## Foreword

The formulation of this National Standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Enhancing the Implementation of AFMA Through Improved Agricultural Engineering Standards" which was funded by the Bureau of Agricultural Research (BAR) of the Department of Agriculture (DA).

This standard has been technically prepared in accordance with PNS 01-4:1998 (ISO/IEC Directives Part 3:1997) – Rules for the Structure and Drafting of International Standards. It provides specifications and proper application of engineering plastics for agricultural machinery and structures.

The word “shall” is used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted.

The word “should” is used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that certain course of action is preferred but not necessarily required.

In the preparation of this standard, the following documents, publications, and websites were considered:

John, V. B. 1983. Introduction to engineering materials. Second Edition. Macmillan Publishers Ltd., London.

Dietz, Albert, G. H. 1949. Materials of construction: Wood, plastics, fabrics. D. Van Nostrand Company Inc. New York.

Plastics: www.aetnaplastics.com/engineer.htm

Polymers: http://www.encyclopedia.com

Polyvinyl chloride: http://bsuvc.bsu.edu/home/slhyso/pvc.htm

# Engineering Materials – Engineering Plastics – Specifications and Applications

## 1 Scope

This standard establishes specifications and applications of engineering plastics for agricultural machinery and structures.

## 2 Reference

The following normative reference contains provisions which, through reference in this text, constitute provisions of this Standard:

PAES 310:2001: Engineering Materials – Journal Bearings for Agricultural Machines – Specifications and Applications

## 3 Definition

**3.1**
**plastic**
synthetic organic material, including cellulose derivatives, with or without the incorporation of fillers, binders, pigments, dyes, which is capable of being shaped more or less permanently by casting or molding under increased temperatures and pressures

**3.2**
**monomer**
simple unpolymerized form of chemical compound

**3.3**
**polymer**
chemical compound with higher molecular weight consisting of a number of structural units linked together by covalent bonds

**3.4**
**copolymer**
polymers consisting of more than one monomer

**3.5**
**covalent**
non-ionic chemical bond formed by stored electrons

**3.6**
**thermoplastic**
substances that melt on heating and are processes in this state by a variety of extrusion and molding process

**3.7**
**thermosets**
substances that cannot be melted and remelted

**3.8**
**service temperature**
temperature at which the plastic can withstand without incurring a change in its physical properties

## 4 Types

### 4.1 Acetals

Acetal provides high strength and stiffness while offering enhanced dimensional stability and ease of machining. A semi-crystalline material, acetal also has a low coefficient of friction and good wear properties-especially in wet environments. Because it absorbs little moisture, acetal demonstrates excellent stability for close-tolerance machined parts. In high-moisture or submerged applications, acetal bearings outperform nylon 4 to 1. This material is resistant to a wide range of chemicals, including many solvents. And it is available in a broad range of grades (see below), with properties addressing specific needs.

### 4.2 Acrylic

Cast acrylic shall be made from virgin acrylic monomer and offers superior optical clarity and light transmission. It shall not affected by sunlight; it resists aging; and it remains stable across a wide range of temperature, moisture, and exposure conditions. It will not crack, craze, or corrode. Cast acrylic is preferred for some industrial and commercial applications because of its optical superiority over molded or extruded acrylic products. Cast acrylic can be machined or cemented and, with standard equipment, will fabricate like wood, metal, or other plastics. It weighs half as much as comparable glass and yet has good shatter resistance and durability.

### 4.3 Polyamide (Nylon)

Polyamide, also known as nylon is one of the most versatile and widely used thermoplastic materials. Its physical properties and reasonable price combine to make it a popular choice for numerous applications. It can replace steel, brass, bronze, aluminum, wood, and rubber, while reducing noise, using less lubrication, and increasing gear life. Using standard metalworking equipment, nylon can easily be machined and fabricated into precision parts.

### 4.4 Polycarbonate

Polycarbonate is an amorphous thermoplastic with excellent dimensional stability and good strength and stiffness over a wide range of service temperatures. It is often used for structural applications when transparency and impact strength are essential-such as lenses, manifolds, site glasses, and machine guards. Polycarbonate suits a wide variety of electrical applications as well, because of its low moisture absorption, good insulation and excellent flammability rating.

## 4.5 Polyethylene (Ultra High Molecular Weight)

For the purpose of this standard, only Ultra High Molecular Weight (UHMW) from the different types of polyethylene shall be discussed. UHMWPE is 1/8 the weight of mild steel but is high in tensile strength and as simple to machine as wood. Also unlike steel, it reduces noise in many applications. It is an inexpensive alternative to metals, ceramics, and wood because it is self-lubricating; long-wearing; and shatter-, abrasion-, and corrosion-resistant. UHMWPE is well suited for applications that demand durability and low friction. It causes no undesirable taste, smell, or discoloration, and it can be cleaned with water, steam, detergents, or disinfectants. UHMW Polyethylene will withstand intermittent temperatures of up to 100 °C (212 °F), while at the same time being ideal for use in freezing lines.

## 4.6 Polypropylene

Polypropylene is noted for its light weight, being less dense than water; it is a polymer of propylene. It resists moisture, oils, and solvents. Since its melting point is 121°C (250°F), it is used in the manufacture of objects that are sterilized in the course of their use.

