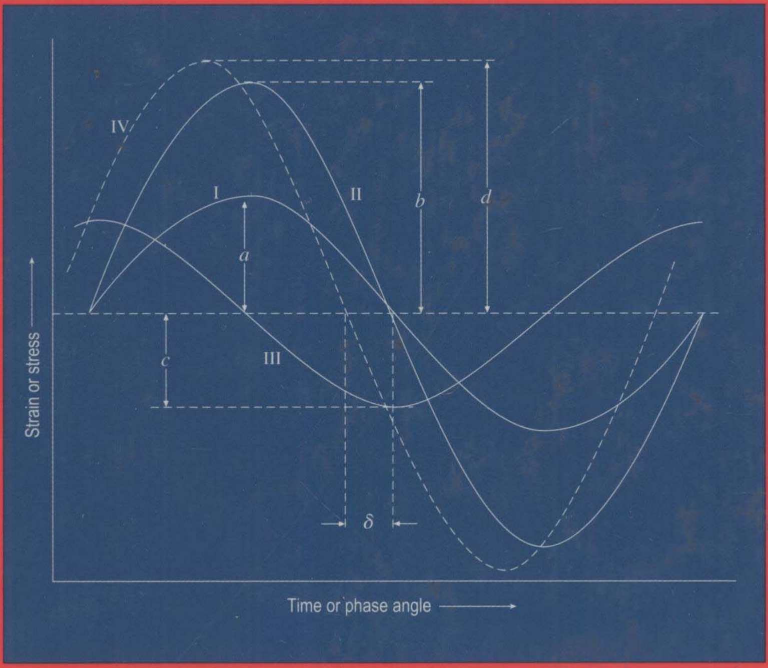
Roger Brown

Physical Testing of Rubber



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Preface

Knowledge of the physical properties of materials is essential for design, specification and quality control, and the particular nature of rubbers demands that specific test procedures, rather than methods for materials in general, are used to measure almost all of the properties. The importance of the subject of rubber testing to industry and to research is witnessed by the large number of national and international standards which have been produced.

A text devoted to the physical testing of rubbers based on experience at Rapra first appeared in 1965 with the publication of the work of the late Dr J R Scott, who was widely regarded as the "father of rubber testing". The first edition of my own book came in 1979 and the second, third and now this fourth edition reflect the continuing technical developments over four decades. There have been many changes in the methods used but, more especially, there have been vast improvements to much of the instrumentation as more modern technologies are adopted by instrument manufacturers and the requirements of industry become more sophisticated. Since the last edition of the book, the majority of International (ISO) and ASTM test methods standards have been revised.

The book collates the many standard methods, comments on their virtues and defects and considers procedures needed for both quality control and the generation of design data. The content owes much to the experience gained due to Rapra's position over many decades as an international centre for rubber research, as a test house with a history of developing test procedures and making a very significant contribution to national and international standardisation. The literature relating to the development and application of rubber test methods has also been reviewed.

The book is primarily intended as a reference for those directly concerned with testing rubbers, whether it be for quality control, evaluation of products, production of design data or research, and for students of rubber technology. However, it is believed that it will also be of considerable value to those indirectly involved in testing such as design engineers and technical specifiers.

Roger Brown

Contents

Chapter 1

INTRODUCTION

The aim of this book is to present an up to date account of procedures for testing rubber materials. It intends to be comprehensive in covering the complete range of physical properties and all of the tests in common, and sometimes not so common, use. Inevitably the bulk of methods are the standard ones, often somewhat arbitrary and primarily intended for quality assurance purposes, but in each case the requirements for testing to predict performance and for obtaining meaningful design data are considered.

Knowledge of the physical properties of materials is of critical importance for the design, production, quality control and performance of all products. Consequently, it is not surprising that a vast spectrum of test methods have been devised to measure these properties. Whilst many features of physical testing are common to all materials, the particular characteristics and uses of each group of materials, metals, ceramics, polymers etc, have provided good reason why each group has developed its own procedures. That is not to say that there are also bad reasons, such as insularity, and that there is not room for greater cooperation and, hence, unification of methods.

