PRODUCTS DESIGN

<u>Steps</u>

1. Identify the requirements of the product
2. Draw up a short list of materials to be used
3. Sketch the shape and identify crucial dimensions and features
4. Design the shape using date chosen to reflect the effects of time, temperature an environment appropriate to the application
5. Identify possible production methods bearing in mind the numbers required and the proposed shape of the part
6. Make a test prototype
7. Modify the shape or materials selection as required
8. Finalize design for production

<u>I. Requirements</u>

- Should not fail in function of aesthetics during prescribed service life
- Should not fail by rupture within life time

Other functional requirements

- Abrasion resistance
- Environmental stress cracking
- Hardness
- Ambient temperature and temperature changes
- Effect of shock loads etc

<u>II. Based on this a short list of materials may then be drawn:</u>

There are two ways to do this:

From personal experience 2) from standard data

<u>Personal experience</u> of the same or similar materials, moulding process, alternate possible methods, desing features, discussion with mould makers and material suppliers etc

Strandard data from Plastics advisory service and Rubber and Plastics Research Association at Shawbury

- Standard data - tested on individual plastics primarily for quality control using standard tests conditions , not on products.
- It takes no attempts or it does not reflect the time or temperature dependence of properties.
- Application of table is for primary selection only. All requirements will not be met by one sample. Compromise is necessary.

In addition to material property the following are also some times critical: Availability, cost, processability, manufacturing method and availability.

Material Property

A thorough knowledge of the materials property and its relation to the structure si important for proper selection of the raw material.

Shape and number of articles: These decide the processing method:

Prototype: Helps to asses 1) performance, 2) Appearance, 3) Market appeal etc

Processing methods other than the selected one can be used to make prototype; but difficult to simulate all properties eg. Blow moulded as injection moulded prototype are costlier. Other method may be cheaper. It is advisable to do the prototype by the same method as intended for commercial production

Design Data for Plastics

Strength and stiffness are rate dependent. Creep curves are convenient to represent time dependency. Tensile creep flexural creep or torsional creep are available from the material manufacturer.

Structure – Property Relationship

Strength, Stiffness, Hardness, Dynamic, Set, Creep, Electrical, Optical, Thermal, Solvent Resistance, Weather Resistance etc

PSEUDOELASTIC DESIGN APPROACH

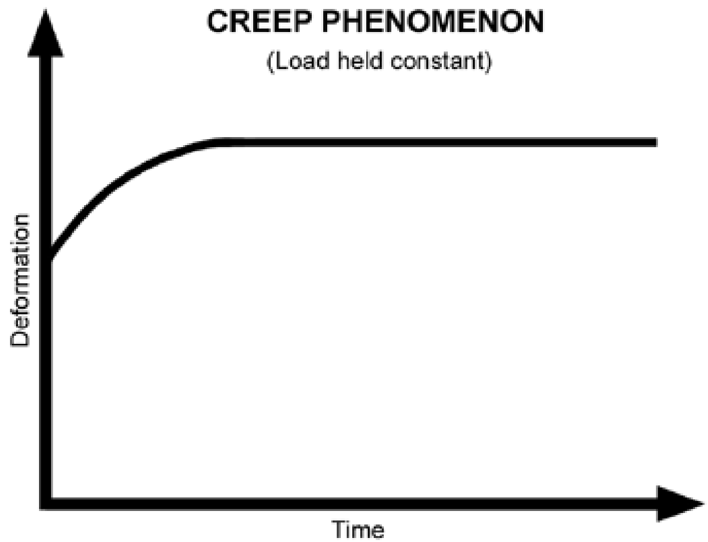
Classical equation available is for design of springs, beams, plates, cylinders etc are based on:

