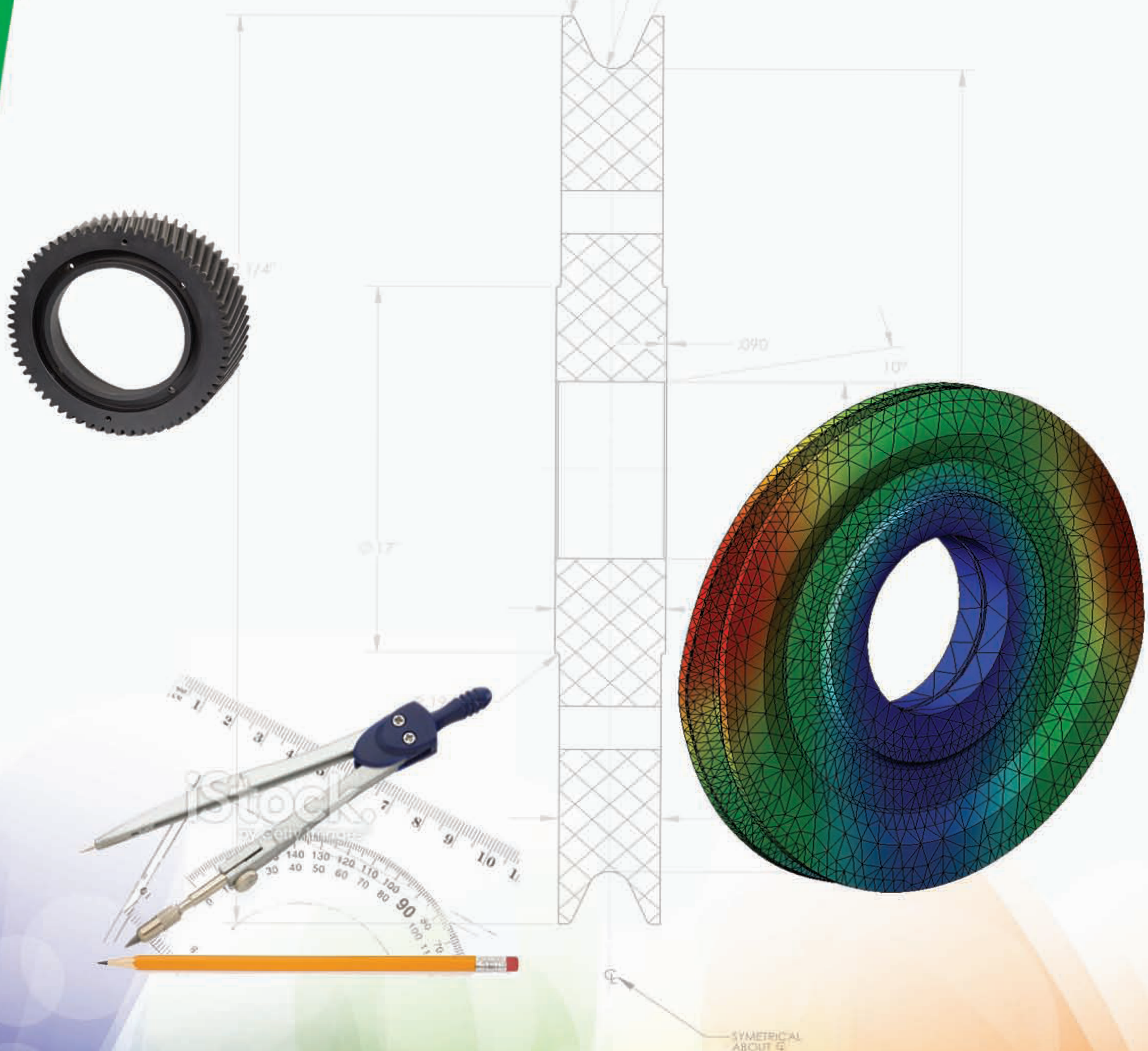
CAST NYLONS LIMITED

Discover the NYCAST® Advantage

Technical Guideline for Design and Fabrication



Distributed by: Polymershapes

Cast Nylons Limited

Technical Guidelines for Design and Fabrication

Table of content

History of Plastics

1. History of plastics

Plastics (former name synthetic material) are materials built of organic macromolecules with a relative molecular weight >10000. One main part of plastics is the atom carbon.

In the middle of the 19th century the first chemical modified natural

materials were developed.

1859: vulcanised fibre (Ebonit)

1869: cellulose nitrate (Celluloid)

1897: casein plastics (Galatith)

The first full synthetic developed material was reported in 1908 by a

Belgian chemist, Leo Baekeland, it was named Bakelite, a thermoset

material, phenolic-formaldehyde. Since then many synthetic produced plastics were developed. After World War I the improvement in

synthesizing plastics evolved into numerous new plastic materials with mass production starting in the 40’s. One of the early new materials was polystyrene (PS), first produced by BASF in the 30’s, polyvinyl chloride (PVC) and polyethylene (PE)

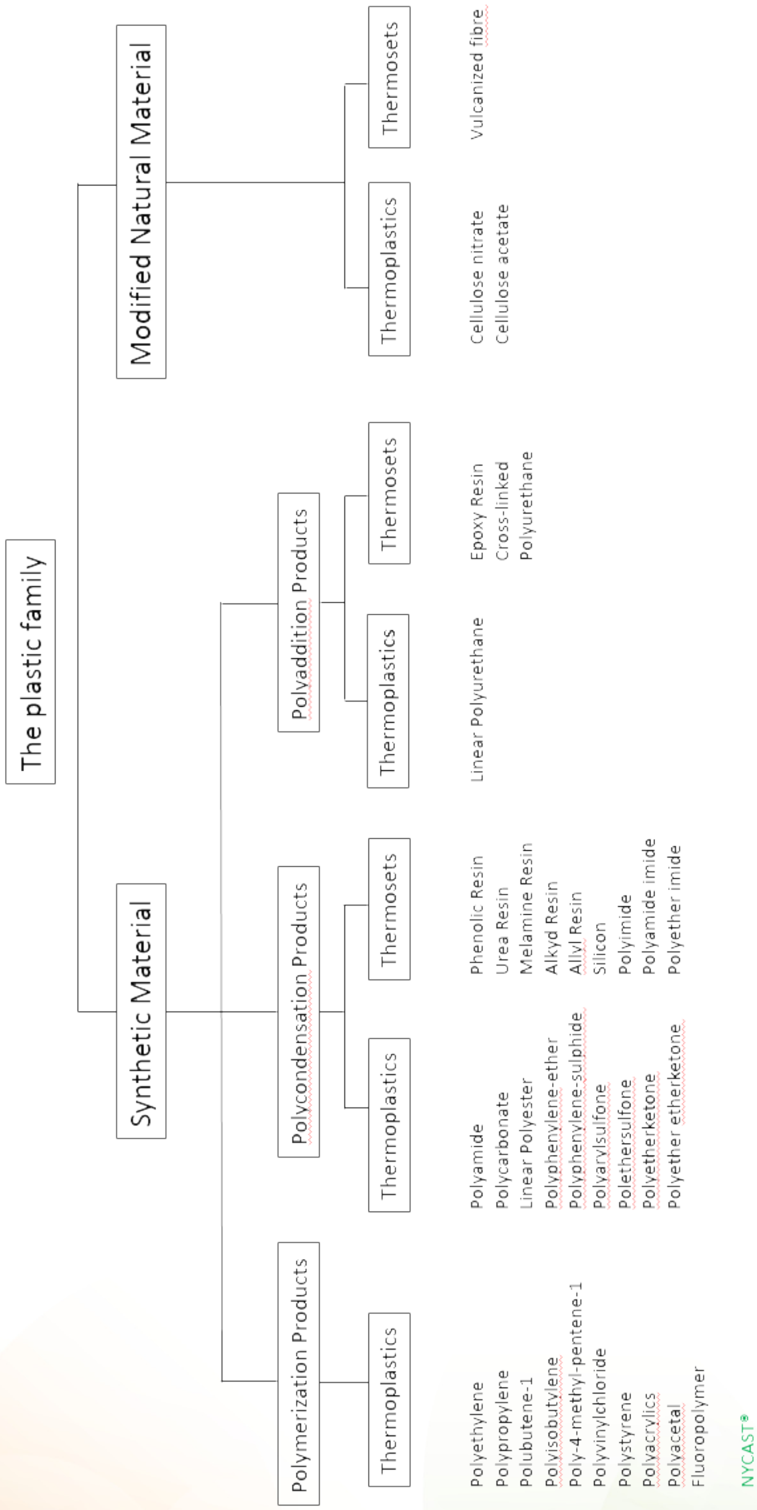
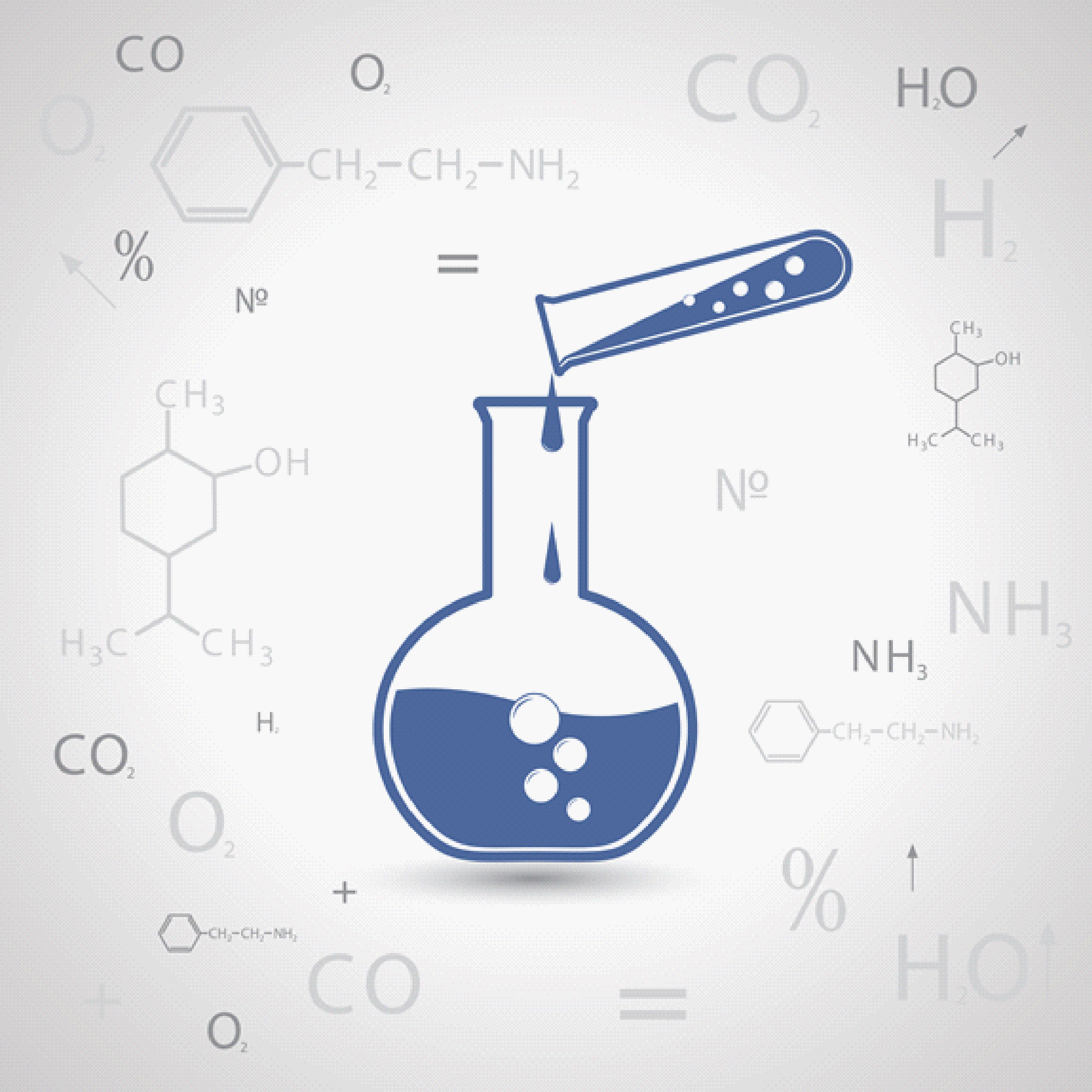


Chart: classification of polymer

Polymer Chemistry



2. Polymer Chemistry

A. Principles

The basic principles for all chemical reactions are based on the theory of Niels Bohr; each nucleus has an electron cloud. Free electrons in this cloud can go into a reaction with other free electrons on outer clouds from other atoms to form a molecule.

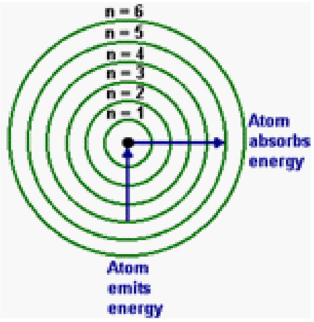
The electron configuration is a way of showing how the electrons are arranged in an atom. Recall that electrons are placed in energy levels around the nucleus. The energy level can hold a maximum of electrons.

An easy way to calculate the total numbers of electrons that can be held in a given energy level is to use the formula 2n2.

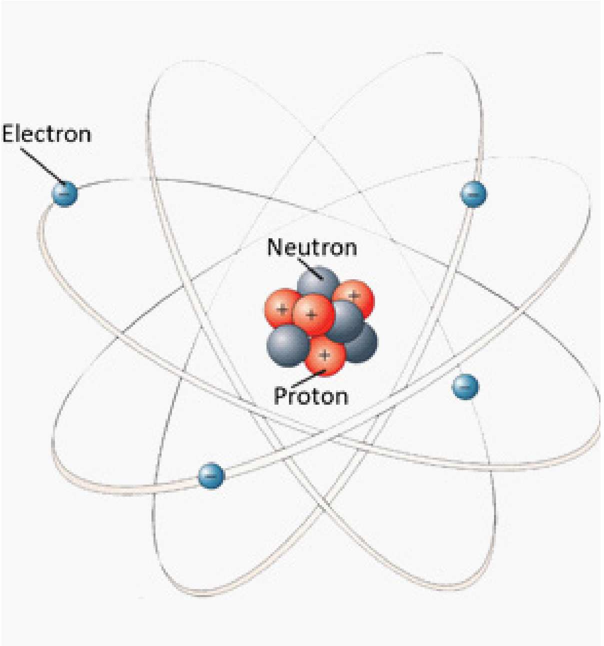
- First energy level (n=1) can hold 2 (1)2 = 2 electrons

- Second energy level can hold 2 (2)2 = 8 electrons

- Third energy level (n=3) can hold 2 (3)2 = 18 electrons etc.



Polymers are based on carbon atoms. To understand the carbon chemistry we have to look into the Bohr'sche atom model of carbon:



The 4 electrons on the outer shell can go into reactions with other atoms. The carbon atoms are the backbones of the polymers.

It can also be shown as:

•
• C •
•

The 4 dots show the 4 electrons on the outer cloud of the carbon atom. If we add 4 Hydrogen atoms the following reaction will occur:

•　　　　　　　　H
4 H • + • C • ⟶ H – C – H
•　　　　　　　　H

The 4 hydrogen atoms formed with the carbon atom the molecule methane.

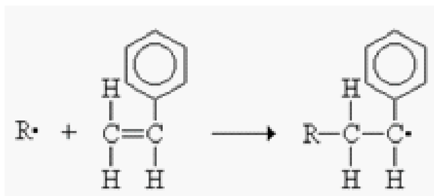
B. Polymer reactions

Polymers are formed by three different reactions:

- Polymerization

Polymerization processes are characterized by double bonding's. One bonding will open and form a bonding with another electron,

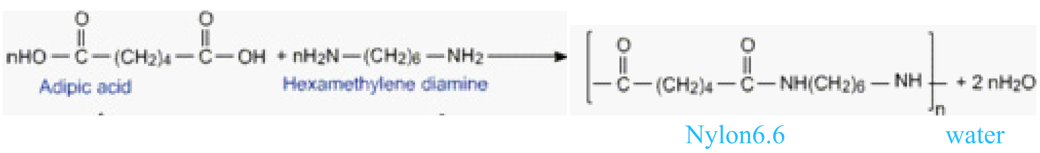
e.g. polyvinyl chloride, PVC



- Polycondensation

Polycondensation, also called substitution reaction, is the reaction of similar groups with the split of e.g. water, alcohols or other low molecular weight groups.

e.g. polyamide 6,6 or PA 6,6



- Polyaddition

Polyaddition is the reaction of two duo functional molecules

e.g. polyethylene, PE

C. Classification of polymers

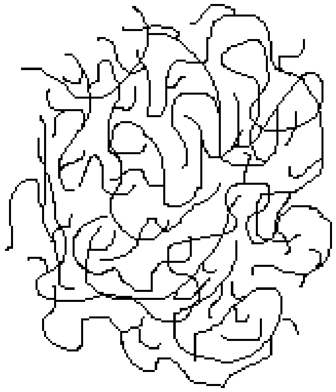
Through these reactions different types/ classifications of polymers can be synthesized. We differentiate as follows:

- Thermoplastic Materials

These polymer materials become moldable or pliable at a certain temperature and they solidify when cooled under a specific temperature. Thermoplastic polymers can be repeatedly softened by heating and then solidified by cooling - a process similar to the repeated melting and cooling of metals. Most linear and slightly branched polymers are thermoplastic. All the major thermoplastics are produced by chain polymerization.

