



International Standards for Comparable Data for Plastics

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INTERNATIONAL STANDARDS FOR COMPARABLE DATA FOR PLASTICS

by

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SUMMARY

Over recent years, a series of international standards has been under development in ISO TC61 that specify test methods, specimen geometries and test conditions for the acquisition and presentation of data on plastics. The main purpose of these data presentation standards is to aid materials selection by directing the acquisition of certain data on polymer properties so that these data for materials supplied by different manufacturers will be comparable. The data identified by these standards are not an exhaustive characterisation of properties but represent a core of information that will permit a detailed selection to be made of suitable materials for a wide range of applications. In this paper, the purpose and content of these standards and current progress with their development are described. Some ideas for future work on the standardisation of data for design are also presented.

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1 INTRODUCTION

The properties of plastics depend on a wide range of factors. For example, the result obtained for a modulus measurement will depend on the time under load or the rate at which the load is applied, the temperature and the magnitude of the stress at which the measurement is made if this is above the limit for linear behaviour. In general, property values will also depend on the thermal history of the specimen and the methods and conditions used to process the specimen. The latter arise because of the strong dependence of many properties on the molecular structure of the polymer and, if reinforced, on the concentration and orientation of fibres or fillers. This can give rise to a further dependence of property measurements on the geometry and size of the specimen on which measurements are made. In addition, the values obtained for certain properties will depend upon the test method used to carry out the measurement. Clear examples of this lie with the range of test methods available for assessing the durability of a polymer under different environments.

A complete characterisation of the behaviour of plastics that includes the influence of all of these variables would clearly involve considerable effort to generate the data. Plastics materials manufacturers will only be able to supply, routinely, a fraction of these data. They will therefore be selective in the choice of test method, test conditions, specimen type, processing conditions and so on that they employ and, historically, different manufacturers have used different test procedures to acquire and present information on their materials. Users of plastics are then faced with the problem that the data available on materials from different manufacturers are not readily comparable, and this complicates the task of materials selection.

2 THE SCOPE FOR DATA PRESENTATION STANDARDS FOR PLASTICS

In recognition of these problems, groups have been formed in recent years in the UK, Germany and France to establish standard procedures to be used to acquire and present data on plastics. The main objective of the work of these groups has been to specify preferred test methods, test conditions, specimen geometries etc to be used by all materials manufacturers so that certain data generated on their materials will be comparable. In addition, materials manufacturers should benefit from a rationalisation of testing practice leading to a reduction in the overall cost of data generation.

In considering the scope for such a task, it is instructive to classify data into 4 sets or categories according to the purpose for which the data are generated. The most basic set of required data is allocated to the first category and consists of a wide variety of common properties each property being described by a single measurement value. These single-point data are used for the initial phase of materials selection and for setting specifications for particular applications.

In the second category, selected properties are described by multipoint data which are measured using standard tests and which demonstrate how those properties depend upon important variables such as time, temperature and different environments. Here, a more substantial quantity of data is recorded which enable more discriminating decisions to be made regarding a materials suitability for a particular application.

In order to achieve comparability in the single and multipoint data referred to here, it is necessary to make measurements on standard test specimens whose geometry, moulding method and moulding conditions are specified in ISO standards. The polymer structure in these specimens will, in general, be different from that in specific regions of a moulded component. For purposes of component design, therefore, additional data will be needed which reflect how properties depend on the processing method and conditions. These data fall in the third category together with other data that are needed primarily for design rather than materials selection.

To complete this classification, in the fourth category it is necessary to include all other data and these will be obtained mainly for purposes of materials research and development.

International standards for data presentation are currently concerned only with the data in categories 1 and 2. Whilst the main purpose of these standards is to enable comparable data to be presented for materials selection, some of the multipoint data will also be useful for undertaking design calculations for predicting performance in service and for selecting optimum processing conditions [1]. The information identified by the multipoint data standards therefore serves as a basis from which to decide what further data and standards are needed for design. This subject is considered in section 4 but in the next section, further details are given of the status and contents of the ISO data presentation standards.

3 PROGRESS TOWARDS INTERNATIONAL STANDARDS

Work on standardising data presentation in the UK was initiated by the British Plastics Federation (BPF) and coordinated by the National Physical Laboratory. Effort in Germany was carried out independently and at about the same time by a working party formed by their Plastics-Producing Industries Association (VKE). French companies were also involved through the affiliation of their Society of Plastics Materials Producers (SPMP) to the VKE. Based on the proposals prepared by the UK, the British Standards Institute (BSI) initiated a New Work Item in ISO TC61 for the preparation of International Standards. A new Working Group (WG4) was formed in Subcommittee 1 (SC1). Recently this Working Group has moved to SC2 and is now SC2/WG8.

