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(71) Applicant: **Kiswire SDN. BHD**
81787 Pasir Gudang, Johor (MY)

(72) Inventors:
- **ROZLAN, Muhammad Nur Annas**
  Pasir Gudang
  81700 Johor (MY)
- **CHO, Myung Hyun**
  Haeundae-gu, Busan 48118 (KR)

(74) Representative: **Maiwald Patentanwalts GmbH**
Elisenhof
Elisenstrasse 3
80335 München (DE)

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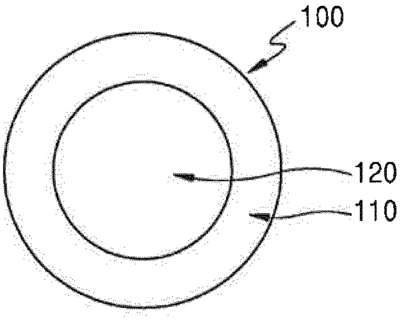
(54) POLYMER COMPOSITE MATERIAL

(57) The present invention relates to a polymer composite having a multi-layered structure formed by implanting one or more steels and fibers into a polymer and adhering the one or more steels and fibers to the polymer and thus being lightweight and having high strength, high toughness, and high wear resistance. The polymer composite includes a polymer, a filament implanted into the polymer and adhered to the polymer, and a fiber implanted into the polymer and adhered to the polymer, in which either only the filament or the fiber is implanted into the polymer and adhered to the polymer, or the filament and the fiber are simultaneously implanted into the polymer and adhered to the polymer.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a polymer composite, and more particularly, to a polymer composite having a multi-layered structure formed by implanting one or more steels and fibers into a polymer and adhering the one or more steels and fibers to the polymer, thus being lightweight and having high strength, high toughness, and high wear resistance.

BACKGROUND ART

[0002] Generally, steel wires are used in mooring steel ropes of sea oil and gas production equipment, steel ropes for floating cranes, mining ropes, cables for structures and bridges, and so on. Steel Wires are also used as reinforcing materials for sporting goods, industrial materials, automobile vehicles, and tires.

[0003] To use steels in such applications, increasing the high strength of steel wire shows continuous progress. For mooring steel ropes or steel ropes for floating cranes, a steel with high corrosion resistance must be used due to corrosive environment, and a steel having a low self-weight and high corrosion resistance must be used as the depth of water applied to the ropes increases.

[0004] However, currently, when manufacturing steels having high strength or steels with high corrosion resistance, problems arise such as an increase in steel weight itself. When the self-weight of a steel increases, a self-weight of equipment using the steel also increases. Accordingly, problems may occur in terms of energy reduction of equipment using steels, and inconveniences may arise in equipment using steels due to the increase in self-weight of the steel used.

[0005] Therefore, there is a need to develop a material that is light and has strength and toughness similar to steels. According to technologies published in the previous literatures, there are methods of increasing the strength of a steel, however, there are limitations in achieving light weight through the method of reducing steel weight at the same time.

DETAILED DESCRIPTION OF THE INVENTION

TECHNICAL PROBLEM

[0006] To address the problems described above, the present invention provides a polymer composite which becomes lightweight and has high strength, high toughness and high wear resistance by means of a multi-layered structure formation by implanting one or more steels and fibers into a polymer and adhering the one or more steels and fibers to the polymer.

TECHNICAL SOLUTION

[0007] According to an aspect of an embodiment, a polymer composite includes a polymer, a filament implanted into the polymer and adhered to the polymer, and a fiber implanted into the polymer and adhered to the polymer, wherein either only the filament or the fiber is implanted into the polymer and adhered to the polymer, or the filament and the fiber are simultaneously implanted into the polymer and adhered to the polymer, and thus the polymer composite is lightweight and has high strength and high toughness.

[0008] To achieve above mentioned objective, the filament of the polymer composite may include at least one steel or fiber. The polymer may be adhesion-treated with an adhesive and adhered to the filament or the fiber. The filament or the fiber may be surface-modified with plasma and adhered to the polymer.

[0009] In the polymer composite, the polymer and the filament or the polymer and the fiber may have an adhesion force ratio of 5% or more. An adhesion interface formed between the polymer and the filament or between the polymer and the fiber may have a void ratio of 90% or less.

[0010] In the polymer composite, the filament may be positioned at a center of the polymer, and the fiber may be positioned around the filament. The fiber may include a plurality of fibers to form a fiber layer around the filament, and the fiber layer may be formed as at least one layer.

[0011] The composite polymer may further include a filler implanted into the polymer and adhered to the polymer, and the filler may include a steel or a fiber. The filament and the fiber may be implanted into the polymer in at least one form selected from three forms which are a linear form, a twisted pair form, and a fabric form.

[0012] In the polymer composite, the polymer may include at least one selected from thermoplastic polyurethane (TPU), high density polyethylene (HDPE), polyethylene (PE), polypropylene (PP), and polyester, and the fiber may include at least one selected from aramid, polyester, nylon, and PE.

[0013] The polymer composite may have any one of circular, rectangular, plate, and sheet cross-sectional shapes.

The polymer may be rapidly cooled at a high pressure and thus may have an internal void area ratio of 2% or less.

[0014] Among the polymers of the polymer composite according to the present invention, the HDPE polymer may include HDPE and HDPE-g-MAH as an additive. When HDPE is used as the polymer, the polymer may be adhesion-treated with a solution of 5% silane and 95% deionized water or a solution of 5% silane and 95% ethanol to be adhered to the fiber or the filament.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0015] According to one or more embodiments of the present invention, in a polymer composite, one or more steels and fibers are implanted into a polymer and adhered thereto. By implanting and adhering the one or more steels and fibers into and to the polymer, a polymer composite with high tensile strength and a high breaking load can be obtained.

[0016] In addition, the polymer may be adhesion-treated and adhered to the filament or the fiber, and the filament and the fiber may be adhered to the polymer with plasma surface treatment, thereby increasing an adhesion force between the filament and the polymer or between the fiber and the polymer.

[0017] Moreover, the polymer may be rapidly cooled at a high pressure to minimize the size of internal voids of the polymer, thereby increasing a tensile strength of the polymer. The polymer and the fiber have smaller self-weights than that of steel and thus a light polymer composite having a high tensile strength and a high breaking load can be obtained.

DESCRIPTION OF THE DRAWINGS

[0018]

FIGS. 1 to 3 are views of polymer composite according to embodiments of the present invention.

FIG. 4 is a view illustrating a cross-section of FIG.3.

FIGS. 5 to 7 are views of polymer composite according to embodiments of the present invention.

FIG. 8 is a graph showing a relationship between an adhesion force ratio (%) and a spinning factor (%).

FIG. 9 is a graph showing a relationship between a spinning factor (%) and a tensile load.

FIG. 10 is a graph showing a tensile strength of a polymer composite according to an embodiment of the present invention.

FIG. 11 is a graph showing a breaking load of a polymer composite according to an embodiment of the present disclosure.

FIG. 12A is an image showing an adhesion interface between a polymer and a filament or a fiber, adhered to each other, according to an embodiment of the present invention.

FIG. 12B illustrates energy-dispersive X-ray (EDX) analysis results of the adhesion interface between a polymer and a filament or a fiber, adhered to each other.

FIG. 13A is an image showing an adhesion interface between a polymer and a filament or a fiber that are not adhered to each other.

FIG. 13B illustrates EDX analysis results of the adhesion interface between a polymer and a filament or a fiber that are not adhered to each other.

FIG. 14 is a graph showing an adhesive strength between a polymer and a filament or a fiber before and after adhesive treatment, according to an embodiment of the present invention.

FIG. 15 is a graph showing an adhesive strength of a polymer including an adhesion accelerator added thereto, according to an embodiment of the present invention.

FIG. 16 illustrates images of adhesion interfaces before and after plasma surface modification treatment, according to an embodiment of the present invention.

