Title: OVERMOLDED PLASTIC ARTICLES, USES THEREOF, METHOD OF MAKING

Abstract: Overmolded high performance plastic articles useful for example in the replacement of currently utilized, multi-component, anti-frictional, load bearing components in lubricated and non-lubricated environments.
Overmolded plastic articles, uses thereof, method of making

Field of the Invention

The present invention relates to overmolded plastic articles, especially articles wherein a metal component (M) is overmolded with a polymer composition comprising a high performance plastic, especially TORLON® PAI. Such articles, for example thrust, needle, ball and roller bearings, have particular advantage in the replacement of anti-frictional, load bearing components in both lubricated and non-lubricated environments, made possible by utilizing a modified or unmodified polymer with excellent friction and wear capability as the wear surface. In this regard the invention overmolded articles provide good weld line, avoid fatigue problems, and yield good strength and stiffness.

Additional advantages and other features of the present invention will be set forth in part in the description that follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from the practice of the present invention. The advantages of the present invention may be realized and obtained as particularly pointed out in the appended claims. As will be realized, the present invention is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the present invention. The description is to be regarded as illustrative in nature, and not as restrictive.

Reference to related applications

This application claims priority to U.S. provisional application 60/615,023, filed October 4, 2004, and to U.S. provisional application 60/619,694, filed October 19, 2004, whose disclosures are incorporated herein by reference.

Background of the Invention

Currently, many articles, such as bearings, are fabricated as multi-component roller-element systems comprising stationary and rotating components, typically made of metal. Such devices, for example thrust, needle, ball and roller bearings, are relatively complex, making their fabrication and assembly both costly and time consuming. In addition, generally speaking, such parts can be undesirably heavy.

The inventors investigated the fabrication of single component articles using high performance polymers as replacements for such generally used multi-
component roller-element systems, etc. However, the material costs associated
with high performance plastics such as polyamide-imide (PAI),
polyetheretherketone (PEEK), polyimide (PI) generally do not justify such
replacement. This is especially true when the multi-component article becomes
sufficiently large that the material and processing costs to produce a single
component replacement system out of high performance plastic, for example to
be used as a “drop-in” replacement article for, e.g., a multi-component metal
bearing, become more expensive than fabricating the multi-component article
itself. “Drop-in” replacement refers to removing a currently utilized multi-
component article (e.g., a bearing) and replacing it with a present invention
overmolded article without need for special modification or alterations.

Japanese Patent Publication 08232945A discloses a roller for supporting
and moving high load wherein a thermoplastic resin is injection molded to form
a core part. The molded part is then removed, and adhesive is applied to the
outer circumferential part of the core part. This is then fitted back into a die,
wherein a thermoplastic elastomer is poured to form the outer circumferential
part by insert forming. The plastic materials do not form a wear surface.

US Patent 6,513,986 discloses a rolling bearing having an insulating film
made from a polymer composition containing polyphenylene sulfide, polyamide-
imide, and inorganic insulating materials to prevent electrolytic corrosion
produced between the bearing rings and the rolling elements. The insulating film
is injection molded, and is not utilized as a wear surface.

US Patent 6,485,608 discloses a plain bearing which comprises a metal
backing, a sintered layer on the metal backing, and a lining layer infiltrated into
pores of the sintered layer as the bearing surface. The lining layer is primarily
comprised of fluororesins.

Polyether ether ketone and polyamide imide may be incorporated as
organic fillers to improve wear resistance. The lining layer is applied by forming
a slurry of the fluororesin, fillers and water, and casting the slurry followed by a
dewatering process. The disclosed lining layer thickness is 50 to 400 μm.

US Patent 6,416,226 discloses bearing assembly, primarily used for
steering columns in automotive vehicles, having an axially split bearing and an
improved elastomeric crown. The patent further discloses that inner surface of
the bearing is lined with an anti-friction material such as PTFE, polyacetal or
PEEK, which allows the lining material to perform with or without lubrication.
US Patent 5,871,262 discloses a precision wheel, roller and track tread product utilizing engineering thermoplastic resins (ISOPLAST® 202 or VICTREX® PEEK 450G) which is injection molded around the wheel hub body.