Rubbers can claim a particularly strong case for needing their own test methods, being complex materials exhibiting a unique combination of properties, whilst a virtually infinite number of rubber compounds, each with their own detailed characteristics, is possible. They differ very considerably from other engineering materials; being extremely highly deformable but exhibit almost complete recovery, and are virtually incompressible with a bulk modulus some thousand times greater than shear or Young's modulus. For the design engineer particularly, it is important that such properties are measured and understood. The fact that so many variations in compounds, and hence properties, are possible simply means that standard grades hardly exist and one must evaluate every rubber compound which is met with. The basic structure of rubbers and their sensitivity to small compounding or processing changes means that they are prone to unintended variations in properties from batch to batch and present the processor with a difficult quality control problem.

Hence, it is not surprising that with such unusual and complicated materials the procedures used for measuring their physical properties often differ markedly from procedures used for other materials. Methods and philosophies taken from other materials often cannot be simply transferred if meaningful results are to be obtained, so that there is a particular technology of rubber testing. Over the years an enormous effort has been put into developing satisfactory procedures both for quality control and for providing design data, but particularly from the design aspect many procedures remain painfully inadequate. The difficulty of formulating meaningful test procedures for rubbers is due to a number of reasons, some of which are general to testing materials, but some because of the rubber's intrinsic properties. Some aspects of this are discussed in Chapter 2.

Standard tests have the unfortunate habit of not being standard, in that different countries and different organisations each have their own "standards". Fortunately, this tendency has very much diminished in recent times as more countries have the international (ISO) methods. It is perhaps appropriate here to make a plea for the adoption of recognised standards without modification when there is really no strong technical reason for change. It goes without saying that this makes for efficiency because, if we all use the same, well documented method, silly disputes due to the effects of apparently minor differences will be lessened.

The principal standard methods discussed in this book are those of the International Standards Organisation (ISO). Less emphasis is placed on the various national bodies than was the case in earlier works, reflecting the increased importance of ISO, or rather the increased tendency for national methods to be aligned with ISO. However, the equivalent ASTM International and the British Standards Institute (BSI) methods are also considered. Most British standards are now dual numbered so that the national standard is in fact verbatum the same as ISO. In Europe the intention is to align all the national standards by producing European (CEN) standards. This has been done for plastics by adopting the ISO methods but at the time of writing this process has not been carried through for rubbers as it is found easier to reference the ISO methods directly. Unfortunately for the cause of universal standardization, ISO methods are not widely adopted in the United States of America and ASTM methods are mostly not directly technically equivalent to the ISO ones. Generally, test methods peculiar to particular commercial companies have not been considered at all.

It is inevitable that between writing and publication there will have been new editions of standards produced. To counteract this as far as possible the likely trends in test methods have been estimated from the current drafts in circulation and the known activities of relevant committees.

The dividing line between what to include and what to omit is inevitably a little blurred. Firstly, there is bound to be some overlap between rubbers and other polymers, particularly with plastics. In this context it is useful to refer to complementary books. Handbook of Plastics Test Methods[1] is now out of print but the part on short term mechanical tests has been updated[2] (with a slightly misleading title). The Handbook of Polymer Testing[3] covers rubbers, plastics, cellular materials, composites, textiles and coated fabrics. There is in particular the question of thermoplastic elastomers and this has been given a section in Chapter2.

Cellular rubbers have been deliberately omitted as they are a very distinct class of materials that should be treated separately, both rubbers and plastics being considered together. Similarly, tests on latex have also been omitted although products made directly from latex, by for example by dipping, will have many properties tested in the same way as for those formed from solid rubber. Ebonite has not been included as it was accepted some years ago by ISO TC 45 and TC 61 that it should be treated as a thermosetting plastic. Some tests on simple composites have been included, e.g. rubber/metal and rubber fabric, although the majority of tests on coated fabrics have not been considered as, once again, this particular product type can be considered as a special subject in its own right.

Comment is made, as appropriate, about testing finished products but a separate chapter on this has not been written, simply because such procedures are too specialised for general treatment. It is apparent, however, that increasingly specifications include tests on the complete product as in many cases this is the best or the only way of being sure that the product will perform satisfactorily. A short discussion of when to test products is given in chapter 2.

I have lost no sleep in debating what is physical - if popular opinion treats tests as part of the physical spectrum (e.g. ageing tests) then they are physical. Not surprisingly, chemical analysis is excluded but it can be noted that the thermal analysis techniques straddle both camps and they have been included or excluded depending on their purpose. The intention has been to include every type of physical test and, hopefully, this has been, in the main, achieved. However, three areas immediately come to mind which do not have their own section, acoustic properties, optical properties and non-destructive testing.

