

## Engineering Polymers - Material Properties of Polymeric Caster Wheels

In this article we will be looking at the most common Polymer based Castor wheel materials, their manufacturing methods and mechanical properties....

Castor Wheels were officially patented in 1876 for furniture use. Today they are utilised in almost all industries and environments, from home appliances, aerospace applications, industrial machinery to medical devices, primarily to assist with material handling requirements. Due to the broad range of applications Castors are manufactured in a vast array of materials and composites to suit the demands and environmental factors where they are used. The correct material selection is imperative to ensure the best performance and extended life of the wheel are achieved, resulting in reduced costs and increased productivity of equipment.

### POLYMER AS AN ENGINEERING MATERIAL

The word Polymer is derived from two parts, “Poly” which means “many” and “mers” which means “parts” – Therefore a Polymer is considered a substance of many parts. The scientific definition is a compound consisting of large molecular chains of similar monomers.

Since the invention of modern natural rubber in 1844 by Charles Goodyear, most famous for his Goodyear Tire Company, there have been extensive scientific breakthroughs in the development of new polymer materials and improvements in their mechanical properties. The first synthetic polymer, Bakelite, was invented in 1907 by Mr Leo Baekeland and has remained a popular thermosetting material to date. Since these inventions the development of polymers has exploded, particularly during World War II where restricted supply of natural materials necessitated the development of alternative replacement materials such as Nylon and Synthetic rubbers such as Neoprene<sup>®</sup> (Chloroprene). In later years materials such as Kevlar were developed. The polymer industry has since boomed with many organisations and scientists working to develop new exotic polymers, with regular new developments being seen. A company to note is Dupont<sup>®</sup>, an American chemical company, who is responsible for the development of many Polymers including Neoprene, Nylon, Teflon and Kevlar.

### RUBBER POLYMERS AS A CASTOR WHEEL MATERIAL

Rubber can be split into two categories – Natural Rubber and Synthetic Rubber. The former being manufactured from Latex derived from the Hevea Brasiliensis Tree, whilst the latter is manufactured from chemicals derived from petroleum refining. The company, DuPont<sup>®</sup>, are extremely active in this area having developed Neoprene (Chloroprene) in 1930 which is still widely used today. There have since been many other synthetic rubber materials developed. It should therefore be considered that there are many different rubber materials, many of which appear identical in appearance, but with differing mechanical properties.



*Fig.1 Natural Rubber (Brown) & SBR (White)*

### Black Rubber Castors – Ideal for Industrial applications

The common Black Rubber Castor is typically manufactured from a blend of Natural Rubber (NR) and Styrene-butadiene (SBR), See Fig.1, with formulations similar to automotive tires. Alternatively, Castors can be produced from Nitrile Rubber (NBR) or Chloroprene Rubber (CR) which provide improved resistance to Oils & Fuels.

In order to offer the required mechanical properties of the rubber wheel, such as Tensile Strength, Wear Resistance and Resilience, the raw material must be mixed with various fillers, additives and chemicals. This mixture is called a compound.

The primary ingredients of a Black Rubber compound will include between 40% to 60% raw rubber and Carbon Black, see Fig.2, which increases the Tensile Strength & Wear Resistance. Carbon black content will be in the region of 30-35%, and in addition to the mechanical properties mentioned above, provides the “Black” colour of the rubber, which is ideal for Industrial applications where dirt and debris will not discolour the rubber. The exact formula can be varied to produce different rubber hardness' – For Castor Wheels this typically ranges from 70 Shore A to 85 Shore A. In terms of mechanical properties, Carbon Black is the ultimate filler, however the main disadvantage is that Carbon Black filled rubber may mark floors and surfaces, particularly hard surfaces such as Solid Wood Floors. This is why non-carbon black filled rubbers, used in Non-Marking Castors, have been developed.



In addition to the carbon black filler there are many other additives that are used to provide various mechanical properties and also assist the material processing and manufacturing process. These include Anti-Ozone & Anti-Oxidant Agents, such as Wingstay 100, See Fig 3, which protect the rubber from environmental factors such as Ozone from sunlight. Oil will be used as a processing aid, and Sulphur, See Fig 4, which is used to vulcanise the rubber, which links the molecular structure of the compound during the moulding process.