US Patent Application Number 2002/0025241 discloses a part mounting bolt for use in applications such as mounting a headlight, a fog lamp, a bicycle lamp, mirrors and the like onto an existing mounted member such as a car bumper or a base plate. The mounting bolt has a gear which facilitates fine adjustments of, for example, a headlight after being mounted to the mounted member. The gear is injection molded onto the bolt body in a die. The resins disclosed are various types of nylons, polyamide-imide and polyacetals.

WO 98/28120 discloses fiber-reinforced structures made by injection molding PEEK or PEI onto a PEEK or PEI insert.

French Patent Number 2,704,799 discloses the injection of PEEK on inserts made from PEEK composites.

US Patent 5,395,171 discloses a one-piece bearing housing made by injection molding a polymer, such as PEEK, polysulfone or polyphthalamides. A bearing placed in the bearing housing could then be expected to rotate or spin with respect to the housing. In certain embodiments a metallic strap is insert molded as a “fail safe” in the case of catastrophic failure.

**Detailed Description of the Preferred Embodiments**

The present invention provides low cost, high performance overmolded plastic article. The article according to the present invention is an article (A) comprising at least one metal component (M), said metal component (M) being overmolded with at least one polymer composition (C) comprising at least one high performance plastic (P). The overcoating may be partial or complete (i.e., varying from greater than zero to 100 % overcoated), the polymer composition (C) may comprise one high performance plastic or a mixture of two or more such plastics, the metal component (M) may be a single metal component (M) or multiple metal components (M) per article. In addition, the shape of the overall article, and the shape of the overcoated metal component(s) (M), is not limited. In a preferred embodiment the invention provides a bearing system (for example thrust, needle, ball or roller bearing) by overmolding a metal component (M) with a polymer composition comprising a high performance plastic, the polymer composition forming at least one wear surface, thereby advantageously reducing the material costs associated with expensive high performance plastics but providing excellent performance.
characteristics. In a highly preferred embodiment the metal component (M) approximates the overall shape and size of the final product but is reduced in one or more, preferably several and including all, dimensions by some percentage, and is completely or nearly completely overcoated with the polymer composition (C) comprising the high performance plastic. The surface of the polymer composition (C) comprising the high performance plastic overcoat may have any feature, shape, size, etc., necessary to its function, regardless of the shape and size of the underlying metal component(s) (M). Thus, the present invention allows for, among other things, the “drop-in” replacement of a multi-component, moving bearing system with an overmolded polymer composition (C) comprising a high performance plastic bearing system with no moving parts and which appears to be, and in essence is from a functional perspective, a single component, satisfying both performance and cost requirements.

The present invention also provides a method of manufacturing the articles as above described.

The present invention further provides a process of replacing a currently utilized multi-component roller-element bearing, such as a thrust bearing, with an invention plastic overmolded bearing in various applications including automobile powertrain applications (such as the transmission), industrial equipment applications, and any other application where, e.g., bearings are currently used. Of particular note are the bearings used in transmission and air conditioning compressor devices.

According to a first aspect of the present invention, a metal component (M) is overmolded with a polymer composition (C) comprising a high performance plastic. As used herein, the term “metal component (M)” refers to any structural material having a shape that can be at least in part overcoated with a polymer composition comprising a high performance plastic material. Preferred metal components (M) are made of metal, such as steel, iron, titanium, copper, tin, aluminum, gold, silver, etc, and mixtures thereof such as bronze, etc. Preferably, the metal component (M) is less expensive than the polymer composition (C) comprising the high performance plastic. Metal components (M) may be self supporting, non-self-supporting, solid, perforated, honeycomb, etc. In a preferred embodiment the metal component (M) is approximately the same shape and dimension as the final product. More than one metal component (M) can be present in one invention article (A).
Overmolding can provide an article (A) such that little, some, most, or all, of the metal component (M) is overcoated with the polymer composition (C) comprising the high performance plastic. In this invention the term “overmolding” simply describes the location of the polymer composition (C) comprising the high performance plastic in contacting relation to the underlying metal component (M), and does not denote a particular process for producing the article, or the amount of material that is in contacting relation with the metal component (M). The overmolded articles of the invention thus comprise, in a broad sense, at least one metal component (M) and, thereon and in contact therewith, at least one polymer composition (C) comprising a high performance plastic. In many applications not all areas of the metal component (M) need be covered by the polymer composition (C) comprising a high performance plastic. Preferably, the polymer composition (C) comprising the high performance plastic is overmolded at least at those areas of the article where the polymer composition (C) will advantageously function as a wear surface. In this preferred embodiment, the metal component (M) is partially overmolded with polymer composition (C).