Amorphous Polymers

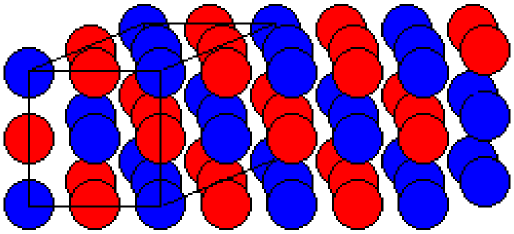
Polymer chains with branches or irregular pendant groups cannot pack together regularly enough to form crystals. These polymers are said to be amorphous.



amorphous structure

Crystalline Polymers

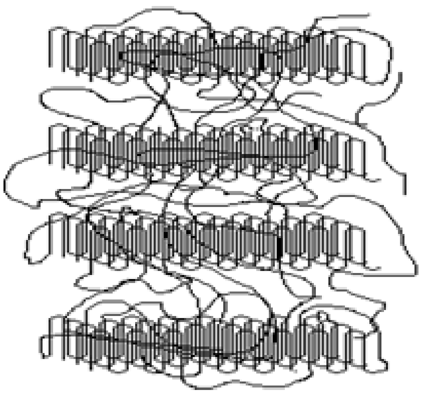
Highly crystalline polymers are rigid, high melting, and less affected by solvent penetration. Crystallinity makes a polymer strong, but also lowers their impact resistance.



crystalline structure

Semi Crystalline Polymers

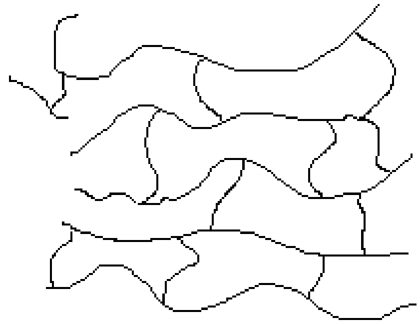
Semi-crystalline polymers have both crystalline and amorphous regions. Semi-crystallinity is a desirable property for most plastics because they combine the strength of crystalline polymers with the flexibility of amorphous. Semi-crystalline polymers can be tough with an ability to bend without breaking.



semi-crystalline structure

- Thermoset Materials

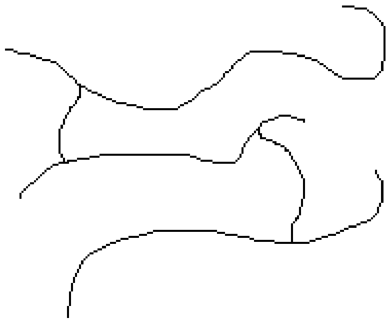
Thermoset or duroplastic materials are cross linked structured. They do not soften when they are heated up.



structure of thermoset materials

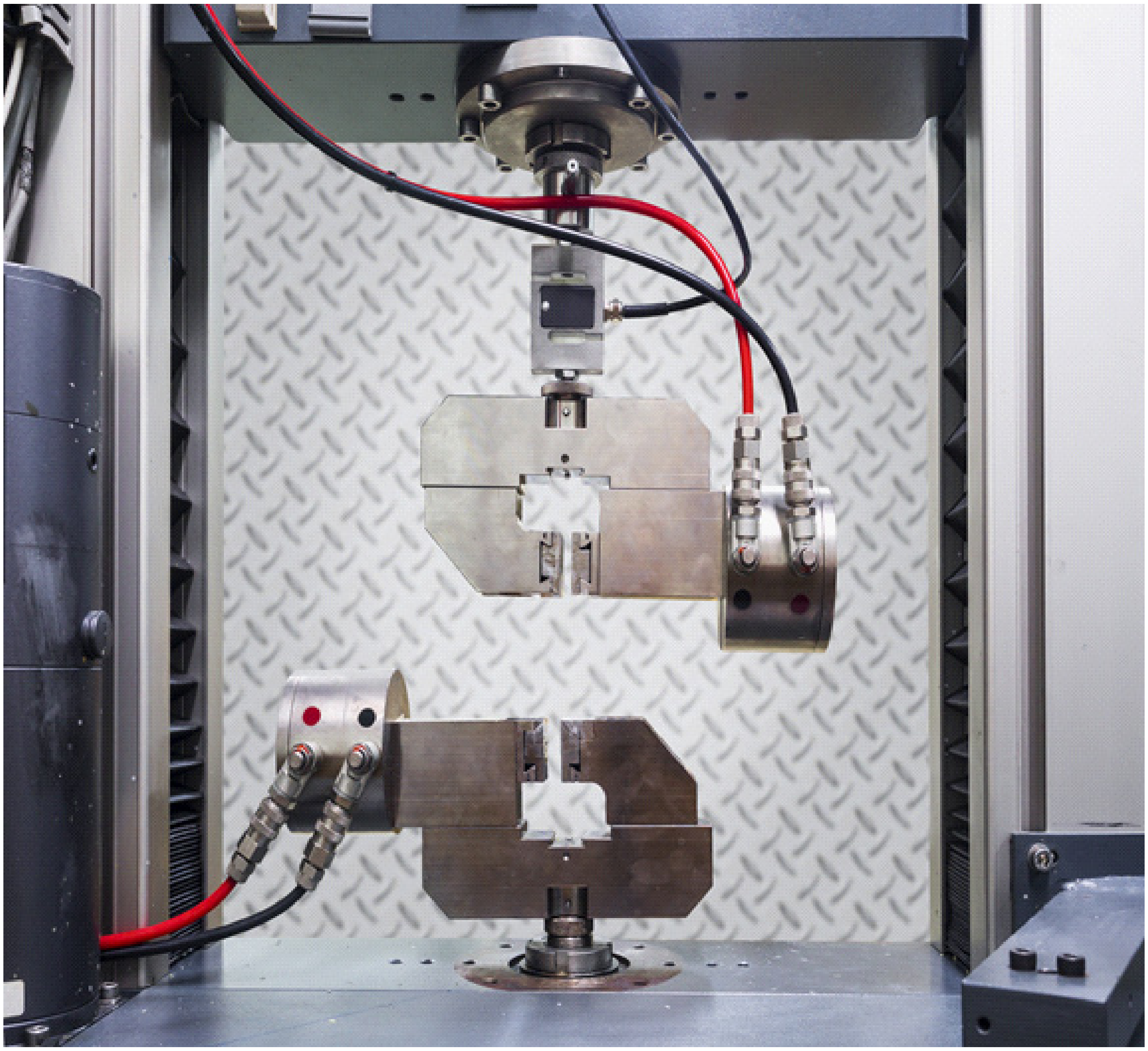
- Elastomer Materials

These materials are rubber elastic, they have elasticity and small intermolecular forces.



structure: elastomer materials

Properties of Plastics



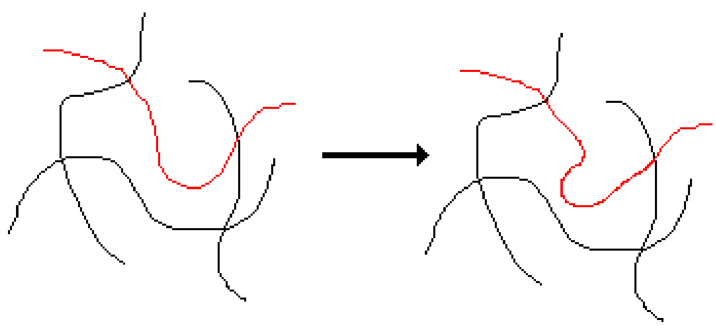
3. Properties of plastics

Plastic materials do behave different than metal. All plastics have more or less a visco-elastic behavior. If mechanical stress is applied, the secondary bonding in the polymer structure break and the chains move apart. The longer the stress is applied the more the polymer strains and the chains move farther away from each other.

Glass-transition temperature

Semi-crystalline polymers have amorphous and crystalline areas. According to the temperature, the amorphous area can be either in the glassy or rubbery state. The temperature at which the transition in the amorphous area between the glassy and rubbery state occurs is called the glass transition temperature.

The glass transition is only a function of the amorphous part of the polymer.

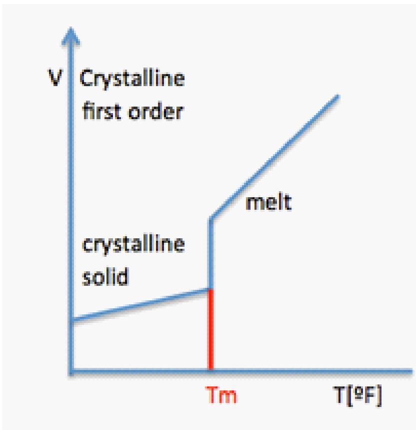


The red line shows the amorphous part of the polymer. At low temperatures (left) the polymer is in a solid state, at higher temperatures the amorphous phase can move around and soften the polymer (right)

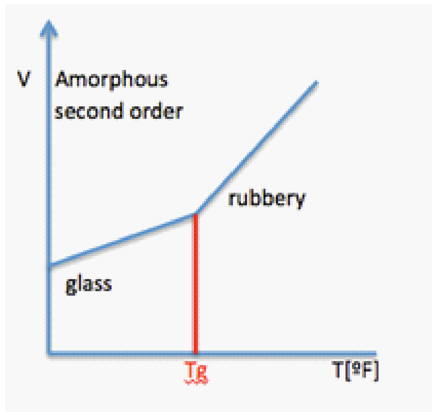
The glass transition is not the same as melting!

Thermodynamic transitions are classified by first or second order. In a first order transition there is a transfer of heat and the polymer undergoes an abrupt change in volume. In a second order transition the heat capacity changes. The volume change accommodates the increase motion of the polymer molecules.

Melting



Glass transition



The mechanical properties of polymers involve their behavior under stress. The main questions are:

- How strong is the polymer? How much can it be stretched before is breaks?

- How stiff is the polymer? How much does it deflect under load?

- How brittle is the polymer? Does it break easy under sudden impact?

- How is the polymer reacting under repeated stress?

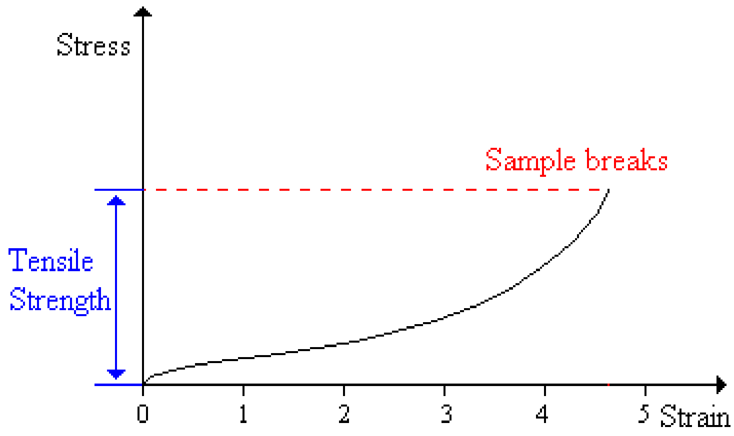
Properties simplified

Properties	Amorphous	crystalline
Tensile strength	Lower	Higher
Tensile modulus	Lower	Higher
Ductility, elongation	Higher	Lower
Resistance to creep	Lower	Higher
Maximum service temp.	Lower	Higher
Chemical resistance	Lower	Higher
Wear resistance	Lower	Higher

Mechanical Properties

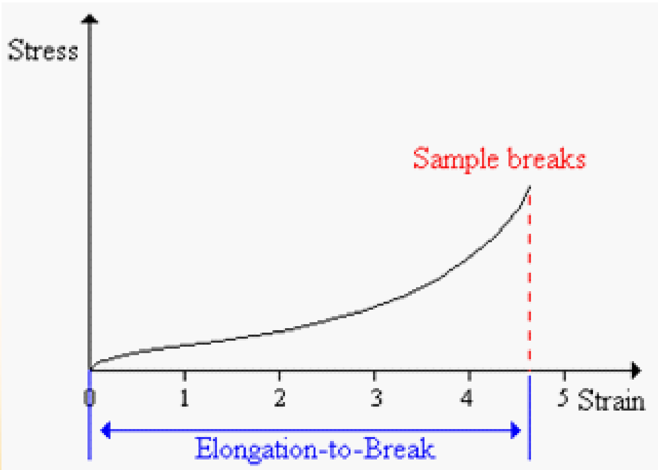
Tensile Strength ASTM D638

The tensile strength of a material is defined as the maximum stress a material can withstand while pulled or stretched before it breaks. Some material will fail sharply without deformation: brittle failure, while other materials will deform before breaking.



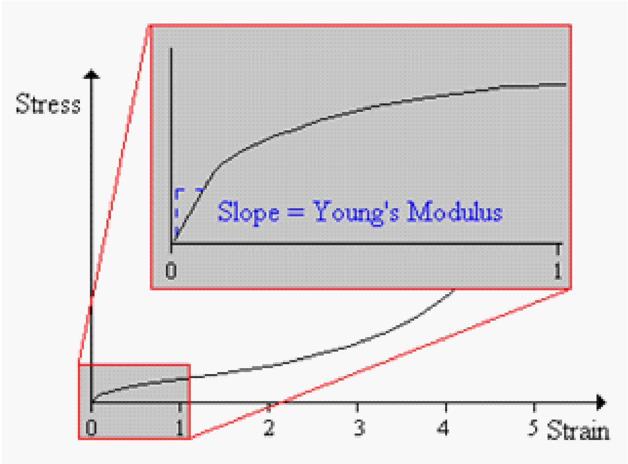
Elongation at break ASTM D638

The elongation-to-break is the strain on a sample when it breaks. It is also known as fracture strain. The test describes the ratio between initial length and the length after breaking oft he test sample. It is usually is expressed as a percent.



Young’s modulus ASTM D638

Young's modulus, or modulus of elasticity, is the ratio of stress to strain. Young's modulus is the slope of a stress-strain curve. Stress-strain curves often are not straight-line plots, indicating that the modulus is changing with the amount of strain. In this case the initial slope usually is used as the modulus, as is illustrated in the diagram below. Rigid materials, such as metals, have a high Young's modulus.



Compressive strength ASTM D695

The compressive strength is the materials ability to withstand a compressive force with a specific deformation. There are three different test methods

- Ultimate compressive strength

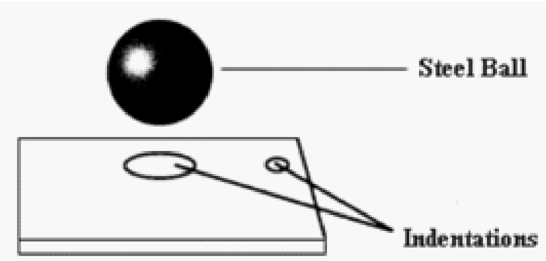
- Compressive strength at specific deformation (e.g. 0.1%, 1% and 10%)

- Compressive yield strength (stress measured at point of permanent yield)

Hardness ASTM D785

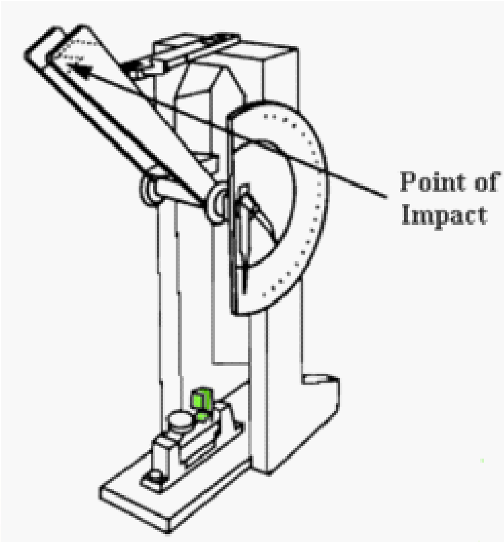
The testing of the hardness of a material is performed by indentation. The result shows the resistance of a material to plastic deformation. It can be measured in Rockwell, ball pressure hardness or Shore. Each test is different from each other.