FIG. 17 is a graph showing adhesion forces before and after plasma surface modification treatment, according to an embodiment of the present invention.

FIG. 18 illustrates an adhesion interface according to an embodiment of the present invention.

FIGS. 19A and 19B illustrate images showing changes in void area of a polymer before and after rapid cooling at a high pressure.

FIGS. 20A and 20B illustrate images showing internal void ratios (%) of a polymer before and after rapid cooling at a high pressure, according to embodiments of the present invention.

MODE OF THE INVENTION

[0019] The present invention relates to a polymer composite, and more particularly, to a polymer composite having a multi-layered structure formed by implanting one or more steels and fibers into a polymer and adhering the one or more steels and fibers to the polymer, thus being lightweight and having high strength, high toughness, and high wear resistance.

[0020] Tensile strength (N/mm^2) increases in proportion to tensile load (N), and breaking strength (N/mm^2) increases in proportion to breaking load (N). Thus, as the tensile load (N) and the breaking load (N) increase, the tensile strength (N/mm^2) and the breaking strength (N/mm^2) increase. Thus, in the description below, an increase in the tensile load (N) or the breaking load (N) denotes an increase in the tensile strength (N/mm^2) or the breaking strength (N/mm^2).

[0021] Hereinafter, exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings.

[0022] A polymer composite 100 includes a polymer 110, a filament 120, and a fiber 130. Here, either only the filament 120 or the fiber 130 may be implanted into the polymer 110 and adhered thereto, or the filament 120 and the fiber 130 may be simultaneously implanted into the polymer 110 and adhered thereto.

[0023] Referring to FIGS. 1 and 2, the filament 120 is implanted into the polymer 110 and adhered thereto. In this regard, the filament 120 may include at least one steel or fiber. That is, the filament 120 may be formed of a steel or a fiber. The filament 120 may include one filament and also may be made up of at least two filaments.

[0024] Referring to FIGS. 3 and 4, the polymer composite 100 may further include the fiber 130. The fiber 130 may be positioned in the vicinity of the filament 120 and include a plurality of fibers to form a fiber layer 131 in the vicinity of the filament 120. That is, the polymer composite 100 may include the filament 120 at a center thereof and the fibers 130 surrounding the filament 120 and forming the fiber layer 131.

[0025] The filament 120 and the fibers 130 are implanted into the polymer 110 and adhered thereto. Referring to FIGS. 3 and 4, the polymer 110 may include a first polymer 111 and a second polymer 112. The first polymer 111 surrounds the filament 120. The second polymer 112 surrounds the fibers 130. The filament 120 is implanted into the first polymer 111 and adhered thereto, and the fibers 130 are implanted into the second polymer 112 and adhered thereto. In this regard, the first polymer 111 and the second polymer 112 may be identical to or different from each other.

[0026] The fiber layer 131 formed of the fibers 130 may be formed as a single layer or as at least two layers.

[0027] Referring to FIG. 5, fillers 140 are implanted into the polymer 110 and adhered thereto, and the fillers 140 may be formed of a steel or a fiber. The fillers 140 may be implanted in an empty space between the fibers 130 or in an empty space between the fibers 130 and the filament 120. Since the fillers 140 may be implanted in the empty space, a decrease in strength of the empty space may be prevented. Thus, the strength of the polymer composite 100 is increased by implanting the fillers 140 having high strength into the empty space. The fillers 140 are formed of a steel or a fiber having high toughness and thus also have an effect of increasing the toughness of the polymer composite 100.

[0028] Referring to FIG. 6, the polymer composite 100 may have various cross-sectional shapes. The cross-section of the polymer composite 100 may generally have a circular shape, but the present invention is not limited thereto. For example, the cross-section of the polymer composite 100 may have a rectangular, plate, or sheet shape. In addition, the cross-section of the polymer composite 100 may have other heterogeneous shapes (e.g., a trapezoidal shape, an H cross-sectional shape, a Z cross-sectional shape, and the like).

[0029] The filament 120 and the fiber 130 may be implanted into the polymer 110 in various forms and adhered thereto. The filament 120 and the fiber 130 may be implanted into the polymer 110 in a linear form, and referring to FIG. 3, the filaments 120 and the fibers 130 may be implanted into the polymer 110 in a twisted pair form. In addition, the filaments 120 and the fibers 130 may be implanted into the polymer 110 in a mesh or braided form.

[0030] That is, the filament 120 and the fibers 130 may be implanted into the polymer 110 so as to extend in one direction, or may be implanted into the polymer 110 in a fabric form so as to extend simultaneously in horizontal and vertical directions. Shapes in which the filament 120 and the fibers 130 are implanted into the polymer 110 are not limited to the above examples and the filament 120 and the fibers 130 may be implanted into the polymer 110 in various forms.

[0031] The shape of the polymer composite 100 is not limited to the shapes described above, and the polymer composite 100 may have various other shapes. Referring to FIG. 7, two filaments 120 may be implanted at a center of the polymer 110, and four fibers 130 may be bound together to form the fiber layer 131. In addition, the polymer composite 100 may have various other shapes so long as they increase the strength of the polymer composite 100.

[0032] Non-limiting examples of the polymer 110 include thermoplastic polyurethane (TPU), high density polyethylene (HDPE), polyethylene (PE), polypropylene (PP), and polyester, and non-limiting examples of the fiber 130 include aramid, polyester, nylon, and PE. Types of the polymer 110 and the fiber 130 are not limited to the above examples, and various other types thereof may be used so long as they increase the strength of the polymer composite 100. The types of the polymer 110, i.e., TPU, HDPE, PE, PP, and polyester, and the types of the fiber 130, i.e., aramid, polyester, nylon, and PE, are known in the art, and thus a detailed description thereof will not be provided herein.

[0033] The steel may be a metal-plated steel or a steel not plated with a metal. The metal-plated steel may be a zinc (Zn)-plated steel, a brass-plated steel, or the like and the steel may be plated with various other metals.

[0034] The vital quality characteristics of the polymer composite 100 is a spinning factor (%), and the spinning factor (%) is determined by an adhesion force ratio (%) among the polymer 110 and the filament 120 and the fiber 130 that are implanted into the polymer 110.

[0035] In this regard, the spinning factor (%) is defined by the following equation: spinning factor (%)=(tensile load of the polymer composite 100/(sum of individual tensile loads of the fibers 130 and the filament 120+tensile load of the polymer 110))*100. That is, the spinning factor (%) is a ratio of the tensile load of the polymer composite 100 to a value obtained by adding together the individual tensile loads of the filament 120 and the fibers 130 which are implanted into the polymer 110 and also by including the tensile load of the polymer 110.

[0036] In this regard, the adhesion force ratio (%) is defined by the following equation: adhesion force ratio (%)=(adhesive strength (N/mm^2)/tensile strength of polymer (N/mm^2))*100. The adhesive strength is a value obtained by dividing an adhesion force (N) between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130 by an area of an adhesion interface.

[0037] FIG. 8 is a graph showing a relationship between an adhesion force ratio (%) and a spinning factor (%). FIG. 9 is a graph showing a relationship between a spinning factor (%) and a tensile load (N). Referring to FIGS. 8 and 9, it is confirmed that the greater the adhesion force ratio (%), the greater the spinning factor (%), and the greater the spinning factor (%), the greater the tensile load of the polymer composite 100. In addition, as the adhesion force between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130 increases, the breaking load of the polymer composite 100 increases.

[0038] Thus, the adhesion force ratio (%) between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130 may be 5% or more. When the adhesion force ratio (%) is 5% or less, the tensile load and breaking load of the polymer composite 100 decreases, and thus it is difficult to obtain a desired strength of the polymer composite 100. Accordingly, the adhesion force ratio (%) between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130 may be 5% or more.