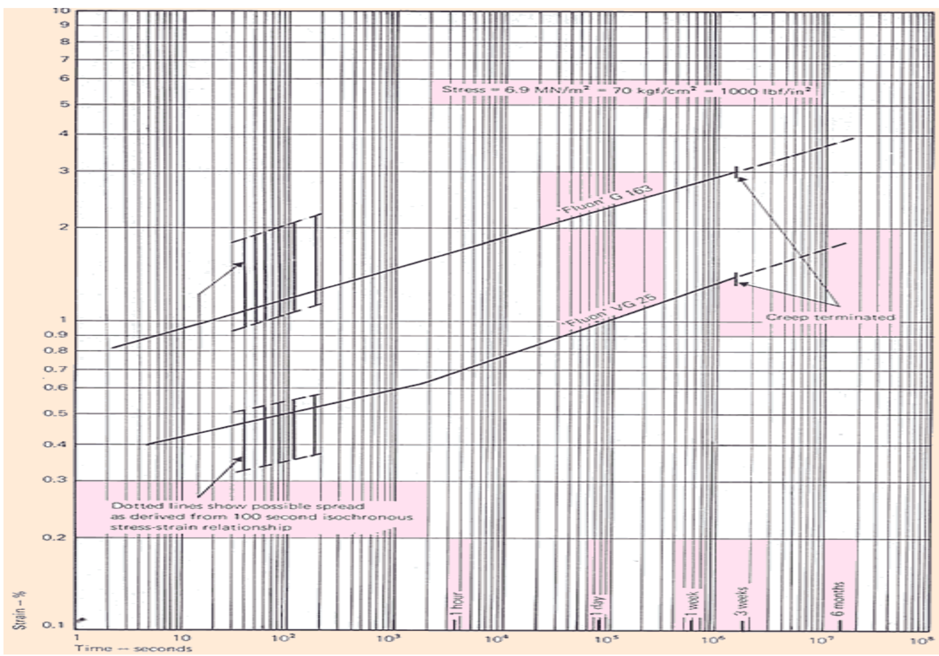
- Strain is small
- Modulus is constant
- Strain is independent of loading rate or history and are immediately reversible
- Material is isotropic
- Material behaves in the same way in tension and in compression

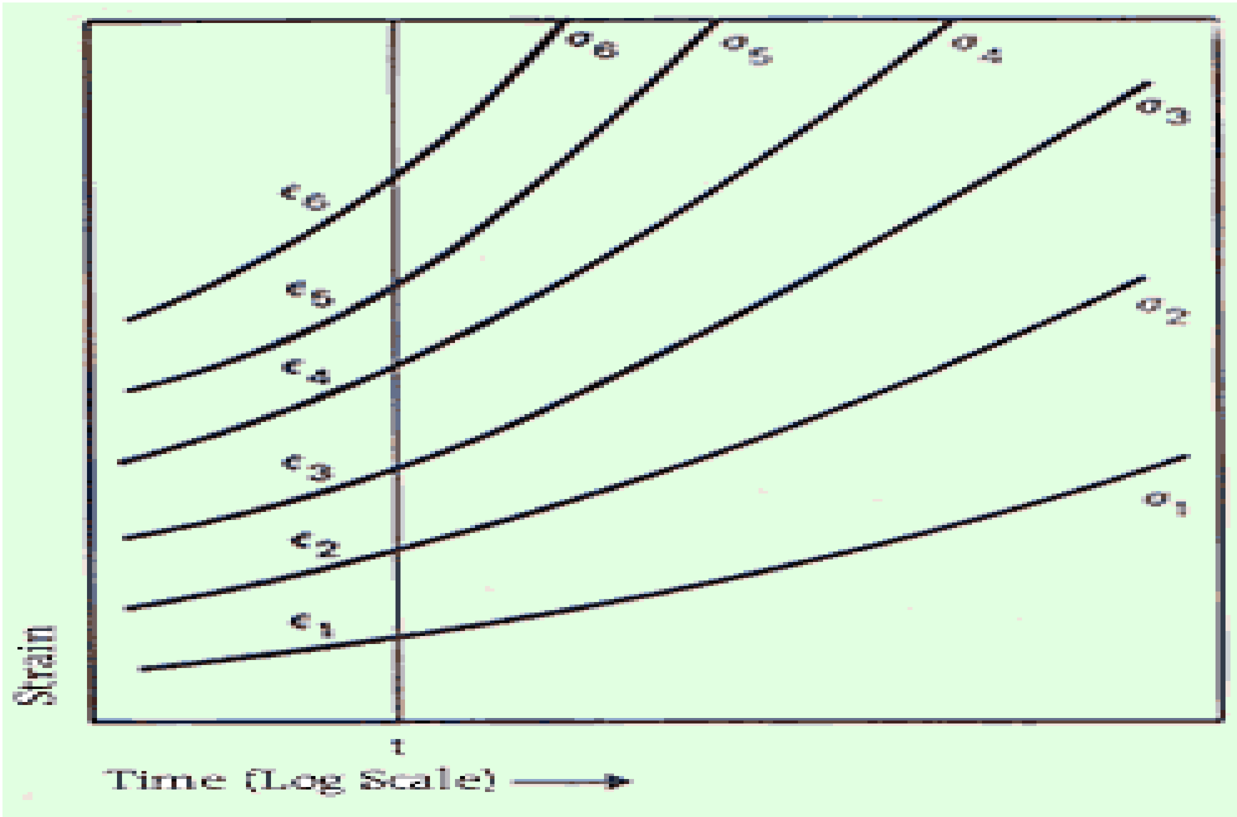
Elastomers do not conform to these. Allowances should be given (Laplace transforms or numerical methods etc)