The Shore test is a quick test and can be performed on a part without a problem. The results are not very exact for thermoplastic materials such as cast nylon 6. Rockwell and ball pressure hardness test require a certain sample, which makes both test more exact and reproducible.



Impact resistance/ toughness ASTM D256

Impact resistance or toughness is the material's ability to withstand sudden occurring energy such as an impact. It can be measured in a Charpy or Izod test.

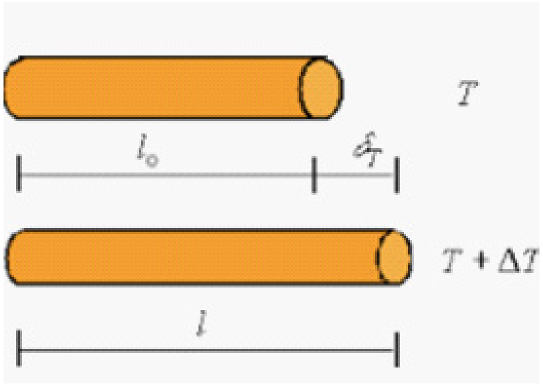


Izod test machine (green: sample to be tested)

Thermal Properties

Coefficient of linear thermal expansion ASTM D696

This coefficient of linear thermal expansion describes how the material changes in linear direction under the influence of temperature. It is given in the ratio between the change in linear dimension to the original dimension for a unit change in temperature.



lo: original dimension at temperature T,

l: dimension at higher temperature T+ ΔT

Continuous service temperature

This value is normally defined as the ambient temperature the material can operate for a long time (10 years) and retain its initial properties at a level of at least 50%.

Melting point ASTM D3418

This is the temperature at which a crystalline polymer changes is state from solid to liquid.

Electrical Properties

Dielectric strength ASTM D149

Dielectric Strength is a measure of the electrical strength of a material as an insulator. Dielectric strength is defined as the maximum voltage required to produce a dielectric breakdown through the material and is expressed as Volts per unit thickness. A higher dielectric strength shows a better insulator.

Dielectric constant ASTM D150

Dielectric Constant is used to determine the ability of an insulator to store electrical energy. If polymers are exposed to an electrical field, molecules can align through absorbing energy. Some of this energy gets converted to heat, the loss of electrical energy in form of heat is called dielectric loss. A low dielectric constant is required for an insulator. The dielectric constant is dependent on temperature, moisture content, frequency and other parameters.

Surface resistivity ASTM D257

The surface resistance of a polymer material is the resistance to the flow of electrical current across the surface. A low surface resistivity is important in applications where static electricity dissipation is required, e.g. oil and gas industry.

Other Properties

Water absorption

Water absorption is the percentage increase in weight due the exposure to water. The exposure can be performed by a humid environment or storage in water. The material properties are affected by the amount of water absorbed. Cast nylon 6 absorbs up to 6% water if stored in water, cast nylon 12 only 1.5%.

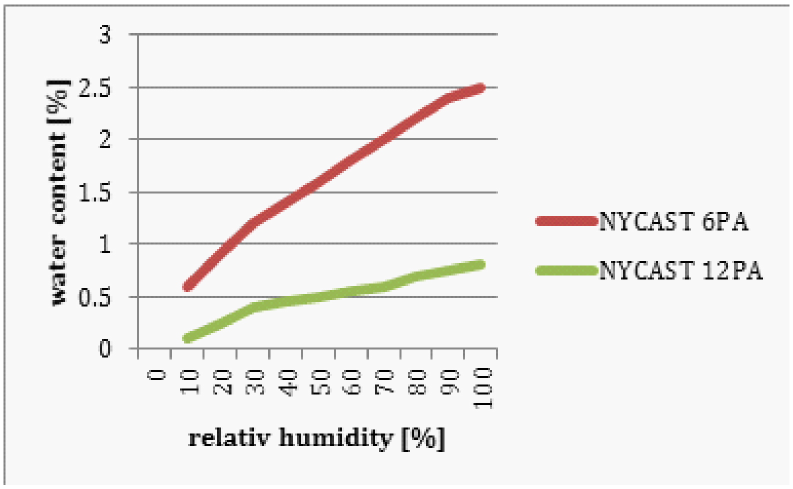


chart: equilibrium moisture content under air humidity at 70ºF

NYCAST 6PA does absorb water through humidity in the air or immersion in water. The speed of the absorption of water is dependent on temperature. The process is reversible, which means that once the material is exposed to drier conditions it will dry itself by "sweating" the water back out.

To calculate the water content in a part, the following equation can be used:

Water absorption equation as a function of time as defined by BASF:

$$\frac{C_t}{C_s} = \frac{2.256}{s}\sqrt{Dt}$$

with:

Ct = moisture content at time (5)

Cs = moisture content at saturation (%)

s = wall thickness in cm

D = diffusion number (cm2/sec)(function of t0)

t = time (sec)

This equation can be used to calculate:

- The degree of saturation after time

- The time required for full saturation

- The wall thickness which will be saturated after a time

example: to what degree is a 10mm thick NYCAST 6PA plate saturated after 1.5 years immersion in water at 200C?

$$\frac{C_t}{C_s} = \frac{2.256}{s}\sqrt{Dt}$$

$$\frac{C_t}{6.5} = \frac{2.256}{1}\sqrt{0.16 * 10^{-6} * 47304000}$$

$$C_t = 4.0\%$$

The resulting water content has to be considered for design purposes.

Flammability UL 94

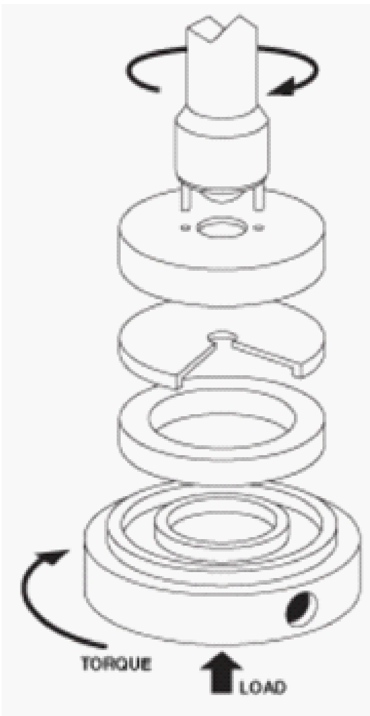
In electrical or indoor applications (e.g. aircraft) the exposure to an open flame to a polymer has to be determined. Flammability tests measure ignition temperature, smoke generating and combustibility. The test according to UL 94 exposes a polymer material to a flame and classifies the ability to burn after the flame is removed. The materials, which extinguish themselves without burning drops rapidly, are given the best classification. The UL rating:

HB – V2 – V1 – V0 – 5V

Increase flame retardant →

Coefficient of friction

The coefficient of friction is a dimensionless scalar, which describes the resistance of two surfaces sliding over another. We distinguish between static and dynamic coefficient of friction. Static refers to resistance of initial movement from a rest position while dynamic refers to resistance of movement at a given speed.



Test Specimen

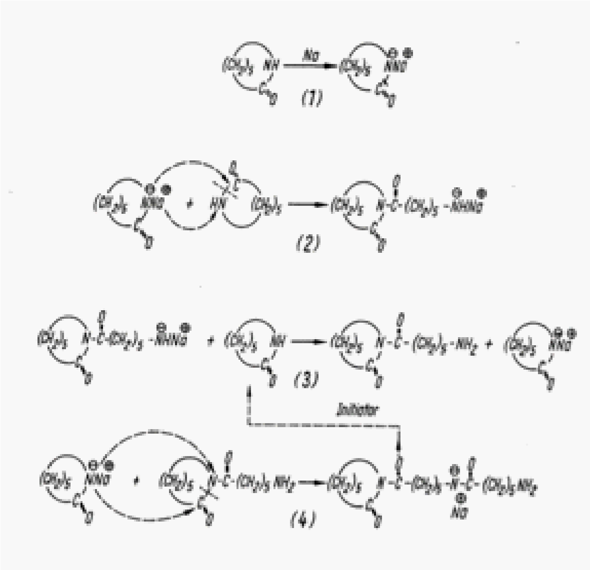
test device for friction test

Cast Nylons LIMITED

Materials

4. Cast Nylons Limited materials

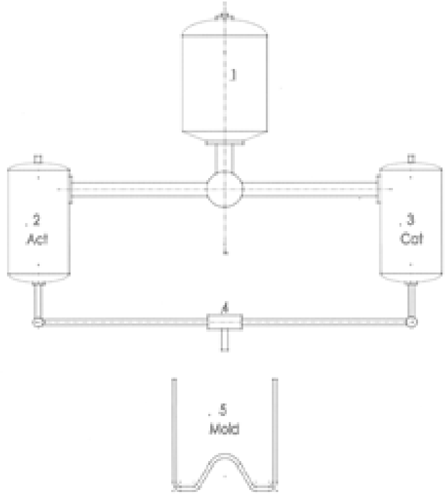
Cast Nylons materials are produced in a propriety process, the so-called anionic polymerization of ε-caprolactam.



1. The reaction 1 leads to the Lactam anion
2. This lactam anion reacts with a lactam molecule under attack on the carbonyl group. The lactam molecule gets split and forms an acyllactam.
3. The Sodium-Ion is replaced with a proton and a refreshed lactam anion is again available
4. The so formed acyllactam is now the initiator for the rapid polymerization at high temperatures.

Chart: reaction mechanism of cast nylon 6 process

The material is synthesized from raw ε-caprolactam in a 2-reactor system. One reactor consist of the activator the other the catalyst. Both melts are mixed together in a mixing head before introduced into the mold. The material solidifies in the mold within a short time. Due to change in density the part can be extracted out of the mold and be stored in an annealing environment.



1: caprolactam storage
2: reactor activator
3: reactor catalyst
4: mixing head
5: mold

Chart: process flow

Cast Nylons materials have been used in the industry successfully for more than 35 years. In order to accommodate various industries CNL developed multiple special grades throughout the years to enhance the performance of the material in special applications. Our engineers are geared to work with our customers on customized solutions regarding material and design.

Cast Nylons material, NYCAST® PA6 and others are nylon 6 materials, which are offering various advantages for the industry:

Low specific weight

The specific weight of NYCAST® 6PA is 1.15 – 1.17 g/cm3. This is much lower than metals.

Specific weight comparison:

Steel	Aluminum	Bronze	NYCAST® 6PA
7.84	2.7	8.8	1.15

Corrosion resistance

Cast nylon 6 does not corrode! Therefore it is a perfect metal substitute in outdoor applications.

Vibration and Noise dampening

Through the visco-elastic behavior of cast nylon 6, NYCAST® materials prolong the lifetime of machinery by reducing vibrations. Wheels and gears made out of NYCAST® reduce the noise in many applications.

Wear resistance

NYCAST® materials have very good wear resistance due to the high crystallinity of the material. NYCAST® materials do wear better than other polymer materials.

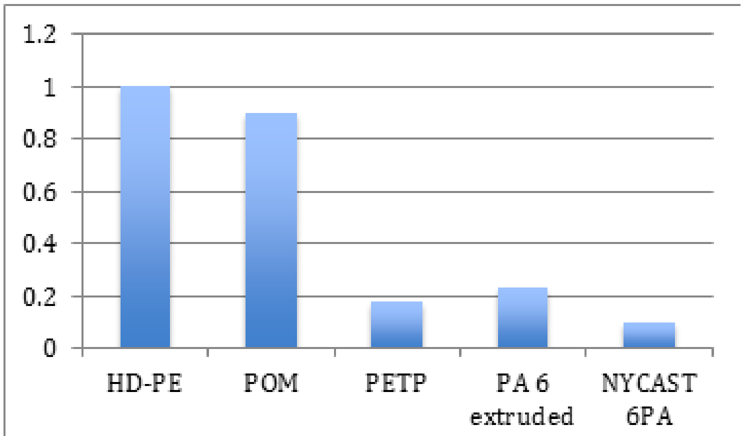


Chart: relative friction wear of different materials (pin on disc test)

Sliding properties

Unlubricated NYCAST® material has relative low coefficient of friction and has been used widely in the industry, enhanced and impregnated with oil NYCAST® NYLOIL® offers outstanding sliding properties for multiple applications such as wear pads for crane booms.

Machinability

NYCAST® materials can be easily machined on equipment used to machine wood or metals. Due to reduced machining times in comparison to metals NYCAST® materials can be price competitive.

The grades CNL is offering are available in a variety of different shapes, plates, rods, rectangular bars, tubes and near net shape castings. All shapes come in multiple sizes, special sizes upon request.

Shapes:

- Plates

	plate sizes			
thickness	24 x 48	28 x 57	36 x 48	48 x 120
0.125				x
0.25	x	x	x	x
0.375	x	x	x	x
0.5	x	x	x	x
0.625	x	x	x	x
0.75	x	x	x	x
0.875	x		x	x
1	x	x	x	x
1.25	x	x	x	x
1.5	x	x	x	x
1.75	x	x	x	x
1.875	x	x	x	x
2	x	x	x	x
2.25	x			x
2.375	x			x
2.5	x			x
3	x			x
4	x			x
6	x			
8	x			

Other dimensions and sizes upon request

- Rods

OD	rod length		
	24"	48"	120"
1.000	x	x	x
1.250	x	x	x
1.375	x	x	x
1.500	x	x	x
1.750	x	x	x
1.875	x	x	x
2.000	x	x	x
2.250	x	x	x
2.500	x	x	x
2.750	x	x	x
3.000	x	x	
3.250	x	x	
3.500	x	x	
3.750	x	x	
4.000	x	x	
4.250	x	x	
4.500	x	x	
4.750	x	x	
5.000	x	x	
5.250	x	x	
5.500	x	x	
5.750	x	x	
6.000	x	x	
6.250	x	x	
6.500	x	x	
6.750	x	x	
7.000	x	x	
7.270	x	x	
7.500	x	x	
8.000	x	x	
8.250	x		
8.500	x		
9.000	x	x	

OD	rod length		
	24"	48"	120"
10.00	x	x	
10.25	x		
10.50	x		
11.00	x	x	
11.50	x		
11.75	x		
12.00	x	x	
12.25	x		
12.50	x		
13.00	x		
14.00	x		
14.50	x		
15.00	x		
16.00	x		
17.00	x		
18.00	x		
19.00	x		
20.00	x		
21.00	x		
21.50	x		
22.00	x		
23.00	x		
24.00	x		
25.00	x		
26.00	x		
27.00	x		
27.50	x		
28.00	x		

- Tubes

Nominal OD	Min. ID	Max. ID	21"	length 26"	39"	52"
2.000	0.75	1.5		x		x
2.250	0.75	1.75		x		x
2.500	1.00	2		x		x
2.750	1.00	2.25		x		
3.000	1	2.5		x		x
3.250	1	2.75		x		x
3.500	1	3		x		
3.750	1	3.25		x		
4.000	1.5	3.5		x		x
4.250	1.5	3.75		x		x
4.500	1.5	4		x		x
4.750	1.5	4.25		x		
5.000	3	4.5		x	x	x
5.250	3	4.75		x	x	
5.500	3	5		x	x	x
5.750	3	5.25		x	x	
6.000	3	5.5		x	x	x
6.250	3	5.75		x	x	
6.500	2.75	6		x	x	x
6.750	3	6.25		x	x	
7.000	3	6.5		x	x	
7.500	3	7		x	x	
8.000	4	7.5		x	x	x
8.500	4	8		x	x	
9.000	4	8.5		x	x	
9.500	4.5	9		x	x	
10.000	5	9.5		x	x	
10.500	5	10		x	x	
11.000	5	10.5		x	x	
11.500	6	11		x	x	
12.000	6	11.5		x	x	
12.500	6	12		x	x	
13.000	6	12.5	x	x	x	
13.500	6.5	13	x	x	x	

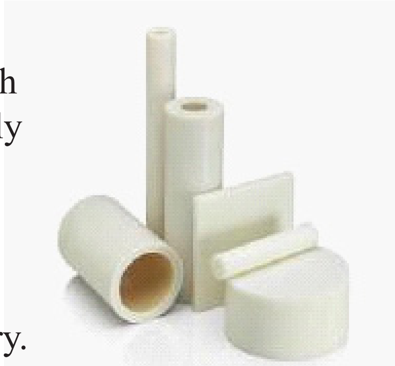
Nominal OD	Min. ID	Max. ID	length 26"
15.500	7.5	15	x
16.000	8	15	
16.500	8.5	16	x
17.000	9	16.5	x
17.500	9.5	17	
18.000	10	17.5	
18.500	10.5	18	x
19.000	11	18.5	
19.500	11.5	19	
20.000	12	19	x
20.500	16.5	19.5	x
21.000	17	20	x
21.500	17.5	20.5	
22.000	18.0	21	x
22.500	18.5	21.5	
23.000	19	22	
23.500	19.5	22.5	
24.000	20	23	
24.500	20.5	23.5	x
25.000	21	24	
25.500	21.5	24.5	x
26.000	22	25	
27.000	22.5	25.5	x
28.000	23	26	x
29.000	23.5	26.5	
30.000	24	27	
31.000	24.5	27.5	
32.000	26	28	
32.500	26.5	28.5	x
33.000	27	29	
34.000	27.5	30	
35.000	28	30.5	
36.000	28.5	31	x
37.000	29	31.5	
38.000	29.5	32	

- Rectangular bars

- Width from 4”to 20”
- Thickness from 4”to 16”
- Length up to 132”

4.1 Standard Grades

NYCAST® 6PA Natural & black



Cast Nylons standard grades have delivered successful perfoman with and without lubrication- in a wide variety of applications, particularly as a bearing material. They are light weight, offer extremely good wear resistance, high tensile strength and high module of elasticity.

