CHAPTER -VI

SUMMARY
SUMMARY

Conventional explosives (RDX/Al/TNT) have major drawbacks of poor mechanical properties, shrinkage and higher sensitivity. Improvement in these properties can be achieved by application of plastic binder system.

Aluminized plastic bonded explosives & PBXs are composite material in which solid explosive particles are uniformly embedded in a polymer matrix. PBXs includes three major components namely polymeric binder, metallic fuel and nitramine (RDX/HMX) explosives. The PBX system has the characteristic of high mechanical strength, low vulnerability, high thermal stability and high-energy output.

The damage potential can be achieved with the use of one of the following three categories of explosives:

- Brisant (non-Auminized)
- Aluminized
- Under water (Auminized, oxidizer)

The preliminary studies show that PBXs can be prepared and manufactured with explosive properties superior to well known universally used TNT based explosives. These class of explosives fall under low vulnerability class.

Aluminized PBXs are needed for superior blast effect and hence the preparation and evaluation of such compositions assume high technical significance.
In view of the above, a systematic and exhaustive study has been undertaken on Aluminized PBXs to develop high performance and low vulnerable compositions as explosive fillings for futuristic ammunitions/warheads.

Major objectives of present study include -

- Influence of RDX/HMX and Al on the velocity of detonation, detonation pressure, peak pressure, impulse and duration on Aluminized PBX compositions.
- Influence of different formulations on the sensitivity of Aluminized PBXs.
- Influence of RDX, Al and binder matrix on thermal and mechanical properties of Aluminized PBXs.
- Influence of different Al and RDX particle size on mould ability of Aluminized PBXs.

The work plan include:

- To study the process conditions for processing cast able Aluminized plastic bonded explosive and achieve the optimum solid loading.
  
The effects of following parameters were studied for optimizing the process conditions.

- Particle size distribution of high explosives and Aluminium.
- NCO: OH ratio.
- Binder to plasticizer ratio.
- Processing aids (lecithin, silicon oil, liquid paraffin etc.).
- Cross-linking agents (TMP, Pyrogallol, Hexane triol etc.)
❖ BKW Code (developed by Becker-Kistiakowsky- Wilson) has been used to predict detonation parameters of Plastic bonded high explosive compositions used in the present study.

❖ Compositions have been evaluated for their mechanical, thermal, sensitivity and explosive properties. Some of the compositions were found to have superior mechanical and thermal properties.

❖ PBXs developed have detonation parameters comparable to the currently used explosive compositions like Dentex. (RDX/TNT/Al/ParaffinWax 48.5/33.5/ 18/1)

❖ Method and conditions for casting the cast able PBX composition in different moulds have been established. The casted grains were found to be void free.

❖ Flexible PBX compositions with good mechanical properties were formulated to suit the deformable phenomenon required for futuristic advance warhead.

In this study, methods have been established for preparing cast able Aluminized PBXs based on Aluminium & RDX, using HTPB as polymer matrix. The processing of PBXs was done by mixing the ingredients in a planetary mixer for about 3 hours under vacuum at 45°C. The casting was done under vacuum at ambient temperature. Finally the charges were cured at 60°C for 7 days with TDI as a curative. However the curing temperature and duration depend on the curing agent used for curing the composition.

To achieve a high solid loading of RDX/HMX in HTPB based PBXs, attention was paid to particle size distribution of the explosive component. Solid loading was optimized by using bimodal and tri-modal mixtures of the explosive.
Packing fraction experiments were carried out on combination of the fine and coarse grades of RDX to establish the proportions required to give optimum packing in a PBX. The optimum packing i.e. optimum density was achieved with a bimodal mix of RDX and tri modal mix of HMX having the size ratio of at least 70:30.

The enemy targets are generally defeated by high velocity fragments generated from bursting of casing or high blast energy in the form of blast pressure produced after detonation. Addition of energetic materials like RDX and HMX in higher proportions increases the fragment velocity because of their higher detonation pressure and higher velocity of detonation (VOD) but the blast damage capability improves with the addition of Aluminium metal powder. Studies on effect of variation of Aluminium powder in high-energy formulation of PBXs have been carried out. Density is a measure of the distribution of solid in the polymer matrix and depends upon solid loading density of the explosive used, particle size distribution of the filler and cross – link density of the polymer among other factors. In the present study density of the charges was achieved more than 95% of the theoretical maximum density. From the plots of VOD and detonation pressure verses Aluminium content it is discernable that initially VOD and detonation pressure decrease gradually with incorporation of Al up to 10% followed by an increase upto15%. On further increase of Al content the detonation parameters decrease steadily. A similar trend is observed with the theoretical values from B.K.W method. It is also observed from theoretical values from B.K.W method that, in Aluminized PBX composition the
C - J temperature increases steadily with the increase of Aluminium content due to highly exothermic process of oxidation of Aluminium and the C - J volume per gram of explosive decrease with increase of Aluminium content due to increase of number of solid carbon atoms as the oxygen balance becomes more negative. The practical values are close to the theoretical ones and within the experimental errors. The data of peak over pressure, impulse and duration has been generated the values of peak over pressure, duration and impulse of PBXs are almost equal to TNT based Aluminized composition viz. Dentex.

Sensitivity tests were performed to obtain a better understanding of the response of polymer bonded explosive (PBX) compositions containing (RDX or HMX) to mechanical and electrical stimuli, which ultimately determines the vulnerability of the compositions. Sensitivity is essentially a hazard factor inherently associated with high-energy materials. The PBX compositions were tested for sensitivity to Impact, Friction and Electrical Spark. It is observed from sensitivity test experiments that, the polymeric component, explosive ingredient and their percentages have significant effect on the sensitiveness of Aluminized PBX compositions. The results indicate that, sensitivity to impact decrease with the improvement in mechanical properties by introducing suitable polymeric binder system and the sensitivity to impact also decrease with the increase of Aluminium content and decrease of nitramine explosive. It is also observed from the comparative study that sensitivity of Dentex and Aluminized compositions is comparable.