Another method: Pseudo elastic design method- values of time dependent variables are selected and substituted in the classical equations – gives reasonably good approximation

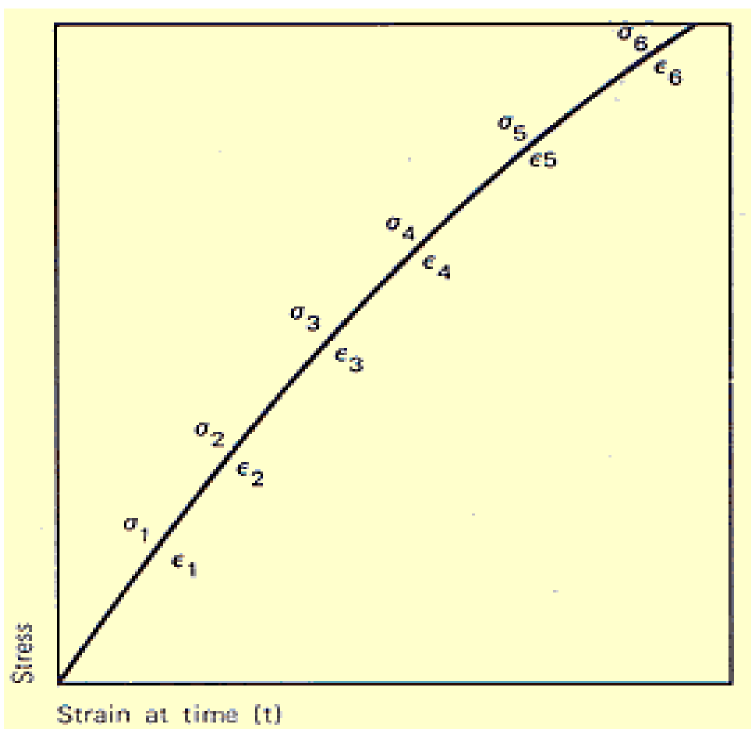
CREEP CURVES


CREEP PHENOMENON
(Load held constant)
Deformation
Time

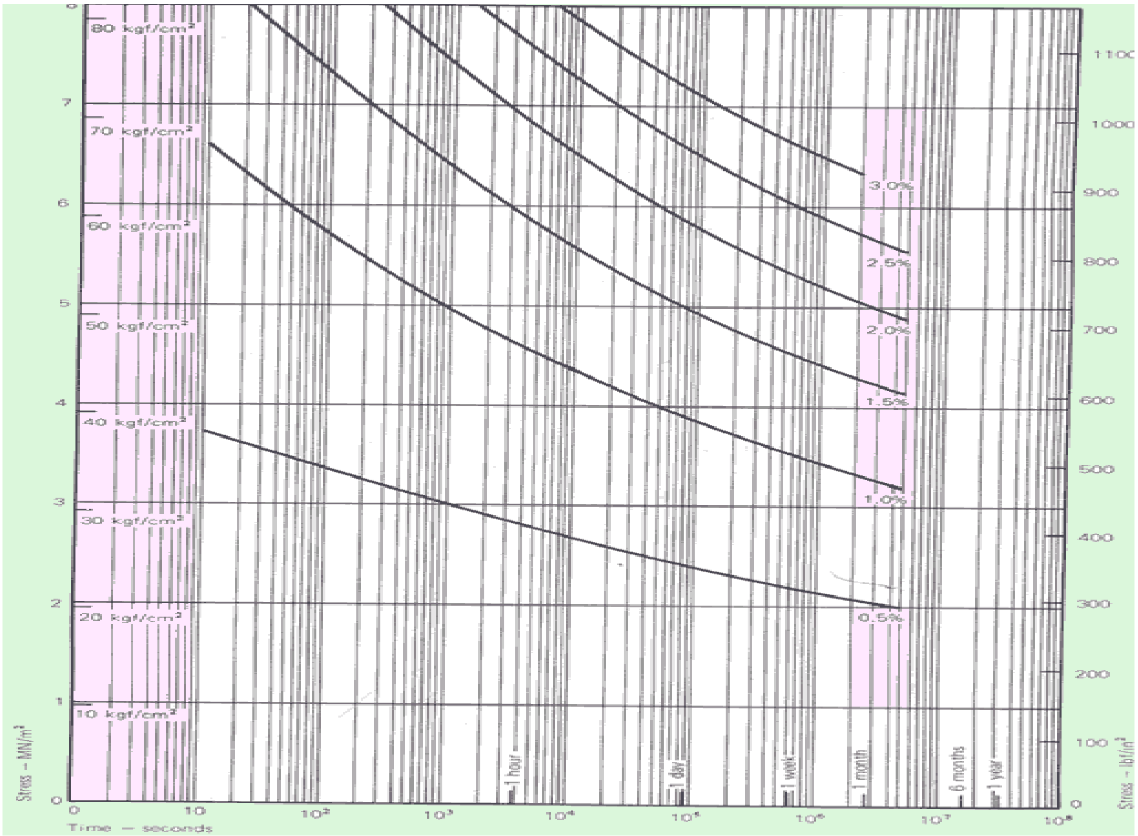

Stress = 6.9 MN/m² = 70 kgf/cm² = 1000 lbf/in²
'Fluon' G 163
'Fluon' VG 25
Creep terminated
Dotted lines show possible spread
as derived from 100 second isochronous
stress-strain relationship
1 hour
1 day
1 week
3 weeks
6 months
Strain – %
Time — seconds



Compressive Creep



Isochronous Stress - Strain Relationship in Compression