**Fig 2. Carbon Black**



**Fig 3. Wingstay 100**



**Fig 4. Sulphur**

After the compound has been produced it is ready to be used for moulding.

For the majority of Castors, the wheels are manufactured by Compression moulding. This is a relatively simple technique whereby a Mould Tool is manufactured to the required size and profile of the wheel. The Rubber Compound is put into the cavity of the mould tool along with the wheel hub which has been coated with a bonding agent. The mould is closed and held under pressure by a heated hydraulic press for between 10-30 minutes at around 150°C allowing the rubber to cure. The Mould is then opened and the finished product is removed.

Rubber Castors can also be manufactured using Transfer Moulding and Injection Moulding techniques, both of which require increased complexity mould tools compared to Compression Moulding, considerably increasing the initial outlay. Transfer and Injection moulding produce a more homogeneous rubber moulding, however for the majority of industrial applications this improved mixture does not provide a significant benefit and therefore these alternative methods would only be used for particularly demanding applications such as Automotive or Aerospace where small improvements in mechanical properties may be beneficial. However it should be noted that Injection Moulding can reduce the cost of high volume, mass produced components.

#### **Features & Benefits of Black Rubber Castors:**

- **Low Noise**
- **Floor Protection**
- **Low Permanent Set**
- **Ideal for Uneven & Rough Ground**
- **Good Wear Resistance**
- **Excellent Grip & Traction**
- **Long Life Expectation**
- **Vibration & Shock Absorption**

- **Temperature Range from -40°C to + 70°C**
- **Suitable for both Outdoor & Indoor Use**
- **Low Cost**

**Non Marking Rubber Castors – Ideal for sensitive environments**

Non-Marking Rubber, which is typically coloured grey for the Castor industry, has many materials and ingredients in common with the Black Rubber Castor. The primary difference being the type of filler that is used to manufacture the rubber compound. The Carbon Black Filler normally providing the “black” colour of the rubber is substituted with an alternative filler, typically Calcium Carbonate or Silica.



Both Calcium Carbonate and Silica come in the form of a fine white powder (See Fig.5) and act as a non-colourant filler for rubber. Using these alternative fillers allow for coloured pigments to be added to the compound to provide a broad range of coloured rubbers including Grey, Blue & Red materials typically used for Castors.

Unfortunately these non-colourant fillers are considered “Non-Reinforcing” which means that they do not improve the Tensile & Tear Strength of the finished material. For this reason Carbon Black, which is “Reinforcing”, is the filler of choice where colouring is not required and where non-marking properties are not required.



**Fig. 5 – White Filler**

Where Pure White Rubber is required the base polymer may be changed to 100% synthetic materials such as SBR or EPDM (Ethylene Propylene Diene Monomer), which are semi-opaque and lighter in colour compared to Natural Rubber. In addition a whitening agent, Titanium Oxide, may be added to the compound to further increase the whiteness.

**Features & Benefits of Non-Marking Rubber Castors:**

- **Non Marking – Ideal for Wooden, Vinyl & Tiled Floors**
- **Low Noise**
- **Floor Protection**
- **Ideal for Uneven & Rough Ground**
- **Excellent Grip & Traction**
- **Vibration Absorption**
- **Temperature Range from -30°C to + 70°C**
- **Suitable for both Outdoor & Indoor Use**
- **Low Cost**

**PLASTIC POLYMERS AS A CASTOR WHEEL MATERIAL**

Plastics are commonly used within the Castor and Wheel Industry. They provide many benefits over Rubber based materials dependant on applications, such as increased load capacity, however rubber also has many benefits over Plastics and therefore the user should carefully consider the application and its environment when selecting a Castors. Plastics can be broadly split into 2 categories, Semi-Flexible Plastics and Hard Plastics, both offering their own set of advantages. Semi-Flexible Plastics, such as PVC or Polyurethane typically have a hardness of around 80-95 Shore A, whilst Hard Plastics such as Nylon or Polypropylene typically have a hardness of between 60-90 Shore D.

