



# Plastics in Armaments

RB Marathe



Defence Research & Development Organisation  
Ministry of Defence, New Delhi - 110 011

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RB Marathe

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## Preface

In conventional armament field, the initial influx of officers and staff was graduates/post graduates from engineering as well as from the basic sciences like Physics and Chemistry. Slowly the trend changed and during last four decades, the scientists and technologists belong to engineering disciplines only. With rapid advances in fundamental sciences and especially with arrival of polymeric materials/plastics, the structure/property relationship has assumed a great importance both in the field of design and the manufacture as well. The syllabus for any stream, particularly the engineering side does not change so fast. Therefore, a great difficulty kept developing in proper understanding of plastics and plastic like materials, for their proper use and making correct design for intended high level performance. A crucial need therefore arose to have a handy booklet to cover these aspects, basically of polymeric materials like plastics.

The aim while writing this monograph was to provide more than introductory treatment of the subject to the level, understandable to broad range of scientists/engineers, especially to those, not belonging to chemistry or polymer science stream. Basic knowledge at least at a level where the divisions of chemistry like organic, inorganic, physical chemistry exists and what for these stand for is assumed. However, engineers are quite conversant with mathematical concepts/theory behind strength of materials and also fields of stress analysis, fracture mechanics, viscous flows and the like. Therefore, these mathematical details/formula have been omitted.

The text of the book has been organised to ensure the continuity and logical flow of the subject matter. It starts with an introduction. It vividly brings out the advantages of plastics against metals (metals being usual engineering materials). In addition to number of other advantages, the advantage of considerable weight saving has been highlighted as it is a very crucial advantage for armament field.

The Chapter 1 starts with brief historical background. It then elaborates the orbitals structure of carbon atom, the concept of hybridisation and the magical powers of carbon atom.

The formation of strong backbone chain  $-c-c-$ , is the essence of basis of engineering properties is the result of magical power of carbon atom. The concept of 'functional groups', their existence, properties and versatility is introduced and how, along with typicalities of  $-c-c-$  chain, leads to innumerable varieties of plastics/polymers has been elaborated in enough details with examples.

With this exposure, Chapter 2 deals extensively with the structure/property relationship. It also elaborately brings out the difference in properties and behaviour of plastics verses metals, one being a long molecular chain-based structure and other being ionic crystal-based structure.

Having introduced to what plastics are and their plurality, Chapter 3 and 4 give glimpses of divisions, thermo plastics and thermoset plastics and also describe a few representative individual plastics from each domain.

The plastics are not used in their virgin conditions. A number of additives are added. Chapter 5 deals with 'additives', their functions, their adverse/synergetic effects in sufficient details.

The reinforced plastics are also in common use. Chapter 6 gives an account of the materials used as reinforcing phase, their structures, properties and manufacture. A brief description of matrix materials also is given and the chapter ends with the likely manufacturing defects and the difficulties in calculating/estimating the strength of reinforced materials.

Upto Chapter 6, the raw material plastics have been discussed in good details. Therefore, Chapters 7, 8 and 9 are devoted to describe the various manufacturing technologies, testing of plastics and components and the quality control/quality assurance. The number of variable factors involved in manufacture, their effects and resulting defects, the plurality of testing methods and standards, the aspects of quality and limitations of statistical quality control have been covered very thought-fully.

This is followed by miscellaneous but equally important topics like explosive compatibility, shelf life, failure analysis, selection of plastics and latest trends in plastics in Chapter 10 to Chapter 14. The book ends with suggestions for future work and conclusion in Chapter 15 and Chapter 16.

The author had encountered the problem of quality in incoming plastic components from trade, number of times. He had also found difficult to convey/

convince the concerned parties that the plastics need to be treated differently, with proper understanding of their structural peculiarities and limitations. He has, therefore, made every endeavour to bring out all these aspect in cogent and readable manner but without losing the necessary technical details and aspects of the subjects. It is obviously up to the reader community to decide to what extent, the author has been successful in his endeavour. Any constructive comments/suggestion will always be a welcome.