[0039] FIGS. 10 and 11 are graphs showing a tensile strength and a breaking load according to elongation of the polymer composite 100. Referring to FIGS. 10 and 11, it is confirmed that the polymer composite 100 has a higher tensile strength, a higher breaking load, and a lower elongation than those of polyester. That is, the elongation of the polymer composite 100 when reaching the tensile strength and the breaking load is lower than that of polyester when reaching the tensile strength and the breaking load. In this regard, the decrease in elongation is a characteristic of steel, and the polymer composite 100 has an effect similar to this characteristic of steel due to the structure in which the filament 120 and the fiber 130 are implanted into the polymer 110.

[0040] As described above, in the polymer composite 100, the tensile load and the breaking load increase as the adhesion force ratio (%) increases, and to increase the adhesion force ratio (%), the adhesion force between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130 has to be increased.

[0041] To increase the adhesion force, the polymer 110 may be adhesion-treated with an adhesive and then adhered to the filament 120 or the fiber 130. Types of the adhesive are determined by types of the polymer 110.

[0042] When HDPE is used as the polymer 110, the polymer 110 may be adhesion-treated using a solution of 5% silane and 95% deionized water or a solution of 5% silane and 95% ethanol and then adhered to the filament 120 or the fiber 130. By such adhesion treatment (chemical treatment), the adhesion force between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130 is enhanced and accordingly, the tensile load and breaking load of the polymer composite 100 also increase.

[0043] FIGS. 12A and 12B illustrate an adhesion interface of a sample obtained by adhesion-treating Zn-plated steel with a solution of 5% silane and 95% deionized water and then adhering it to HDPE polymer 110. Referring to FIG. 12A, voids or pores with a very small size exist at the adhesion interface, which means that the polymer 110 and the steel are satisfactorily adhered to each other.

[0044] FIG. 12B is a graph showing energy-dispersive X-ray (EDX) analysis results of the sample described above. Referring to FIG. 12B, it is confirmed that carbon (C) of the polymer 110 and the Zn component of the Zn-plated steel are uniformly distributed. This means that the polymer 110 and the steel are satisfactorily chemically adhered to each other.

[0045] FIGS. 13A and 13B illustrate an adhesion interface of the above-described sample, the HDPE and Zn-plated steel of which have not yet been adhesion-treated with the solution of 5% silane and 95% deionized water. Referring to FIG. 13A, voids or pores with a large size exist at the adhesion interface. This indicates that the polymer 110 and the steel are unsatisfactorily adhered to each other.

[0046] FIG. 13B is a graph showing EDX analysis results of the above-described sample, from which it is confirmed that the carbon (C) component of the polymer 110 is not uniformly distributed. This means that the polymer 110 and the steel are unsatisfactorily chemically adhered to each other.

[0047] As such, when HDPE is used as the polymer 110, HDPE as the polymer 110 may be adhesion-treated with a solution of 5% silane and 95% deionized water and then adhered to the filament 120 or the fiber 130, thereby increasing the adhesion force therebetween. In this case, a solution of 5% silane and 95% ethanol may also be used instead of the solution of 5% silane and 95% deionized water.

[0048] Various types of the adhesive may be determined according to types of the polymer 110, and when TPU or polyester is used as the polymer 110, Chemlok adhesives may be used. Chemlok adhesives are commercially available adhesives and thus a detailed description thereof will not be provided herein. By using such adhesives, the adhesion force between the polymer 110 and the filament 120 or the fiber 130 may be increased. FIG. 14 is a graph showing a comparison of results before and after adhesion treatment of TPU with an adhesive. Referring to FIG. 14, it is confirmed that a higher adhesion force is obtained by the adhesion treatment of TPU with an adhesive. Types of the adhesive are not limited to the above example, and various other adhesives capable of increasing the adhesion force of the polymer 110 may also be used according to types of the polymer 110.

[0049] The polymer 110 may include an adhesion accelerator added thereto. To add the adhesion accelerator, the polymer 110 may be dissolved and mixed with the adhesion accelerator. The adhesion accelerator may enhance the adhesion force between the polymer and the filament 120 or between the polymer 110 and the fiber 130. Various types of adhesion accelerators may be used according to types of the polymer 110, and when HDPE is used as the polymer 110, HDPE-g-MAH may be used as the adhesion accelerator.

[0050] FIG. 15 is a graph showing adhesion force enhancement results obtained using the polymer 110 formed of 90% HDPE and 10% HDPE-g-MAH as an adhesion accelerator. When HDPE is used as the polymer 110, carbon black may also be used as the adhesion accelerator in addition to HDPE-g-MAH. By using the adhesion accelerator, the adhesion force is increased 8 times in the case of using HDPE-g-MAH and the adhesion force is increased two times in the case of using carbon black.

[0051] To enhance the adhesion force between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130, the filament 120 or the fiber 130 may be subjected to atmospheric pressure plasma surface modification (hereinafter, refers to as "plasma surface modification" for the subsequent explanation). When the filament 120 or the fiber 130 is subjected to plasma surface modification, the adhesion force between the filament 120 or the fiber 130 and the polymer 110 is enhanced.

[0052] FIG. 16 illustrates an adhesion portion between the polymer 110 and the filament 120 or the fiber 130 before and after plasma surface modification of the filament 120 or the fiber 130. Through the plasma surface modification, gaps generated at the adhesion interface may decrease. The gaps are voids of the adhesion interface, and the size of the voids of the adhesion interface is reduced by performing the plasma surface modification and, accordingly, the adhesion force between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130 may be enhanced.

[0053] FIG. 17 illustrates adhesion forces without and with plasma surface modification and test results of an adhesion force among TPU as the polymer 110, aramid as the fibers 130, and a brass plate; and an adhesion force among polyester as the polymer 110, aramid as the fiber 130, and a brass plate. Referring to FIG. 17, it is confirmed that the adhesion force is increased by a factor of about two times through the plasma surface modification when TPU is used as the polymer 110, and the adhesion force is increased by a factor of about five times through the plasma surface modification when polyester is used as the polymer 110.

[0054] The polymer 110 and the filament 120 or the polymer 110 and the fiber 130 are adhered to each other and thus voids are formed at an adhesion interface between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130, and a void ratio at adhesion interface (%) may be 90% or less.

[0055] In this regard, the void ratio at adhesion interface (%) is defined by the following equation: void ratio at adhesion interface (%)=(sum of lengths of all voids at adhesion interface/total adhesion interface length)*100, when the polymer composite 100 is cut.

[0056] A method of measuring the void ratio at adhesion interface (%) will now be described with reference to FIG. 18. The polymer composite 100 is cut, lengths of voids in an area of 407.17x542.28 μm^2 is measured using an electron microscope at a magnification of x600, a total adhesion interface length is measured, and the sum of the lengths of all the voids is divided by the total adhesion interface length in order to obtain the void ratio at adhesion interface (%). Referring to FIG. 18, the sum of the lengths of all the voids is 102.76 μm and the total adhesion interface length is 630.83 μm, and thus the void ratio at adhesion interface (%) is determined as 102.76/630.83x100=16.3%.

[0057] When the void ratio at adhesion interface (%) is greater than 90%, the size of voids increases, and thus the adhesion force between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130 decreases and, accordingly, the tensile load and breaking load of the polymer composite 100 decrease. Therefore, the void ratio at adhesion interface (%) may be maintained at 90% or less.

[0058] The polymer 110 may account for 15% to 40% of a total cross-sectional area of the polymer composite 100. Thus, when the strength of the polymer 110 occupying a large area of the polymer composite 100 is increased, the strength of the polymer composite 100 may also be increased. A melted form of the polymer is used to prepare the polymer composite 100. To increase the strength of the polymer 110, the polymer 110 in the melted form may be subjected to high pressure and rapid cooling. That is, the polymer 110 is rapidly cooled while increasing a pressure during solidification. As a result of rapid cooling of the polymer 110 at a high pressure, the size of voids formed inside the polymer 110 decreases and, accordingly, the tensile strength of the polymer 110 increases.