The high performance plastic used in the present invention preferably has properties wherein the wear performance, load bearing capability, thermal stability and/or environmental/chemical resistance are satisfactory during use. Preferably, the overmolded article, in particular bearing, is capable of performing in conditions of pressure and velocity (PV) ranging from 25,000 psi-ft/min to 100,000 psi-ft/min with no lubrication or 200,000 psi-ft/min to 1,000,000 psi-ft/min with lubrication, wherein the lubrication is preferably water, oil, grease, hydraulic fluid, transmission fluid or mixtures thereof.

The polymer composition (C) can consist of a sole ingredient [the case being, high performance plastic (P)] or of several ones. In addition to high performance plastic (P), polymer composition (C) may further comprise notably other polymers than high performance plastic (P), fillers and other conventional ingredients of high performance plastic (P) polymer compositions such as stabilizers, i.e., metal oxides such as zinc oxide, antioxidants and flame retardants.

Should the polymer composition (C) comprise at least two ingredients, it is advantageously prepared by any conventional mixing method. A preferred method comprises mixing the high performance plastic (P) and the optional ingredients in powder or granular form in an extruder and extruding the mixture
into strands and chopping the strands into pellets. Said pellets are advantageously molded for yielding the article of the invention.

Polymer composition (C) comprises advantageously more than 25 wt. % of high performance plastic (P).

In a certain embodiment of the present invention, a preferred polymer composition C) is one comprising more than 50 wt. % of high performance plastic (P) [polymer composition (C*)]. Polymer composition (C*) comprises preferably more than 80 wt. %, more preferably more than 95 wt. % of high performance plastic (P). Still more preferably, polymer composition (C*) consists essentially of, or even consists of, high performance plastic (P).

In another embodiment of the present invention, a preferred polymer composition (C) is one further comprising, in addition to the high performance plastic (P), at least one polymer (P2) other than the high performance plastic (P) [polymer composition (C**)].

High performance plastics are defined as polycondensation polymers that have a heat deflection temperature (HDT) of above 80°C under a load of 1.82 MPa when measured according to ASTM D648. Typical heat deflection temperatures of certain high performance plastics are listed in Table 1.

**Table 1 – High performance plastics**

<table>
<thead>
<tr>
<th>Polycondensation Polymer</th>
<th>Heat Deflection Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysulfone</td>
<td>174</td>
</tr>
<tr>
<td>Polyethersulfone</td>
<td>203</td>
</tr>
<tr>
<td>Polyphenylsulfone</td>
<td>204</td>
</tr>
<tr>
<td>Polyphthalimide</td>
<td>120</td>
</tr>
<tr>
<td>Polyamideimide</td>
<td>278</td>
</tr>
<tr>
<td>Liquid crystalline polymers (LCP)</td>
<td>180 – 310</td>
</tr>
<tr>
<td>(there are several different conventional LCPs)</td>
<td></td>
</tr>
<tr>
<td>Polymide</td>
<td>360</td>
</tr>
<tr>
<td>Polyetherimide</td>
<td>200</td>
</tr>
<tr>
<td>Polyetheretherketone (low flow)</td>
<td>160</td>
</tr>
<tr>
<td>Polyetheretherketone (high flow)</td>
<td>171</td>
</tr>
<tr>
<td>Polyphenylene sulfide</td>
<td>135</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>132</td>
</tr>
</tbody>
</table>

Heat deflection temperatures of polymers are determined according to ASTM D648, Method A, using a span of 4 inches. The polymer is injection molded into plaques that are 5 inches long, 1/2 inch wide, and 1/8 inch thick.
The plaques are immersed in a suitable liquid heat-transfer medium, such as oil, during the HDT test. Dow Corning 710 silicone oil, for example, can be used.

