Nuclear Fusion: Future energy

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ABSTRACT:

The Paper gives Overview of fusion energy. Present study, different ways to achieve fusion on each. Environmental Compatibility, Safety are discussed.

Keywords: Fission Energy, Fusion Energy, Helium, Hydrogen, Tokamak.

1. INTRODUCTION:

We all know fuel sources like petrol, diesel & coal but this fuel sources will cease to exist someday. Currently more than 85% of the primary energy production in the world is originating from burning fossil fuels. At the Current rate of consumption and production coal reserve would last for about 130 yrs & oil would last only for about 20 to 25 years. Burning fossil fuels are environment hazards too but as we don't have so many options, we are using them deliberately.

Other options we have solar power, wind energy. This aren't so efficient. About 30% of sunlight is scattered back into space by outer atmosphere & the balance 70 percent reaches the earth's surface. From the total solar energy falls on the earth's surface we use only 9% for energy production. Nuclear power also uses uranium which will vanish one day & this have got danger radiation danger & of meltdown perhaps the greater challenge facing our modern world is to developed the necessary technology for an affordable, clean & sustainable energy production.

Fusion power is one of the methods we are seeking for fusion is the least developed but has particularly valuable environmental & safety advantages & has virtually inexhaustible resources. Fusion is completely clean energy with helium as it's by product.

2. FUSION REACTIONS:

Nuclear Fusion is remarkably similar to the Nuclear fission. In both the cases it's the interplay between the electric repulsion of nuclear force that holds things together. In case of fission we took advantage of the fact that if we broke the nuclear strong force just a little bit the pieces would fly apart & energy coming but fission associated with splitting uranium atom which has very heavy nuclei, by bombarded with neutrons, This heavy alones nuclei get's divided into several fragments formed emission & large release of energy. This formed neutrons triggered more uranium atoms & such way process goes on by giving large release of energy. Nuclear

Fusion is exactly opposite of nuclear fission. In case of fusion reaction, two atoms of lighter nuclei combines together, or fuse, to form an atom with heavier nuclei, typically one of those neutron goes flying off & we get huge amount of energy. In fusion only the very lightest elements are practical for producing fusion nuclear reactions of net energy yield. The main candidates are isotopes of hydrogen, lithium, helium. There are two chains of reaction to fuse lighter atoms-

1) Proton- Proton reaction (P -P reaction)

2) C-N-O reaction (carbon - Nitrogen oxygen) reaction.

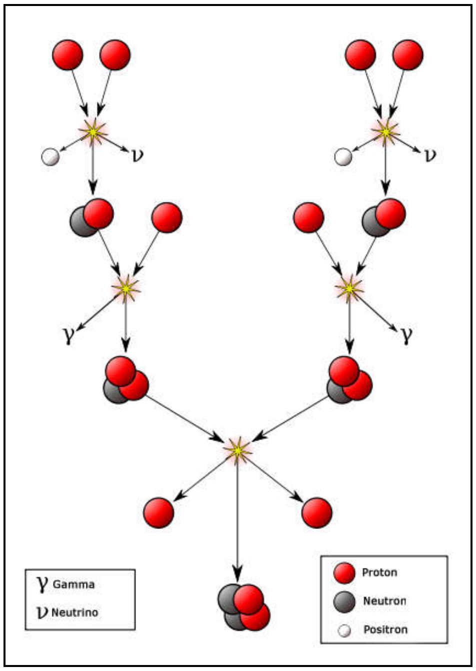

Fig. 1 the proton-proton fusion process that is the source of energy from the sun.

The P.P. reaction in sun essentially converts 4 protons into a helium (^{4}He) Hence conversion of protons into neutrons takes place. -Hydrogen isotopes (Protium, Deuterium & Tritium) are most suitable for fusion because of lightest weight of hydrogen. It is lightest amongst all & has low atomic mass. The fusion reaction between the hydrogen isotopes deuterium (D) & tritium (T) is least difficult ;

$D + T \rightarrow {}^4He\ (3.5\ MeV) + n\ (14.1\ MeV)$

To fuse two hydrogen atoms we need to heat them up because if they move faster they will get closer & finally touches each other because they have this kinetic energy & heat basically means high velocity particles.