Independent proposals for data presentation standards prepared in Germany [2,3], France and the UK had much in common but the differences that existed were significant and likely to cause slow progress if left to the ISO Working Group to resolve since this Group only meets once a year. In order to extend discussion of the issues involved in the development of these standards and speed their progress through ISO, an international technical committee was formed consisting of representatives from France, Germany and the UK.

The objective of this committee (currently referred to as the Tripartite Committee) is to reach agreement, at least within these three countries, on detailed proposals for international standards and present these to the ISO Working Group. The plastics producers trade federations for each country (VKE, BPF and SPMP) act as a national focus for identifying representatives to the Tripartite Committee and coordinating technical input from each country.

3.1 SINGLE-POINT DATA

The current status regarding the development of data presentation standards for plastics is summarised in table 1. The development of these standards started with a consideration of single-point data. Table 2 lists the properties included in the single-point standard ISO 10350 [4]. For each property, test conditions are specified for the measurement of a single value using the appropriate ISO test standard. In order to ensure comparability of the data generated, use of the multipurpose test specimen described in ISO 3167 [5] is stipulated where possible. For some properties, use of alternative standard specimens in the shape of a small plate is necessary. The preparation of these specimens by injection moulding is described in ISO 294 part 3 [6]. Important moulding conditions for the preparation of

standard specimens by injection and compression moulding are, or will be, specified in materials standards that are being developed for the majority of plastics.

The single-point standard is currently being revised because of progress over recent years with the development of new and revised test-method standards so that additional important properties can now be included (see table 2). The revised standard will also specify how each property value can be supported by information that indicates a level of uncertainty that is associated with each value arising from material and specimen reproducibility. The most effective way of obtaining this information is still open to debate. To obtain realistic bounds for every property would require a significant amount of additional testing, and the associated costs are unacceptable at present. A compromise is being sought, and it is appreciated that the information thereby generated will only give an indication of property variability under restricted circumstances.

Table 1. ISO standards for the acquisition and presentation of comparable data for plastics

Standard	Subject	Status May 95
ISO 10350 [4]	Single-point data	Published Dec 93
ISO 11403-1 [7]	Multipoint data Part 1 Mechanical properties	Published Dec 94
ISO 11403-2 [8]	Multipoint data Part 2 Thermal and processing properties	Awaiting publication later in 1995
ISO 11403-3 [9]	Multipoint data Part 3 Environmental influences	Currently being balloted as a Draft International Standard
ISO 10350 revision	Single-point data	Currently being balloted as a Committee Draft.

Table 2. Properties included in the single-point data presentation standard ISO 10350. Properties in *italics* are included in a revision of ISO 10350 currently under preparation

<u>Mechanical</u> Tensile modulus Yield stress Stress at break Yield strain Elongation at break Tensile creep modulus Flexural modulus Flexural strength Charpy impact strength Tensile impact strength <i>Multiaxial impact behaviour</i> <u>Electrical</u> Permittivity and dissipation factor Electric strength Volume and surface resistivity Comparative tracking index	<u>Thermal</u> Melting temperature Glass transition temperature Temperature of deflection under load Vicat softening temperature Linear thermal expansion Flammability Ignitability <u>Rheological</u> Melt mass-flow rate Melt volume-flow rate Moulding shrinkage (thermosets) <i>Moulding shrinkage (thermoplastics)</i> <u>Other</u> Density Water absorption
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3.2 MULTIPOINT DATA

The preparation of a standard for the presentation of multipoint data involves the identification of substantially more information. The standard ISO 11403 [7-9] is therefore being developed in three parts. The titles of each part, the properties and standard tests included and the variables over which data are presented are shown in table 3. Owing to the wide ranges of stress, strain and temperature over which different polymers can satisfactorily perform, it has not been possible in all the tests to identify specific values for these variables. Whilst this will prevent the direct comparison of some of the data presented for different materials, valid comparisons can still be made through interpolation between the values recorded.

**Table 3. Properties included in the multipoint data presentation
standards ISO 11403-1, 2 and 3**

Part	Property	ISO Standard	Variables
1	Mechanical properties		
	Dynamic modulus	6721	T
	Ultimate values of stress and strain	527	T
	Tensile stress/strain curves	527	ϵ, T
	Tensile creep strain	899	σ, t, T
	Charpy impact strength	179	T
2	Thermal and processing properties		
	Enthalpy	Under preparation	T
	Linear expansion	Under preparation	T
	Melt viscosity	11443	$\dot{\gamma}, T$
3	Environmental influences		
	Liquid chemicals	175	L, t, T, I
	Prolonged action of heat	2578	t, T, I
	Artificial weathering	4892-2	H, t, I
	Environmentally assisted stress cracking	6252	L, t, T

Symbols

T - temperature

 σ - stress

H - radiant exposure

t - time

 $\dot{\gamma}$ - shear strain rate

I - indicative property

 ϵ - strain

L - liquid chemical

Some important properties have been excluded from the multipoint standards because international standards describing their measurement do not exist. These properties are:

- thermal conductivity
- pressure-volume-temperature data
- fatigue resistance
- creep rupture.