This material is an off white unmodified type 6 nylon which is FDA, USDA, and 3A – dairy compliant and can be used in the food industry.

Cast Nylons Limited offers NYCAST 6PA Natural in more standard sizes that any manufacturer in the industry. The ability to cast nylon vs. extrusion allows Cast Nylons Limited to create custom Near Net Shapes with ease for special applications.

Cast Nylons Limited also has the capability to produce type 6 nylon in 12 different colors. Custom colors are available as well.

Typical applications for NYCAST 6PA Natural would include:

- Bearings
- Gears
- Pulleys
- Sheaves
- Wear Shoes
- Components in Food Processing Industry
- Wear Pads
- Valve seals
- Sprockets
- Wear Plate
- Thrust Washers

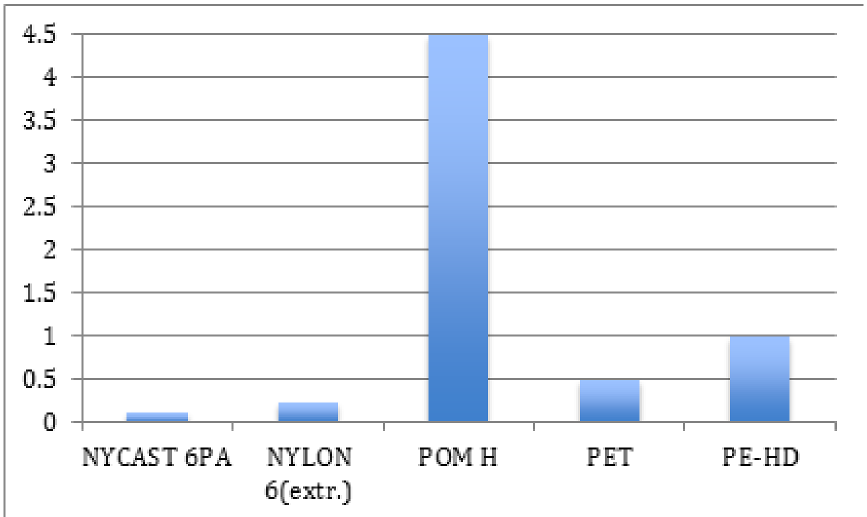


chart: wear factor of different polymers (condition: unlubricated, steel roughness 2um, v= 0.6m/s, P= 26psi)

NYCAST® 6PA MoS2

NYCAST 6PA MoS2 is manufactured to be a more crystalline product with improved wear resistance, improved compressive strength, and to be a popular choice as a dry lubricant -filled bearing material.

Cast Nylons Limited offers this material in more standard sizes than any manufacture in the industry. The ability to cast nylon vs. extrusion allows Cast Nylons Limited to create custom Near Net Shapes with ease for special applications

- Bearings
- Gears
- Pulleys
- Sheaves
- Wear Shoes
- Wear Pads
- Valve seals
- Sprockets
- Wear Plate
- Thrust Washers

NYCAST® XHA blue

Cast Nylons Limited offers a heat stabilized cast nylon 6. The heat stabilizer retards the loss of physical properties as temperature increases This allows the material to function at approximately 10% higher temperatures than standard grades; meaning NYCAST XHA operating at 2000F (930C) will have approximately the same physical properties as a standard material at 1850F (850C). This material has delivered successful performance throughout the years.

The main advantages of NYCAST XHA blue are:

- Can work at higher operating temperatures
- Retains physical properties under higher temperatures
- Light weight
- Excellent abrasion and wear resistance
- Easy to machine

4.2 Premium Grades

NYCAST® NYLOIL®

Only NYLOIL from Cast Nylons Ltd. offers three grades of self-lubricating Nylon bearing material tailored to meet your specific application. A cast nylon with built-in oil lubrication, NYLOIL provides superior machinability, performance, and durability compared to other plastic and traditional bearing materials. Three grades of NYLOIL are available to fit the most demanding applications: original green NYLOIL for most bearing applications; food-grade, Natural NYLOIL-FG for direct contact with food; and MoS2 filled Gray NYLOIL-MDX with slightly higher compressive load capabilities than original NYLOIL.

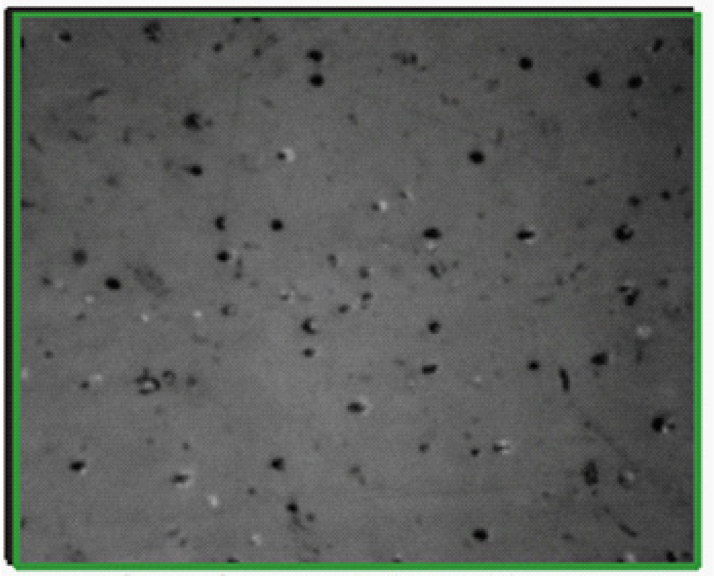
The incorporation of an oil lubricant package into the nylon matrix provides significant advantages over other bearing materials:

Lubrication results in 25% lower coefficient of friction than other grades of nylon

Performs in harsh environments where lubrication is difficult, impossible or not desirable (food contact)

- Works successfully in marine applications.
- Reduced water absorption promotes higher dimensional stability.
- Works and machines as easily as brass.
- Oil will not spin out, dry out, or drain out, even under the harshest operating conditions.

• During NYLOIL's manufacturing process, an oil lubricant package is completely dispersed within the cast nylon matrix, making it an integral part of the casting's structure.



350x Magnification of NYLOIL sample showing oil dispersion.

Although not evident by sight or touch, the oil lubricant in NYLOIL is always at the surface regardless of the amount of material removed during finish machining or normal wear.

NYLOIL-FG is a self lubricating nylon bearing material which meets the provisions of FDA Regulations 21 CFR, Section 177.15 (and others) and USDA 3A Sanitary Standards 20-17 for direct contact with food. This is a particularly useful material where additional lubrication is not desirable because of clean ability, contamination, or other considerations.

Gray NYLOIL-MDX is formulated with Molybdenum Disulfide filler, which promotes higher crystallinity in the cast polymer, in addition to the oil lubricant package. This yields a bearing material with more consistent intermolecular structure and generally a narrower distribution within the range of physical property values, while retaining the advanced friction properties of unfilled NYLOIL

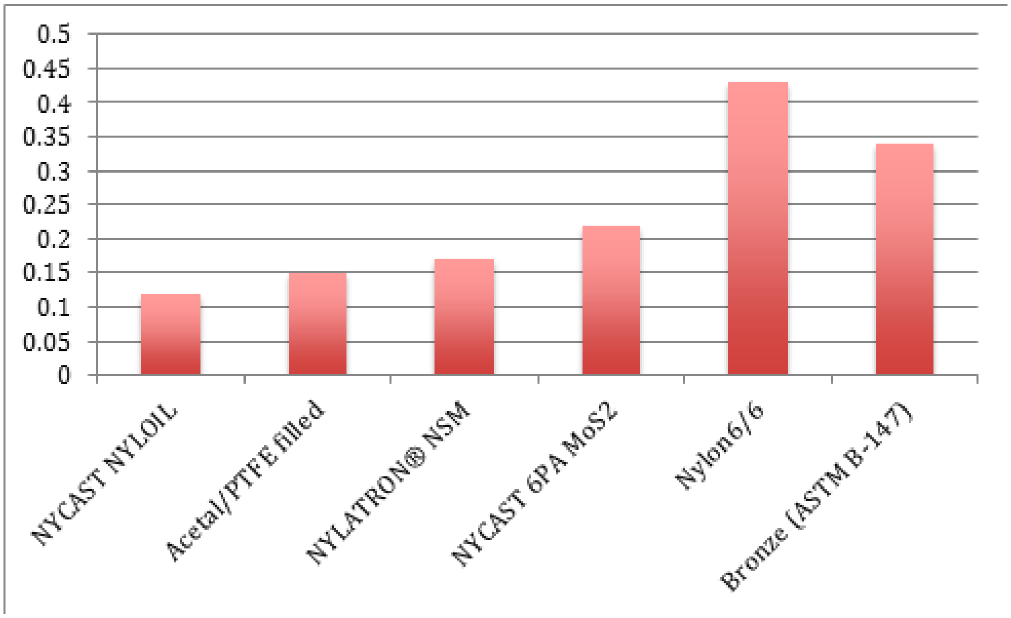
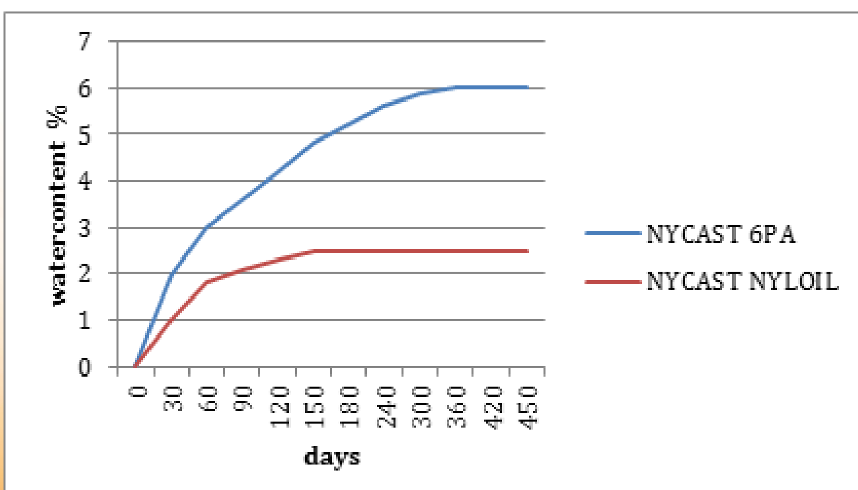
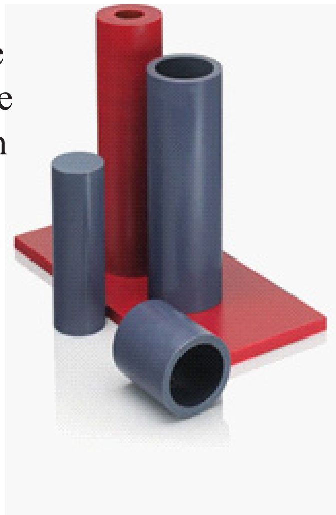


Chart 1: comparison coefficient of friction different materials, measured on thrust washer testing machine, unlubricated @ 40 fpm and 50 lb/in2

Dimensional Stability

With their higher crystallinity, all NYCAST products exhibit improved dimensional stability compared to their extruded nylon counterparts. But NYLOIL provides even better dimensional stability than regular grades of cast nylon: Its oil droplets fill gaps in the amorphous structure of the polymer, allowing less room for water to be absorbed into these areas. The moisture absorption graph shows that despite a slow absorption rate, NYLOIL stabilizes at approximately 2.5% moisture content - less than half the moisture content of other unfilled nylons.





NYCAST RX (red), NYCAST GX (grey) and NYCAST BX (black) are our solid lubricant-filled cast nylons. This material is designed to provide low coefficient of friction with superior wear resistance, making them an excellent choice for high-load, low-speed applications.

- Low coefficient of friction
- Good sliding properties at low speed
- Good wear resistance
- High young’s modulus
- Easy to machine

NYCAST® SLX

NYCAST SLX joins the NYCAST family of premium bearing grades as an engineering and design solution for bearing and wear applications. NYCAST SLX closes the gap between static and dynamic coefficients of friction with superior performance where customers require the best material for overcoming “stick-slip” tendencies.

Unlike the competition, Cast Nylons Limited offers SLX in all our standard stock shape configurations. We never limit your design to only a few options. This is one more reason to put the NYCAST Advantage to work for you.
Manufactured with a proprietary lubrication package, NYCAST SLX is available as plate up to 4” thick, rod up to 12” diameter, and tubular bar up to 40” diameter.

4.3 Impact Modified Grades

NYCAST® CP 6/12

Highly resilient, with higher tensile elongation and impact strength than standard grades, NYCAST CP has proven itself in many applications requiring an extra degree of toughness. A copolymer of caprolactame and laurinlactame, NYCAST CP was originally developed specifically for use in ball valve seats in the oil and gas industry. This durable material provides an economical, high-performance bridge between NYCAST 6 and NYCAST 12 formulations.

NYCAST CP with its higher elongation, superior dimensional stability and safety yellow color has found itself a superior choice for wobbler box inserts and coupling boxes in the cold rolling steel industry as well as mandrels covers used in paper tube manufacturing plants.

- High impact resistance
- High tensile elongation
- Reduced water absorption
- Lower hardness
- Easy to machine

NYCAST® CP 6PA MP (MPB) blue & (MPY) yellow

Designed to address the problems associated with impact loads, NYCAST 6MP formulations provide performance advantages in applications that require improved impact properties over standard grades. NYCAST 6MP cushion pads protect the hammer from metal-to-metal damage in pile drivers and provide many performance advantages in certain gear, die block, valve seat and other applications. This formulation also provides superior performance in extreme cold ten ,
where standard grades are prone to impact failure.

- High impact resistance
- High tensile elongation
- Resistance to brittleness and deterioration
- Can work under low temperature circumstances
- Noise dampening

NYCAST® 12

With its extremely low moisture absorption, the mechanical properties of NYCAST 12 remain virtually unaffected in a wide range of environments. NYCAST 12 offers superior performance in applications where dimensional stability, chemical resistance, dielectrics, abrasion resistance and impact strength are important factors. In wet or dry environments, indoor or outdoor, the low deformation and superior fatigue resistance properties of NYCAST 12 delivers unmatched performance in many high-speed wheel and roller applications.

This material is also well suited to use for power transmission components in material handling and transportation environments, as well as in structural and enclosure elements in sensitive electronic and manufacturing equipment.

Cast Nylons Limited is the only producer of cast nylon 12 in North America.

- High impact resistance
- Low moisture absorption
- Excellent chemical resistance
- Low creep factor
- Excellent dimensional stability

4.4 FDA Compliant Grades

NYCAST® 6 PA FG

Cast Nylons Limited offers FDA compliant grades. NYCAST 6PA FG can be in direct contact with foods. The material offers high wear resistance and is an ideal substitute for stainless steel wherever lubrication is not a concern.

If you need a lubricated material please look at our NYCAST NYLOIL FG.

Cast Nylons is offers NYCAST 6 FG in various colors.