Consider a plastic cantilever beam is to be designed out of PP which is 50 mm long. The beam width is fixed at 12 mm and its depth is to be assigned so that the free end of the beam will not deflect more than 4 mm when a steady load of 10 N is applied to it for a period of 1 year.

Deflection = $WL^3 / (3EI)$. I = width x depth^3 /12

$$\frac{\text{Beam width /2}}{\text{Radius of curvature of the bent beam}}$$

Recommended limiting strain = 1%

$[10 \times 12500 / (12 \times 360)]^{1/3}$ = 6.6 mm

PROCESSING LIMITATIONS ON PRODUCT DESIGN

Processing methods used causes limitations on the product that can be made. The limitations may be due to:

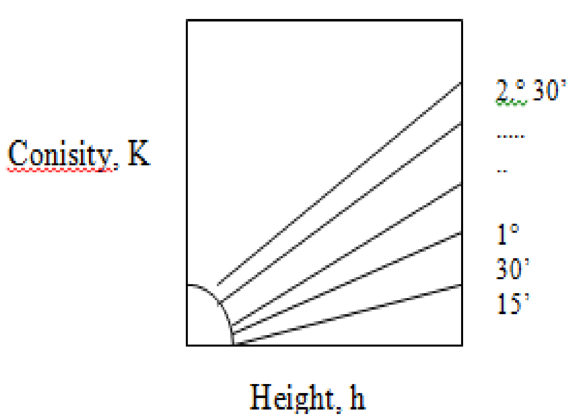
- Physical size
- Shape of the product
- Ie. all methods can not be used to produce all types of products. Eg. Injection moulding of spheres, compression moulding with inserts etc