From the study of polymeric binder system with different curatives it was observed that, filled (HTPB) and diphenyl
methane diisocyanate (DDI) based polyurethane showed highest compression strength and were selected for further study due to their low viscosity as well as for the ambient curing of the explosive charge. Di (2-ethyl hexyl) adipate was used as a plasticizer. The polymer binder consists of aliphatic (non-polar) chains. However, the explosive is a rather polar compound due to its nitro groups. This means that in spite of good wetting, the adhesion between HTPB and explosive can still be insufficient. This adhesion is of great importance for sensitivity of PBX. When under tension, the binder gets loose from the particle, neighbouring particle gets under increase tension and so the phenomenon propagates throughout the PBX, resulting in cracks. This is detrimental on sensitivity, because cracks can form hot spots under pressure and cause temperature increase, which may lead to initiation of explosion.

Cross-linking agents improve bonding between the explosive and binder. It has been found that a combination of 0.25 parts of TMP and 0.05 part of pyrogallol gives more than 50 percent increase in the compression strength of PBX charge. The amount of tri-functional cross-linkers and NCO/OH ratio determine the cross-link density. The cross-link density, in turn, determines the mechanical properties. The higher the cross-link density, the higher is the hardness of PBX. The effect of variation of NCO/OH ratio was studied. However, NCO/OH ratio was maintained at 1:1 to get similar cross link density in all PBXs prepared and also to get optimum results in the presence of wetting and cross-linking agents.

Knowledge of rheological behavior is useful in all processing step for optimum quality PBX. Plastic bonded
explosive composition must flow uniformly and rapidly into all part of die, mould and warhead. It must be sufficiently fluid during fabrication to allow the easy escape of gases. It must have sufficient yield stresses so that it may not sediment before curing. It must have minimum effect of temperature and gel structure must not deteriorate by repeated handling. The polymer is polyurethane based on HTPB as pre-polymer and different types of isocyanates as a curing agent; both components have low viscosity and therefore add to the cast ability.

To attain a high solid loading and still have a cast able composition the viscosity has to be reduced further. This can be achieved by using plasticizers. The effect of binder/plasticizer ratio on the viscosity and compression strength of PBX has been studied and it is found that binder/plasticizer ratio of 60/40 is better for getting the optimum mechanical strength. Values of viscosities of 0.5 percent solutions of various wetting agents with 60/40 HTPB/DOA ratios have also been studied. It has been found that a combination of lecithin and silicon oil gives satisfactory viscosity and processability.

The effect of various types of plasticizer on the viscosity and compression strength of HTPB matrix has been studied.

Explosive can be decomposed by heat and light at relatively moderate temperatures. During decomposition, considerable heat is liberated since these reactions are exothermic. When the rate of decomposition in the condensed phase is sufficiently high, then an explosion may result due to self- heating i.e. the heat generated during decomposition exceeds the heat loss to the ambient atmosphere by conduction and other means. Ingredients in the PBX
compositions can influence the course of the reactions. It is perhaps essential to have a phase change or melt the solid before an appreciable decomposition rate can be measured.

Thus, knowledge of the behavior of explosive substance at different temperatures is of importance in assessing their chemical stability. Furthermore, in investigating the influence of additives on explosives, it is of interest to know the temperature range within which the reactions occurring are endothermic or exothermic. DTA, TG, DTG, DSC etc have been used for studying these phenomena.

The compatibility of various materials with the explosives was determined by vacuum stability. The thermal properties and vacuum stability data for some of PBXs was generated. The onset of a thermal change in the PBXs studied is above 204 °C. This is due to the high thermal stability of the polymer matrix. The better storage life of the PBXs is indicated by the results of the vacuum stability test as well. RDX and HMX based PBXs release only 0.86 ml and 0.40 ml of oxides of nitrogen, respectively. The corresponding values for pure RDX and HMX are 1.0 ml and 0.49 ml, respectively.

Optical study was carried out to observe the thermal characteristics and behaviour of filler and polymeric binder during heating. Microscopic examination has been performed to investigate the dispersion of various-component and their interaction with binder under hot stage polymerizing microscope at 200 times magnification at 185°C and optical observations was made at several other temperature. Thermal and optical examination revealed better thermal performance as well as significant improvement in overall performance i.e. better dispersion and interaction of filler in Aluminized PBXs with the addition of Silane coupling agent.
It is possible to manufacture Aluminized cast able PBX based on an HTPB – DDI binder and with a high percentage of nitramine explosives (RDX/HMX) and Aluminium, better mechanical properties and low vulnerability. The selected cast able compositions have an edge over the conventional high explosive charges.

All the explosive formulations have been evaluated for their explosive power hence can directly be computed for their improved thermal effects for a given type of casting/design.

Results of mechanical properties, detonation velocity and shock sensitivity of PBXs studied indicate superior properties as compared to conventional explosives. Optimizations of the mechanical properties have been done. The results show that Aluminized cast able PBXs can be manufactured with detonation properties comparable with Dentex, but with better mechanical properties and lower sensitivity. Optimum solid loading can be achieved by using bimodal tri modal mixtures of the different particle sizes.

In the Aluminized PBX composition about 15% Al content is suitable for achieving optimum explosion by blast wave in air. At about 15% Al content in the composition optimum VOD, peak pressure is achieved. Thus, data generated in the present investigation are of immense technical importance for practical applications.