[0059] FIGS.19A and 19B are images showing voids inside the polymer 110 before and after rapid cooling of the polymer 110 at a high pressure. FIG. 19A illustrates a state of the polymer 110 before rapid cooling at a high pressure, and FIG. 19B illustrates a state of the polymer 110 after rapid cooling at a high pressure. Referring to FIGS. 19A and

19B, when the polymer 110 is rapidly cooled at a high pressure, the area of voids inside the polymer 110 decreases from 2698.57 μm to 173.78 μm, which is 1/15 of the original void area. Such a decrease in the size of voids results in an increase in tensile strength of the polymer 110.

[0060] When the polymer 110 is rapidly cooled at a high pressure, the polymer 110 may have an internal void area ratio of 2% or less. The polymer internal void area ratio (%) is measured by cutting the polymer composite 100 and is defined by the following equation:

Polymer internal void area ratio (%)=(sum of areas of voids existing in cutting area of polymer/cutting area of polymer)x100.

[0061] The polymer internal void area ratio (%) may be measured as follows. The polymer composite 100 is cut and photographed using an electron microscope at a magnification of x5000. The areas of voids viewed in the photograph are added together and the obtained value is divided by the area of the photograph to obtain the polymer internal void area ratio. In this regard, a portion of the polymer composite 100, in which an adhesion interface is not formed and only the polymer 110 exists, is cut, and the polymer internal pore area ratio (%) may be measured by observation using a microscope.

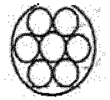
[0062] FIGS. 20A and 20B illustrate a polymer internal void area ratio (%) before and after rapid cooling of the polymer 110 at a high pressure. FIG. 20A illustrates a state of the polymer 110 before rapid cooling at a high pressure, and FIG. 20B illustrates a state of the polymer 110 after rapid cooling at a high pressure. When the polymer 110 is rapidly cooled at a high pressure, a sum of areas of voids is decreased and, accordingly, the polymer internal void area ratio (%) decreases. FIGS. 20A and 20B illustrate measurement results of two samples, from which it is confirmed that by rapidly cooling the polymer 110 at a high pressure, the polymer internal void area ratios (%) of the two samples decrease from 2.71% to 0.11% and from 4.14% to 0.18%, respectively.

[0063] Hereinafter, the present invention is specifically described below based on examples, but these examples are provided only for illustrative purposes and are not intended to limit the scope of the present invention.

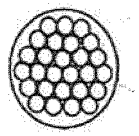
[Example 1]

[0064] Table 1 shows types of the polymer 110, the filament 120 and the fiber 130 used for manufacturing polymer composite samples and adhesion forces of polymer composite samples made with different adhesive materials (=bonding agents) as example of a particular embodiment of the present invention. Polymer composite samples were manufactured in in-line equipment using the polymer 110, the filament 120, and the fiber 130 via an adhesive. Processes of in-line equipment were composed of adhesive coating, drying, and polymer binding in an extruder. An adhesion force N of the sample was obtained by measuring a tensile load when the polymer 110 and the filament 120 or the fiber 130 were separated from each other by using a tensile tester. As a result of an adhesion force test, it is confirmed that, in a case in which HDPE was used as the polymer 110 and the filament 120 is plated with Zn, when the polymer 110 was adhesion-treated with a solution of 5% silane and 95% deionized water or a solution of 5% silane and 95% ethanol, the adhesion force was enhanced. In addition, it is confirmed that when the polymer 110 including 90% HDPE and 10% HDPE-g-MAH as an adhesion accelerator was used, the adhesion force was enhanced. The following example is provided only for illustrative purposes and is not intended to limit the scope of the present invention.

[Table 1]

Sample No.	Mnufacturring conditions					Property of composite	Remark
	Filament	Polymer	Fiber	Bonding Agent	Steel surface Treatment	Adhesion Force (N)	
1-1	Galvanize Strand 1x7 (Ø 12.70 mm)	HDPE	NIL	Silane (5%) water (95%)	NIL	486	 Galvan HDPE
1-2	Galvanize Strand 1x7(Ø 12.70 mm)	HDPE	NIL	NIL	NIL	58	
2-1	Single Galvanized Wire (Ø 1.24mm)	HDPE	NIL	Silane (5%) water (95%)	NIL	401	 Galvanized wire HDPE Coating
2-2	Single Galvanized Wire (Ø 1.24mm)	HDPE	NIL	Silane [5%] Ethanol (95%)	NIL	335	
2-3	Single Galvanized Wire (Ø 1.24mm)	HDPE	NIL	NIL	NIL	406	
3-1	Single Galvanized Wire (Ø 1.24mm)	HDPE-g-MAH grafted Maleic Anhydride	NIL	Silane (5%) water (95%)	NIL	758	
3-2	Single Galvanized Wire (Ø 1.24mm)	HDPE-g-MAH grafted Maleic Anhydride	NIL	Silane (5%) Ethanol (95%)	NIL	710	
3-3	Single Galvanized Wire (Ø 1.24mm)	HDPE-g-MAH grafted Maleic Anhydride	NIL	NIL	NIL	734	

(continued)

Sample No.	Mnufacturring conditions					Property of composite	Remark
	Filament	Polymer	Fiber	Bonding Agent	Steel surface Treatment	Adhesion Force (N)	
4-1	Steel cord 3+9+15x0.175mm.	HDPE	NIL	Silane (5%) Ethanol (95%	NIL	374	 SteelCord HDPE Coating
4-2	Steel cord 3+9+15x0.175mm.	HDPE	NIL	Silane (5%) water (95%)	NIL	560	
4-3	Steel cord 3+9+15x0.175mm.	HDPE	NIL	NIL	Oxidize	301	
4-4	Steel cord 3+9+15x0.175mm.	HDPE	NIL	NIL	Ultrasonic	238	
5-1	Steel cord 3+9+15x0.175mm.	HDPE-g-MAH grafted Maleic Anhydride	NIL	Silane (5%) Ethanol (95%	NIL	1,009	
5-2	Steel cord 3+9+15x0.175mm.	HDPE-g-MAH grafted Maleic Anhydride	NIL	Silane (5%) water (95%)	NIL	1,102	
5-3	Steel cord 3+9+15x0.175mm.	HDPE-g-MAH grafted Maleic Anhydride	NIL	NIL	Oxidize	946	
5-4	Steel cord 3+9+15x0.175mm.	HDPE-g-MAH grafted Maleic Anhydride	NIL	NIL	Ultrasonic	644	
6-1	Steel cord 3+9+15x0.175mm.	Thermoplastic Polyurethane (TPU)	NIL	Chemlock 218	Ultrasonic	425	 SC Construction TPU Coating
6-2	Steel cord 3+9+15x0.175mm.	Thermoplastic Polyurethane (TPU)	NIL	NIL	Ultrasonic	25	

[Example 2]

[0065] Table 2 shows results of an experiment performed to confirm a degree at which plasma surface modification contributes to enhancement of the adhesion force between the filament 120 or the fiber 130 and the polymer 110, according to a particular embodiment of the present invention.

[0066] As shown in FIG. 17, samples shown in Table 2 were produced by such process where a brass plate and a fiber were subjected to plasma surface modification at room temperature, a melted polymer was injected between brass plate and fiber and followed by adhesion at a constant pressure. The polymer melting temperature was from 195°C to 205°C, and the plasma surface modification rate was 5m/min. Samples shown in Table 2 below were prepared through the experiment, and an adhesion force between the polymer and the brass plate of each sample was tested. Adhesion force results for cases with and without plasma surface modification according to types of polymers are shown in Table 2. Referring to Table 2, it is confirmed that after the plasma surface modification, in all cases of TPU polymer and polyester polymer, improvement of adhesion forces was observed and in particular, polyester showed a significantly increased adhesion force. In addition, microstructural analysis of an adhesion interface showed that a void ratio at adhesion interface was significantly decreased, as illustrated in FIG. 16. In particular, high adhesion was exhibited when polyester was used as a polymer and aramid was used as a fiber. As such, when the filament or the fiber is surface-modified with plasma, the size of voids formed at the adhesion interface decreases, thereby resulting in enhancement of the adhesion force between the polymer and the filament or between the polymer and the fiber. The following example is provided only for illustrative purposes and is not intended to limit the scope of the present invention.