Required heating temp. of D-T plasma is about 150-200 million C. The temp. to reach is for hotter than the surface of sun which is estimated as 5,505ºC. The reaction products are 3.5 MeV helium nucleus & 14.1 MeV neutron, i.e. in total about 17.6 MeV is released per fusion reaction. One out of every 6,500 atoms of hydrogen in water is deuterium. Deuterium contained in 1 lit. of sea water (about 30 mg) & by D-T reactions will produce as much energy as burning 250 lit. of gasoline.

3. STATUS OF NUCLEAR FUSION:

State of research & development (R&D) of nuclear fusion can the called embryonic -

Now we have two challenges to make fusion power practical:

1) Heating the Fuel to required degree of temp.

2) Confining the plasma.

The problem is that until now every fusion experiment has operated on an energy deficit. Decades of disappointment in the fusion experiment has led to the joke that fusion is the energy of the future & always will be.

Presently we have two approaches :- Magnetic & Inertial Fusion.

- Magnetic Confinement fusion-
  The temp. necessary to ignite fuel is around 100- 200º million ºC. Obviously no metal on the earth is able to confine the plasma with such a high temp. This dilemma is solved by using magnetic field, all particles carry an electrical charge & thus can be confined by magnetic field. Stronger the magnetic force it will more compress fuel & magnetic field will restrict the plasma from touching walls. In Magnetic fusion research two main toroidal devices are used; tokomaks & stellarator.

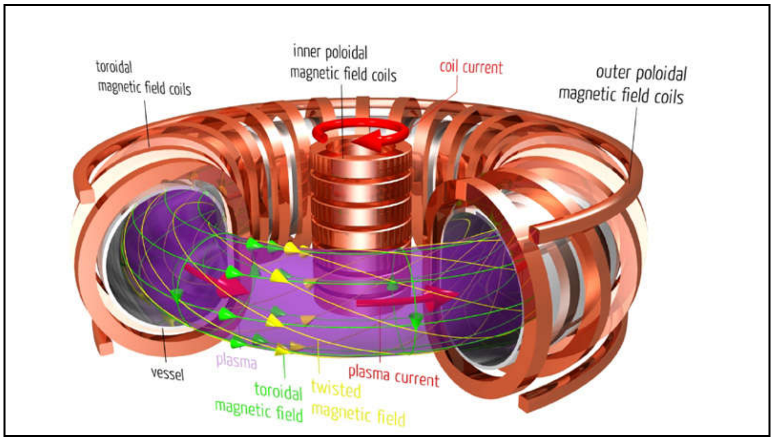

Fig. 2 : magnetic confinement scheme

- Inertial fusion-
  In inertial fusion a small pallet (a size of pencil eraser) containing fuel a 50/50 min of D & T) is compressed using laser. In this method a very small pallet of gold or silver kept in reactor chamber & compression of pallet is achieved by focusing the laser beam on small pallet causing the raise in temp. of pallet & result in fuel ignition the laser focused on a pallet or hohlraum is first transmitted through massive chain of glass amplifiers.

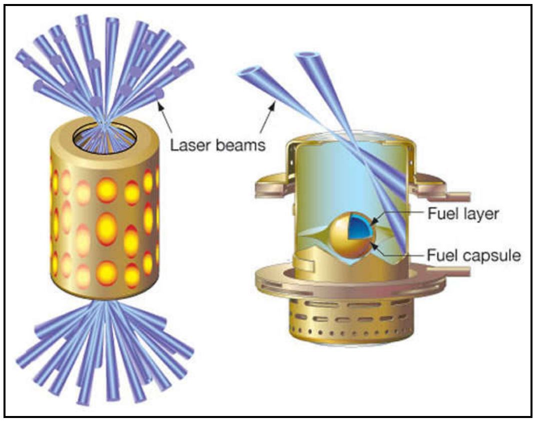

Fig.3: a tiny capsule inside the hohlraum contains atoms of D and T that fuels the ignition process.

