1. Comparison of materials

Plastic is not metal

Comparison of materials – Many plastic designs still continue to be derived from “metal parts”. In the series commencing here the authors set out to describe the points that require attention when designing in plastics rather than traditional materials.

Different basic material characteristics
The properties of plastics materials can vary over a far wider range than all other engineering materials. Through the addition of fillers/reinforcing materials and modifiers the property profile of virtually any base polymer can be radically altered. Most basic properties of plastics, however, form a marked contrast to those of metals. For example, in a direct comparison, metals have higher

- density
- maximum service temperature
- rigidity/strength
- thermal conductivity and
- electrical conductivity,

while the

- mechanical damping
- thermal expansion
- elongation at break and
- toughness

of engineering thermoplastics are greater by orders of magnitude (see Fig. 1). To produce functional parts in plastic and at the same time save costs, radical design modification is generally necessary if the plastic is being used to replace metal. This process affords an opportunity for complete redesign of the component with possible integration of functions and geometric simplification.
Different material behaviour

Plastics sometimes exhibit completely different behaviour to that of metals under the same service conditions. For this reason, a functionally efficient, economic design in cast metal can easily fail if repeated in plastic with excessive haste. Plastics designers must therefore be familiar with the properties of this group of materials.

Temperature and time dependence of deformation characteristics

The nearer the service temperature of a material is to its melting point, the more the material’s deformation behaviour will be temperature- and time-dependent. Most plastics exhibit a change in their basic mechanical properties at room temperature or on exposure to short-term stress. Metals, on the other hand, usually display largely unchanged mechanical behaviour right up to the vicinity of their recrystallization temperature (> 300 °C).

If the service temperature or deformation rate is varied sufficiently, the deformation behaviour of engineering thermoplastics can change from hard and brittle to rubbery-elastic. An airbag cover, for example, in its particular application involving explosive opening, exhibits completely different deformation behaviour from that of a slowly assembled snap-fit element made of the same material (Fig. 2). Similarly, this snap-fit element has to be assembled in a different way according to whether the temperature conditions are hot or cold. The effect of temperature here is significantly greater than the effect of loading rate.
Factors influencing component properties
The characteristics of plastics are not purely material properties. The basic property level of a plastic component can be changed by various factors (e.g. UV radiation, see Fig. 3) right up to the point of unserviceability. A well designed moulded part can easily fail if the material is processed under inappropriate conditions. Similarly, processors cannot generally eliminate moulding design faults during processing. Only through a process of optimization that takes into account all influencing factors (Fig. 4) can a good plastics component be guaranteed.
Since plastics are less tolerant of faulty design than metals, greater attention must be devoted to correct material design in designing plastics components. Every design process must therefore start with a thorough and precise analysis of all requirements and boundary conditions.

**Fig. 3**
Material degradation as a result of excessive UV radiation

**Fig. 4**
Factors influencing component properties

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**Factors influencing component properties**

**Production**
- Orientation
- (molecules, fillers and reinforcing materials)
- Internal stresses
- Degree of crystallization
- Weld lines
- Air occlusions
- Processing conditions
- (material degradation)

**Service environment**
- Temperature
- Chemicals
- UV radiation
- Moisture

**Stress**
- Deformation rate
- Stress rate
- Type of stress
- Force application
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