[Table 2]

Sample No.	Polymer thickness (mm)	Polymer	Fiber	Plasma treatment	Adhesion force (N)	Adhesion interface area (mm2)
7-1	0.300	TPU	Aramid	without treatment	38	0.253
7-2	0.300	TPU	Aramid	with treatment	87	0.253
7-3	0.300	TPU	Polyester	with treatment	100	0.253
7-4	0.300	TPU	Nylon	with treatment	90	0.253
7-5	0.475	Polyester	Aramid	without treatment	43	0.212
7-6	0.475	Polyester	Aramid	with treatment	220	0.212
7-7	0.475	Polyester	Polyester	with treatment	240	0.212
7-8	0.475	Polyester	Nylon	with treatment	190	0.212
7-9	0.475	HDPE	Aramid	with treatment	155	0.212
7-10	0.475	HDPE	Polyester	with treatment	130	0.212
7-11	0.475	HDPE	Nylon	with treatment	140	0.212
7-12	0.475	HDPE	Polyethylene	with treatment	133	0.212
7-13	0.475	PP	Aramid	with treatment	146	0.212

[Example 3]

[0067] Table 3 below shows measurement values of tensile strength and breaking load according to void ratio at adhesion interface (%) and adhesion force ratio (%), according to a particular embodiment of the present invention. Five samples were prepared using a composite formed of a brass-plated steel cord (filament), aramid (fiber), and TPU (polymer) by varying an adhesion force therebetween. Each sample was prepared such that a brass-plated steel cord was subjected to plasma surface modification or Chemlock adhesion treatment, and the resulting cord was adhered to TPU as a polymer. Nine strands formed of aramid were twisted on the resulting structure, followed by plasma surface modification thereof, and then adhered to TPU as a polymer (Preparation of polymer composite illustrated in FIG. 7). In this case, five samples exhibiting different adhesion force ratios (%) were prepared by varying plasma surface modification conditions. A binding temperature of TPU was from about 195°C to 205°C.

[0068] Results of calculation of void ratio at adhesion interface (%) of each sample through the aforementioned measurement method of void ratio at adhesion interface (%) are shown in Table 3 below. Referring to Table 3 below, it is confirmed that as the adhesion force ratio (%) increases, the spinning factor and the breaking load increase. In particular, a very low breaking load is obtained at an adhesion force ratio of 3% and thus, to obtain a desired breaking load, the adhesion force ratio (%) may be 5% or more. In addition, it is confirmed that the adhesion force ratio (%) is related to the void ratio at adhesion interface (%). Referring to Table 3 below, it is confirmed that the lower the void ratio at adhesion interface (%), the higher the adhesion force ratio (%). Thus, to achieve a desired breaking load, the void ratio at adhesion interface (%) may be 90% or less. The void ratio at adhesion interface (%) may be reduced by the above-described plasma surface modification and the above-described adhesion treatment using an adhesive. That is, through the plasma surface modification and the adhesion treatment described above, the void ratio at adhesion interface (%) may be formed to be 90% or less and, accordingly, the tensile strength and breaking load of the polymer composite 100 may be increased. The following example is provided only for illustrative purposes and is not intended to limit the scope of the present invention.

[Table 3]

Sample No	Property of composite				
	spinning factor (%)	breaking load (N)	tensile strength (N/mm2)	adhesion force ratio (%)	Void ratio at adhesion interface (%)
8-1	25	1,141	763	3	91
8-2	37	1,689	1,130	15	81
8-3	52	2,373	1,588	25	68
8-4	70	3,195	2,137	55	40
8-5	80	3,651	2,442	65	16

[Example 4]

[0069] Table 4 below shows properties of the polymer 110 before and after rapid cooling at a high pressure, according to a particular embodiment of the present invention. In the present experiment of Table 4 below, four samples including TPU as a polymer were prepared by increasing a polymer binding pressure and a cooling rate. Working conditions of the four samples were as shown in Table 4 below.

[0070] As shown in Table 4 below, it is confirmed that polymer internal voids decreased by about 96% after the polymer binding pressure was increased and the rapid cooling rate was applied and, accordingly, the tensile strength of TPU increased by about 2.6 times. That is, from the results shown in Table 4, it is confirmed that when the pressure and the cooling rate are increased, an internal void area ratio (%) of the polymer decreases, thereby resulting in an increase in breaking load. Thus, the polymer internal void area ratio (%) may be maintained to be 2% or less by rapidly cooling the polymer at a high pressure. The following example is provided only for illustrative purposes and is not intended to limit the scope of the present invention.

[Table 4]

Sample No.	Polymer bonding conditions			Mechanical Properties		Void percentage (%)
	Pressure (kN)	Melting Temperature (°C)	Cooling Temperature (°C)	Thickness (mm)	Breaking Load (N)	
9-1	2	195	Leave at Room Temperature (25°C)	2.225	90.27	2.71
9-2	2	195	Leave at Room Temperature (25 °C)	2.235	91.2	4.14
9-3	10	195	Pressure at 10kN and Rapid Cooling from Heated Sample	2.300	226.85	0.11
9-4	10	195	Pressure at 10kN and Rapid Cooling from Heated Sample	2.275	243.48	0.18

[0071] In the polymer composite 100 according to the present invention, the adhesion force between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130 may be enhanced by adhesion-treating the polymer 110 using an adhesive and through an adhesion accelerator (e.g., HDPE-g-MAH when HDPE is used as the polymer 110). In addition, the filament 120 and the fiber 130 maybe subjected to plasma surface modification, thereby enhancing the adhesion force. Through this, the adhesion force ratio (%) may be 5% or more and the void ratio at adhesion interface (%) may be 90% or less. As such, the polymer composite 100 may obtain desired tensile strength and breaking load by maintaining the adhesion force ratio (%) to be 5% or more and maintaining the void ratio at adhesion interface (%) to be 90% or less.

[0072] In addition, the internal void ratio (%) of the polymer 110 may be 2% or less by rapidly cooling the polymer 110 at a high pressure. When the internal void ratio (%) of the polymer 110 decreases by 2%, the tensile strength of the polymer 110 may be enhanced and the strength of the polymer composite 100 may be increased because the polymer 110 accounts for a large volume of the polymer composite 100.

[0073] The polymer composite 100 produced by such treatment: chemical adhesion treatment, adhesive accelerator, plasma surface modification, and high-pressure rapid cooling can have the following effects.

[0074] First, the polymer composite 100 according to the present invention may have high tensile strength and breaking load by adhering the filament 120 and the fiber 130 to the polymer 110. In addition, since the polymer 110 and the fiber 130 have lighter self-weight than steel, the excellent polymer composite 100 having a light weight characteristic and a high tensile strength at the same time can be produced. Moreover, the polymer composite 100 has a small elongation property similar to steel. That is, the polymer composite 100 is lightweight and has high strength and high toughness at the same time.

[0075] In addition, the polymer 110 may be adhesion-treated with a solution of 5% silane and 95% deionized water or a solution of 5% silane and 95% ethanol to be adhered to the filament 120 and the fiber 130, and the filament 120 and the fiber 130 may be surface-modified with plasma to be adhered to the polymer 110, thereby enhancing the adhesion force between the polymer 110 and the filament 120 or between the polymer 110 and the fiber 130. The polymer 110 may be rapidly cooled at a high pressure to decrease the size of internal voids thereof, thereby increasing the tensile strength of the polymer 110. These are advantages of the present invention.