- Food compliant according to FDA 21 CFR § 177.1500
- Excellent vibration resistance
- Resistance to brittleness and deterioration
- Easy machinability and abrasion resistance
- Good chemical resistance

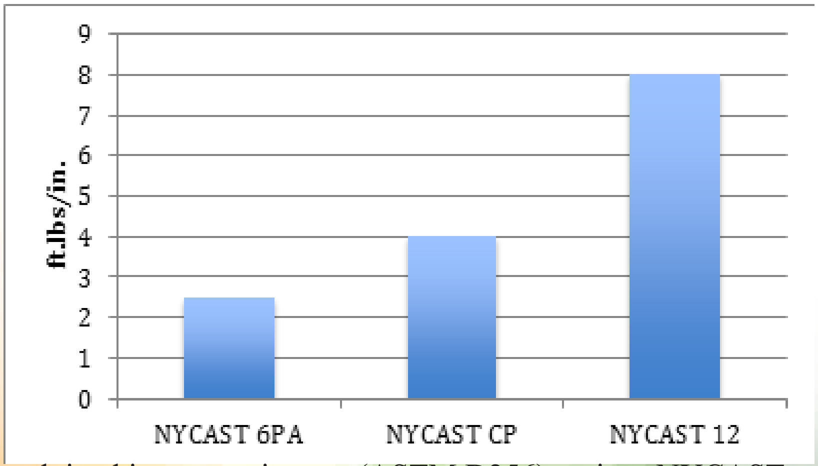


chart: notch izod impact resistance (ASTM D256) various NYCAST grades

NYCAST® NYLOIL® FG

Cast Nylons Limited offers a FDA compliant oil filled Cast Nylon 6. This material can be in direct contact with foods. High wear resistance combined with low moisture absorption and good resistance against most cleaning agent's makes this material a prefect substitute for stainless steel. The incorporated oil enables most applications to run without additional lubrication. Multiple color options are available.

- Food compliant according to FDA 21 CFR § 177.1500
- Excellent vibration resistance
- Resistance to brittleness and deterioration
- Easy machinability and abrasion resistance
- High heat distortion temperature
- Withstands chemicals used to wash down equipment

4.5 Special Grades

NYCAST® 12

With its extremely low moisture absorption, the mechanical properties of

NYCAST 12 remains virtually unaffected in a wide range of environments.

NYCAST 12 offers superior performance in applications where dimensional stability, chemical resistance, dielectrics, abrasion resistance and impact strength are important factors. In wet or dry environments, indoor or outdoor, the low deformation and superior fatigue resistance properties of NYCAST 12 delivers unmatched performance in many high-speed wheel and roller applications.

This material is also well-suited to use for power transmission components in material handling and transportation environments, as well as in structural and enclosure elements in sensitive electronic and manufacturing equipment.

Cast Nylons Limited is the only producer of cast nylon 12 in North America.

- High impact resistance
- Low moisture absorption
- Excellent chemical resistance
- Low creep factor
- Excellent dimensional stability

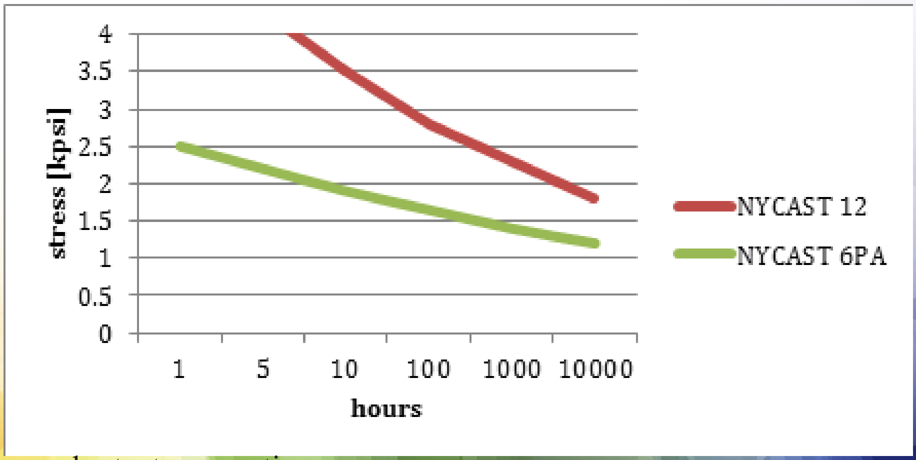
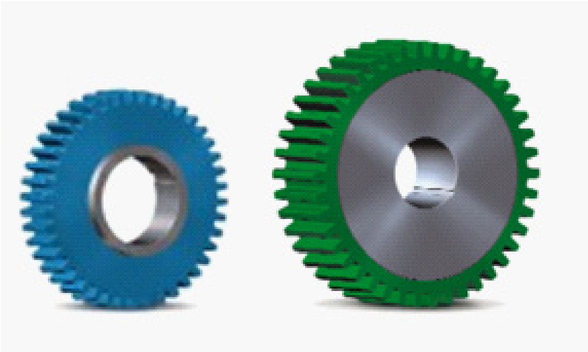


chart: stress vs. time

Cast Nylons Ltd., the largest independently- owned North American manufacturer of cast nylon, has combined the best of both worlds – cast nylon and metal – to produce its NYMETAL composite.



NYMETAL billets made exclusively with NYCAST nylon and a variety of metal cores, are available for use in manufacturing gears, rollers, and sprockets primarily for power transmission. By combining the performance advantages of nylon and metal into one cohesive unit, NYMETAL offers advantages that cannot be obtained from traditional all metal or all nylon components.

NYMETAL advantages

Whether you are considering a new application or redesigning an existing one, you should consider the NYMETAL advantages. NYMETAL is manufactured from the highest quality cast nylon available in North America. The nylon is bonded to metal cores using a proprietary process, producing nylon to metal interface that stands up to the toughest engineering applications. This bond far exceeds the performance of mechanically bonded thermoplastic to steel components. NYMETAL billets can be made with various NYCAST grades (including food-grade materials)

The use of cast nylon produces a quiet running part, good vibration dampening, shock absorption, reduced part weight, longer wear, and the ability to reduce or eliminate lubrication.

The metal core provides optimum strength in the bore for power transmission and keyway integrity. All these advantages can be delivered at cost competitive prices.

NYMETAL applications

NYMETAL billets can be manufactured into many different components, including gears of all types, rollers, sprockets, and augers. If you have a difficult power transmission application, NYMETAL may provide you with the required solution. If you work in the food processing industry, NYMETAL with NYLOIL FG on stainless steel can offer you a food grade solution that is FDA, USDA and 3-A compliant.

Torque testing

The torque-testing fixture determines the amount of torque required to separate the steel core from the NYCAST outer rim. The NYMETAL part is mounted in the fixture body and the torque arm is attached to the steel core. The fixture is mounted in a hydraulic press and force applied to the torque arm which induces rotation of the steel core within the NYCAST rim. Note that the torque arm applies force equally to both sides of the specimen, eliminating any bending moment created by a single torque arm attached to only one side of the specimen. A load cell positioned on the torque arm accurately measures applied force from which torque values are determined. Torque capability at the nylon/metal interface is critical to successful NYMETAL part performance. Testing has shown that torque values in NYMETAL parts are more than double those of nylon shrunk or press fit onto steel cores and up to 20 times greater than the torque transmission capabilities of gear teeth machined into the nylon rim. This superior bond allows engineers to approach NYMETAL gear application switch confidence, knowing that they have the strength of a metal core with the advantages of a NYCAST nylon rim and no loss of part integrity at the interface.

Design Guidelines

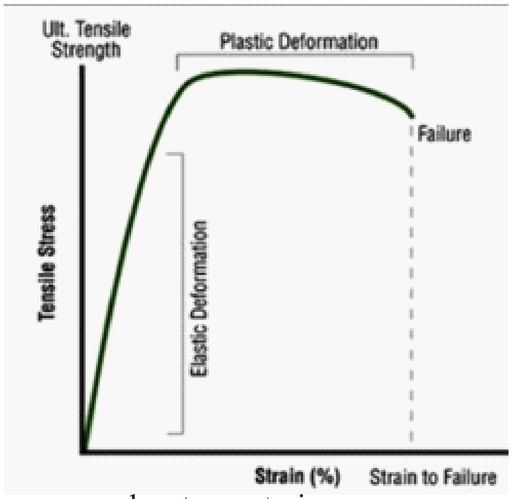
Distributed by: Polymershapes

5. Design guidelines

Designing plastic materials, their shapes and machining follows the general rules of metal designing but special behaviors of plastic material have to be taken into consideration.

- Elastic- and visco-elastic behavior
- Thermal properties
- Dimensional stability
- Energy absorption on sudden impact

The elastic behavior of plastic materials differs from metals and can be seen in the stress-strain curve. The stress-strain curve describes the deformation at distinct intervals of tensile or stress. It is unique for each material.



example: stress-strain curve

The thermal behavior of plastic material is dependent on the class of polymer, thermoplastic, thermoset or elastic. Thermoplastic materials, such as cast nylon 6 have various unique behaviors, which should be considered:

- Coefficient of thermal expansion

Cast Nylon 6 expands about 4 times more than aluminum and 7 times more than steel

- Continuous service temperature

The continuous service temperature of polymer materials are well below of metals. This value is defined as the temperature above the material degrades over time

- Heat deflection temperature

The heat deflection temperature, also called heat distortion temperature describes the temperature at which the polymer deforms under a certain load

The dimensional stability of polymers is greatly dependent on the type of polymer. For cast nylon 6 some considerations have to be made:

- Dimensional changes due to thermal exposure

Cast Nylon 6 and Cast Nylon 12 do expand more than metals. This has to be taken into consideration for dimension and tolerances

- Dimensional change due to water absorption

Cast Nylon 6 can absorb up to 8% of water in weight. This results into an approx. dimensional change of 3%. Cast Nylon 12 absorbs only up to 1.5% water. The maximum change due to water absorption is 0.5%

Impact strength, energy absorption under sudden impact

The impact resistance is a very important factor for the structure of a part and depends on the material. The impact resistance is the ability of a material to absorb energy during plastic deformation. For thermoplastic materials such as cast nylon 6 and 12 the impact resistance is also dependent on the temperature and the moisture content.

All these unique behaviors of the polymer material have to be taken into account upon design of parts. All applied loads and environmental circumstances should be known to perform a good design of a part.

5.1 Bearing design

Nylon materials intended for bearing applications with or without lubrication must be designed with consideration of the individual physical characteristics and operating conditions of each actual requirement. The design data below is provided as an introduction to nylon bearing design. It is suggested that actual field-testing be conducted under proper environmental conditions.

PV Value

The frictional build-up of heat is a major consideration in the design of nylon bearings.

The two significant factors that affect heat generation are unit pressure (P) and surface velocity (V). Pressure velocity (PV), therefore, is the product of unit pressure and surface velocity. Surface velocity for sleeve-type bearings can be computed using the following:

$$V = 0.262 \times rpm \times D$$

Rpm represents shaft revolutions per minute, and D is the shaft diameter in inches.

Pressure can be computed for flat bearing units by dividing the total load in pounds by contact area expressed in square inches:

$$P = \text{Total Load} / \text{Contact Area}$$

For sleeve bearings, the total load is divided by the projected area of the bearing surface (bearing I.D. in inches x bearing length in inches). Once pressure and surface velocity are known, PV can be determined by using the following:

$$PV = P \times V$$

Now that the PV has been determined for the application, it must be checked against the PV limits for NYCAST materials as listed in the following chart.

Limiting PV Values

	unlubricated	continuously lubricated
NYCAST 6PA-Natural	3,600	14,000
NYCAST XHA blue	3,600	14,000
NYCAST 6PA-MoS2	3,600	14,000
NYCAST NYLOIL	16,000	16,000
NYCAST NYLOIL MDX	16,000	16,000
NYCAST RX/GX/BX	16,000	16,000

Note: max P for dynamic bearings is 2,000 psi, max V is 400 fpm

Ambient temperature correction

When the ambient temperature is higher or lower than 75°F, the PV capabilities change. The following graph indicates the relationship between ambient temperatures and the necessary PV modifications. From the graph below, establish the Ambient Temperature Correction Factor for the bearing operating environment temperature and multiply this value by the limiting PV for the material being used. The value obtained is the actual limiting PV value for the application in question. For a NYCAST NYLOIL bearing operating in a 150°F environment, the temperature correction factor would be 0.7, multiplying 16,000 x 0.7 produces a new limiting PV value of 11,200.

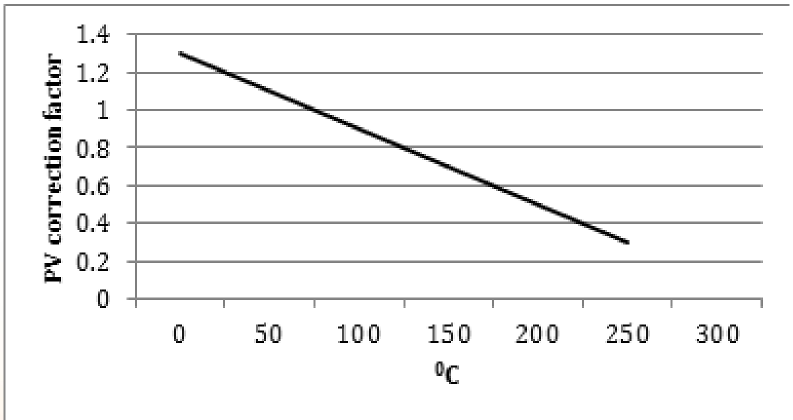


chart: ambient temperature correction factors

Basis Nylon bearing design

Nominal wall thickness

In the design of new equipment, the engineer has some latitude in establishing nominal wall thickness. For bearings that will be subjected to severe impact, maximum walls are suggested, while minimum walls can be used for bearings that operate near the material's maximum recommended PV.

Nominal wall thickness is the difference between shaft diameter and the housing I.D. divided by 2.

Bearing Shape

The ratio of bearing length to shaft diameter has an important effect on the coefficient of friction. For a bearing with a ratio of one (bearing length equal to shaft diameter), the coefficient is generally lowest. As the bearing length increases to two or three times the diameter of the shaft, the probability of localized heating increases due to slight shaft vibration and out- of-roundness.

Clearance

Because the clearances required for nylon bearings are larger than those normally required for metal bearings, attention to proper clearances is one of the most important factors in bearing design. Most premature nylon bearing failures occur because of insufficient initial clearance that results in seizure on the shaft and even melting of the bearing. Because of the self-dampening nature of nylon materials, the increased clearances required do not result in shaft vibration or scoring of the bearing. Total running clearance can be calculated by adding the basic shaft allowance (C1), the wall thickness allowance (C2), the press fit allowance (C3), and, if applicable the moisture expansion allowance (C4). This running clearance is then added to the shaft diameter to obtain an actual I.D. for the bearing. For press fit bearings, the O.D. should be machined to the nominal I.D. of the housing plus the press fit allowance (C3).

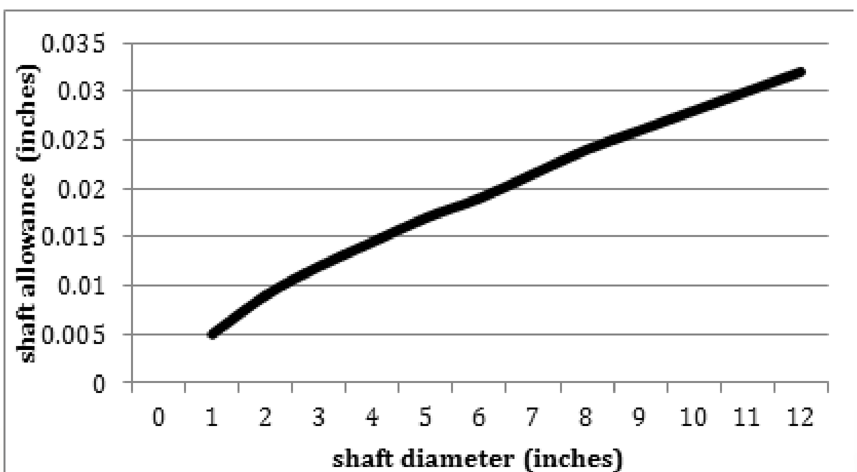
Machining Tolerance

Proper running clearances for bearing I.D. and O.D. can be assured by holding tight machining tolerances. It is recommended that I.D.s be machined to plus best commercial tolerance, minus 0.00 inches. O.D.s should be machined to plus or minus best commercial tolerance.

Lubrication

Except where dry applications are required (as in some food and textile machinery), lubrication should always be used. The lubrication of the nylon bearing results in a higher PV limit on sliding parts when compared to dry operation. Any general-purpose grease or oil can be used, providing that they do not contain acids. Acid containing lubricants cause a swelling of the nylon material, which decreases the clearance and can cause seizure on the shaft. An initial start-up application of grease or oil will facilitate bedding-in and increase both bearing performance and life, even if no further lubricant is provided during operation.

C1 shaft allowance



shaft allowance C1 is the normal running clearance required on bearing I.D.