High performance plastics useful herein include, but are not limited to, aromatic polyimides (PI), in particular polyamide-imides (PAI), polyaryletherketones (PAEK), such as polyetheretherketone (PEEK), polyetherketoneketone (PEKK), and liquid crystal polymers (LCP). Preferably, the high performance polymer is an aromatic polyimide chosen among aromatic polyesterimides and aromatic polyamide-imides (PAI). Most preferably the high performance polymer is a PAI.

To the purpose of the present invention, “aromatic polyimide (PI)” is intended to denote any polymer comprising recurring units, more than 50 wt. % of said recurring units comprising at least one aromatic ring and at least one imide group, as such (formula 1A) or in its amic acid form (formula 1B) [recurring units (R1)] :

![Formula 1A](image1)

![Formula 1B](image2)

The imide group, as such or in its corresponding amic acid form, is advantageously linked to an aromatic ring, as illustrated below :

![Formula 2A](image3)

![Formula 2B](image4)

whereas $\text{Ar'}$ denotes a moiety containing at least one aromatic ring.

The imide group is advantageously present as condensed aromatic system, yielding a five- or six-membered heteroaromatic ring, such as, for instance, with
benzene (phthalimide-type structure, formula 3) and naphthalene (naphthalimide-type structure, formula 4).

The formulae here below depict examples of recurring units (R1) (formulae 5A to 5C):

where:

- Ar is typically:

  with X = \(\text{O}, \text{C}, \text{H}_2\), \(\text{CF}_3\), \(\text{CF}_2\)\(n\)

  with \(n = 0, 1, 2, 3, 4\) or 5;

- R is typically:
Polyimides commercialized by DuPont as VESPEL® polyimides or by Mitsui as AURUM® polyimides are suitable for the purpose of the invention. The recurring units (R1) of the aromatic polyimide can comprise one or more functional groups other than the imide group, as such and/or in its amic acid form. Non-limitative examples of polymers complying with this criterion are aromatic polyetherimides (PEI), aromatic polyesterimides and aromatic polyamide-imides (PAI).

The high performance plastic is more preferably an aromatic polyimide chosen from aromatic polyamide-imides (PAI) and aromatic polyesterimides. Still more preferably, the high performance plastic is an aromatic polyamide-imide (PAI).

To the purpose of the present invention, “aromatic polyesterimide” is intended to denote any polymer more than 50 wt. % of the recurring units comprise at least one aromatic ring, at least one imide group, as such and/or in its amic acid form, and at least one ester group (recurring units (R2)). Typically, aromatic polyesterimides are made by reacting at least one acid monomer chosen from trimellitic anhydride and trimellitic anhydride monoacid halides with at least one diol, followed by reaction with at least one diamine.

To the purpose of the present invention, “aromatic polyamide-imide (PAI)” is intended to denote any polymer comprising more than 50 wt. % of recurring units comprising at least one aromatic ring, at least one imide group, as such
and/or in its amic acid form, and at least one amide group which is not included in the amic acid form of an imide group [recurring units (R3)].

The recurring units (R3) are advantageously chosen among:

- \( \text{Ar} \) is typically
  - \( \text{Ar} \) is typically

  \[
  \begin{align*}
  &\text{[Image of Ar structures]} \\
  &\text{[Image of Ar structures]} \\
  &\text{[Image of Ar structures]} \\
  &\text{[Image of Ar structures]} \\
  &\text{[Image of Ar structures]}
  \end{align*}
  \]

  with \( X = \) \( \text{[Image of X structures]} \) or \( n = 0, 1, 2, 3, 4 \)

- \( R \) is typically:

  \[
  \begin{align*}
  &\text{[Image of R structures]} \\
  &\text{[Image of R structures]} \\
  &\text{[Image of R structures]} \\
  &\text{[Image of R structures]} \\
  &\text{[Image of R structures]}
  \end{align*}
  \]

  with \( Y = \) \( \text{[Image of Y structures]} \) or \( n = 0, 1, 2, 3, 4 \) or 5.
Preferably, the aromatic polyamide-imide comprises more than 50 % of recurring units (R3) comprising an imide group in which the imide group is present as such, like in recurring units (R3-a), and/or in its amic acid form, like in recurring units (R3-b).