As new standards are developed for these properties, opportunities will arise for including these into revised versions of the data presentation standards.

4 STANDARDS FOR THE PRESENTATION OF DESIGN DATA

In the short term, future developments with data standardisation are likely to involve revisions of the current drafts to include additional properties and data. Alongside this work, consideration is being given to data requirements for design [10,11] and associated needs for standardisation. Two areas are now discussed in which the development of new standards would assist the acquisition and presentation of data needed specifically for design.

4.1 DATA ON THE ANISOTROPY OF CERTAIN PROPERTIES

As mentioned in sections 2 and 3, most of the data for mechanical properties currently specified in the data presentation standards are obtained on the ISO standard multipurpose test specimen. When prepared by injection moulding, these specimens will have molecular or reinforcement structures that are preferentially oriented along the length of the bar. This means that many properties will be anisotropic and, owing to the geometry of the specimen, property values transverse to the orientation direction cannot be determined. The availability of alternative specimen geometries, in the form of a plate for example, would enable the anisotropy of properties to be measured using test-pieces cut at different angles to the direction of preferred orientation. If these data are to be included in new or revised data presentation standards, then the dimensions and geometry of the new plate specimens, the design of suitable moulds and conditions for specimen preparation should be standardised. In this way, the data presented will be traceable to well defined moulding and flow conditions for the specimen.

At present, a standard is being developed for moulding specimens in the form of a plate that is 60 mm square [6]. These specimens will allow the anisotropy in certain properties to be measured but it is likely that a larger standard plate will be needed to characterise the anisotropy that can be obtained in a wider range of properties. For this reason, a proposal for a new work item has recently been submitted to ISO TC61 for the development of a standard for moulding a plate that is 150 mm square. Test specimens having the multipurpose test specimen geometry can then be cut out along different directions to the main axis of melt flow into the plate, and the anisotropy of tensile behaviour can be determined using standard test procedures. For the proposal, mould designs have been considered with the aim of achieving high and uniform levels of fibre or molecular orientation in the central region of the plate moulding.

This will at least enable maximum and minimum bounds for property data to be measured. Procedures for the acquisition of data corresponding to intermediate levels of orientation are still undecided. It may be that additional standard specimens will have to be moulded and tested with alternative levels of fibre or molecular orientation. Alternatively, mathematical models are available, and others may be developed, that relate properties to material parameters and orientation functions [12-14]. Where these are shown to be sufficiently accurate, certain of the data needed to characterise anisotropy could be generated by calculation.

4.2 THE USE OF PARAMETRIC EQUATIONS FOR PRESENTING MULTIPOINT DATA

It is apparent from the current drafts for multipoint data standards that for certain properties it will be necessary to measure and record a large amount of data. In principle, the availability of mathematical models that relate a property to test variables through parametric equations would enable that property to be recorded in computerised databases in terms of an equation and associated parameters for that material. Property data could then be retrieved from a database at required (arbitrary) values for the test variables thereby avoiding the need for interpolation which is necessary when data are recorded at discrete values for the variables. Whilst for purposes of interpolation, a polynomial fit to available data is satisfactory, there are certain advantages to be gained from using specific functions that are based upon a physical understanding of the behaviour that is being modelled. The parameters in these functions are usually associated with materials properties that can be determined from a relatively short measurement programme. Furthermore, greater confidence could then be placed on data derived by extrapolation thereby yielding opportunities for significantly reducing the cost and effort of data acquisition.

A good example of how effective mathematical models can be for the acquisition and representation of property data for plastics is given in [15] and [16]. These papers show how specific functions are able to describe the dependence of the creep modulus of plastics on the time under load, the applied stress, the temperature and the physical age of the material. The parameters in the equations can be determined from tests of short duration and thus enable data over wide and continuous ranges of the variables to be derived by calculation.

The definition of appropriate functions for particular property characterisations are subjects for further research which would identify the types of materials and ranges of the variables for which the accuracy of the function is satisfactory. Such work should interact closely with the development and identification of the materials models that are employed in finite

element calculations used for design. If the same functions are adopted, then the parameters used to present material property data will be consistent with those required by the design method. There is clearly a need here for obtaining international agreement on the functions that should be chosen which would then lead to new standards for the acquisition and presentation of design data.