[0076] The polymer composite 100 of the present invention may go through all the following processes which are adhesion treatment using an adhesive, use of an adhesion accelerator, plasma surface modification of the filament 120 or the fiber 130, and high-pressure rapid cooling of the polymer 110. However, the present invention is not limited thereto and, for example, only a part of the above-described processes may be performed.

[0077] While one or more embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims.

Claims

1. A polymer composite comprising: a polymer; a filament implanted into the polymer and adhered to the polymer; and

a fiber implanted into the polymer and adhered to the polymer,
wherein either only the filament or the fiber is implanted into the polymer and adhered to the polymer, or
the filament and the fiber are simultaneously implanted into the polymer and adhered to the polymer.

2. The polymer composite of claim 1, wherein the filament comprises at least one steel or fiber.

3. The polymer composite of claim 1, wherein the polymer is adhesion-treated with an adhesive and adhered to the filament or the fiber.

4. The polymer composite of claim 1, wherein the filament or the fiber is surface-modified with plasma and adhered to the polymer.

5. The polymer composite of claim 1, wherein the polymer and the filament or the polymer and the fiber have an adhesion force ratio of 5% or more.

6. The polymer composite of claim 1, wherein an adhesion interface formed between the polymer and the filament or between the polymer and the fiber has a void ratio of 90% or less.

7. The polymer composite of claim 1, wherein the filament is positioned at a center of the polymer, and the fiber is positioned around the filament.

8. The polymer composite of claim 7, wherein the fiber comprises a plurality of fibers that form a fiber layer around the filament,
wherein the fiber layer is formed as at least one layer.

9. The polymer composite of claim 7, further comprising a filler implanted into the polymer and adhered to the polymer, wherein the filler comprises a steel or a fiber.

10. The polymer composite of claim 1, wherein the filament and the fiber are implanted into the polymer in at least one form selected from a linear form, a twisted pair form, and a fabric form.

11. The polymer composite of claim 1, wherein the polymer comprises at least one selected from thermoplastic polyurethane (TPU), high density polyethylene (HDPE), polyethylene (PE), polypropylene (PP), and polyester, and
the fiber comprises at least one selected from aramid, polyester, nylon, and PE.

12. The polymer composite of claim 1, wherein the polymer composite has any one of circular, rectangular, plate, and sheet cross-sectional shapes.

13. The polymer composite of claim 1, wherein the polymer is rapidly cooled at a high pressure, thus resulting in a polymer internal void area ratio of 2% or less.