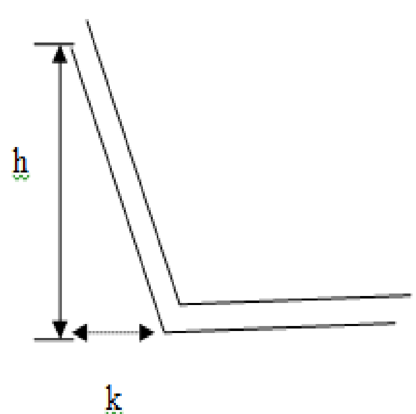
MAIN FEATURES OF GOOD DESIGN FOR INJECTION MOULDED GOODS

1. Taper
2. Undercuts
3. Wall thickness / Corner radii
4. Gating
5. Shrinkage
6. Annealing

1. Taper

ID and OD must be provided with taper in the direction of mould cavity opening
0.5 – 3.0 for polyolefins and acetals.
1.5 for PS, Acrylic type of rigid materials
Standard charts available





Higher taper is not recommended for it increases injection pressure. Minimum taper needed for easy ejection

2. Undercuts

This makes ejection difficult. Whenever possible undercuts are to be avoided. Ejection requires split moulds and moving cores etc

3. Wall thickness/ corner radii

Strength depends on wall thickness. Very thick sections are to be avoided because;

It slows down the production rate
It causes voids and sink marks

Sharp corners – stress concentration – likely failure areas . For injection moulding inside radius ½ wall thickness
Outside 1 ½ wall thickness

Wall thickness must be uniform as far as possible. This is true for lugs and bosses

4. Gating

Channels through which the plastic melt enters the mould cavity. The principal requirements are:
Cause little stress concentration in the moulding
Enable easy degating after ejection from the mould
Leave little or no witness mar on the moulding

Gates; Side or Edge gate, pin gate, film or flash gate, submarine / tunnel gate

Precautions:
Gate should not be kept in the area of stress concentration during service.

Gate is positioned so as to avoid weld lines. If it can not be helped gate position is selected such that the weld line does not occur at the critical sections of the moulding

Jetting should be avoided

5. Shrinkage

It is a in the range 0 to 5% in polymers. More pronounced in semi crystalline than in amorphous materials

Shrinkage is due to
- Liquid-solid transformation
- Closer molecular packing
- Relaxation of stretched molecules

Injection pressure gradient with respect to distance from the date cause une3ven shrikagt3 in different part of the moulding. So gate location and stiffening ribs are strategic. Fillers reduce shrinkage

6. Annealing

Annealing is done to reduce the frozen in stress to avoid long term variations in size and shape.

Extrusion

Basic design features:

Uniform wall thickness. Complicated wall thickness configurations require intensive adjustment of tool and melt that exhibit high degree of melt stiffness.
The tolerance obtained with one dia for a particular product will not be feasible with different compound or a different formulations of the same compound or a in a different extruder.

Certain shapes are difficult to extrude

Due to shrinkage and flow patterns.

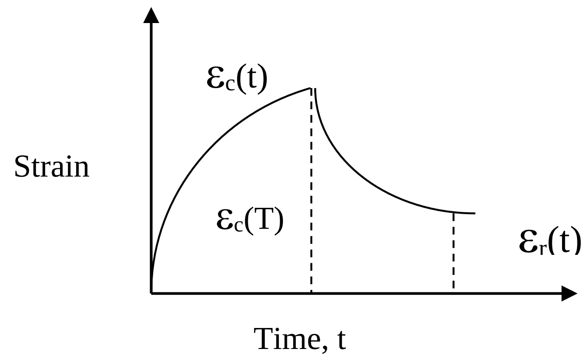
Die swell to be taken into account. Stretching or dewing – can lead to equal or smaller than the die opening.

Blow moulding

Wall thickness varies
Use thicker wall and wide tolerance
Avoid sharp changes in direction in a part
Surface configuration should be simple
Radii at bends
The region of removal of parison tail is generally weak. In complex shapes its position should be adjusted so as not to interfere with the function.

Thermoforming

Sharp corners to be avoided, no inserts, no very deep drawings.



$\varepsilon_c(t)$
Strain
$\varepsilon_c(T)$
$\varepsilon_r(t)$
Time, t