MKR1163 PLASTICS DESIGN AND PROCESSING

Materials Selection Criteria

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Case Study

A tale of two materials of different MW

Better flow can mean trade-offs in long-term material performance.

- Molders prefer higher-flow materials.
- They enable processors to fill the same part with less pressure or at a lower melt temperature, which can translate to shorter cycle times and lower clamp tonnage.
- They can also extend the complexity of the geometries that can be produced.
- However, more often than not, molders fail to address sacrifices in long term properties.

What makes materials flow faster?

1. Additives technology and
2. Modification of the polymer itself.
   - Both may be used, and it is not always simple to determine the approach a material supplier has taken.
   - In most cases the differences in flow are achieved by reducing the average molecular weight of the materials.

Property changes are not always obvious

- Most commonly used method to measure MW is the melt-flow-rate test, or melt-volume rate, or melt index.
- Short-term tests that are typically used to characterize a material often miss the alterations that occur when the flow of a material is modified.

The top four properties show little or no difference between materials with different melt-flow rates.

Table 1. Comparative properties of acetal copolymers

Property	Units	2.5 MFR	9.0 MFR	27.0 MFR
Tensile strength	psi	8800	8800	8800
Flexural modulus	psi	375,000	375,000	375,000
DTUL @ 264 psi	°F	230	230	230
Notched Izod impact	ft-lb/in	1.5	1.3	1.0
Elongation @ break	%	75	60	40
Tensile impact	ft-lb/sq in	90	70	60
Fatigue endurance, 10^7 cycles	psi	4000	3300	3000

Case Study - Large Chute Deflector

- Parts of this type are traditionally made in some variation of a high-molecular-weight impact copolymer, referred to as a 2-melt (2 g/10 min) 12-Izod copolymer.
- This part was launched in just such a compound and was successful.

Chute Deflector - materials change

- At some point, to increase productivity, the molder was persuaded to change to a material with a nominal melt-flow rate of 15 g/10 min.
- The two data sheets showed virtually no difference in strength or modulus and a decline in Izod from only 12 to 11 ft-lb/in.

Table 2. Izod and falling dart impact test results

Material	Notched Izod (ft-lb/in)	Falling dart energy @ max load (ft-lb)	Total energy (ft-lb)	% falling dart energy after max load
2-melt	12.24	12.06	25.19	52.0
15-melt	10.67	11.37	21.68	47.6

The Chute fails, why?

- However, within four months chutes began to come back from the field with cracks.
- At first, improper processing was suspected. However, notched Izod and instrumented falling dart impact tests both showed that the 15-melt material was quite ductile. The different in values were not different enough to cause any concern.
- In addition, all breaks were ductile.

Hints from Tensile Tests

- The elongation at break is a relative measure of ductility, and in this test, the 2-melt material exhibits almost three times the elongation.
- But perhaps even more important is the difference in elongation at yield.
- One of the shortcomings of traditional impact tests is that they measure the response from a single catastrophic event. But impact failures seldom occur in this manner in the real world.

As the Chains Unravel

- Fundamentally, thermoplastics consist of an entangled network of long chains.
- Failure occurs when sufficient energy is applied to the system to disrupt this entanglement. Longer individual chains found in higher-molecular-weight materials are more thoroughly entangled, so more energy is required to create this disruption.

Table 3. Tensile test results

Material	Tensile strength @ yield (psi)	Elongation @ yield (%)	Elongation @ break (%)	Tensile modulus (psi)
2-melt	2549	11.62	174	117,420
15-melt	2580	6.89	62	121,940

Elongation results show why the chutes failed in the field.

Plastic Materials Selection Criteria

1. Physical & Mechanical Considerations
2. Thermal Considerations
3. Chemical Considerations
4. Bearing and Wear Considerations
5. Others

Plastic Materials Selection Criteria - Physical & Mechanical Considerations

* What are the overall part dimensions (diameter, length, width, thickness)?
* What load will the part have to carry?
* Will the design carry high loads?
* What will the highest load be?
* What is the maximum stress on the part?
* What kind of stress is it (tensile, flexural, etc.)?
* How long will the load be applied?
* Will the load be continuous or intermittent?
* Does the part have to retain its dimensional shape?
* What is the projected life of the part or design?

Plastic Materials Selection Criteria - Thermal Considerations

* What temperatures will the part see and for how long?
  * What is the maximum temperature the material must sustain?
  * What is the minimum temperature the material will sustain?
  * How long will the material be at these temperatures?
  * Will the material have to withstand impact at the low temperature?
  * What kind of dimensional stability is required (is thermal expansion and contraction an issue)?

Plastic Materials Selection Criteria - Chemical Considerations

* Will the material be exposed to chemicals or moisture?
* Will the material be exposed to normal relative humidity?
* Will the material be submerged in water? If so, at what temperature?
* Will the material be exposed to steam?
* Will the material be painted? If so, what kind of paint?
* Will the material be glued? If so, what kind of adhesive will be used?
* Will the material be submerged or wiped with solvents or other chemicals? If so, which ones?
* Will the material be exposed to chemical or solvent vapors? If so, which If so, which ones?
* Will the material be exposed to other materials that can outgas or leach detrimental materials, such as plasticizers or petroleum-based chemicals?

Plastic Materials Selection Criteria - Bearing and Wear Considerations

* Will the material be used as a bearing? Will it need to resist wear?
* Will the material be expected to perform as a bearing? If so, what will the load, shaft diameter, shaft material, shaft finish, and rpm be?
* What wear or abrasion condition will the material see? Note: Materials filled with friction reducers (such as PTFE, molybdenum disulfide, or graphite) generally exhibit less wear in rubbing applications.

http://www.boedeker.com/regcomp.htm

Plastic Materials Selection Criteria - Other Considerations

* Will the part have to meet any regulatory requirements?
    - o FDA | USDA | Canada AG | 3A-Dairy | NSF | USP Class VI
* Is UL94 Flame retardant rating required? What level?
    - o 5VA | 5VB | V-0 | V-1 | V-2 | HB
* Should the material have a special color and/or appearance?
    - o Natural | White | Black | Other Colors
    - o Color match to another part or material?
    - o Window-Clear | Transparent | Translucent | Opaque
    - o Smooth | Polished | Textured | One-Side or Both
* Will the part be used outdoors?
* Is UV Resistance needed?
* Is static dissipation or conductivity important?
    - o Insulator | Static Dissipative | Conductive

Metals Replacement
a key market strategy

- In order to compete in today's very competitive environment, manufacturers put a lot of emphasis on product differentiation while maintaining good margins and low cost.
- This differentiation is done by design, visual appearance or by development of new functionalities requiring miniaturized or more sophisticated systems.