Recurring units (R3) are preferably chosen from recurring units (l), (m) and/or (n):

![Chemical Structure](image1)

(l-a)

and/or the corresponding amide-amic acid containing recurring unit:

![Chemical Structure](image2)

(l-b)

wherein the attachment of the two amide groups to the aromatic ring as shown in (l-b) will be understood to represent the 1,3 and the 1,4 polyamide-amic acid configurations;

![Chemical Structure](image3)

(m-a)

and/or the corresponding amide-amic acid containing recurring unit:

![Chemical Structure](image4)

(m-b)
wherein the attachment of the two amide groups to the aromatic ring as shown in (m-b) will be understood to represent the 1,3 and the 1,4 polyamide-amic acid configurations; and

and/or the corresponding amide-amic acid containing recurring unit:

wherein the attachment of the two amide groups to the aromatic ring as shown in (n-b) will be understood to represent the 1,3 and the 1,4 polyamide-amic acid configurations.

Very preferably, the aromatic polyamide-imide comprises more than 90 wt. % of recurring units (R3). Still more preferably, it contains no recurring unit other than recurring units (R3). Polymers commercialized by Solvay Advanced Polymers, L.L.C., as TORLON® polyamide-imides comply with this criterion.

The aromatic polyamide-imide can be notably manufactured by a process including the polycondensation reaction between at least one acid monomer chosen from trimellitic anhydride and trimellitic anhydride monoacid halides and at least one comonomer chosen from diamines and diisocyanates.

Among the trimellitic anhydride monoacid halides, trimellitic anhydride monoacid chloride is preferred.

The comonomer comprises preferably at least one aromatic ring. Besides, it comprises preferably at most two aromatic rings. More preferably, the comonomer is a diamine. Still more preferably, the diamine is chosen from the
group consisting of 4,4'-diaminodiphenylmethane, 4,4'-diaminodiphenylether, m-phenylenediamine and mixtures thereof.

For the purpose of the invention, the term “polyaryletherketone (PAEK)” is intended to denote any polymer, comprising recurring units \( (R''') \), more than 50 wt. % of said recurring units are recurring units \( (k-A), (k-B) \) and/or \( (k-C) \):

![Chemical Structures]

wherein the attachment of the ketone and/or ether groups to the aromatic ring as shown in \( (k-A), (k-B) \) and \( (k-C) \) will be understood to represent, independently at each occurrence, each of the possible ortho, meta and para configurations.

Preferably at least 70 wt. %, more preferably at least 80 wt. % of the recurring units \( (R''') \) of the polyaryletherketone \( (K) \) suitable for the polymer composition of the invention are recurring units \( (k-A), (k-B) \) and/or \( (k-C) \). Excellent results have been obtained with polyaryletherketone \( (K) \) comprising no recurring units other than recurring units \( (k-A), (k-B) \) and/or \( (k-C) \).

Polyaryletherketones \( (K) \) are generally crystalline aromatic polymers, readily available from a variety of commercial sources. Methods for their preparation are well known, including the processes described for example in U.S. Pat. Nos. 3,441,538, 3,442,857, 3,516,966, 4,396,755 and 4,816,556. The
polyaryletherketones (PAEK) have preferably reduced viscosities in the range of from about 0.8 to about 1.8 dl/g as measured in concentrated sulfuric acid at 25° C and at atmospheric pressure.

Preferably the polyaryletherketone (PAEK) is chosen among polyetheretherketones (PEEK) and polyetherketoneketone (PEKK).

A polyetheretherketone (PEEK) is a polyaryletherketone (PAEK) wherein more than 50 wt. % of recurring units (R") are recurring units (k-C).

A polyetherketoneketone (PEKK) is a polyaryletherketone (PAEK) wherein more than 50 wt. % of recurring units (R") are recurring units (k-B).