## **PVC Casters (Polyvinyl Chloride) – Tough & Durable**

Polyvinyl Chloride is a synthetic material developed in the late nineteenth century, like many materials, by accident. However the material was brittle and difficult to process. In 1932 a method was developed to plasticise the material whereby the PVC is combined with the chemical compound Phthalates. Plasticising the PVC produces an increase in flexibility and makes the material easier to process. The process allowed the material to be used in many different applications and is now the 2nd most common plastic on the planet.

PVC is manufactured by Polymerisation, a chemical reaction of Vinyl Chloride Monomer, resulting in PVC resin. After manufacture the resin is compounded with additives which alter and improve its mechanical properties. For the Castor Industry these additives will include Plasticisers, Fillers, UV Stabilisers and Colour Pigments, providing various mechanical properties including Flexibility, Shock & Impact Resistance, Weather Resistance, Wear Resistance and an extremely tough and durable material. These properties allow PVC to be utilised by many industries including, Construction, Medical and Automotive.



**Fig. 6 – PVC Resin**

PVC Castors are manufactured by injection moulding, however other techniques are used for different product types, such as Vacuum Moulding. The reciprocating screw injection moulding machine heats the material to its melt temperature of between 190°C and 200°C. The reciprocating screw amalgamates the melted material and transfers (injects) the material into the cavity of the mould to form the Castor Wheel. Ideally the mould cavities should be manufactured from Grade 420 Stainless Steel to provide resistance to acid attack which is a by-product of the moulding process. The hardness of the finished product can range from 75 Shore A to 90 Shore A

### **Features & Benefits of PVC Casters:**

- **Strong, Durable & Flexible**
- **Non Marking – Ideal for Wooden, Vinyl & Tiled Floors**
- **Wear Resistance**
- **Low Noise**
- **Floor Protection**
- **Ideal for Uneven & Rough Ground**
- **Excellent Grip & Traction**
- **Impact Resistant**
- **Temperature Range from -30°C to + 70°C**
- **Suitable for both Outdoor & Indoor Use**
- **Weather Proof**
- **Low Cost**

## **Polyurethane Casters (PU) – The material of choice**

Polyurethane has been in use since the 1930's and became widespread during World War II as an alternative to Natural rubber which, at the time, was hard to obtain.

Polyurethane is the material of choice for many industries, including the Castor Wheel Industry. This preference is due to its outstanding mechanical properties, being one of the toughest and most abrasion resistant elastomeric materials offering properties associated with both flexible rubbers and hard plastics.



Polyurethane is a synthetic material with a complex chemical make-up, with the primary formula being manufactured by reacting a Polyol with a Polymeric Isocyanate. The wide variety of these two types of compound allow for a vast range of Polyurethane materials to be manufactured, including semi-flexible materials used in the Castor industry.

Polyurethane is a relatively easy material to process during the manufacturing stage.

Within the Castor Wheel industry the most common manufacturing technique is injection moulding, as per the above PVC wheel, however standard Steel moulds can be used. The material can also be Hot Poured where small batch runs are required. Hot pouring for low volume production allows for extremely economical tooling to be utilised.



The material is translucent yellow in appearance however is commonly coloured with pigments to provide a pleasing aesthetic appearance, giving a professional and quality finish to its installation.

#### Features & Benefits of Polyurethane Casters:

- **Strong, Durable & Flexible**
- **Non Marking – Ideal for Wooden, Vinyl & Tiled Floors**
- **Ultimate Wear Resistance**
- **Low Noise**
- **Floor Protection**
- **Ideal for Uneven & Rough Ground**
- **Excellent Grip & Traction**
- **Impact Resistant**
- **Temperature Range from -30°C to + 70°C**
- **Suitable for both Outdoor & Indoor Use**
- **Resistance to many chemicals & cleaning materials.**

#### Nylon Castors – The most popular Castor in the World

Nylon was patented in 1935 by Dupont® invented by Wallace Carothers, who also invented the synthetic rubber Chloroprene (Neoprene®). Nylon 6 shortly followed, and the 2 similar materials are the most commonly used nylon grades today. Nylon is a low cost material compared to other castor materials. It is one of the toughest and most hard wearing of all hard plastics, offering extremely high load capacity and extended life cycle. Nylon is considered a “structural” plastic.