## 4.7 Polyterafluoroethylene (PTFE)

Polytetrafluoroethylene more popularly known as Teflon is based on chain of carbon atoms, the same as all polymers. Given their good dynamic mechanical properties and sufficient flexibility, PTFE and modified PTFE-based materials are ideally suited for use as dynamic seals and bearings, even when the stress is extreme.

## 4.8 Polyvinyl chloride

Polyvinyl chloride (PVC) is a thermoplastic that is a polymer of vinyl chloride. Resins of polyvinyl chloride are hard, but with the addition of plasticizers a flexible, elastic plastic can be made. This plastic has found extensive use as an electrical insulator for wires and cables.

# 5 Application

Engineering plastics are used as materials for manufacture of different machine and structural components especially where corrosion resistance is a factor. Specific uses of engineering plastics are as specified in Table 1.

**Table 1 – Uses of different types of engineering plastics**

| Type | Uses |
|---|---|
| **Acetals** | |
| **Homopolymer** | |
| Standard | Gears, bushings, and plumbing |
| Toughened | High impact and abuse applications |
| 20% Glass reinforced | Same as standard grade and for applications where high stiffness and dimensional stability is required |
| 22% TFE filled | Same as standard grade and for applications where low friction and high resistance to wear is required |

**Table 1 – Continued**

| Type | Uses |
|---|---|
| **Copolymer** | |
| Standard | Gears, bushings, and plumbing |
| 25% Glass coupled | Same as standard grade and for applications where high stiffness and greater thermal stability are required |
| High flow | Same as standard copolymer |
| **Acrylic** | |
| **Cast sheets, rods** | |
| General purpose Type I | Signs |
| General purpose Type II | |
| **Moldings** | |
| Grades 5, 6, 8 | Decorative and functional automotive parts, protective goggle lenses |
| High impact grade | Control knobs, pump parts, sprinkler heads, tool handles |
| Modified | Packaging, lenses, containers, shields |
| **Nylon** | |
| **Type 6** | |
| General purpose | Bearings, gears, bushings, coils, rod, tubings, tape |
| Glass fiber (30%) reinforced | |
| Cast | Bearings, wearplates, bushings, gears, rollers, shapes |
| Flexible copolymers | Parts requiring high impact strength or flexibility |
| **6/6 Nylon** | |
| General purpose molding | Bearings, gears, bushings, coil forms, brush backs, rod ,tubing |
| Glass fiber reinforced | |
| Glass fiber molybdenum disulfide filled | Mechanical parts where lubrication is undesirable or difficult |
| General purpose extrusion | Tubing, rod, pipe, sheeting, laminations |
| High impact | Protective helmets, tool handles and housings |
| 6/9 Nylon | Jacketing for wire and cable, special molded parts |
| 6/12 nylon | |
| Mineral reinforced nylon | Electrical housings and mechanical parts |
| Type 11 | Electrical insulation and other nylon where low moist absorption is needed |
| Type 12 | Filament, rod, tubing sheet, moldings, regular dimensions stability and low moist absorption |
| Transparent | Lenses, containers, gauges, fuel tanks, processing equipment housing |
| **Polycarbonates** | |
| General purpose | Electrical parts, portable tool housings, glazing sheet, impellers, body armor |
| High modulus | |
| Wear resistant | |
| 40% gl reinforced | |
| **Polyethylene** | |
| UHMWPE | Packaging, structural housing panels, pipes, wire and cable insulation |
| **Polypropylene** | |
| General purpose | |
| High impact | |
| Flame retardant | |
| **PTFE** | Chemical pipes, valves and liners, gaskets, packings, pump bearings and impellers, electrical equipment, anti-adhesive coatings |
| **Polyvinyl chloride** | |
| Non-rigid general | Parts made by molding, high speed extrusion, garden hose, handlebar grips |
| Non-rigid electrical | Parts made by extrusion. |
| Rigid normal impact | Sheets and shapes for decorative panels, storage tanks, pipes |
| Rigid 30% glass coupled | |
| Vinylidene chloride copolymer | Gasket, valve seats, |
| Chlorinated polyvinyl chloride | Pipes |

## 6 Mechanical and physical properties

Mechanical and physical properties of engineering plastics shall conform to Table 2 and 3. Operating limits of plastics when used as journal bearings shall be in accordance with PAES 310:2001.