14. The polymer composite of claim 1, wherein the polymer comprises HDPE and HDPE-g-MAH as an additive.

FIG. 1

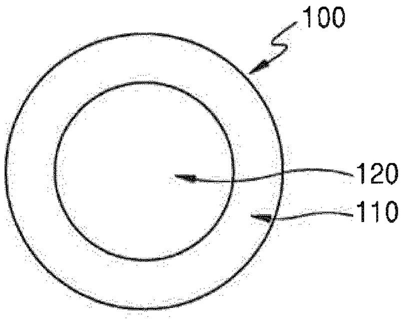


FIG. 2

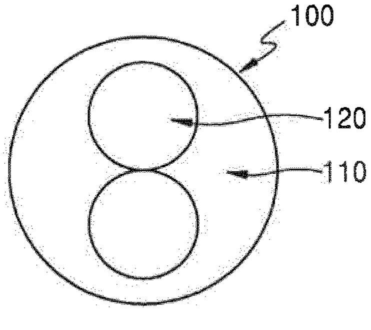


FIG. 3

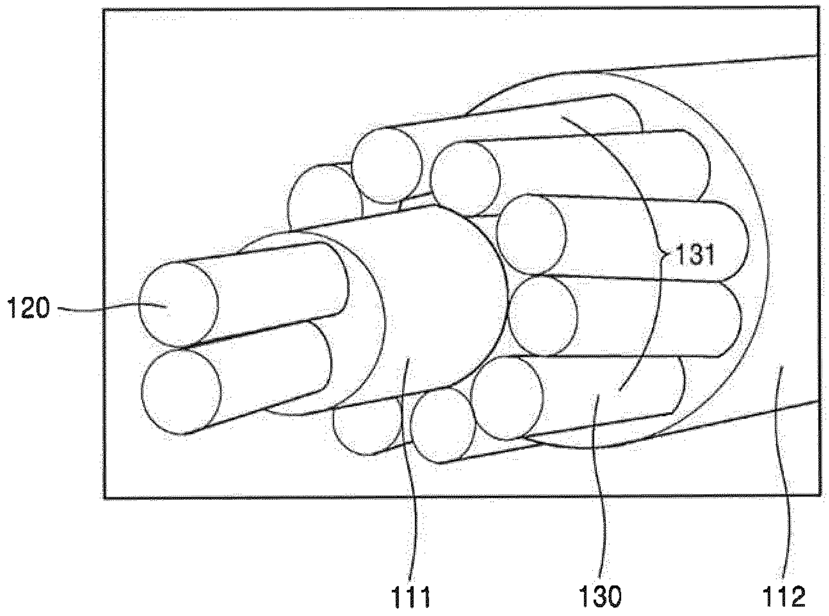


FIG. 4

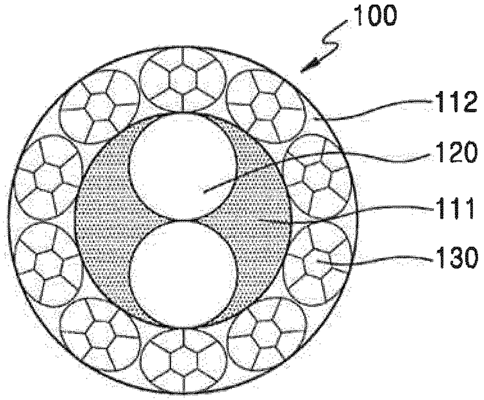


FIG. 5

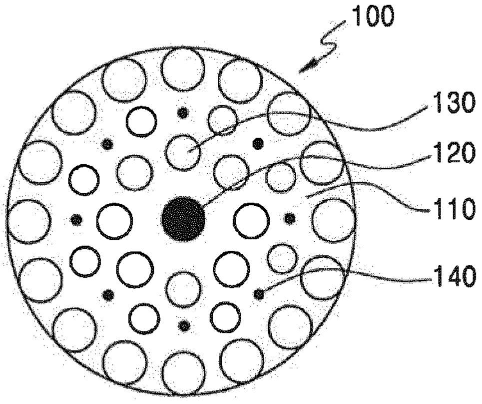


FIG. 6

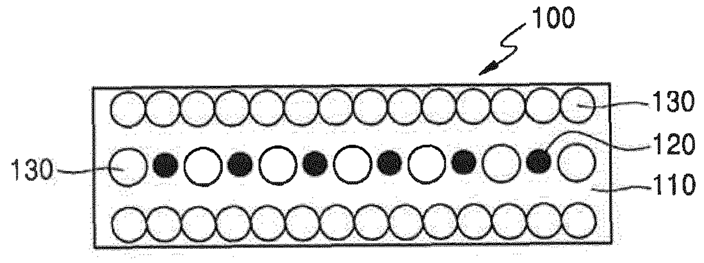


FIG. 7

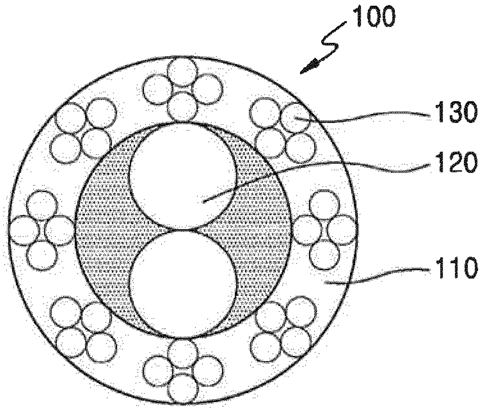


FIG. 8

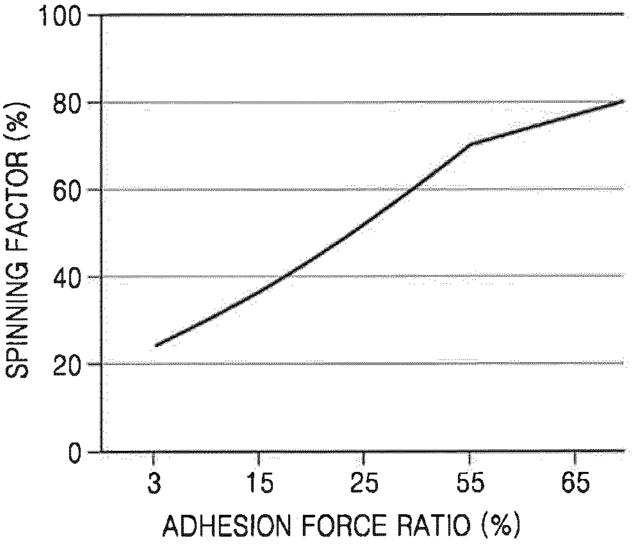

100
80
60
40
20
0
SPINNING FACTOR (%)
3
15
25
55
65
ADHESION FORCE RATIO (%)

FIG. 9

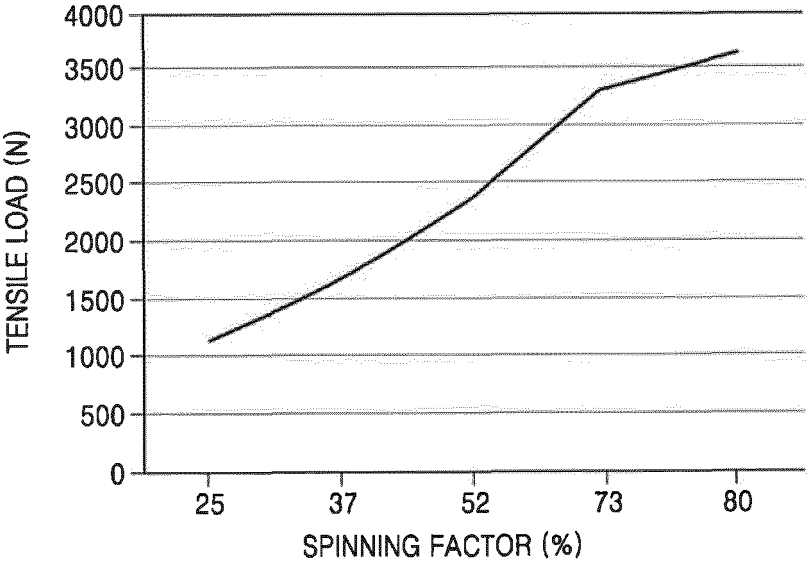

4000
3500
3000
2500
2000
1500
1000
500
0
TENSILE LOAD (N)
25
37
52
73
80
SPINNING FACTOR (%)

FIG. 10

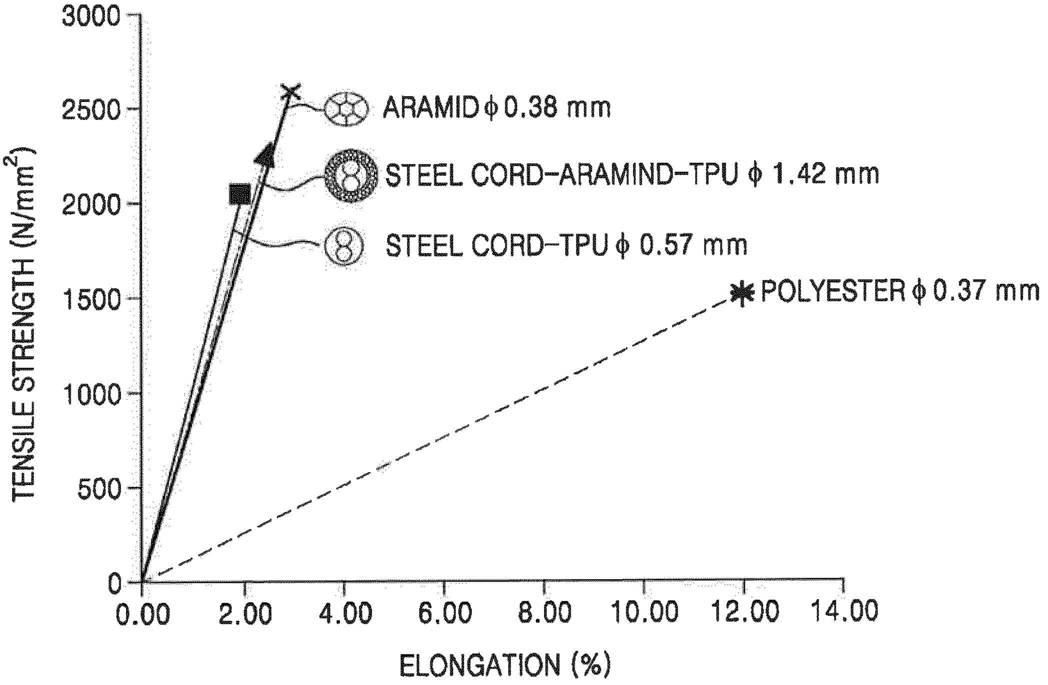

3000
2500
2000
1500
1000
500
0
TENSILE STRENGTH (N/mm²)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
ELONGATION (%)
ARAMID ϕ 0.38 mm
STEEL CORD-ARAMIND-TPU ϕ 1.42 mm
STEEL CORD-TPU ϕ 0.57 mm
POLYESTER ϕ 0.37 mm

FIG. 11

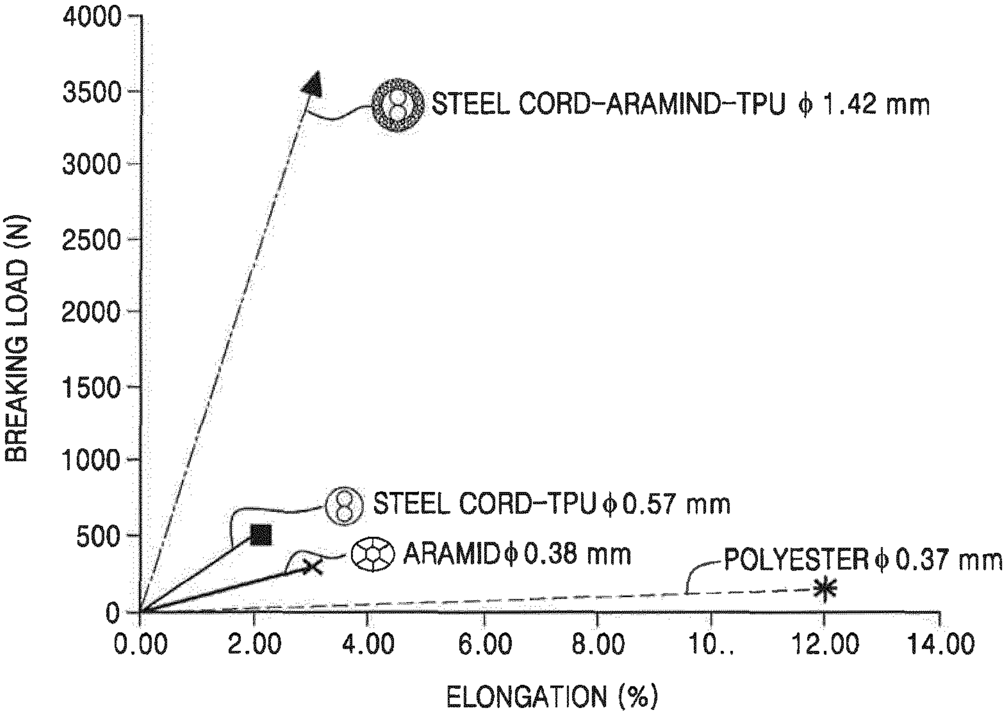

STEEL CORD-ARAMIND-TPU ϕ 1.42 mm
STEEL CORD-TPU ϕ 0.57 mm
ARAMID ϕ 0.38 mm
POLYESTER ϕ 0.37 mm
BREAKING LOAD (N)
4000
3500
3000
2500
2000
1500
1000
500
0
0.00
2.00
4.00
6.00
8.00
10..
12.00
14.00
ELONGATION (%)