C2 Wall thickness allowance

Material	average bearing temp.	1/8"	1/4"	3/8"	1/2"	5/8"	3/4"	1"	1-1/4"	1-1/2"
All Nycast materials (operation in normal surroundings at 50% RH)	75°F	0.002	0.004	0.006	0.007	0.009	0.011	0.015	0.019	0.022
	100°F	0.002	0.004	0.006	0.008	0.010	0.012	0.016	0.02	0.024
	125°F	0.002	0.004	0.007	0.009	0.011	0.013	0.018	0.022	0.027
	150°F	0.002	0.005	0.007	0.009	0.012	0.014	0.019	0.024	0.028
	175°F	0.002	0.005	0.007	0.010	0.013	0.016	0.021	0.026	0.031
	200°F	0.003	0.006	0.008	0.011	0.014	0.017	0.023	0.028	0.034
	225°F	0.003	0.006	0.009	0.012	0.015	0.018	0.024	0.03	0.036
	250°F	0.003	0.006	0.009	0.013	0.016	0.019	0.026	0.032	0.039

(data given is for bearings with ends free to expand. When ends retained, increase value by 50%)
C2 is the clearance required in the bearing I.D. to allow for expansion of the bearing wall during operation

C3 Press fit allowance

Press fit allowance C3 is added to bearing I.D. when bearing is pressed into housing. When NYCAST materials are pressed into a housing the bearing experiences close-in. C3 added to the bearing I.D. allows for the close-in

C4 Moisture expansion allowance (submerged/water lubricated applications only)

Bearing wall thickness (inches)	1/8"	3/16"	1/4"	3/8"	1/2"	3/4"	1" and over
C_4	0.012	0.017	0.021	0.026	0.03	0.032	0.0333

figures shown represent maximum bearing I.D. closure as a result of bearing wall expansion for full moisture saturation and must be added to bearing I.D. for correct clearance.

5.2 Roller/ wheel design

Polymer wheels and rollers are used widely in the industry. Besides the soft polyurethane rollers for many high load applications thermoplastic wheels are used. They offer great benefits over existing metal wheels and castors. Some of the main advantages for NYCAST wheels and rollers are:

- Protective to tracks
- Wear resistant
- Corrosion resistant
- Quite running
- Vibration dampening

When designing NYCAST wheels or castors the relative lower young's modulus vs. metals has to be taken into consideration. Due to the lower elasticity modulus NYCAST wheels do deform under pressure. If the load remains in permitted range this deformation is reversible and the wheel comes quickly to its original shape. This enables the material to provide more surface to the track under same load conditions, the specific pressure is less than with metal wheels and the track is protected better from damage.

NYCAST 6PA and NYCAST 12PA can be used for wheel and roller applications. For higher load applications NYCAST 12PA is the preferred material.

Design

There are multiple designs for wheels and rollers, depending on the application. The running surface can be shaped according to the track if needed. The NYCAST wheels can be designed to run directly on the shaft, use a friction bearing or are fitted with a roller bearing. Please consult our engineers for your special request.

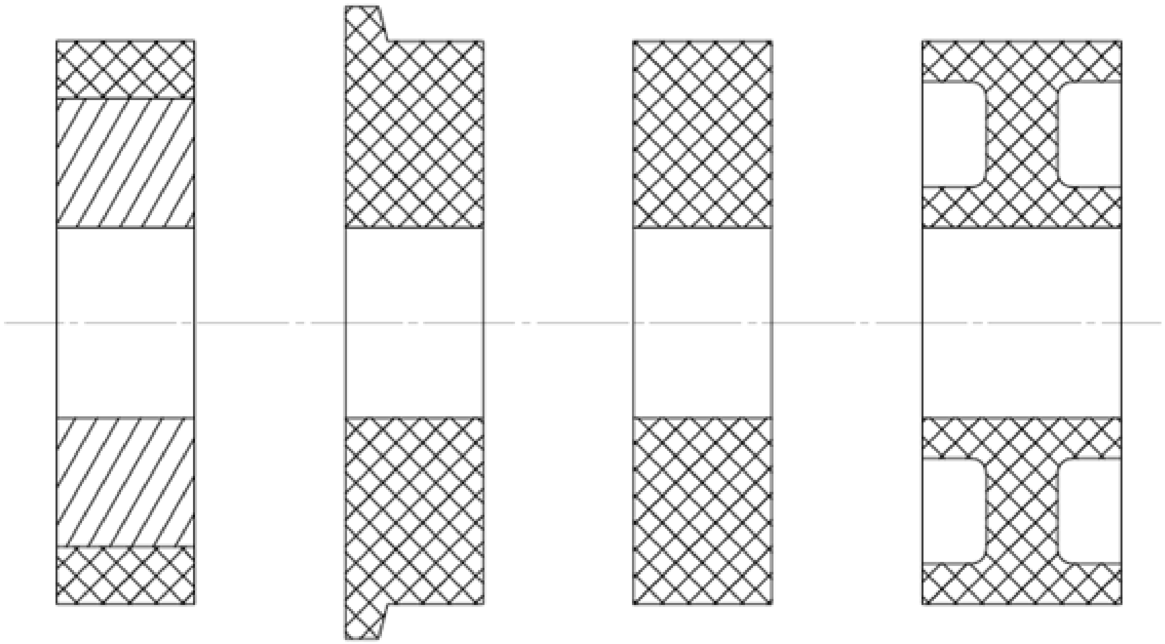


figure 1: common wheel design

Calculation guidelines

To calculate the load capacities for NYCAST wheels the visco-elastic behavior has to be considered. Under static load the material has a tendency to creep. This creep behavior increases with temperature and moisture content. This means that under this circumstances the running surface of the wheel can flatten and upon start the eccentricity will quickly go back into its original shape. If the permitted load is exceeded, a permanent deformation can occur. Therefore calculation of NYCAST wheels should be performed sourly.

The Hertzian relationship cannot be used as standard for calculating NYCAST wheels and rollers because they do not fulfill all criteria for this approach.

With different design of wheels and tracks different calculations occur. As an example for a calculation we will use a cylindrical flat wheel on a flat track.

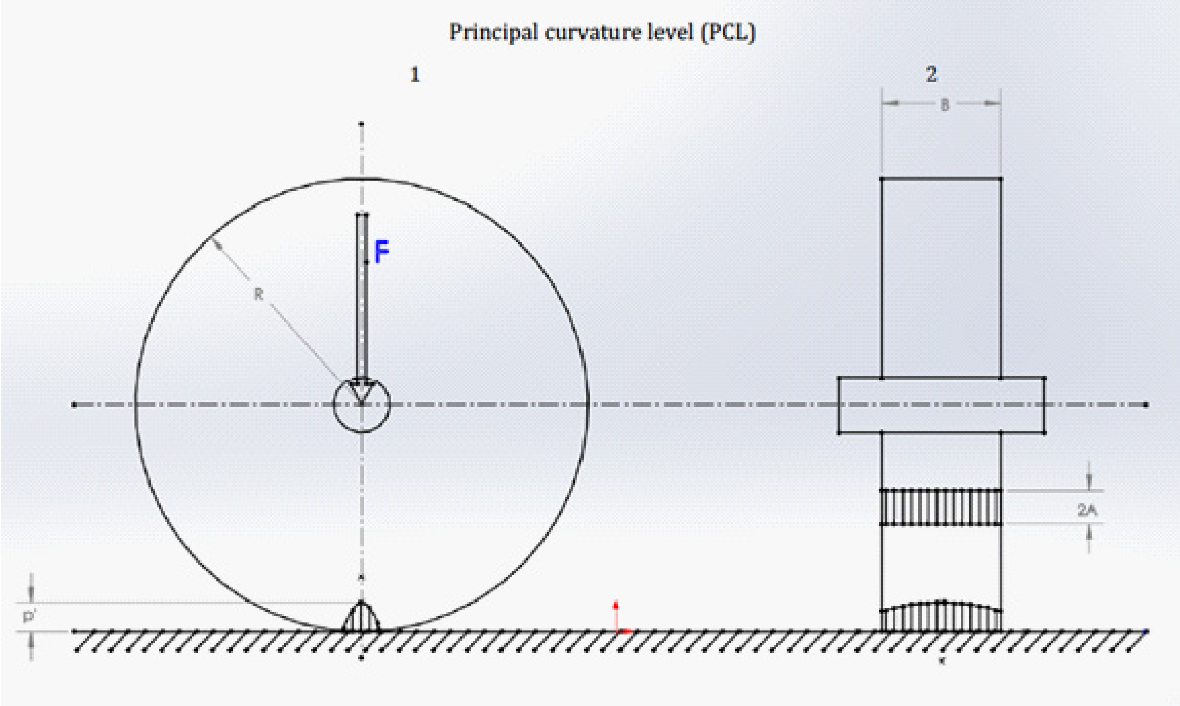


Figure 2: flat wheel on flat track

With an applied load a projected contact area of the wheel is formed and can be described as: 2A x B, with the compression distributed in a hemi ellipsoidal form. The stress increases at the edges of the wheel, which is generated by shear stresses that occur across the running direction. The visco-elastic behavior of the NYCAST material is the reason for this. Assuming the track material has a much higher module of elasticity (normally metal tracks) and the radii in the principle curvature

level (PCL) are infinite we can calculate the compression factor p' as follows:

F = wheel load in N

B = wheel width in mm

R= wheel radius in mm from PCL 1

fw= material factor NYCAST 25.4

With the static load capacity been calculated it has to be determined if the wheel can operate at given loads and temperatures.

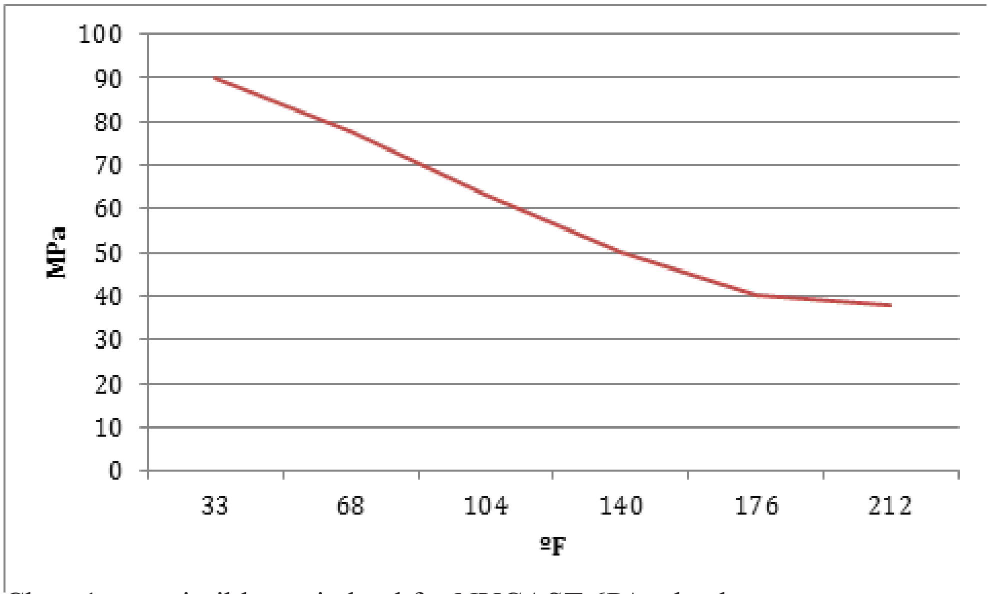


Chart 1: permissible static load for NYCAST 6PA wheels

The chart below exhibits the permissible loads for running speeds up to 5m/sec for wheels with ball bearings.

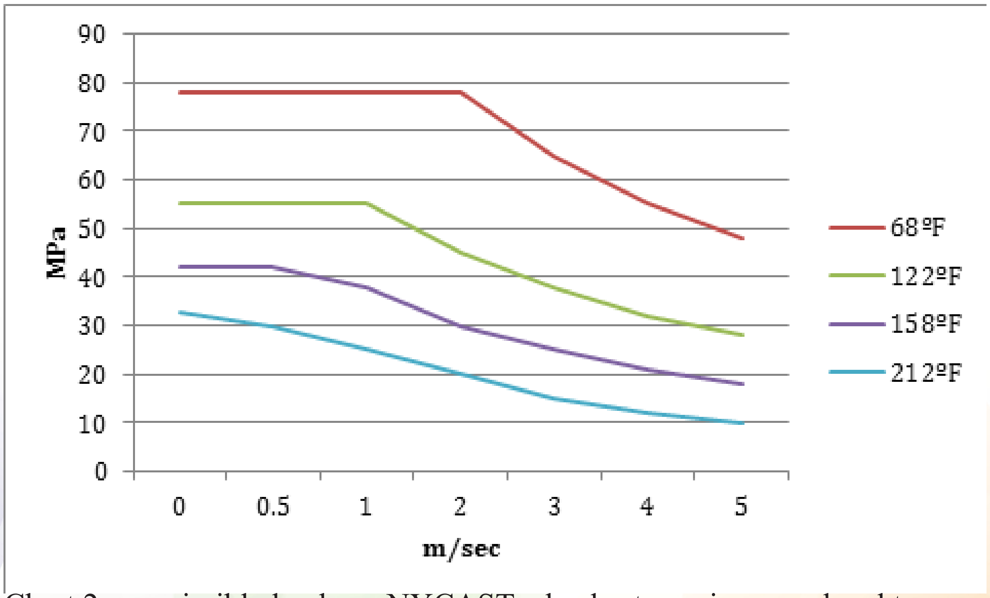
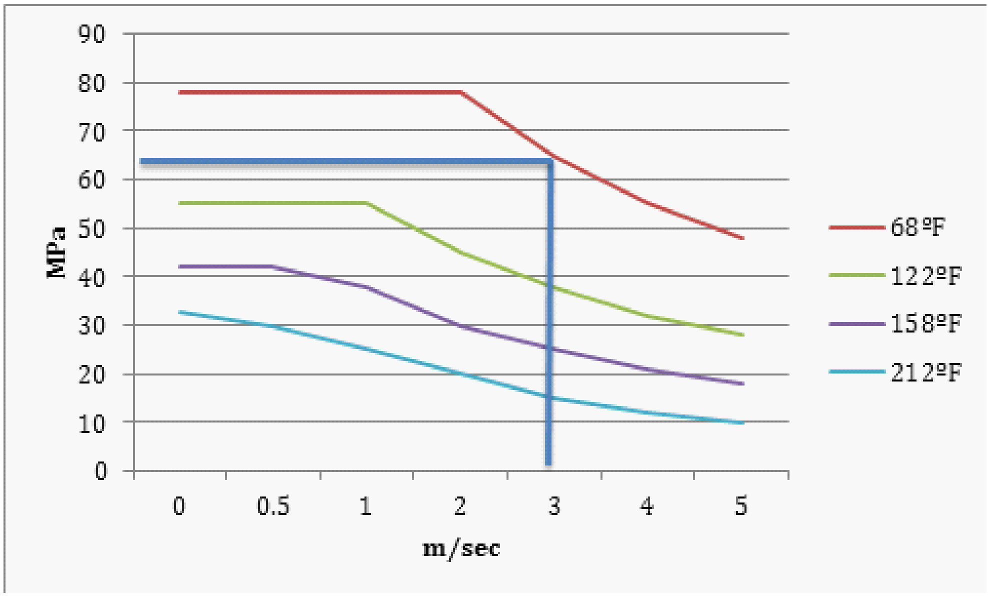


Chart 2: permissible loads on NYCAST wheels at running speed and temperature

At 680F the permissible load is 78 MPa.

To determine the permissible loads at a speed of 3m/sec and 680F we go to chart 2

In the chart we go to the graph at 68ºF and determine the permissible load at a running speed of 3m/sec.



The permissible load is 64 MPa at a running speed of 3m/sec and 68ºF

The results are :

Values at 680F	Calculated	Permitted
Static	51.82 MPa	78 MPa
Dynamic (3m/sec)	51.82 MPa (static)	64 MPa

Therefore a NYCAST wheel can operate under the given circumstances in the example.

5.3 Gear design

The use of plastic gears in the industry is becoming more common. Form small gears in plan-etraian gear drives in automotive to gears up to 7 feet (2 meters) in diameter in bottling industry, polymer gears offer great advantages:

- Dry running- no lubrication needed
- Maintenance free
- Noise dampening
- Vibration dampening
- Corrosion resistance

Especially the dry run operation facts become more important due to environmental rules.