## Table 2 –Service temperatures of engineering plastics

| Material | Nomenclature | Service temperature, °C | Service temperature (Short term), °C |
|---|---|---|---|
| Acetal | POM | 100 | 140 |
| Acrylic | PMMA | 100 | 110 |
| Polyamide (Nylon) | Pa | 100 | 160 |
| Polycarbonate | PC | 120 | 140 |
| Ultra high molecular polyethylene | UHMWPE | 90 | 110 |
| Polypropylene | PP | 100 | 130 |
| Polytetrafluoroethylene (Teflon) | PTFE | 260 | - |
| Polyvinyl chloride | PVC | 100 | 110 |

## Table 3 – Mechanical and physical properties of engineering plastics

| Type | Physical properties | | Mechanical properties | | |
|---|---|---|---|---|---|
| | Specific gravity | Water absorption, 24 hr (%) | Tensile strength (MPa) | Compressive strength, 2% offset (MPa) | Hardness |
| **Acetals** | | | | | |
| **Homopolymer** | | | | | |
| Standard | 1.425 | 0.3 | 69 | 36 | M94 |
| Toughened | 1.34 | - | 45 | - | M54 |
| 20% Glass reinforced | 1.56 | 0.3 | 59 | 36 | M90 |
| 22% TFE filled | 1.54 | 0.2 | 48-52 | 31 | M78 |
| **Copolymer** | | | | | |
| Standard | 1.41 | 0.2 | 61 | - | M80 |
| 25% Glass coupled | 1.59 | 0.3 | 110 | 130 | M88 |
| High flow | 1.41 | 0.2 | 61 | 31 | M80 |
| **Acrylic** | | | | | |
| **Cast sheets, rods** | | | | | |
| General purpose Type I | 1.17-1.19 | 0.3-0.4 | 41-62 | 83-97 | M80-90 |
| General purpose Type II | 1.18-1.20 | 0.2-0.4 | 55-69 | 97-124 | M80-103 |
| **Moldings** | | | | | |
| Grades 5, 6, 8 | 1.18-1.19 | 0.23-0.4 | 66-7 | 100-117 | |
| High impact grade | 1.12-1.16 | 0.2-0.3 | 38-72 | 50-83 | |
| Modified | 1.10-1.12 | 0.3 | 48-55 | 66-79 | |
| **Nylon** | | | | | |
| **Type 6** | | | | | |
| General purpose | 1.14-1.36 | 0.9-1.8 | 59-160 | 67 | R118-R120 |
| Glass fiber (30%) reinforced | 1.37 | 1.3 | 90-172 | 131, 138 | R121 |
| Cast | 1.15 | 0.6 | 88 | 97 | R95-120 |
| Flexible copolymers | 1.12-1.14 | 0.8-1.4 | 52-69 | - | R72-R119 |
| **6/6 Nylon** | | | | | |
| General purpose molding | 1.13-1.15 | 1.5 | 12, 59 | 34 | R118, R108 |
| Glass fiber reinforced | 1.37-1.47 | 0.9, 0.8 | - | 138, 165 | E60 |
| Glass fiber molybdenum disulfide filled | 1.37-1.41 | 0.5-0.7 | - | - | M95-100 |
| General purpose extrusion | 1.13, 1.15 | 1.5 | 87, 59 | 34 | R118-108 |
| High impact | 1.09 | - | | 13 | R112 |
| 6/9 Nylon | 1.07-1.09 | 0.5 | 59, 45 | | R111 |
| 6/12 nylon | 1.06-1.08 | 0.4 | 61, 51 | 17 | R114, - |
| Mineral reinforced nylon | 1.47 | 0.5-0.8 | 62-69 | | R119-121 |
| Type 11 | 1.04 | 0.4 | 59 | | - |
| Type 12 | 1.01 | 0.3 | 38-45 | | - |
| Transparent | 1.06-1.12 | | 68-74 | 23 | - |
| **Polycarbonates** | | | | | |
| General purpose | 1.19-1.22 | 0.2 | 59-62 | 69-86 | M68-74 |
| High modulus | 1.25 | 0.1 | 66 | 97 | M85 |
| Wear resistant | 1.18 | - | 59 | | - |
| 40% gl reinforced | 1.52 | 0.1 | 159 | 145 | M93 |

## Table 3 - Continued

| Type | Physical properties | | Mechanical properties | | |
|---|---|---|---|---|---|
| | Specific gravity | Water absorption, 24 hr (%) | Tensile strength (MPa) | Compressive strength, 2% offset (MPa) | Hardness |
| UHMWPE | 0.94 | <0.01 | 21-43 | | 60-66D |
| **Polypropylene** | | | | | |
| General purpose | 0.900-0.910 | <0.01-0.03 | 34-36 | 38-45 | R80-R100 |
| High impact | 0.900-0.910 | <0.01-0.02 | 19-30 | 30 | R28-95 |
| Flame retardant | 1.2 | 0.02-0.03 | 25-29 | | R60-R105 |
| **PTFE** | 2.1-2.3 | 0.0 | 17-45 | 5-12 | 52D |
| **Polyvynil chloride** | | | | | |
| Non-rigid general | 1.20-1.55 | 0.2-1.0 | 7-24 | | A50-100 |
| Non-rigid electrical | 1.16-1.40 | 0.4-0.75 | 14-22 | | A78-100 |
| Rigid normal impact | 1.32-1.58 | 0.03-0.40 | 34-40 | 69-76 | R110-120 |
| Rigid 30% glass coupled | 1.53-1.57 | - | 103 | | 118 |
| Vinylidene chloride copolymer | 1.68-1.75 | >0.1 | 28-55, 103 -276 | 517-586 | M50-65 |
| Chlorinated polyvinyl chloride | 1.49-1.58 | 0.02-0.15 | | | R117-122 |