Pune

RB Marathe

## Acknowledgements

It has been brought out in preface that the necessity for this monograph was very much felt. The author is therefore indebted to Director, ARDE for recommending the proposal and to Director, DESIDOC for prompt approval and making available the necessary grant and all the help received from his office so far. I am grateful to the staff and officers of Monographs Division, DESIDOC for their instant actions and help and encouragement received from them.

I am really indebted to the Director, ARDE for allowing me the access to the Technical Information Resources Centre (TIRC) all the time. I am particularly grateful to Mrs SS Awachat, Sc 'G', GD, TIRC for her constant support, help and encouragement for this task. The writing of monograph would not have been possible but for whole hearted support and assistance received by me from all officers and staff of TIRC, in particular Mr Pandey, Sc 'D'; Mrs Tare, TO 'D'; Mrs Khadke, TO 'C' and Mr Kambale, TO 'C'.

I express my gratitude to my colleagues from ARDE Pashan, Pune and HEMRL, Sutarwadi, Pune for very helpful discussions on various topics in the monograph.

I want to express my gratitude to Shri Ashok Bhagat, Director of 'Praj' Metallurgical Laboratory for very useful discussions on testing of plastics and for the photographs of various test machines/apparatus. I am also grateful to Mrs Bhagyashri Bhagawat Director, Chemtek Testing Laboratory for making me available the IR spectrographs of Nylon 6/6, Nylon 6 and the Polycarbonate and useful discussion on the subject.

Pune

RB Marathe

## **Introduction to Monograph**

Engineering plastics are being extensively used in Armament stores for Army. The stores range from a large family of munitions, from engineering explosive stores to many high performance stores and fuses, etc. The plastic packages have almost completely replaced all wooden, metal and paper packages for all the armament stores.

Armament stores are generally costly. In relation to it, the cost of the plastic components used appears to be trivial. However, the failure of a plastic component can lead to the failure of the main store, which ultimately can prove very catastrophic. Similarly, any defect occurring in the plastic package will adversely affect the life of an explosive store packed inside.

Unlike any other commercial/domestic plastic product, Armament stores face a very harsh environment and a very rough handling during their service life of about 15-20 long years. These range from a temperature of  $-20\text{ }^{\circ}\text{C}$  to  $70\text{ }^{\circ}\text{C}$ , very dry to very humid atmospheric conditions and many cycles of temperature and humidity together. In addition to this, these stores face very rough handling during their journey from the production place to the depots. From main depot to the field depot and from there to the field use proper. Therefore, the choice of the correct plastic and its correct testing procedures are very important considerations.

It is a general experience that the Armament scientists being basically engineers, don't get the opportunity to go deep into the vast and specialised field of plastics, the theory and technology of it. Therefore, they are always inclined to use and apply the engineering practices to plastics also.

This places unjust demands on plastics under consideration, leads to inadequate specifications and is likely to lead to misleading conclusions from

test results, sentencing and the failure analyses. A handy monograph, covering all these aspects, can be of a great help to them. This monograph will satisfy the need of Armament scientists, felt over a very long time.

## CHAPTER 1

# Plastics and Polymers

### 1.1 INTRODUCTION

#### 1.1.1 Why Plastics are there in Armament Industry?

Armament discipline deals with developing and producing war like explosive mechanisms to inflict maximum damage at enemy end at farthest ranges. To achieve this objective effectively, huge quantities of ammunitions and weapon platforms are produced and used. Bulk quantities of metals, explosives and non-explosives are consumed to produce these. Plastics are a typical class, in non-explosive materials used.

Plastics possess a number of unique and superior qualities, as compared to metals/other non-metals. This makes the use of plastics very attractive in certain domains of this industry. These properties of plastics are discussed in brief as follows:

Plastics being light as compared to metals and wood, a lot of weight saving is achieved. This is very much a prime requirement as reduction in weight helps in achieving longer range at lower pressure.