Fuel Pallet made of two hydrogen isotopes necessary for fusion will be inside the chamber. As the laser pallet converge on the pallet cylinder will heat up at millions of degree C. This will cause an intense burst of X-rays that implodes the pallet & forces hydrogen atoms together result in nuclear fusion reaction would create a more energy than the laser pulse is delivered.

4. NUCLEAR FUSION EXPERIMENTS :-

Nuclear Fusion on earth isn't just possible it's been done repeatedly !

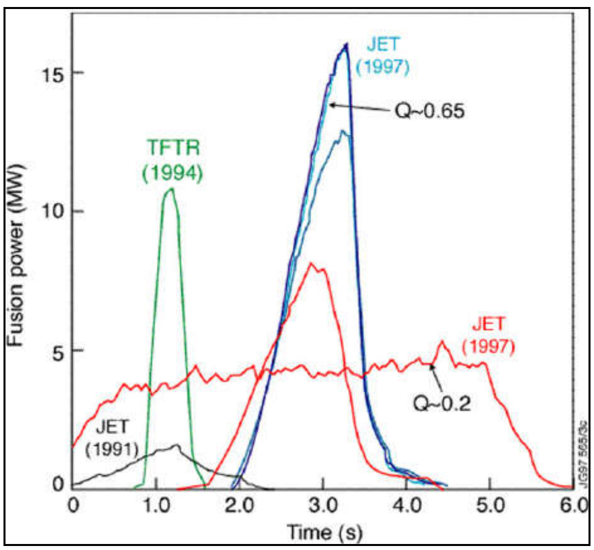

Fig.4 : fusion experiments in Joint European Torus(JET)

1) Most notable & well documented (D/T) fusion took place in the Russian tokomak 'Joint European torus' (JET) reactor in cal hum, UK in 1997. Construction of the joint European torus (JET) started at the end of seventies. It went in operation in 1983 & remain the largest fusion device in the world.

At JET experiments with Deuterium & Tritium have led to considerable power production 16.1 Must fusion power was produced for a about a seconds (see Figure 4). While in experiment conducted (24 MW) was an input power that is amount of energy needed was more than was generated by fusion. 1.0

means balance and the gain was about 0.7 & more than 1 is needed for net energy output while this is an outstanding result in itself.

2) In addition , ion-temperatures up to 45 KeV, which is about 30 times higher as that in the center of the sun, have been achieved in Japanese tokomak JT-600 (Japanese Atomic Energy Agency, Naka Fusion Institute, Naka Japan) in 1997 Magnetic fusion research has thus now arrived at the point where large amounts of fusion energy can be produced in a controlled way.

- One of the largest helical device LHD was constructed in NIFS. Since 1998 LHD has conducted 18th experimental campaign, & remarkable progress has been demonstrated. That is about 10 KeV temperature plasma has been achieved & long pulse operation during about 50 min. has been demonstrated.

3) In 2014 at Lawrence Livemore national laboratory; California, forced a 192 powerful lasers on tiny sphere encasing 170 millionths of a gram of 'H' Releasing a whopping 173 KJ of energy.

This might sound a bit over the top when you consider low little power is actually released; 173 KJ but this amount is equal to amount of solar energy that falls on sq. yard (0.83 m²) of earth in full daylight over 17 sec & this fusion reaction lasted more little 0.0000000001 sec. i.e. 1×10^{-9} sec. In this experiment a fuel energy gain of about 2 has been reached wise an input energy of 8.5- 9.4 KJ delivered to the D-T plasma.

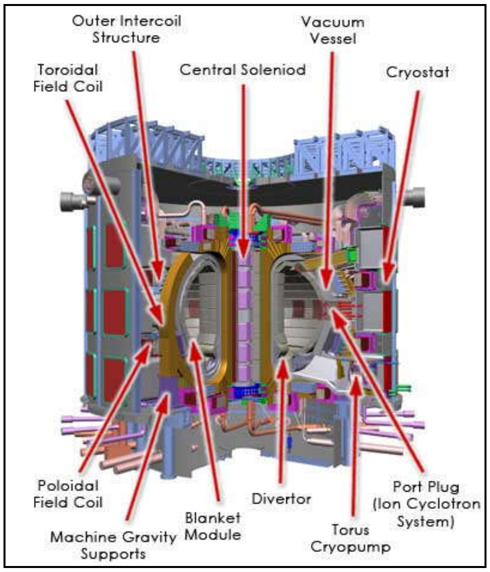

Fig. 5 : sketch of ITER fusion reactor tokamak.

