सत्यमेव जयते

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MESSAGE

The dedicated work of the scientists and engineers of the Defence Research & Development Organisation has largely contributed to the indigenisation of a large number of Defence technologies.

Ordnance Factories are working in close tandem with DRDO for realising their technologies into products for ultimate use by the Armed Forces. We have now reached a stage where we can compete internationally and market our indigenously developed and produced Defence technologies/products in other countries.

The **Technology Focus**, a bi-monthly publication of DRDO, is contributing to project the achievements of DRDO in a proper perspective in and outside the country.

I take this opportunity to convey my best wishes to all the members of DRDO and wish the publication all success.

(S.S. NATARAJAN)

The AFVs are the mainstay of future wars. Significant innovations in the armour of AFVs have made KE/CE projectiles insignificant in the actual battlefield conditions and antitank missiles redundant because of their unaffordable cost. Today, the frontal and side armours of AFVs are very heavily protected. This has made the weapon designers to find an effective solution to defeat the armour in the critical juncture of the war. In this armament race to constantly improve, upgrade and modernise the systems, wherever feasible, the smart weapons concept has gained importance.

The ammunition is considered to be smart if it is capable of finding, identifying and attacking the target automatically. The smart ammunition has the capability to defeat the armour from the top, as the top armour of the AFVs is not yet protected that heavily.

DRDO has successfully developed several technologies under a technology demonstration project for the development of SADARM type of top attack ammunition for 120 mm mortar. These technologies include:

- Explosively Formed Projectile (EFP) Technology. A copper liner of parabolic shape is used to serve as an antenna for MM wave guidance and also to form a single projectile from it.

- Detonator arming safety device to activate EFP at desired stand-off.

- Thin-walled high strength carrier bomb body to accommodate all sub-systems.

- Efficient capsule ejection system from carrier body ensuring correct ejection of sensor fuze munition module.

- A highly compact MM wave radar sensor with search and target sensing capability.

- A rotafoil parachute system to stabilise the submunition with desired rate of descent, and required spin of the submunition to enable the MM wave sensor to scan the ground targets.

- Overall system integration.

A new parallel body carrier bomb has been designed to accommodate 'P' charge, sensor unit and parachute system. The existing time mechanical fuse is used for the first separation– for ejection of capsule at a predetermined height above the ground level. After a certain delay, secondary charge functions and a submunition is ejected out from the capsule. At the same time, all safeties are removed, rotafoil parachute is deployed, and the battery gets connected to the MM wave sensor. The sensor starts scanning the area under its footprint. As soon as the target is detected and is within the range of the warhead, a pulse is given to the detonator to initiate the warhead. This warhead forms the explosively formed projectile which defeats the target with high velocity.

This is a novel kill mechanism that can be used for attacking the armour from its vulnerable top using an explosively formed projectile. The projectile is formed from a metallic liner on detection of a target. Once the target is identified, the sensor initiates the kill mechanism which projects the EFP at required velocity to defeat the top armour of the target AFV. A 120 mm mortar has been used as the delivery platform for this technology demonstration. The technology can later be horizontally inserted into other platforms like *Prithvi*, *Pinaka* and 155 mm ICM. Only a handful of advanced countries possess these technologies. The smart munition is in advanced stage of development and integration; the validation tests are in progress.

Various static/dynamic trials were conducted to prove all sub-systems. Limited system integration trials were also conducted to prove the technology.

ADVANCED HIGH ENERGY NITRAMINE-BASED PROPELLANT FOR SPACE AND MILITARY APPLICATIONS

Worldover, intensive research is on to develop ecofriendly solid propellants, a combination of high performance and smokeless plume. Double-base propellants, in use since World War II, have major advantage of smokeless plume and superior structural integrity. However, these systems have low performance due to their fuel-rich combustion products.

For high performance, AP-*Al*-based composite and composite modified double-base propellants have been introduced. These systems take advantage of exothermic oxidation of metallic fuel (*Al*) and binder-cum-fuel polymeric system (polybutadienes/double-base matrix) by oxygen-rich AP leading to high flame temperature and consequently high performance. However, AP-*Al* propellants have the drawback of high smoke level (primary smoke of *Al* and secondary smoke due to AP) which is detrimental in case of specific applications. Moreover, the presence of chlorine and chlorine compounds in the combustion products of these systems pose pollution hazards.

This problem has led to the emergence of the concept of nitramine-based propellants. Nitramines offer high energy due to their positive heat of formation and low mean molecular weight of combustion products. Moreover, decomposition products of nitramines are free from chlorine, and do not produce secondary smoke. However, these systems are beset with the problem of low burn rates and high pressure index value due to typical combustion behaviour of RDX and HMX. Nitramines melt at the surface and develop full-fledged flame away from the surface, thereby, acting as a diluent on the surface resulting in the reduction of condensed phase temperature.

