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Use of Rare Earth Materials As An Alloy For Increasing Power to Weight Ratio in Armoured Fighting Vehicles

Ashok Kumar Panda, ME (Power Systems)
Executive Engineer, MIE, C Engg (India)
Course Control Officer
Faculty of Electrical and Mechanical Engineering
Military College of Electronics and Mechanical Engineering
Secunderabad, Telengana State – 500015
{akp.eme@gmail.com}

ABSTRACT

Rare earth elements play an essential role in our national defence. The military uses night-vision goggles, precision-guided weapons, communications equipment, GPS equipment, batteries, and other defense electronics requiring need for rare earth alloying. These give the military an enormous advantage. As the world becomes a more volatile and dangerous place, the use of rare earth elements for defence purposes is growing. They are key ingredients for the very hard alloys used in Armoured Fighting Vehicles (AFVs) and projectiles that shatter upon impact into thousands of sharp fragments. Neodymium – laser range finders, guidance systems, communications and Europium in fluorescents and phosphors in lamps and monitors are good examples of emerging applications. All together the aim is to enhance combat efficiency in general and reduction in weight to power ratio in particular. The current focus of Indian R & D related to AFVs is based on scope that, rare earth elements are used in battery, telescope lenses, permanent magnets, motors, optoelectronics, lighting, and computer hard drives to enable them to be smaller, cheaper and more efficient in general and power to weight reduction in particular. A target of 25 horse power per tonne is a better choice for an efficient Armoured Fighting Vehicle.

KEYWORDS Armoured Fighting Vehicles, Power to Weight , Indigenization, BSM, RETA

INTRODUCTION

"**Rare earths**" are a group of 17 chemically similar elements crucial to the manufacture of many hi-tech products for Defence applications and otherwise. Despite their name, most are abundant in nature but are hazardous to extract. The name *rare earths* itself is a misnomer. At the time of their discovery in the 18th century, they were found to be a component of complex oxides, which were called "earths" at that time. Furthermore, these minerals seemed to be scarce, and thus these newly discovered elements were named "rare earths." Actually, these elements are quite abundant and exist in many workable deposits throughout the world. The 17 Rare Earths are cerium (Ce), dysprosium (Dy), erbium (Er), europium (Eu), gadolinium (Gd), holmium (Ho),lutetium (Lu), lanthanum ((La), neodymium (Nd), praseodymium (Pr), promethium (Pm), samarium (Sm), scandium (Sc), terbium (Tb), thulium (Tm), ytterbium (Yb) and yttrium (Y). Despite their classification, most of these elements are not really "rare". The promethium is radioactive.

The most common uses of rare earths includes in manufacturing of optical glass, gems, stones, abrasive blasters, powder metallurgy based products, uses in nano science and technology, memory chips, additives in polymers, paint manufacturing, nuclear medicine, florescence materials, refractories, catalyst in chemical industry, carbon luminaries, permanent magnets, space craft components and submarine anti rust durable components are the few amongst many. According to the Rare Earth Technology Alliance (RETA), the estimated size of the Rare Earth sector is more than 15 billion USA dollars and harvesting capacity is more than 110,000 tonnes. Presently China is leading in this sector

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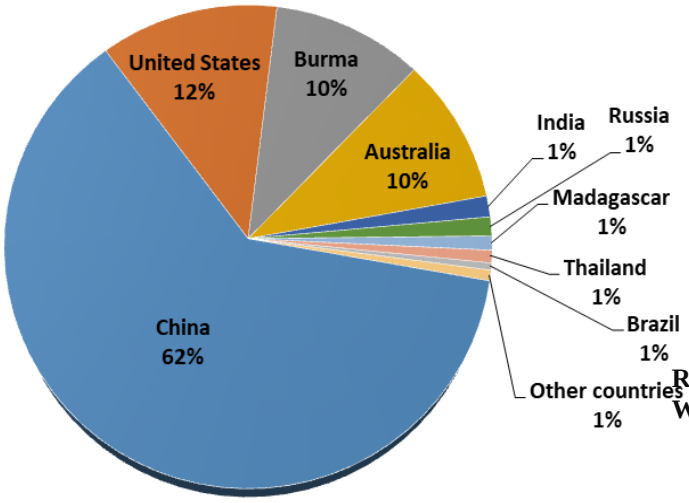
POTENTIAL OF RARE EARTH MATERIALS