4)Iter is the one of the most ambitious project ever attempted. Seven partners representing 35 nations of joint forces to tackle one of the most urgent challenges of mankind. Developing a new source of energy with a potential to supply an electricity to the ever growing word population and ultimately deliberate us from burning fossil fuels. Fusion is the nuclear reaction which powers the sun and the stars. Here on the earth the machine is needed to reproduce a prodigious display on the skies, an amazing machine.

Iter meaning 'a way' in Latin is a tokamak. Measuring 30m in diameter, 30m in height, this tokamak will be the largest fusion machine ever build. The goal of Iter can be summed up by a simple equation $Q \geq 10$. From 50MW input power Iter will generate 10 times output power or 500MW of thermal energy. Sounds easy right? Believe it's not!

Iter stands for innovation. A whole army of heating system will fire the plasma up to 100-150 millions of ºC. Supersize means superconducting magnets. Some producing magnetic field that is 280,000 times stronger than earth's magnetic field and well confined the hot plasma inside the torus. Only centimeters away of fusion furnace a sophisticated cryogenic and thermal shielding system will guarantee temperature colder than on the dark side of the moon. So the magnet for remains a super conducting at -269ºC. Iter is arranging to fire the first plasma in Dec. 2025.

5. FUSION FUEL RESOURCES:

Fuel required for fusion reaction is basically deuterium and tritium which are isotopes of hydrogen, because every experiment is working on either D-D or D-T reaction as they have low masses amongst all elements. Deuterium is extremely plentiful, as we discussed earlier they is one deuterium atom in every 6500 atoms of hydrogen in seawater. By burning per ton of deuterium energy obtain is 35×10^{16}J. On earth, total amount of deuterium is estimated as 46×10^{14}t. Which will last for trillions of years. This two isotopes of hydrogen, deuterium is non-radioactive and tritium is radioactive in nature.

Tritium can be produced by irradiating lithium metal. Lithium is widely available on earth as like deuterium on earth. It founds in earth's crust. It has two isotopes ^{7}Li and ^{6}Li naturally occurs (92.5% and 7.5% respectively). Out of these two, ^{6}Li is most useful isotope. Per ^{6}Li atom energy released is 22.38MeV. That is if we extract T from only ^{6}Li, it would produce an energy of about 270×10^{14}J/ton in D-T reaction. Lithium is 25th most abundant element on earth. As of January 2010, USGS estimated world's total Lithium reserves at 99×10^{8}kg (extractable economically) and identified Lithium resources at 255×10^{8}kg.

6. ENVIRONMENTAL ASPECTS:

Fission energy has danger of meltdown and produces highly radioactive waste. The major difference between fusion and fission reactor is no possibility of catastrophic accidents in fusion reactor. The primary reason is that fusion requires precisely controlled pressure, magnetic field and temperature. If the reactor gets leaked, this parameters would be disrupted and the heat generation in the reactor would rapidly cease.

Second thing about pollution, fusion reaction has Helium (^{4}He) as it's byproduct which is not radioactive, do not contribute to the greenhouse effect or destruction of ozone layer and also do not pollute environment. In addition, Helium is non-toxic and inert. It will not react with any element to form any toxic harmful compound. There is no problem in Lithium mining because it's found in very upper layer of earth's crust.

7. CONCLUSION:

The research of fusing Hydrogen atoms is going on since 90's and will have an inexhaustible power source by the middle of this century. It will fit into a sustainable energy system and be able to supply electricity for next trillions of years. we come to know methods of fusion, need, necessity, waste of fusion, and current ongoing research of fusion.

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