DRDO has undertaken an exhaustive research programme due to key importance of these systems. Initially, an RDX-based minimum signature composition was developed containing minor quantity of AP and *Al* to achieve combustion stability while maintaining low smoke level. Intensive research has now led to selection of highly effective ballistic modifier system based on basic lead salicylate. The burn rate realised was 10 mm/s at 50 kg/cm^2 and ISP achieved was 238 s (theoretical). Subsequently, glycidyl azide polymer (GAP) was evaluated as energetic plasticiser. After detailed work, the GAP-RDX-based smokeless composition (without AP-*Al*) was realised with performance comparable to minimum signature compositions.

During further research, a combustion efficient (stable combustion at 10 kg/cm^2), high performance (257 s) metallised RDX-based composition was realised. Both slurry cast and extrusion technologies were established for production of smokeless nitramine-based propellants to realise a wide range of mechanical properties. Ageing and sensitivity characterisation has proved the superiority of nitramine-based systems over AP-based systems in double-base matrix. DRDO has now developed state-of-the-art as well as futuristic combustion efficient, minimum signature, smokeless and high performance nitramine-based propellants by overcoming their inherent problems.

DIGITAL BEARING DISCRIMINATOR FOR DIRECTION FINDING APPLICATIONS

A wide open direction finding (DF) receiver has been designed and developed on a digital bearing discriminator (DBD). The DBD employs a 16-element circular antenna array followed by a complex microwave network, namely, Butler Matrix. It also uses RF channels and phase measurement components to estimate the direction of arrival of signals within its pass band.

The DF system is required to meet stringent performance specifications like -60 dBm sensitivity, 2 degree DF measurement accuracy, 60 dB instantaneous dynamic range, and less than one microsecond processing time. Initially, the laboratory prototype of the DF receiver was configured and developed. The capability of the DF receiver to provide DF accuracy of better than 2 degree was demonstrated.

Technological Breakthroughs

- Design and development of circular antenna array using 16 vertically polarised slot line radiators. The antenna array has to meet stringent gain and phase matching specifications. In addition, it has to provide adequate beam width in both E and H planes.

- Design and development of a simplified and innovative truncated Butler Matrix using only 8 microwave components compared to the conventional 84 components. Detailed performance analysis and simulation studies were carried out to arrive at the new configuration of the Butler Matrix. This resulted in achieving excellent phase and gain tracking among the microwave components and hence very high DF accuracy.
- Development of signal processing techniques which include novel and highly error tolerant algorithms for phase ambiguity resolution and online phase calibration of RF channels as well as Butler Matrix. The incorporation of calibration improved the DF accuracy considerably. It also enabled easy self-diagnosis and fault finding.

For the first time in the world, such a simple and cost-effective technique has been used for wide open high accuracy DF. There are only two manufacturers in the world who offer DF systems based on DBDs. Even they do not have this kind of simple technology. Their cost is about three times the production cost of this indigenous product.

The technology has been transferred to CEL, Ghaziabad, for production and subsequent induction. The first production model of the DF receiver is ready for system evaluation/qualification. The technology is highly repetitive and reliable.

BUND BLASTING DEVICE

Reduction of a high bank is a critical activity in an opposed crossing across a water obstacle/river/canal/ ditch-cum-bund, within the tactical timeframe available for launching a suitable bridge to ensure the mobility of mechanised army. Conventionally, the task is accomplished with the help of earth augers or by placing plastic explosive inside the hole and creating breech by initiating it. The method is quite cumbersome, time consuming and expose the army personnel to the enemy for a longer duration. DRDO has designed and developed a man-portable Bund Blasting Device to overcome these problems. The newly developed device is based on the priniciple of hollow charge and a rocket-assisted high explosive (HE) follow-through projectile.

Main Features

- Man-portable (total weight around 20 kg)
- Deployable on top of the bund
- Number of devices put in an array can be detonated from one point
- Manual deployment
- Total time taken by an exercise is between 40-45 min
- Size of crater created is around 4 m diametre and 2 m deep
- Easy operation, can be deployed at night
- Complete array can be fired with full safety with a small dynamo.

Technological Features

The system consists of a hollow charge initiation device and the main HE-filled projectile attached to a rocket motor. The hollow charge on initiation creates a deep pilot hole. HE projectile on entering this hole detonates, creating a big crater fulfilling the requirement. To remove/lower the height of bunds, an array of such devices is fired to get the desired result within the shortest possible time.