Non limitative examples of commercially available polyaryletherketone (PAEK) resins suitable for the invention include the VICTREX® PEEK polyetheretherketone, from Imperial Chemicals, Inc., which is a polymer, the recurring units of which are recurring units (k-c1):

![Chemical Structure](chart)

(k-c1)

The terms “liquid crystal polymers (LCP)” encompass not only fully aromatic liquid crystalline polyesters.

Fully aromatic liquid crystalline polyesters can be produced in the melt by three main processes:

- direct esterification of optionally substituted phenols with aromatic carboxylic acids in the presence of catalysts such as titanium tetra butyrate or dibutyl tin diacetate at high temperature;
- reaction between phenyl esters of aromatic carboxylic acids with relevant optionally substituted phenols;
- acidolysis of phenolic acetates with aromatic carboxylic acids.

Non limitative examples of commercially available fully aromatic liquid crystalline polyesters are notably VECTRA® LCP from Hoechst-Celanese and XYDAR® LCP from Solvay Advanced Polymers.

VECTRA® LCP is typically synthesized from 4-hydrobenzoic acid and 6-hydroxy-2-naphtoic acid; VECTRA® LCP is a polymer the recurring units of which are recurring units (lcp-A) and (lcp-B), typically in a ratio (lcp-A)/(lcp-B) of about 25/75:
XYDAR\textsuperscript{\textregistered} LCP is typically synthesized from 4-hydroxybenzoic acid, 4,4’-dihydroxy-1,1’-biphenyl, and terephthalic acid; the basic structure can be modified by using other monomers such as isophthalic acid or 4-aminobenzoic acid; XYDAR\textsuperscript{\textregistered} LCP is generally a polymer the recurring units of which are recurring units (lcp-C), (lcp-D) and (lcp-B), typically in a ratio $(lcp-C)/(lcp-B)$ of about 1/2:

Polymer composition (C\textsuperscript{**}) comprises preferably high performance plastic (P) as main polymer (i.e., in polymer composition (C\textsuperscript{**}), the weight fraction of high performance plastic (P) is greater than or equal to the weight fraction of polymer (P2)). More preferably, polymer composition (C\textsuperscript{**}) comprises more than 50 wt. % of high performance plastic (P). Still more preferably, polymer composition (C\textsuperscript{**}) comprises preferably more than 75 wt. % of high performance plastic (P).

Still in another embodiment of the present invention, a preferred polymer composition (C) is one further comprising, in addition to high performance plastic (P), at least one filler [polymer composition (C\textsuperscript{3**})].
Non limitative examples of suitable fillers include flake, spherical and fibrous particulate reinforcement fillers and nucleating agents such as talc, mica, titanium dioxide, potassium titanate, silica, kaolin, chalk, alumina, mineral fillers, and the like. Other suitable fillers include notably glass fiber, carbon fiber, graphite fiber, fibers formed of silicon carbide, alumina, titania, boron and the like, and may include mixtures comprising two or more such fibers.

Polymer composition (C₃*) comprises preferably at least one fibrous filler. The weight amount of filler comprised in polymer composition (C₃*) is advantageously at least 5 wt. %, and preferably at least 20 wt. % based on the total weight of the polymer composition. Besides, it is advantageously at most 40 wt. %, and preferably at most 20 wt. % based on the total weight of the polymer composition.

Polymer composition (C₃*) comprises preferably more than 50 wt. % of high performance plastic (P). Still more preferably, polymer composition (C₃*) comprises preferably more than 75 wt. % of high performance plastic (P).

Polymer composition (C) is comprised in article (A) in an amount of advantageously at least 10 volume %, preferably at least 20 volume % and still more preferably at least 30 volume %, based on the total volume of the article.

Besides, polymer composition (C) is comprised in article (A) in an amount of advantageously at most 70 volume %, preferably at most 65 volume %, more preferably 50 volume % and still more preferably at most 40 volume %, based on the total volume of the article.

Good results have been obtained with articles wherein the volume fraction of the polymer composition (C) is from 20 to 65 % [based on total volume of article (A)].