5 CONCLUDING REMARKS

New international standards for the acquisition and presentation of comparable data for plastics offer several benefits to both the users and manufacturers of plastics materials.

- Users will increasingly benefit from the availability of comprehensive information on a wide range of materials in a form that allows easy comparison of properties between different materials. The CAMPUS database is structured on the ISO standards for data presentation described here [17] and is enabling plastics producers who are licensed members of the CAMPUS Group to supply data on their materials in a standard format.
- Manufacturers benefit through a rationalisation of effort, and hence a reduction in the cost, associated with the acquisition of data for their materials that are needed for specifications and selection.
- By identifying the metadata associated with each property measurement, the standards will simplify the storage of property data in computer databases and the subsequent exchange and retrieval of the data for purposes of materials selection or design [18].

The data generated by the use of these standards represent a core of useful information which, under certain circumstances, may be used more widely than for materials selection. Some of the data are needed for optimising the manufacture of components by injection moulding whilst other data may be suitable for predicting performance in service. In general, however, additional data are required for purposes of design, and there is scope for the development of new standards in the following areas.

- Test procedures are needed to obtain data on the influence of processing conditions on properties, specifically on the influence of fibre or molecular orientation on property anisotropy.
- The availability of standard materials models that relate properties to test and material variables would aid the acquisition storage and exchange of data and facilitate the use of the data for design calculations.
- In the light of developments in design methods, it is necessary to continually review the need for new standard test methods for the measurement of property data required for design.

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REFERENCES

1. H. Breuer and G. Dean. Progress with international standards for the acquisition and presentation of data on plastics for computerised databases, ASTM STP1140 Computerisation and Networking of Materials Databases Vol III ed T.I. Barry and K.W. Reynard, 101-115 (1992).
2. K. Oberbach and L. Rupprecht. Plastics properties for databanks and design, Kunststoffe 77 no 8, 23-28 (1987).
3. H. Breuer, G. Dupp, J. Schmitz and R. Tüllmann. A standard materials data bank - an idea now adopted, Kunststoffe 80 no 11, 1289-94 (1990).
4. ISO 10350:1993, Plastics - Acquisition and presentation of comparable single-point data.
5. ISO 3167:1993, Plastics - Multipurpose test specimens.
6. ISO 294-3:1995, Plastics - Injection moulding of test specimens of thermoplastics - Part 3: Plates.
7. ISO 11403-1:1994, Plastics - Acquisition and presentation of comparable multipoint data - Part 1: Mechanical properties.
8. ISO 11403-2:1995, Plastics - Acquisition and presentation of comparable multipoint data - Part 2: Thermal and processing properties.
9. ISO 11403-3: Plastics - Acquisition and presentation of comparable multipoint data - Part 3: Environmental influences on properties (under preparation).
10. R.K. Shastri. Material properties needed in engineering design using plastics. Proceedings of the SPE 52nd Annual Technical Conference, Plastics-Gateway to the Future, 3097-3101 (1994).
11. F.J. Lockett. Engineering design data for plastics. Proceedings of the SPE ANTEC '95, 3806-10 (1995).

12. S.G. Advani and C.L. Tucker. The use of tensors to describe and predict fibre orientation in short fiber composites. *Journal of Rheology* 31, 751-784 (1987).
13. M.W. Darlington, O. Cattet and A.T. Steffner. Prediction of fibre orientation and performance under load for injection moulded short fibre reinforced nylon 66 components. *Proceedings of the PRI Conference on Fibre Reinforced Composites. Paper 5* (1992).
14. M. Gupta and K.K. Wang. Fibre orientation and mechanical properties of short-fiber-reinforced injection-molded composites: simulated and experimental results. *Polymer Composites* 14, 367-382 (1993).
15. G.D. Dean, P.E. Tomlins and B.E. Read. A model for non-linear creep and physical ageing in poly(vinyl chloride). *Polym. Eng. & Sci.* 35, no 16 (1995) (to be published).
16. P.E. Tomlins, B.E. Read and G.D. Dean. The effect of temperature on creep and physical ageing of poly(vinyl chloride). *Polymer* 35, no 20, 4376-81 (1994).
17. H. Breuer, G.D. Dean, M.H. Tiba and R. Shastri. International standards for the acquisition and presentation of comparable data on plastics. *Proceedings of the SPE Conference, Challenging the Status Quo in Design*, 176-185.
18. A.H. Fairfull. Materials data management: integrating materials data, STEP and CAE. *Polymer Properties for CAD/CAM II, Polymat 94*, 415-20 (1994).