to ensure the continuity of the operation of the reactors, one of the important tasks in Aries-RS is to provide tritium self-sufficiency. In particular, the $Li_{17}Pb_{83}$ composition is carried for nuclear heating. Blanket and harvest high-temperature $Li_{17}Pb_{83}$ composition is breeding material, important for both good tritium reproductive potential and self-cooling conditions. In the case of no additions to the blanket, TBR ≥ 1.20 values are observed for molten. In the case of no additions to the blanket, TBR ≥ 1.20 values are observed in a molten liquid such as plasmas have been enhanced by compatibility between high temperature materials, MHD model inside and outside the blanket, and the effects of electromagnetic forces. It will also assist in neutron activation analysis used in various sites. Due to the low fission rates in the fusion zone, among the types of fusion energy studied, the matrix material, ^{232}Th and ^{233}U, selected as fuel, was more efficient in terms of performance of the ARIES-RS reactor. The world's present thorium reserves are many times more than the uranium reserves, this type of ARIES-RS reactor or the use of less costly and ergonomic high performance will allow the efficient use of efficient thorium fuel to provide fissile fuel for conventional fission reactors.

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