Besides, polymer composition (C) is comprised in article (A) in an amount of advantageously at least 1 wt. %, preferably at least 3 wt. %, more preferably at least 5 wt. % based on the total weight of the article.

Besides, polymer composition (C) is comprised in article (A) in an amount of advantageously at most 50 wt. %, preferably of at most 40 wt. %, more preferably of at most 30 wt. %, based on the total weight of the article.

Good results have been obtained with articles wherein the weight fraction of the polymer composition (C) is from 5 to 30 % [based on total weight of article (A)].

The thickness of overmolded polymer composition (C) is not limited, but is preferably from 0.25 to 1.5 mm, including for example 0.3, 0.4, 0.5, 0.6, 0.7, 0.8,
0.9, 1.0, 1.1, 1.2, 1.3, and 1.4 mm. Very preferably, the thickness of overmolded polymer composition (C) is above 0.5 mm. Still more preferably, the thickness of overmolded polymer composition (C) is above 0.8 mm.

A second aspect of the invention relates to a process for producing the invention articles. The process for producing the article as above described comprises the step of applying the polymer composition (C) to a surface of metal component (M). Preferred methods for applying the polymer composition (C) to a surface of metal component (M) include, but are not limited to, injection molding, casting, extruding, compression molding, sintering, machining, or combinations thereof. Injection molding is especially preferred.

The molding process will be further understood with reference to the following non-limiting examples.

Example 1: Molding a high performance plastic onto a metal insert by injection molding

A high performance plastic overmolded bearing 1 is produced as a drop in for a roller-element multi-component metal thrust bearing. In order to produce the article, a metal component (M), in the form of a washer with an outer diameter of 71 mm, inner diameter of 47 mm and a thickness of 2.5 mm, is heated to 260 °C and inserted into a mold of an injection molding machine. The mold is designed so that the metal component (M) remains fixed in place during injection of the high performance plastic. The metal component (M) is then injection molded using the high performance plastic TORLON® PAI. The injection molded TORLON® PAI almost completely covers the metal component (M), with only small section on the inner and outer diameter exposed. However, TORLON® PAI covers the wear faces of the washer. TORLON® PAI is then cured leading to a final TORLON® PAI thickness of 1 mm. The finished article has approximately 6 g less TORLON® PAI as compared to the same article produced only with TORLON® PAI without the metal component (M), and allows a high polymer material cost saving of approximately 50 %.

Example 2: Molding a high performance plastic onto a metal insert by heat and pressure followed by machining

A sintered bronze was poured onto a substrate consisting of steel in a substantially uniform layer (from a macroscopic point of view), however exhibiting important local variations of thickness (at microscopic scale); then, it was bonded to the steel substrate by sintering (i.e. by the action of heat and pressure), to obtain a composite element insert.
A roll of PAI film was positioned adjacent to the composite element and brought in contact with the sintered bronze layer of composite element. The film was then bonded to the sintered bronze coated metal substrate using heat and pressure. The bond was achieved by both the flow of the film into the sintered bronze layer (mechanical) and by the ionic attraction of the PAI to the bronze metal.

Additional curing was conducted in the case where the film had not been cured at all or had only weakly been cured. This additional curing was accomplished by processing through an oven.

High performance plastic overmolded bearings were then shaped from the composite material.
CLAIMS

1. An article (A) comprising at least one metal component (M), said metal component (M) being overmolded with at least one polymer composition (C) comprising at least one high performance plastic (P).

2. The article according to claim 1, wherein the high performance plastic (P) is chosen among aromatic polyimides (PI), polyaryletherketones (PAEK), and liquid crystal polymers (LCP).

3. The article according to claim 1, wherein the high performance plastic (P) is an aromatic polyamide-imide (PAI), more than 50 wt. % of the recurring thereof comprising at least one aromatic ring, at least one imide group, as such and/or in its amic acid form, and at least one amide group which is not included in the amic acid form of an imide group [recurring units (R3)].

