1 – General

Introduction

This handbook is to be used in conjunction with the product data for specific DuPont Engineering Thermoplastic resins – DELRIN® acetal resins, ZYTEL® nylon resins including glass reinforced, MINLON® engineering thermoplastic resins and CRASTIN® (PBT) and RYNITE® (PET) thermoplastic polyester resins. Designers new to plastics design must consider carefully the aspects of plastic properties which differ from those of metals: specifically, the effect of environment on properties, and the effect of long term loading.

Property data for plastics are obtained from physical tests run under laboratory conditions, and are presented in a similar manner as for metals. Test samples are moulded in a highly polished mould cavity under optimum moulding conditions. Tests are run under ASTM and / or ISO conditions at prescribed tensile rates, moisture levels, temperatures, etc. The values shown are representative, and, it should be recognized that the plastic part being designed will not be moulded or stressed exactly as the test samples.

The following aspects affect, for instance, the strength and toughness of a plastic part:

- Part thickness and shape
- Rate and duration of load
- Direction of fibre orientation
- Weld lines
- Surface defects
- Moulding parameters

The designer must also have information regarding the effect of heat, moisture, sunlight, chemicals and stress.

In plastic design, therefore, it is important to understand the application thoroughly, use reference information which most closely parallels the application, prototype the part and test it in the end-use application.

The purpose of this handbook is to provide the designer with the information necessary to create good designs with the best materials in terms of factors, such as: environment, process, design and end use effects. The objective is to obtain a cost effective and functional part design that can be achieved in the shortest possible time.

This information allows parts to be designed with a minimum weight and, at the same time, with a maximum of possibilities for disassembly and recycling, so that the impact on the environment can be reduced.

A good design reduces the processing cost, assembly cost, production waste in the form of rejects parts, sprues and runners and end-use waste of the whole device produced, through avoidance of early failure of the device.

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Defining the End-Use Requirements

The most important first step in designing a plastic part is to define properly and completely the environment in which the part will operate. Properties of plastic materials usually are substantially altered by temperature changes, chemicals and applied stress. These environmental effects must be defined on the basis of both short and long term, depending of course on the application. Time under stress and environment is all-important in determining the extent to which properties, and thus the performance of the part will be affected. If a part is to be subject to temperature changes in the end-use, it is not enough to define the maximum temperature to which the part will be exposed. The total time the part will be at that temperature during the design life of the device must also be calculated. The same applies to stress resulting from the applied load. If the stress is applied intermittently, the time it is applied and the frequency of occurrence is very important. Plastic materials are subject to creep under applied stress and the creep rate is accelerated with increasing temperature. If loading is intermittent, the plastic part will recover to some extent, depending upon the stress level, the duration of time the stress is applied, the length of time the stress is removed or reduced, and the temperature during each time period. The effect of chemicals, lubricants, etc, is likewise time and stress dependent. Some materials may not be affected in the unstressed state, but will stress crack when stressed and exposed to the same reagent over a period of time. DuPont engineering thermoplastic resins are particularly resistant to this phenomena.

The following checklist can be used as a guide.

Design Check List

Part Name ______________________________

Company ______________________________

Print No. ______________________________

Job No. ______________________________

A. PART FUNCTION ______________________________

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B. OPERATING CONDITIONS	NORMAL	MAX.	MIN.
Operating temperature	______	______	______
Service life (HRS)	______	______	______
Applied load (N, Torque, etc., – describe fully on reverse side)	______	______	______
Duration of load — Time on	______	______	______
Duration of load — Time off	______	______	______

Other (Impact, Shock, Stall, etc.) ______________________________

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C. ENVIRONMENT Chemical ______________ Moisture ______________

Ambient temp. while device not operating ______________ Sunlight direct ______________ Indirect ______________

Waste disposal dispositions ______________ Production waste ______________ End-use waste ______________

D. DESIGN REQUIREMENTS

Factor of safety ______________ Max. deflection/Sag ______________

Tolerances ______________ Assembly method ______________

Finish / Decorating ______________ Agency / Code approvals ______________

Disassembly after service life ______________ Recyclability ______________

E. PERFORMANCE TESTING – If there is an existing performance specification for the part and/or device, include copy. If not, describe any known requirements not covered above

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F. APPROVALS Regulation ______________ Classification ______________

Food, automotive, military, aerospace, electrical ______________

G. OTHER

Describe here and on the reverse side, any additional information which will assist in understanding completely the function of the part, the conditions under which it must operate and the mechanical and environmental stresses and abuse the part must withstand. Also add any comments which will help to clarify the above information

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Prototyping the Design

In order to move a part from the design stage to commercial reality, it is usually necessary to build prototype parts for testing and modification. The preferred method for making prototypes is to simulate as closely as practical the same process by which the parts will be made in commercial production. Most engineering plastic parts are made in commercial production via the injection moulding process, thus, the prototypes should be made using a single cavity prototype mould or a test cavity mounted in the production mould base. The reasons for this are sound, and it is important that they be clearly understood.
The discussion that follows will describe the various methods used for making prototypes, together with their advantages and disadvantages.