Gear drive types

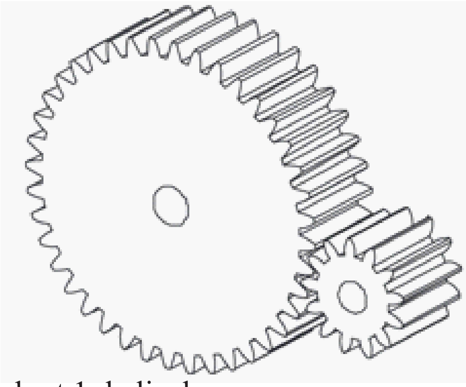


chart 1: helical gears

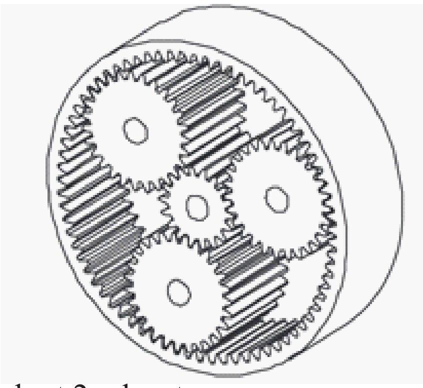


chart 2: planetary gear

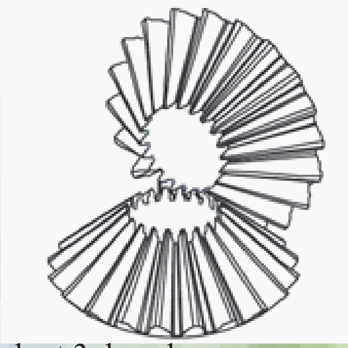


chart 3: bevel gears

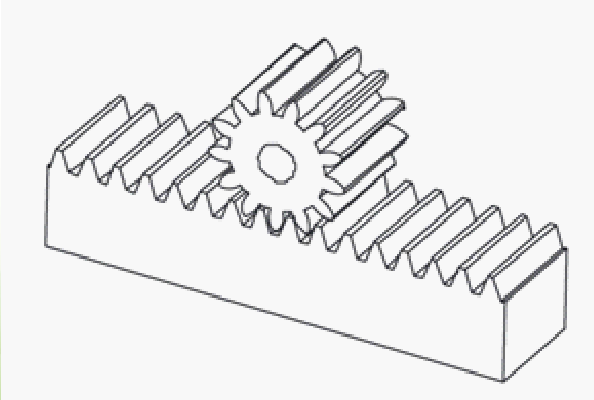


chart 4: rack and pinion gear

Material grades

Various CAST NYLONS material grades have been used for designing gears, depending on the application the following materials are used:

- NYCAST NYLOIL
- NYCAST 6PA MoS2
- NYCAST NYMETAL
- NYCAST 12

For more information concerning the design of NYCAST gears, please contact us.

5.4 Sheave design

NYCAST custom cast sheaves offer some very important advantages to the equipment designer searching for ways to reduce component

weights, improve service life, and provide protection against corrosive environments at a cost, which is competitive with other sheave materials.

NYCAST sheaves are custom formulated and cast from anionically polymerized Type 6 Nylon, yielding a technologically advanced part, free from localized stresses, which occur in most other plastics processing methods. In addition, NYCAST sheaves can be specifically formulated with modifiers and internal lubricant packages appropriate to the end use, which further enhance performance.

Advantage #1•Reduced Component Weight

NYCAST nylon castings are approximately one seventh the weight of cast steel sheaves of the same dimension, and approximately one-half the weight of aluminum sheaves. The use of NYCAST sheaves results in reduced dead weight at the end of a boom and thus increased working capacity, and lower inertial loads in operation.

Component weight reductions in the crane translate to lower gross vehicle weights, an important consideration in mobile crane design. Furthermore, reduced weight NYCAST sheaves are easier to handle during installation and replacement than their metallic counterparts.

Advantage #2 •Improved Service Life

NYCAST type 6 nylon custom cast sheaves not only provide exceptional durability and performance in demanding applications, but their unique combination of physical properties significantly improve wire rope life in operation. In addition to high tensile and compressive strength, NYCAST sheaves possess excellent toughness and high elongation properties normally associated with less-rigid, elastomeric materials. This provides a cushioning effect in the groove areas, which are in contact with the rope strands. This has proven to significantly extend wire rope life. Due to the visco-elastic behavior of NYCAST material the material deflects upon load on the rope and provides more surface contact area for the strands of the rope. (after load is released the material goes back into its original shape!) This behavior results in a significant reduction of contact pressure at the rope-groove interlace, almost 12 times less than a steel sheave in the same configuration. The resulting maximum pressure within the rope is reduced by 30%. The lifetime of the rope increases significantly. NYCAST nylon sheaves provide a cushioned bedding area for the wire rope, which translates into improved field performance, increased safety in operation, and reduced expense associated with wire rope replacement.

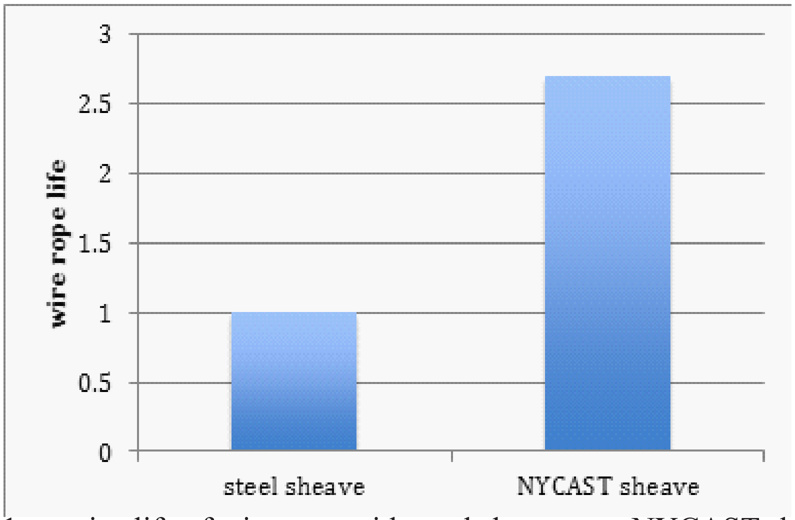


Chart 1: service life of wire rope with steel sheaves vs. NYCAST sheaves

Advantage #3- Corrosion Protection

NYCAST nylon sheaves are impervious to rust and salt water corrosion. This corrosion resistance is a property of the material itself, and does not rely on the integrity of a paint or similar thin coating applied to the sheave to maintain protection. In addition, NYCAST sheaves are resistant to attack from most organic chemicals including solvents, degreasers, and cleanup solvents.

Advantage #4- Custom Engineered

NYCAST sheaves can be produced in molds custom engineered to the application. This optimal design for service and production results in components, which outperform their metallic counterparts at a competitive cost. Custom designed molds reduce material waste in production, and NYCAST sheaves require minimal machining after casting to arrive at the finished part. Proper mold design also ensures that material properties are optimized and casting stresses are eliminated, resulting in a superior component.

NYCAST custom sheave design begins with an analysis of some basic key dimensions and load requirements. These are detailed on the sheave design Worksheet. CAST NYLONS LIMITED provides an experienced engineering staff in place to assist in the design of custom cast sheaves and components.

Design of custom cast NYCAST sheaves

NYCAST custom sheaves are designed to perform in all crane operations under all environmental circumstances. Weather it is high heat or humidity, combined with high loads and rope fleet angles, NYCAST custom sheaves are designed to work safely. Our design and material composition ensures the safety of the product.

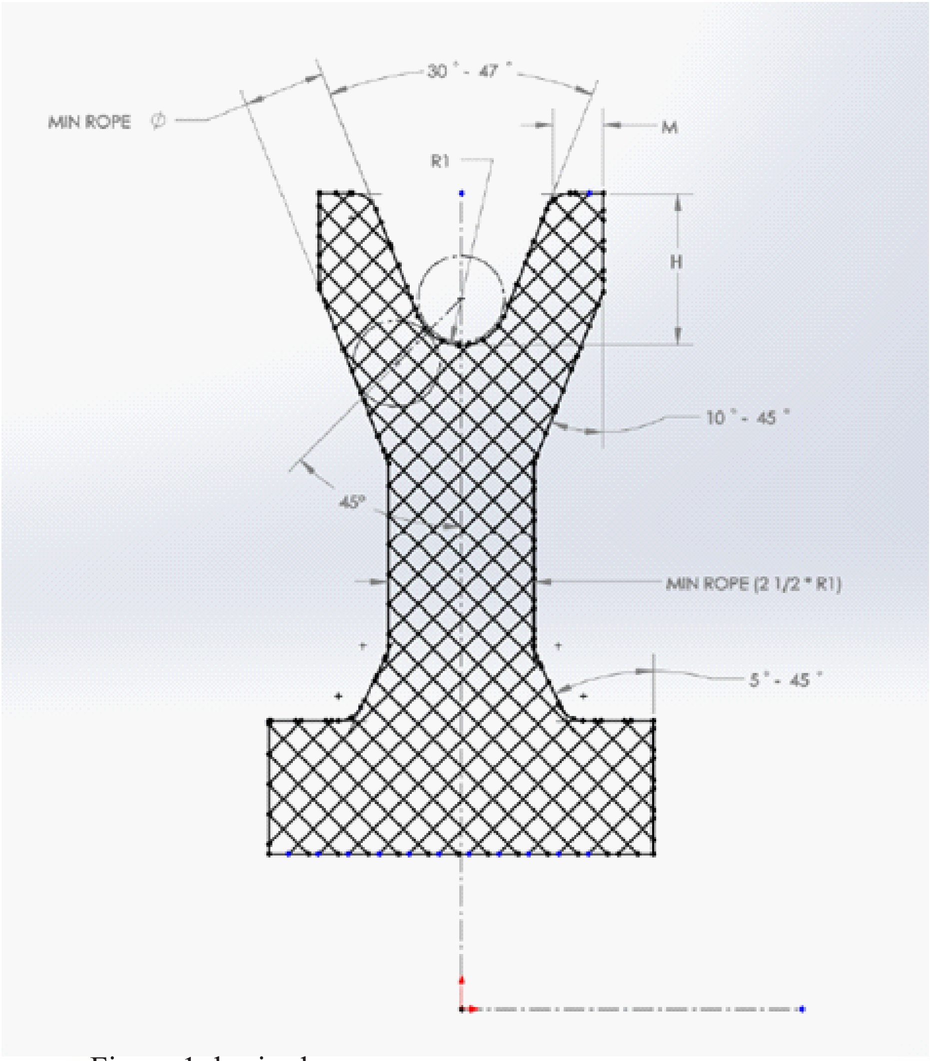


Figure 1: basic sheave

Other designs are available upon request

Groove Configuration

A correct groove angle and groove radius is required to provide maximum support to the wire rope and minimize wear on both the rope and the sheave. Experience has shown that NYCAST nylon sheaves with an included groove angle of 30 deg. provide optimum rope support. The depth of the rope groove [h] is generally specified to be a minimum of 1.75 times the rope diameter. American and European standards recommend a groove diameter approximately 5% larger than the wire rope itself to accommodate rope tolerances and still provide adequate support. NYCAST nylon custom cast sheaves are designed with these guidelines in mind. Recommended groove radius based on rope diameter is presented in Table I.

Wire rope diameter (inches)	Sheave groove radius (inches)
1/4	9/64
3/8	13/64
7/16	15/64
1/2	17/64
9/16	19/64
5/8	21/64
3/4	25/64
7/8	15/32
1	17/32

Table I: rope diameter and groove radius for NYCAST Custom sheaves

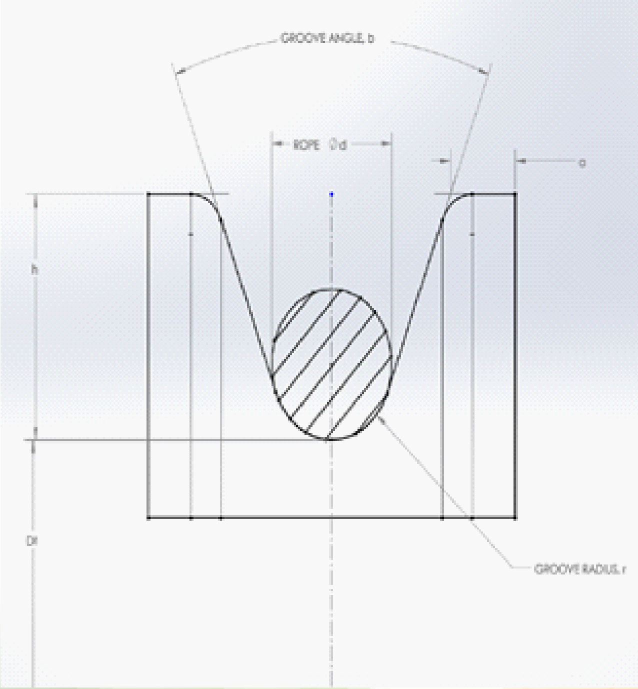


Figure 2: general groove design

Bore configuration

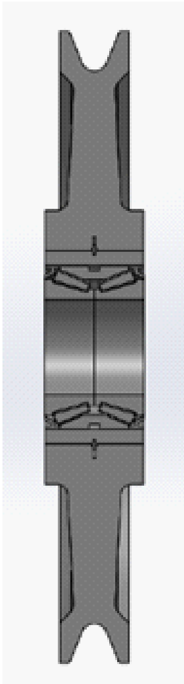
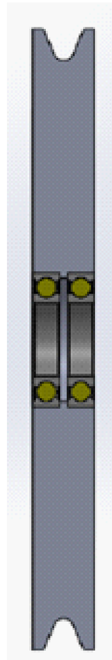
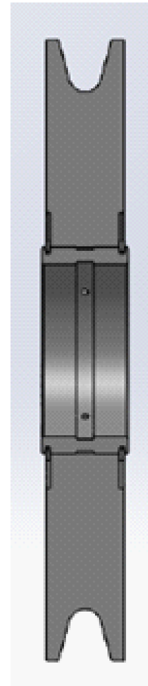
Sheave with bearing/ needle, cylindrical	Sheave with ball bear-ings	Sheave with steel sleeves
		

Figure 3: different bore configurations

Needle type roller bearings are recommended for heavy-duty applications involving heavy loads. If press fit is the method of bearing retention, sufficient stock must be left in the bore to maintain an acceptable press fit and eliminate bearing movement within the bore. Press fit allowance can be determined by the relationship:

$$\mathbf{PF = 0.009 \times \sqrt{\text{bearing OD}}}$$

The press fit allowance is subtracted from the bearing OD to obtain the required bore diameter. This relationship takes into consideration the thermal expansion of NYCAST nylon from - 10 to 140°F operating temperatures. If temperatures outside this range are to be encountered, consult Cast Nylons Ltd. for the proper press fit allowance.

Steel sleeves can be utilized in conjunction with bearings to increase load handling capacity in heavy duty applications due to the resultant increase in bore diameter. Bronze bushings are not recommended for applications involving higher than moderate loads as an alternative to bearings.

Bearing Retention

Bearings can be retained on the circumference through press fit directly into the bore of a NYCAST sheave. By following the formula shown under the Bore Configuration section, sufficient interference can be achieved between the bearing and the bore to hold the bearing in place. Installation can be achieved with a hydraulic press.

Side retention of bearings is required to restrict movement, which may result from side forces in operation. Thrust plates or washers can be placed on either side of the hub to restrict movement. Internal snap rings which lock into grooves, machined into the bore of the hub, have also been utilized successfully in NYCAST sheaves.

Load capacity of NYCAST sheaves

Industry standards identify the sheave pitch to rope diameter ratio (Dp/Dr) and the design factor (Fd) as important variables in the safe design of load bearing crane sheave applications. ANSI standards specify a minimum Dp/Dr of 18:1, and a minimum Fd of 3.5 for live or running wire ropes. The user should determine the values of these important design criteria based on the demands of the specific application as the initial step in custom sheave design.

CAST NYLONS LIMITED can calculate the applied loads on a sheave through a FEA program. Embedded in this program are the specific material data of our NYCAST custom sheaves grades which was especially developed for crane sheave application.

The results of the FEA analysis ensure the safety use of our custom sheaves.