Ammunition stores have to undergo a lot of handling and transport operations in their service life. Plastics possess good strength to withstand these stresses. These also withstand service requirements of very high and low temperature and humidity conditions. Plastics therefore have virtually replaced paper containers, wooden and metal boxes from packings of ammunition stores. These plastic containers and boxes are re-usable and this is a further added advantage.

Many warheads use blast as kill mechanism. Many need non- detectability. Plastics have proved very valuable encasing materials for such warheads.

As far as the manufacture of plastic items is concerned, plastics score very high, as compared to metals, on many points as given below:

- Whether thermoplasts or thermosets, plastic items are produced mainly by 'moulding operation'.
- Detailed knowledge of plastic materials is now available.
- Detailed and exhaustive softwares for mould design are available.
- High speed, high performance computers are available.
- High-end CNC lathes are available.
- High performance automatic moulding machines are available.

Therefore, once the plastic material is selected and proper care is exercised to design and fabricate the mould and maintain moulding conditions, then the desired quality end product is guaranteed. Moulding being 'one go' operation, rate of production is very high with desired surface finish.

- The bulk manufacture is of reproducible quality, hence on line checking at number of inter operation places is eliminated.
- Number of operations being minimal, a lot of saving by way of labor, energy and time is achieved.
- Almost exact quantities of raw material is used, hence wastage/scrap is not involved. This results in material saving, even 'spruce' could be reused to some extent.
- Quality control is quite easy.
- Most importantly, the very intricate parts also can be produced with ease, accuracy and speed.

Almost all plastics are compatible with explosives. This is very essential and critical requirement in this industry.

Almost all plastics are inert to attacks by acids/alkalies. This makes their use very attractive and cost effective. This is due to elimination of costly surface protection treatment and elimination of deterioration due to rusting.

Barring plastics like nylons, plastics are not susceptible to moisture attack and are almost impervious to moisture absorption. This helps in protecting the ammunition items packed inside.

Thus, with such number of outstanding properties, plastics have entered armament industry decades ago. These have withstood tests of time and hence are going to play important role even in future also.

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### About the Book

The monograph presents a perfect blend between the introduction to what really the plastics are, their structure/property relationship, production technologies, quality control & quality assurance and other topics like testing and shelf life. Various chapters covered deal on topics such as varieties of plastics/polymers, structure/property relationships, plastics and their plurality, additives, matrix materials, various manufacturing technologies, testing of plastics and components and aspects of quality control/quality assurance. Important topics like explosive compatibility, shelf life, failure analysis, selection of plastics and latest trends in plastics are also included in details. The monograph is basically aimed at readership for the Armament scientists and technologists, quality control and quality assurance officers and staff, officers and staff ordnance factories. It also will be very useful for ITI students pursuing polymer technology fields and undergraduate course students from academia. It will also be of immense help to design, production and quality control departments of production houses, and testing laboratories.

### About the Author

**Shri RB Marathe**, after post-graduation in Chemistry with honours, joined Armament Research and Development Establishment (ARDE), the Premier Armament Lab in 1967. During his tenure, he was instrumental in implementing the statistical quality control (SQC) methods in three ordnance factories in filling side. On bifurcation of Defence Science Service, he opted for DRDO and was posted to ARDE. He served in ARDE in Ammunition Design Group and as a Technical Staff Officer. He possesses vast experience in the fields of design, development, transfer of technology, production and quality control and quality assurance of Armament Stores. He headed the Ammunition Division and the portfolio as Technical Staff Officer till 1998 when he proceeded on voluntary retirement. Since 2010, he became the member of Institute of Defence Scientists and Technologists where he completed the assignments of production of critical defence component and also failure investigations. He will be pursuing the field of 'smart munitions' for infantry.

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