Machining from Rod or Slab Stock

This method is commonly used where the design is very tentative and a small number of prototypes are required, and where relatively simple part geometry is involved. Machining of complex shapes, particularly where more than one prototype is required, can be very expensive. Machined parts can be used to assist in developing a more firm design, or even for limited testing, but should never be used for final evaluation prior to commercialization.

The reasons are as follows:

- Properties such as strength, toughness and elongation may be lower than that of the moulded part because of machine tool marks on the sample part.
- Strength and stiffness properties may be higher than the moulded part due to the higher degree of crystallinity found in rod or slab stock.
- If fibre reinforced resin is required, the important effects of fibre orientation can be totally misleading.
- Surface characteristics such as knockout pin marks, gate marks and the amorphous surface structure found in moulded parts will not be represented in the machined part.
- The effect of weld and knit lines in moulded parts can-not be studied.
- Dimensional stability may be misleading due to gross differences in internal stresses.
- Voids commonly found in the centre of rod and slab stock can reduce part strength. By the same token, the effect of voids sometimes present in heavy sections of a moulded part cannot be evaluated.
- There is a limited selection of resins available in rod or slab stock.

Die Casting Tool

If a die casting tool exists, it can usually be modified for injection moulding of prototypes. Use of such a tool may eliminate the need for a prototype tool and provide a number of parts for preliminary testing at low cost. However, this method may be of limited value since the tool was designed for die cast metal, not for plastics. Therefore, the walls and ribbing will not be optimized; gates are usually oversized and poorly located for plastics moulding; and finally the mould is not equipped for cooling plastic parts. Commercialization should always be preceded by testing of injection moulded parts designed around the material of choice.

Prototype Tool

Prototype moulds made of easy-to-machine or cheap materials like aluminium, brass, kirksite, etc. can produce parts useful for non-functional prototypes. As the right moulding conditions demanded by the material and the part geometry cannot be employed in most cases (mould temperature and pressure especially), such low-cost moulds cannot produce parts that could be evaluated under operational conditions.

Preproduction Tool

The best approach for design developments of precision parts is the construction of a steel preproduction tool. This can be a single cavity mould, or a single cavity in a multi-cavity mould base. The cavity will have been machine finished but not hardened, and therefore some alterations can still be made. It will have the same cooling as the production tool so that any problems related to warpage and shrinkage can be studied. With the proper knockout pins, the mould can be cycled as though on a production line so that cycle times can be established. And most important, these parts can be tested for strength, impact, abrasion and other physical properties, as well as in the actual or simulated end-use environment.

Computer Simulations

Cost of prototyping often can be reduced significantly by carrying out computer simulations. As for cutting the mould computer models are already required, these models may be used also to derive finite element models, which on their turn can be used for:

- Simulation of the injection moulding process, giving information about required injection pressure, clamping force, melt temperatures in the cavity, location of weld lines, air traps and more.
- Simulation of the behaviour of the part due to mechanical loads, giving information about deformations of - and stresses in the part.

The value of simulation studies is highest if they are carried out in an early stage of the design process, so that unnecessary, expensive mistakes can be avoided and the number of required prototypes can be kept to a minimum.

Testing the Design

Every design should be thoroughly tested while still in the development stage. Early detection of design flaws or faulty assumptions will save time, labour, and material.

- Actual end-use testing is the best development of the prototype part. All performance requirements are encountered here, and a completed evaluation of the design can be made.
- Simulated service tests can be carried out. The value of such tests depends on how closely end-use conditions are duplicated. For example, an automobile engine part might be given temperature, vibration and hydrocarbon resistance tests; a luggage fixture might be subjected to abrasion and impact tests; and an electronics component might undergo tests for electrical and thermal insulation.
- Field testing is indispensible. However, long term field or end-use testing to evaluate the important effects of time under load and at temperature is sometimes impractical or uneconomical. Accelerated test programs permit long-term performance predictions based upon short term ‘‘severe’’ tests; but discretion is necessary. The relationship between long vs short term accelerated testing is not always known. Your DuPont representative should always be consulted when accelerated testing is contemplated.

Writing Meaningful Specifications

A specification is intended to satisfy functional, aesthetic and economic requirements by controlling variations in the final product. The part must meet the complete set of requirements as prescribed in the specifications.

The designers’ specifications should include:

- Material brand name and grade, and generic name (e.g. ZYTEL® 101, 66 nylon)
- Surface finish
- Parting line location desired
- Flash limitations
- Permissible gating and weld line areas (away from critical stress points)
- Locations where voids are intolerable
- Allowable warpage
- Tolerances
- Colour
- Decorating considerations and
- Performance considerations

Further usefull information is given in the “Design Check List”, on page 4.