There are no test methods specific to rubber for acoustic properties and procedures for materials in general would be applied. A section on optical properties would also be rather thin, rubbers usually being opaque and their reflective properties and colour are very rarely of consequence. Optical properties have been covered for polymers generally[3]. Particular uses of microscopy, for example for dispersion, have been mentioned in the appropriate chapter and it is recognised that the microscopist often has a very important role to play in one of the very important reasons for testing - failure analysis. However, microscopy as a subject in its own right is beyond the scope of this work.

It is perhaps less easy to excuse the lack of a chapter on non-destructive testing. The reason is a mixture of the fact that the major NDT techniques are, in the main only applied to a few particular rubber products and the realisation that to properly describe all methods would require a book, not a chapter. It is, however, worth remembering that it is not only ultrasonics, radiography, holography and so on which are non-destructive. A number of the more traditional rubber tests, for example electrical properties, many dynamic tests, hardness and dimensional measures leave you with the product intact. There are text books which deal with NDT techniques generally and. a comprehensive review of NDT of polymers by Gross in Handbook of Polymer Testing[3].

The layout of subject matter in a book on testing is inevitably to some extent subjective. The form adopted has remained essentially the same from the first edition and it is hoped that it is found to be logical and clear. The order is shown below going clockwise with chapter numbers in brackets.

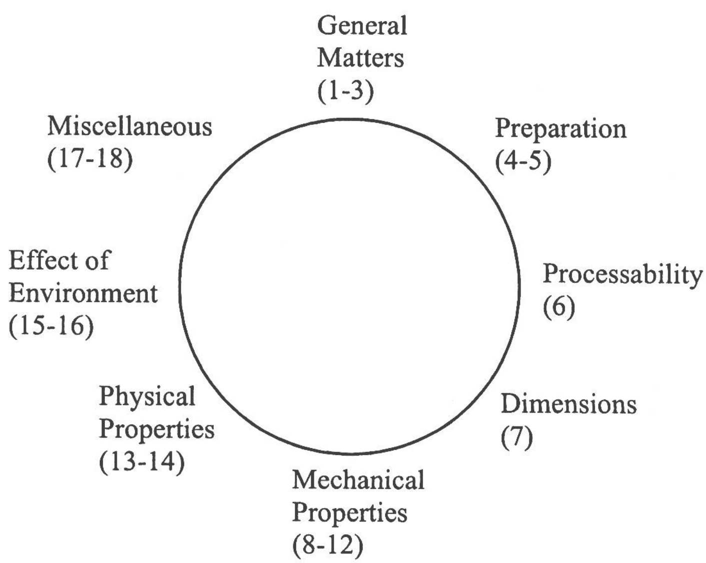

Figure 1-1. Chapter order

A number of subjects common to all areas of physical testing have been addressed in chapter 2. These include discussion of the reasons for testing, the trends in test development, the use of statistics and quality control of laboratories. Whilst these matters are not unique to rubber testing, it is most important that they are fully appreciated in the context of our particular test procedures and class of materials.

The greatest change in test laboratories in recent times, and rubber is no exception, is the improvements made to apparatus by the introduction of more advanced instrumentation and automation, in particular the application of computers both to control tests and to handle the data produced. These developments can and do influence the test techniques which are used and this is discussed in Chapter 2 Section 6. Also, whenever appropriate, comment is made on the form of apparatus now available for any particular test and there is a guide to test equipment for rubbers and plastics in a test equipment suppliers directory[4].

REFERENCES

1. Brown R P (Ed.). Handbook of Plastics Test Methods, Longmans Scientific, 1988.
2. Brown R P (Ed) Handbook of Polymer Testing: Short Term Mechanical Tests, Rapra Technology, Shawbury, 2002
3. Brown R P (Ed). Handbook of Polymer Testing, Marcel Dekker, New York, 1999.
4. Polymer Test Equipment and Services Directory, Rapra Technology, Shawbury, 2002.

Chapter 2

GENERAL CONSIDERATIONS

1. PHILOSOPHY

When a product fails unexpectedly, experience has shown that in almost every case the problem can be traced back to lack of, or inadequate, testing, which in turn resulted from an attempt to save money. It has to be admitted that testing can be very expensive in both time and money; so why is it essential? Put simply, men and women make mistakes, machines go wrong and we don't know enough.