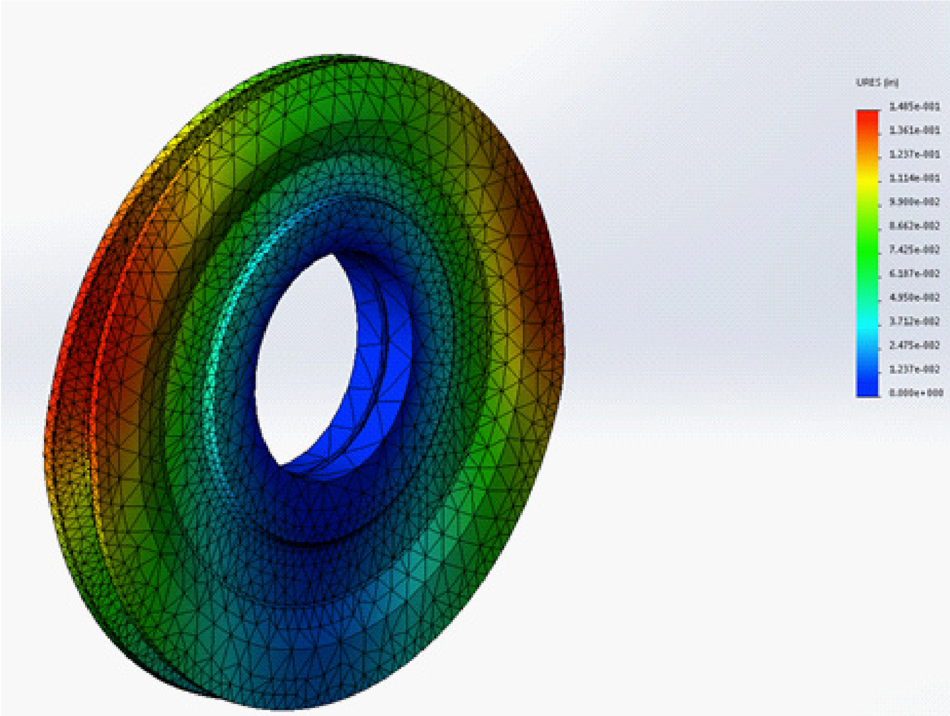
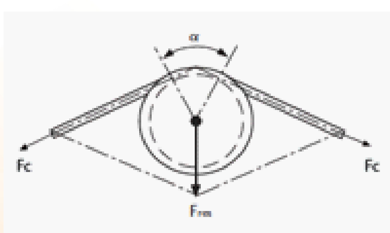


Figure 4: FEA analysis of a NYCAST sheave

Conventional Calculations of NYCAST custom sheaves

Calculation of bore compression

The bearing load for a sheave is dependent on the angle the rope lays in the groove of the sheave. If this angle is 1800, than the load F is twice the rope tension. For angles < 1800 the resulting load must be calculated:



$$Fres = Fc \sqrt{2-2\cos\alpha}$$

With

Fc: cable tension

α: angle of contact between rope and groove

The actual bore pressure would be calculated as:

$$P = \frac{F}{D\,w} * f$$

Where F: resulting tension based on alpha (in case of 1800 F=2F)

d: diameter of bore

w: width of bore

f: correction factor NYCAST = 1.27

The maximum allowable bore pressure for NYCAST sheaves is 3500psi.

Calculation of groove compression

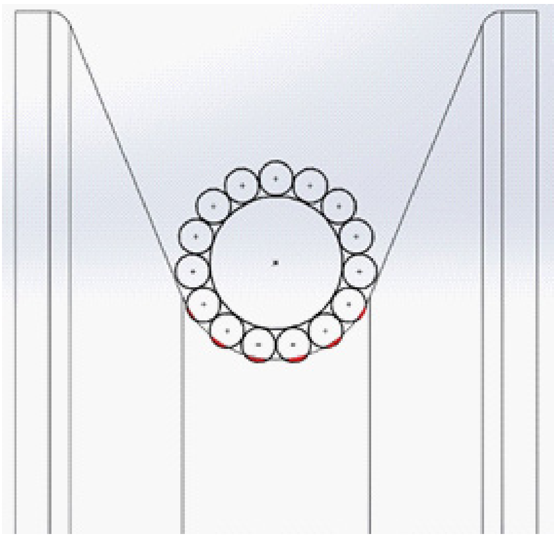
To calculate the loads in the grove of NYCAST custom sheaves the following equation may be used:

$$P_s = \frac{2(U / F_s)}{D_r D_t}$$

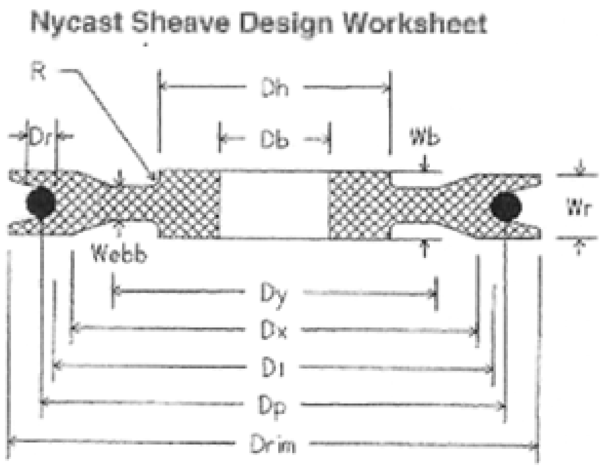
With: U : breaking strength of wire rope (lbs)

Dr : rope diameter (inches)

Dt : tread diameter (inches)



NYCAST sheave design worksheet



In reference to the drawing above, the following need to be determined to calculate load capacities:(assume a bearing is to be used)

Dr = rope diameter = ___________ inches

Dp = Dt+ Dr = ____________ inches

Dt = tread diameter= ___________ inches

Check: is Dp/Dr equal or greater than 18? If not, change Dp or Dt to achieve this ratio.

Db = bore diameter = ___________ inches

Wb = bore width = __________ inches

Maximum load capacities are then:

Max Lgroove = 3500 × Dr × Dt = _________lbs.

Max Lbore = 3500 × Db × Wh = ________lbs.

Choose maximum load to be the smaller of the two quantities above. This is the maximum load in pounds the sheave can carry. To optimize the choice of rope and sheave dimensions, use the actual groove and bore pressure equations and choose values that maximize the Pg and Pb at or near 3500 psi:

U = breaking strength of rope size chosen (lbs)

Fd= safety factor = 3.5

Pg max = 3500 psi

Pb max = 3500 psi

Dp / Dr = 18 (minimum recommended)

Substituting and simplifying:

Minimum Dt = V × 0.0028 × U

Minimum Wb = $\frac{1.47 \times 10-4 \times U}{Db}$

5.5 Wear pads/ sliding pads/ wear liners

Linear movements are widely required in the machine building industry. Where rotational or up and down movements are often designed with circular bushings, linear movements such as a telescopic boom also require a form of a friction "bushing". These parts are called wear pads, sliding pads or sliding shoes. The main function is to separate to sliding surfaces from each other, reduce the friction so that he movement can be operated with a minimum of working force, e.g. hydraulic cylinder. Some technical facts for telescopic booms have to be overcome by the polymer, which is functioning as a sliding pad:

- Corrosion of boom inside → raises the coefficient of friction and roughness
- Tolerances in booms → uneven surface in boom results in point loads on polymer
- Temperature in boom → during the summer temperature in boom can raise up to 1100F, reduces the compressive strength of polymer material
- Stick-slip effect → occurs when static friction> the kinetic friction

The material used for this application has to work under all circumstances. Especially the stick-slip phenomena is of concern because if occurs during telescoping the boom can suddenly jump which can cause an accident.

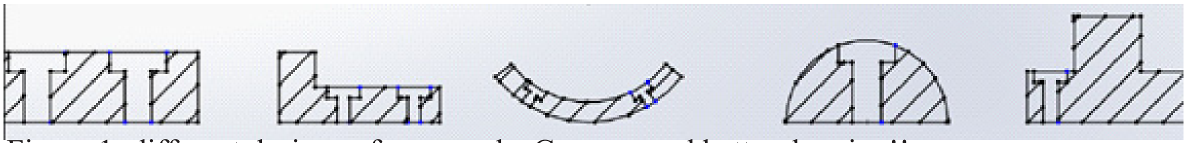


Figure 1: different designs of wear pads: George need better drawing!!

Material grades

Cast Nylons Limited offers various grades for linear movement applications. The grades are filled with solid and or liquid lubricants to reduce the coefficient of friction. To tackle the wear resistance all grades are high crystalline nylon 6 grades.

The following material are offered:

- NYCAST NYLOIL
- NYCAST RX/GX/BX
- NYCAST SLX
- NYCAST MoS2

The combination of low coefficient of friction and high crystallinity guarantees the best results in the working environment.

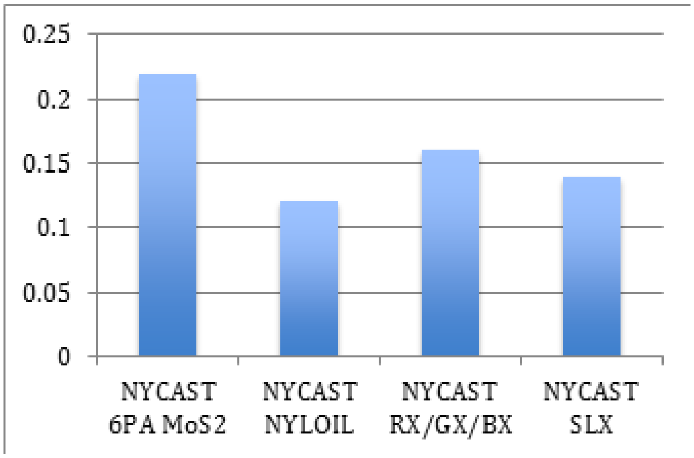


Chart: NYCAST grades, coefficient of dynamic friction (ASTM D1894)

Design guidelines

The running speeds and loads of sliding pads are normally below the materials capabilities; therefore in most cases a calculation is not necessary. As a basic for limiting pressure value 3500psi can be used. For special requirements please contact us.

Dimensions

For design and tolerances the coefficient of thermal expansion and water absorption should be considered. The thermal expansion of NYCAST is approx. 10 times higher than the steel of telescopic booms.

Installation

It is highly recommended to lubricate prior to assembly. The lubrication will reduce the corrosion of the inside of the telescopic boom and will help the sliding pad to “wear in”. Therefore prolonged operational lifetime can be expected.

Applications

Wear liners are used in telescopic booms of cranes, railroad vehicles, conveyor systems, packaging machinery, timber processing machinery, flat bed carriers etc.

Tolerances

5.6 Tolerances

Polymer parts are very often integrated in existing machinery to replace metal parts. Drawings used for the metal parts have to be redesigned to the polymer material. The general design might have to be redrawn and also the existing tolerances have to be changed. Thermal expansion, swallowing through moisture absorption has to be considered. The general machining of plastics also requires different tolerance approaches than the machining of metals due to deflection and heat up during the machining process of the polymer. As a guideline for Tolerances for NYCAST materials please look at the following tables. All data shown are in metric sizes (mm).

General

Tolerance class	Permissible deviations for basic size range								
Designation	Description	from	over	over	over	over	over	over	over
		0.5* up to 3	3 up to 6	6 up to 30	30 up to 120	120 up to 400	400 up to 1000	1000 up to 2000	2000 up to 4000
f	fine	± 0.05	± 0.05	± 0.1	± 0.15	± 0.2	± 0.3	± 0.5	--
m	medium	± 0.1	± 0.1	± 0.2	± 0.3	± 0.5	± 0.8	± 1.2	± 2
c	coarse	± 0.2	± 0.3	± 0.5	± 0.8	± 1.2	± 2	± 3	± 4
v	very coarse	--	± 0.5	± 1	± 1.5	± 2.5	± 4	± 6	± 8
* For normal size below 0.5mm, the deviation shall be indicated adjacent to the relevant nominal size (s).									

Table 1: permissible deviations for linear dimensions except for broken edges (DIN ISO 2768 T1)

Tolerance class		Permissible deviations for basic size range		
Designation	Description	from 0.5* up to 3	over 3 up to 6	over 6
f	fine	± 0.2	± 0.5	± 1
m	medium			
c	coarse	± 0.4	± 1	± 2
v	very coarse			

Table 2: permissible deviations for radius of curvature and height of bevel (DIN ISO 2768 T1)

Tolerance class		Permissible deviations for ranges of length in millimeters of shorter side of the angle concerned				
Designation	Description	up to 10	over 10 up to 50	over 50 up to 120	over 120 up to 400	over 400
f	fine	$\pm 1^0$	$\pm 0.5^0$	$\pm 0.333^0$	$\pm 0.166^0$	$\pm 0.083^0$
m	medium					
c	coarse	$\pm 1.5^0$	$\pm 1^0$	$\pm 0.5^0$	$\pm 0.25^0$	$\pm 0.166^0$
v	very coarse	$\pm 3^0$	$\pm 2^0$	$\pm 1^0$	$\pm 0.5^0$	$\pm 0.333^0$

Table 3: permissible deviations for angular dimensions (DIN ISO 2768 T1)

In general all untoleranced dimensions are chosen in designation class m

Shape and position

Tolerance class	Permissible deviations for basic size range					
	up to 10	over 10 up to 30	over 30 up to 100	over 100 up to 300	over 300 up to 1000	over 1000 up to 3000
H	0.02	0.05	0.1	0.2	0.3	0.4
K	0.05	0.1	0.2	0.4	0.6	0.8
L	0.1	0.2	0.4	0.8	1.2	1.6

Table 4: permissible deviations for straightness and evenness (DIN ISO 2768 T2)

Tolerance class	Permissible deviations for basic size range			
	up to 100	over 100 up to 300	over 300 up to 1000	over 1000 up to 3000
H	0.02	0.3	0.4	0.5
K	0.4	0.6	0.8	1
L	0.6	1	1.5	2

Table 5: permissible deviations for rectangularity (DIN ISO 2768 T2)

Tolerance class	Permissible deviations for basic size range			
	up to 100	over 100 up to 300	over 300 up to 1000	over 1000 up to 3000
H	0.5	0.5	0.5	0.5
K	0.6	0.6	0.8	1
L	0.6	1	1.5	2

Table 6: permissible deviations for symmetry (DIN ISO 2768 T2)

Press fits

For tolerance recommendation in bores, undersize and oversize please contact us

All deviations stated above can only be maintained at normal conditions, 750F and 50% rel. humidity.

after drilling to a depth not more than 1 - 1/2 times the drill diameter. When drilling large or deep holes, start with a small (maximum 1/2" diameter) hole drilled at a speed of 800 to 900 rpm and a feed rate of 0.005" per rev. The web area and cutting lip must be ground as in diagram 1 to prevent "grabbing" and stress cracking. Open the hole to 1" following the same procedures but using a drill speed of 400-500 rpm. ***Peck drill and use generous amounts of coolant for each operation.***

To open the hole to finished size, use a single point-boring tool and follow the procedures in the "turning" section.

Reaming

Whenever possible, reamers of the expansion type should be used, and reamer speeds should approximate those used for drilling (250 to 450 feet per minute). Feed rates should be between 10 and 20 mils per revolution. Since it is difficult to remove less than 0.002 inches when reaming, it is best to leave at least .005 inches for final reaming. This will provide a "bite" for the reamer and will assure accurate cutting.

Feed rates/rev.	1/16 "dia.	¼"dia.	½"dia.	1"dia.
0.004"- 0.015"	5,000 rpm 1,500 rpm	1,700 rpm	1,000 rpm	1,500 rpm
0.008"- 0.016	3,500 rpm	1,500 rpm	1,000 rpm	500 rpm
0.013	3,000 rpm	1,000 rpm	750 rpm	400 rpm

Chart: feed rate up to 1"dia. drills

Drill size	RPM
No. 60 thru 33 No. 32 thru 17 No. 16 thru 1	5,000 3,000 2,500
1/16” 1/8” 3/16” ¼” 5/16” 3/8” 7/16” ½”	5,000 3,000 2,500 1,700 1,700 1,300 1,000 1,000
A thru D	2,500
E thru M	1,700
N thru Z	1,300

Chart: drill speed/ size chart

Tapping

The tapping of NYCAST materials can be performed either by hand or by machine; however, the use of sharp taps is essential. Taps previously used on metal should never be used on nylon work pieces. In tapping, high-speed oversize taps, such as H-3 oversize, can be used for smaller diameters and H-5 oversize for larger diameters. Any high-speed tap used should be oversized by 0.002 to 0.005 inches (0.05 to 0.13mm).

Threading

As in tapping, dies must be sharp and should never have been used on metal. Threads can be cut with any conventional method, but dies must be well backed-off to avoid non-cutting surface contact with the work piece .Threads may be cut with a single point tool. Light cuts of less than 0.005 inches should be avoided, and a maximum cut of 0.010 inches is suggested. Heavy cuts may be used on the initial pass, but the depth of the cut should be reduced to 0.007 inches on the final pass. Since nylon materials have a tendency toward memory or recovery after the die is removed, a slightly oversize die should be used for threading (see tapping section)

7. Post Machining Annealing

All material grades from Cast Nylons are annealed after processed to reduce internal stress, which may have resulted from the manufacturing process. The annealing process guarantees the dimensional stability of machined parts made from stock shapes.

Some parts might require intermediate annealing in between machining operations. such as:

- Parts were large volume is machined away, especially from one side

- Special tolerances or flatness needed

Other parts might need post-annealing process after finished machined if:

- Machined with dull tools

- Machined without cooling and created excessive heat

The annealing process should be done in an oven under nitrogen atmosphere or in an oil bath. The heat up rate should not exceed 150F/ 10 minutes. Annealing temperature to be set at 280 to 3000F. Annealing time should be 30 minutes per ¼"thickness of the part. The cooling rate should not exceed 300F/ hour.