Significant rare earths minerals found in India include ilmenite, sillimanite, garnet, zircon, monazite and rutile, collectively called **Beach Sand Minerals** (BSM). India has almost 35 per cent of the world's total beach sand mineral deposits. Also India is seventh potential country in rare earth reserve. As per estimates by experts belonging to the Beach Minerals Producers Association, the rare earth mineral downstream industry can net a capital employment of about Rs 130,000 crores, including Rs 75,000 crores worth of foreign exchange. As per the Indian Rare Earth Limited (IREL) a Govt of India PSU, industry potentially is worth Rs 90,000 crores in annual turnover, lies wasted and underused. Present development of extracting REEs from red mud produced during alumina extraction in India is a big achievement since India is the fourth largest producer of aluminum in the world. Six odd R&D agencies are working in coordination. Rare Earth Permanent Magnets (REPMs) possess high energy density and performance stability, due to which they have great potential in high technology area like defence, space, atomic energy, medical diagnostics and miniaturization of devices. Rare earth metal production was on the rise in 2019, jumping to 210,000 metric tons (MT) worldwide from 190,000 MT the previous year. China ranks highest in its natural REEs resources followed by US, Australia, Burma, Malaysia, Russia, Thailand and Vietnam



CHARECTERISTICS OF RARE EARTH

The rare earth materials have special unique qualities hence applications in Armoured Fighting Vehicles (AFVs) as alloying element is justified. Few important properties are as follows:-

- The rare earths are silver, silvery-white, or grey metals.
- The metals have a high lustre, but tarnish readily in air.
- The metals have high electrical conductivity.
- There are very small differences in solubility and complex formation between the rare earths.
- Concentration of rare earths decreases by moving from surface soil to deeper soil.
- Such metals pose negative environmental impacts

SCOPE OF APPLICATIONS IN DEFENCE FORCES

The scope of uses in respect of Defence forces of Indian Sub continent is intensive and extensive as well. The facilities and equipment required for day to day activities and war requirements are all high end techno dependent. The priority requirement of application of rare earth through indigenization are in the domain of the following:

- Armoured Technology and Autonomous Vehicles
- Secured Communication Devices
- Radars , Interceptors and Surveillance systems
- Guns and Ammunitions
- Unmanned Arial Vehicles and Drones
- Night Vision and Optical Devices
- Solider comfort equipments
- Battery and power supply
- Non Conventional and Additive Manufacturing
- Test and Diagnostic Equipment
- AI & ML
- Nano Materials and Sensors with Telemetry
- Laser Beam Technology as war head
- Simulator developments for Augmented Reality and Virtual Reality
- Identification of Foe and Friend in War field
- Camouflaging and Image Analysis Technology
- Nuclear, Biological, Chemical and Radiation Protection
- Integrated Tactical Power Management System
- Uninterrupted Navigation
- Non Lethal Weapon

REQUIREMENT OF ENHANCED POWER TO WEIGHT RATIO

- Strategic Mobility
- Tactical Mobility
- Battle Field Mobility
- Cross Country Mobility and Agility
- Protection Parameters Adherence
- Replacement of Conventional Battery
- Adoption of Renewable Energy Facilities
- Feasibility of Autonomous AFV
- Increased Camouflaging
- High Range Target Acquisition

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- Identification of Foe and Friend
- Enhanced Crew Comfort
- Increased Fire Power
- Reduced Specific Fuel Consumption

POWER TO WEIGHT RATIO OF EXISTING AFVs

The current deployed AFVs have the following pattern of power to weight ratio in hp/tonne:

- Main Battle Tank Arjun (India): 24:1
- T 90 (Russia): 21.5:1
- T 72 90 (Russia): 19:1
- ABRAM (America): 23.5:1
- LEOPARD-2 (West Germany):: 27:1
- CHALLANGER-2 (British): 19:1

CRITICAL WEIGHT DISTRIBUTION IN AFVs

Usually a Armoured Fighting Vehicle weighs approximately 40-60 tonnes. The % weight distribution is as follows:-