4. The article according to claim 3, wherein the recurring units (R3) are chosen among:

\[
\begin{align*}
\text{R3-a} & \quad \text{(imide form)} \\
\text{R3-b} & \quad \text{(amic acid form)}
\end{align*}
\]

where:

- Ar is:

\[
\begin{align*}
\quad & , \\
\quad & , \\
\quad & , \\
\quad & , \\
\quad & 
\end{align*}
\]
with $X = \begin{align*}
&\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\end{align*}$

with $n \in \{0, 1, 2, 3, 4\}$

or 5;

- $R$ is:

5

$\begin{align*}
&\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\end{align*}$

with $Y = \begin{align*}
&\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2 \\
\text{CF}_3 \\
\text{CF}_3 \\
\end{array}
\end{align*}$

with $n \in \{0, 1, 2, 3, 4\}$ or 5.

5. - The article according to claim 4, wherein the recurring units ($R^3$) are chosen from recurring units (I), (m) and/or (n):

10

$I$

$I-a$

and/or the corresponding amide-amic acid containing recurring unit:
wherein the attachment of the two amide groups to the aromatic ring as shown in (1-b) will be understood to represent the 1,3 and the 1,4 polyamide-amic acid configurations;

and/or the corresponding amide-amic acid containing recurring unit:

wherein the attachment of the two amide groups to the aromatic ring as shown in (m-b) will be understood to represent the 1,3 and the 1,4 polyamide-amic acid configurations; and
and/or the corresponding amide-amic acid containing recurring unit:

![Chemical Structure](image)

(n-b)

wherein the attachment of the two amide groups to the aromatic ring as shown in (n-b) will be understood to represent the 1,3 and the 1,4 polyamide-amic acid configurations.

6. - The article according to anyone of the preceding claims, wherein polymer composition (C) consists essentially of high performance plastic (P).

7. - The article according to anyone of the preceding claims wherein the volume fraction of polymer composition (C) is from 20 to 65 % [based on total volume of article (A)].

8; - The article according to anyone of the preceding claims wherein the weight fraction of polymer composition (C) is from 5 to 30 % [based on total weight of article (A)].

9. - The article according to anyone of the preceding claims wherein the thickness of overmolded polymer composition (C) is from 0.25 to 1.5 mm.

10. - The article according to anyone of the preceding claims, wherein metal component (M) is partly overmolded with polymer composition (C).

11. - A process for producing the article according to anyone of the preceding claims, which comprises the step of applying the polymer composition (C) to a surface of metal component (M).

12. - The process according to claim 11 wherein the step of applying polymer composition (C) comprises injection molding, casting, extruding, compression molding, sintering, machining and combinations thereof.
**INTERNATIONAL SEARCH REPORT**  
**International Application No**  
PCT/EP2005/054964

### A. CLASSIFICATION OF SUBJECT MATTER

**C08K3/08**

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C08K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and, where practical, search terms used):

EPO-Internal, PAJ, CHEM ABS Data, WPI Data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 5 395 171 A (WASKIEWICZ ET AL)</td>
<td>1-12</td>
</tr>
<tr>
<td></td>
<td>7 March 1995 (1995-03-07) cited in the application claims</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>EP 0 531 867 A (SUMITOMO BAKELITE COMPANY LIMITED; NEC CORPORATION)</td>
<td>1-12</td>
</tr>
<tr>
<td></td>
<td>17 March 1993 (1993-03-17) claims</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>EP 0 486 724 A (NATIONAL STARCH AND CHEMICAL INVESTMENT HOLDING CORPORATION)</td>
<td>1-12</td>
</tr>
</tbody>
</table>

* Further documents are listed in the continuation of box C.  

Patent family members are listed in annex.

**Date of the actual completion of the international search**  
8 December 2005

**Date of mailing of the international search report**  
16/12/2005

**Name and mailing address of the ISA**

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

**Authorized officer**

Andriollo, G

Form PCT/SIA010 (second sheet) (January 2004)
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 5395171</td>
<td>07-03-1995</td>
<td>ES 2088724 A2</td>
<td>16-08-1996</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR 2696217 A1</td>
<td>01-04-1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MX 9304252 A1</td>
<td>31-03-1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 5433530 A</td>
<td>18-07-1995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 5284899 A</td>
<td>08-02-1994</td>
</tr>
</tbody>
</table>