Follow-Through Projectile

A cast aluminium shell has been developed to hold the main bursting charge. A suitable coupling has been made to accommodate the 68 mm arrow rocket motor. The design caters to arrangement for accommodating the booster and the detonator.

It has been developed with a proper MS liner and RDX/TNT explosives in an appropriate ratio to achieve the hole of required diameter and depth.

Holding Stand

A three-legged collapsible stand using extruded MS section has been designed and developed to hold all the sub-systems in the correct sequence. The users trials have been conducted successfully.

An array of six bund blasting devices at blast site (above). Crater formed after the blast (below)

LIFE SUPPORT SYSTEMS

Operational requirements of the Services in varied operational environment of a fighter aircraft, or a high altitude army mission, or hazardous ground environment, or under water, necessitate the use of life support systems for keeping their functional efficiency and fighting morale high. DRDO has carried out extensive R&D in the area of advanced life support systems for LCA and the submarine escape set.

Integrated Life Support System for LCA

Modern fighter aircraft are capable of flying at high altitudes and can pull very high accelerations. Physiologically, these conditions are hostile. The fighter pilots require the assistance of life support system to effectively counter these hostile conditions to carry out a mission successfully. The important functions of such life support system are:

- Providing breathing gas with increased oxygen concentration at higher altitude and reaching 100 per cent at about 30,000 feet.
- Inducing pressure breathing at altitudes higher than 34,000 feet to maintain the required partial pressure of oxygen in the alveoli.
- Inducing pressure breathing during G manoeuvres for better efficiency.
- Producing counterpressure in the lower parts of the body to prevent blood pooling during +Gz acceleration.

The following life support systems for LCA are under development at DRDO:

Submarine escape set

Onboard Oxygen Generating System (OBOGS). It caters to the breathing gas requirement of pilots by generating oxygen in the right concentration on-board.

Demand Oxygen Regulator. It meets the breathing demand and automatically maintains lung pressure by inducing pressure breathing at higher altitudes and during G manoeuvres. It also continuously supplies oxygen during bail-out.

Anti G Valve. It provides the counterpressure in the lower parts of the body by filling the anti G suit to a pressure that is proportional to the +Gz acceleration of the aircraft.

Partial Pressure Oxygen Sensor. It continuously monitors the quality of breathing gas produced by OBOGS.

Electronic Control Unit. It controls and coordinates the functions of various items involved in ILSS.

Back-up Oxygen System. It supports pilots' breathing during OBOGS failure at altitudes higher than 30,000 feet and also on pilots' request.

Life Support System for Submariners

It is self-contained closed circuit breathing apparatus used for escape from a damaged/sunken submarine. This individual escape apparatus consists of a breathing apparatus and a protective hydrosuit.

Breathing apparatus is an automatic equipment with reducers which maintain the partial pressure of oxygen at a given depth to prevent the ill-effects of the oxygen and other gases. The expired carbon dioxide is absorbed in the canister containing carbon dioxide absorbent superoxide which also releases oxygen in the breathing bag. The partial pressure equilibrium in the lungs and in the breathing bag is maintained by the safety release valve and demand valve. Hydrosuit is a buoyant protective clothing made of rubberised fabric. It helps the submariner to float on the surface after the escape and also protects him from the cold and the dangerous sea animals to a certain extent. The positive buoyancy of the set and hydrosuit also helps in the controlled ascent of the submariner from the depth and thus obviates the need for surface decompression. Additional helium cylinder attachment is used for escape from the depths exceeding 100 m up to 120 m.

BREAKTHROUGH IN FULLERENE RESEARCH

Although there have been numerous claims on the preparation of new forms of carbon structures, only two crystalline forms having either Sp3 (cubic and hexagonal diamond) or Sp2 (hexagonal and rhombohedral graphite) carbon structures were well established until the Buckminsterfullerene C60, the third allotrope and first finite molecule of carbon atoms was discovered in 1985. Since then the C60, also popularly known as bucky ball, has rolled into scientific arena.

A simple method for macroscopic production of C60 was announced in 1990. This breakthrough instantly allured a large scientific community to the study of fullerenes. For their efforts in this early work, Professors RE Smalley and RF Curl at Rice University, USA and HW Kroto at the University of Sussex, UK, were awarded the 1996 Nobel Prize in Chemistry.