- Turret and Chassis : 46%
- Engine and power pack: 12%
- Armament, Ammunition & Crew: 10%
- Tracks and Suspension: 20%
- Electrical and electronics Equipment: 8%
- Miscellaneous: 4%

MOTORS USED IN AFVs SUBJECTED TO STUDY

The list of common electric motors are under study by R&D institutions for weight reduction by use of rare earth as an alloy

- Belt Feed Motor: 10 kgs
- Blower Motor: 10 kgs
- Turret Exhaust Motor; 5 kgs
- Starter Motor; 40 kgs
- Fuel Pump Motor: 4 kgs
- Bilge Pump Motor: 10 kgs
- Pre Heater Motor: 5 kgs
- Troop Exhaust Motor: 10 kgs
- Electric Discharge Motor: 7.5 kgs
- Auxiliary Motors: 20 kgs

RECOMMENDED USES OF RARE EARTH

The areas of uses of rare earth for sole purpose of reduction in power to weight ratio in Armoured Fighting Vehicle without compromising war requirements are as follows:

- Power supply through rechargeable batteries
- Development of Composite Body Armour
- Precision Guided Weapons and Guidance Systems
- GPS equipment
- Optoelectronics
- Computing hardware

CHALLENGES

Few common challenges on use of rare earths are brought out as under:

- All rare-earth ores contain less than 10 percent REO (Rare Earth Oxides) and must be upgraded to about 60 percent in order to be processed further. They are first ground to a powder and then separated from the other materials in the ore body by various standard processes that include magnetic and/or electrostatic separation and flotation.

- In the conventional processes minerals containing many rare earth elements are first dissolved in concentrated alkalis or acids. This is by far the simplest step; further separation of the rare earth elements is one of the most difficult problems in inorganic chemistry.

- Rare earth elements find a wide range of applications in metallurgy, fuel cells, the coloring of AFVs, glass and ceramics, and the production of magnets, but their separation is difficult, leading to high prices.

ORGANISATIONS CONTRIBUTING TO DEFENCE INDIGENISATION PROGRAM ON RARE EARTH

Due to restrictions on commercial exploitation front and stringent requirements on field trials, very limited government and private entities are engaged in indigenization support program in particular in product development and manufacturing related to use of rare earth as an alloy for uses in defence technology. The rate of failure of prototypes are nearly 50% and time required to complete different rounds of pilot testing , user extensive validation and maintenance trials is unexpectedly high. The cost factor involved during these validation processes are much beyond anticipated project cost. Further by the time all set to roll on indigenized product on alloying of rare earths, there is every possibilities of modification required keeping in view of changed criteria of AFVs deployment in war field and technical specifications. Keeping in view of above attributes the following entities are engaged in indigenization support work to defence:-

- Directorate of Indigenization under Army HQ

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- Ministry of Science and Technology, Govt of India through Council of Scientific and Industrial Research (CSIR).
- Defence PSUs like MIDHANI, BEL,GRSE,BDL,BEML, MDL,HAL

- Advanced Centre for Energetic Materials
- Defence Metallurgical Research Laboratory
- Defence Research and Development Laboratorieas
- Research Centre Imarat
- Naval Science & Technology Laboratory
- Combat Vehicles Research & Development Establishment
- Microwave Tube Research & Development Centre
- Solid State Physics Laboratory
- Munition India Limited
- Armoured Vehicle Nigam Limited
- Advance Weapons and Equipment India Limited
- Troops Comfort Limited
- Yantra India Limited
- India Optel Limited
- Gliders India Limited

Other Prominent Institutions extending support are as under:

- International Advanced Research Centre for Powder Metallurgy and New Materials
- Raja Ramanna Centre for Advanced Technology
- Indian Rare Earths Limited (India)
- Semiconductor Complex Limited

CONCLUSION

Irrespective of branch of engineering and field of science, the materials and their properties and applications play a decisive role for the end use. Present days developments on new materials, smart materials, powder metallurgy, rare earths, metamaterials, nano materials and diversified alloys are the backbone of present days advancement in science, technology and enhancement of quality of life. Amongst the above domain, rare earth elements are emerging as most sought since application are extensive from lenses to electromagnets and aerospace to submarines. The reduction in power to weight ratio of AFVs are under intensive study by R & D establishments. The outcome is expected by 2024.

ACKOWLEDGEMENT

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