Within the Castor Industry you will find both Nylon 6 and Nylon 66 being used as both a wheel material and also as a wheel hub material. The material is usually moulded in Black or White.

Nylon Castor Wheels can be manufactured by Injection Moulding and also machined from Solid Bar. The majority of Nylon castors are moulded, with the machined versions typically used for Extreme Heavy Duty Applications. Nylon Casters can be manufactured with pure Nylon material or alternatively can be mixed with glass reinforcing fibres to further increase their impact resistance for the most demanding of applications. Nylon Castors most commonly have



a hardness range from 80 shore to 90 shore D and a working temperature range between -30°C and 80°C. They are also light weight compared to most other Castor Materials.

Nylon Castors offer excellent performance characteristics whilst remaining an economical solution. They provide low rolling resistance on hard floors, offer excellent shock, wear and abrasion resistance and provide resistance to many aggressive substances and cleaning materials, making them ideal for many different applications including clean rooms, food handling equipment and hospital environments.

#### **Features & Benefits of Nylon Castors:**

- **Strong, Durable & Light Weight**
- **Non Marking**
- **Wear, Shock & Impact Resistance**
- **Low Roll resistance on smooth floors**
- **Temperature Range from -30°C to + 80°C**
- **Suitable for both Outdoor & Indoor Use**
- **Resistance to aggressive chemicals & cleaning materials.**
- **Low Cost**

#### **Polypropylene Castors – The economical choice**

Polypropylene (PP) is an extremely versatile thermoplastic polymer developed by Italian company Montecatini in the mid 1950's. Due to its range of mechanical properties Polypropylene has become one of the most popular plastics in the world, being used in nearly all industries including Packaging, Office Equipment, Household Items, Industrial Equipment, Medical Devices and even within the Military.



Polypropylene is a synthetic resin manufactured by polymerisation of Propylene. The resin is usually compounded with fillers to provide additional features such as colour pigmentation and wear resistance. Polypropylene is considered a “Structural” plastic.

Dependant and the polymerisation technique the material can be manufactured as a rigid Polypropylene or an elastomeric Polypropylene. Generally Castors are manufactured from the former.

Like Nylon, Polypropylene is a light weight material compared to most other castor wheel materials. It is extremely low cost, more so than Nylon, and is used both for manufacturing the Caster Wheel and also for manufacturing Wheel Hubs.

Polypropylene has high impact strength and offer excellent fatigue resistance. They are resistant to water and chemical absorption, making them ideal for wash-down applications such as medical and food processing equipment, in addition to every day applications. Polypropylene can accommodate regular steam cleaning, ideal for applications where equipment requires regular sterilisation. Polypropylene is also normally free from BPA. Polypropylene has a high working temperature of up to 80°C, and a low working temperature of -20°C

Polypropylene and Nylon provide very similar mechanical properties, with Nylon being only slightly favourable, however due to the significant cost advantage of Polypropylene it is most commonly used in the Castor Wheels Industry.

#### **Features & Benefits of Polypropylene Castors:**

- **Strong, Durable & Light Weight**
- **Non Marking**

- **Wear, Shock & Impact Resistance**
- **Low Roll resistance on smooth floors**
- **Temperature Range from -20°C to + 80°C**
- **Suitable for both Outdoor & Indoor Use**
- **Resistance to aggressive chemicals & cleaning materials.**
- **Non-absorbent properties**
- **Low Cost**

Disclaimer: The above information is for reference only, and any information or specification does not necessarily represent the products supplied by Bulldog Castors Ltd. Customers are advised to contact us to request specific product specifications which may differ from the above information. No reliance should be taken on this information.

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