In 1992, for the first time DRDO started a programme on synthesis, isolation, characterisation, structure-property relationship and applications of fullerenes and family of related compounds. DRDO has now designed, fabricated and commissioned constant arc graphite ablators and established continuous production of soot required for isolation of C60 and C70 by optimising various parameters. Toluene extract of the soot contained the mixtures of fullerenes with abundance of C60 and C70. C60 and C70 were chromatographically isolated using neutral alumina. Isolated components were characterised using 13 C NMR, FAB MASS, IR, Raman, UV visible and XPS.

Fullerenes are not soluble in polar solvents. However, when C60 is nitrated by multiple addition of nitrous oxide, the product isomerises partly to the nitro form with subsequent hydrolysis by atmospheric moisture to yield nitrofullerols consisting of 6-8 nitro and 7-12 hydroxy groups per C60. Surface characterisation of poly Buckminsterfullerense using ESCA reveals the presence of two nitrogen containing species showing instability of nitro group in solid state. This is an interesting observation. As hydroxyl group is known to be quite reactive, such clever functionisations open the door to a variety of further chemical transformations including those only accessible in an aqueous environment.

Fullerenes in general and C60 in particular have numerous applications, as adsorbents, microwave absorbing material, superconductors, optical limiters, frequency doublers, photoconducting fullerene-doped polymers, electronic materials, bucky tubes as chemical messenger, encapsulated nanoparticles and nanotubes for protecting air and moisture sensitive materials, resilient materials, catalysts, and solid lubricants. Bucky balls with claws may pave the way for fullerene-based molecular switching devices.

DRDO PATENTS

Metallic Materials

Process for Preparation of Improved Aluminium-Zinc Magnesium-Copper-based Alloys

Aluminium-zinc-magnesium-copper-based alloys, are the highest strength aluminium alloys which can be produced via ingot metallurgical route. These alloys, when used for high temperature applications for a short duration, require continuous hard anodic oxide coating of thickness beyond 70 microns, which acts as a thermal barrier.

The commercially available alloys of this type have the ability to develop on them a hard anodic oxide coating of 45-55 micron thickness in one step. The bath voltage rises rapidly and reaches 85 V within about 70 min. The process has to be therefore interrupted and has to be carried out in 3-4 stages to get the anodic oxide coating of thickness beyond 70 microns. This problem, in commercially available alloys of this type, occurs due to the impurities of iron, silicon and manganese which may be as high as 0.5, 0.4, and 0.3 per cent, respectively.

DRDO has developed a process for the preparation of improved aluminium-zinc-magnesium-copper-based alloys with low level of impurities of iron, silicon and manganese. These alloys can be hard- anodised to anodic oxide coating of thickness beyond 70 microns in one single operational anodising step without any interruption during the anodising process.

Process for Improvements of Strength of Aramid Fibers

The commercially available high modulus Kevlar fiber are produced by precise control of fibre dope preparation spinning, drawing and heat treatment process during manufacturing. These approaches improve the fibre modulus and strength but it is still much less than the theoretically achievable levels.

DRDO has developed a bio-transformation process of improvement of modulus and tensile strength properties of Kevlar aramid fibres. The strength improvement enhances the suitability of these fibres for use in advanced high performance fibre-reinforced composites. The process involves treatment of aramid fibres with a medium comprising a bacterial cultural isolate in a complete growth medium.

Non-Metallic Materials

Process for Optical Window Grade Zinc Sulphide

Zinc sulphide is an important material for fabrication of IR transmitting windows/domes used in areas like remote sensing. This is because of its excellent thermo-mechanical properties coupled with its very good transmission in 2-12 micron IR range. The known processes for the preparation of zinc sulphide have the drawback that either the yield of optical window grade zinc sulphide is low or the process leads to irregular sized particles with irregular physical properties or has impurities like zinc oxide.

DRDO has developed a process for preparation of zinc sulphide which leads to high yield of the order of 70-80 per cent of optical window grade zinc sulphide. The grain size of the optical window grade zinc sulphide obtained is relatively larger as compared to that obtained by known processes which reduces IR transmission losses. The process leads to optical window grade zinc sulphide of improved IR transmission capability of 65-70 per cent transmission in IR region.

Engineering

Water Current Meter

The measurement of water current in a water gap like a river, canal or stream with known level of accuracy is an essential input in planning the construction of a bridge over a water gap. Conventionally, water current in a river or canal was measured by floating a wooden piece over a specified distance. Ultrasonic transducers have also been used for the measurement of current. However, the instrumentation for the purpose is highly sophisticated and requires specialised skill.

DRDO has developed a water current meter for measuring water current of a river, canal or water stream from one bank to another bank across the entire water gap. It can measure absolute water current from a moving platform across the river. It transmits the measured water current to output port, which is recorded on a recorder of the meter. The device is portable and easy to operate.

NOTE

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