If people are going to make mistakes we have to check their production. Similarly, if machines can vary in their performance we have to check their output. Generally, we don't have enough knowledge to make a product and be sure that it will work. The customer is unlikely to believe us if we said we did and expects us to test to prove fitness for purpose. Demands for greater quality assurance and consumer protection, together with improved performance, are likely to result in more testing rather than less.

We certainly don't know enough to design a new product without making use of material property data, and as new materials are continually developed there is an ongoing need to test their properties. As design methods become more sophisticated and expectations of performance increase we need better data even for established materials. In this context, because rubbers are such complex materials the demands on testing are perhaps particularly onerous.

When things go wrong we often do not know why. If we did we probably would have stopped it happening. Hence, we may also test to fathom out the reasons for failure.

From this reasoning as to why testing is necessary, the purposes of testing can be summarised:-

- Quality control
- Predicting service performance
- Design data
- Investigating failures

Before considering which properties to measure and which methods to use it is essential to clearly identify the purpose of testing because the requirements for each of the purposes are different. This may be an obvious point, but failure to appreciate what purpose the results must satisfy easily leads to unfortunate choice of method and conditions. Also, lack of consideration of why another person is testing and what they need to get from their tests frequently leads to poor appreciation of the merits and limitations of a particular test and inhibits communication between, for example, the university researcher and the factory floor quality controller.

There are a number of general requirements for a test method; it must have adequate precision, reproducibility etc. There are, however, particular attributes related to the purpose of testing:-

For quality control: the test should preferably be as simple, rapid and inexpensive as possible. Non-destructive methods and automation may be particularly attractive. The best tests will additionally relate to product performance.

For predicting product performance: The essence of the test must be that it relates to product performance - the more relevant the test to service conditions the more satisfactory it is likely to be. Extreme speed and cheapness are less likely to be important but there is a need for test routines which are not excessively complex. Non-destructive methods may be acceptable.

For producing design data: The need is for tests which give material property data in such a form that they can be applied with confidence to a variety of configurations. This implies very considerable understanding of the way material properties vary with geometry, time etc. Extreme speed and cheapness are of relatively minor importance, there is little interest in non-destructive methods. For complex and long running test automation may be desirable.

For investigating failures: Having established what to look for, the need more than anything is for a test which discriminates well. There is often little need for absolute accuracy or in some cases even relevance to service.

There is of course nothing black and white about attributing these requirements to the purposes of testing but they indicate the emphasis which usually applies in each case.

Tests are usually classified by the parameters to be measured - mechanical, thermal, electrical etc. These can be sub-divided to list the actual properties so that under mechanical, for example, there are strength, stiffness, creep etc. This form of classification will be used in this book because of its convenience. However, in terms of the purposes of testing discussed above and considering what is required of the results from a particular method, this classification is not particularly useful. A more generalised way of classifying tests is to consider:-

- Fundamental properties or tests
- Apparent properties or tests
- Functional properties or tests

Regardless of the type of property or particular parameter chosen, this classification can be helpful when considering what is needed from the result and, hence, which test method should be used. Taking the example of strength, the fundamental strength of a material is that measured in such a way that the result can be reduced to a form independent of test conditions. The apparent strength of a material is that obtained by a method which has completely arbitrary conditions and the data cannot be simply related to other conditions. The functional strength is that measured under the mechanical conditions of service, probably on the complete product.

This classification can be loosely linked to the purposes of testing. For quality control, fundamental properties are not needed, apparent properties will usually be acceptable, although functional properties would certainly be desirable. For predicting service performance, the most suitable properties would be functional ones. For design data, fundamental properties are really needed, although considerable help can often be got from functional properties. For investigating failures, the most useful test will depend on the individual circumstances but it is unlikely that fundamental methods would be necessary.

When looked at in this way, the gaps in readily available methods become obvious: most measures of mechanical properties yield apparent properties and there is a need for fundamental methods, whereas most dimensional methods and many thermal and chemical tests give fundamental properties. Overall, there is a dearth of fundamental tests. It is worth noting that when measuring the effects of environment, weathering for example, for use as design data, it may not be necessary to use a method giving absolute results to monitor changes with time. An apparent method may suffice because the change in property need only be comparative.

It becomes clear that there can never be one direction for the development of test methods and apparatus. The perceived deficiencies in the existing methods are viewed differently according to the particular purpose under consideration and, hence, development effort is targeted