FIG. 12A

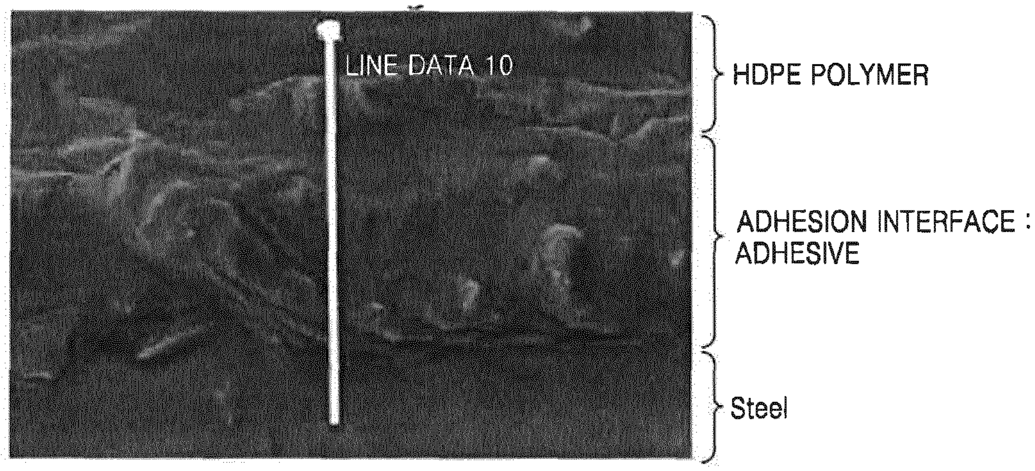

LINE DATA 10
HDPE POLYMER
ADHESION INTERFACE : ADHESIVE
Steel

FIG. 12B

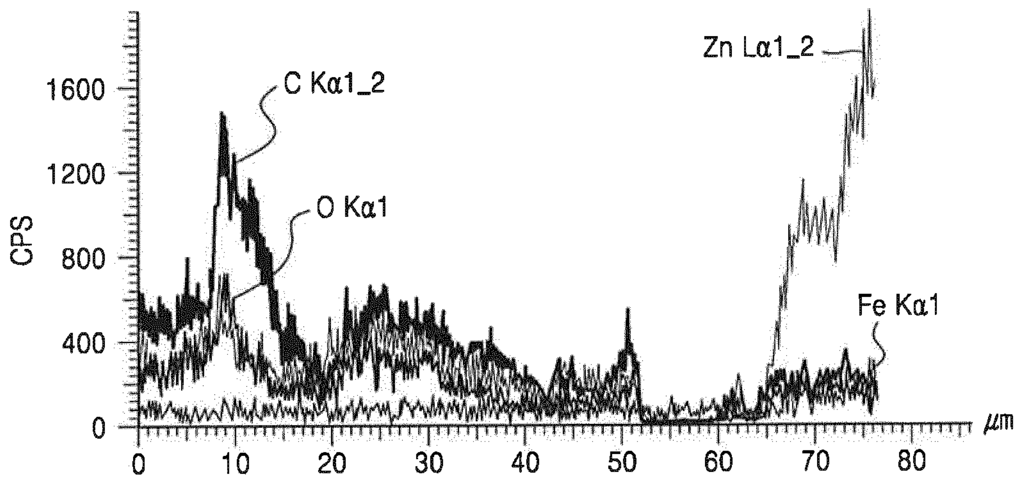

CPS
1600
1200
800
400
0
C Kα1_2
O Kα1
Zn Lα1_2
Fe Kα1
0
10
20
30
40
50
60
70
80
μm

FIG. 13A

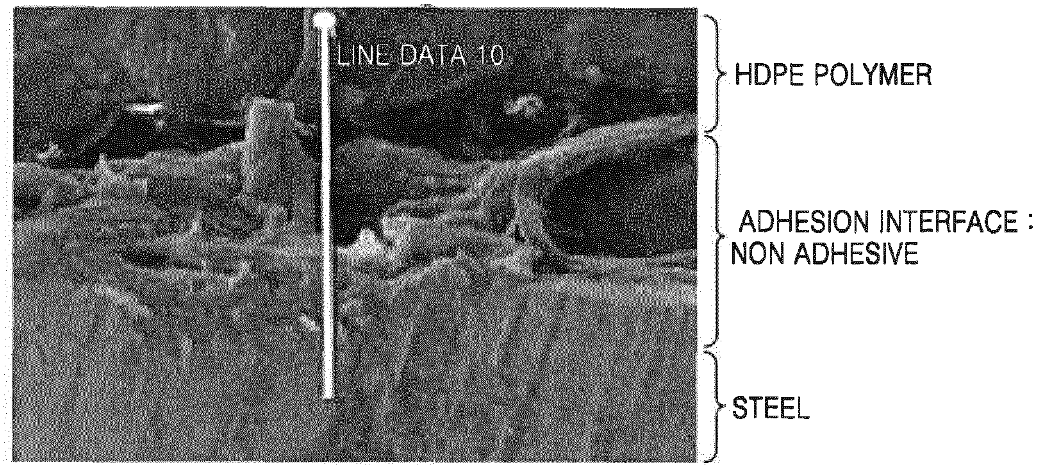

LINE DATA 10
HDPE POLYMER
ADHESION INTERFACE :
NON ADHESIVE
STEEL

FIG. 13B

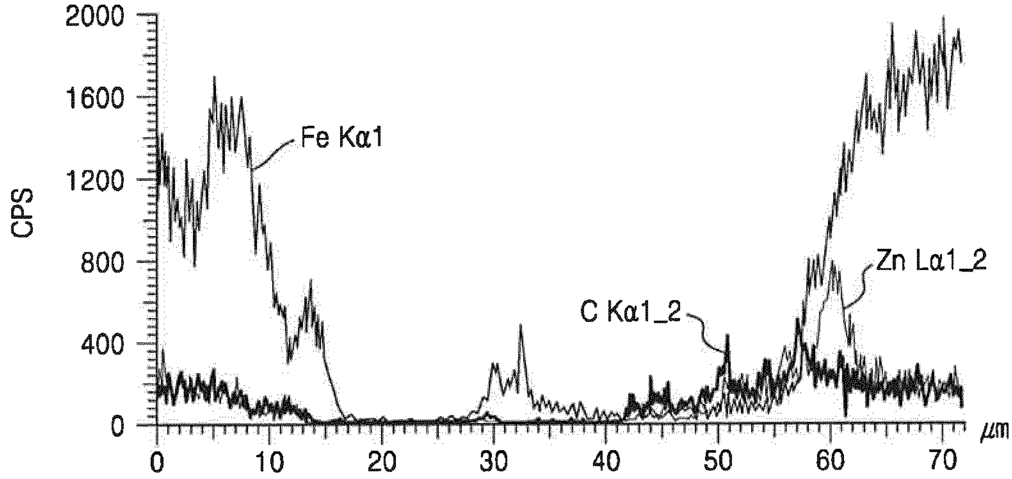

CPS
2000
1600
1200
800
400
0
0
10
20
30
40
50
60
70
μm
Fe Kα1
C Kα1_2
Zn Lα1_2

FIG. 14

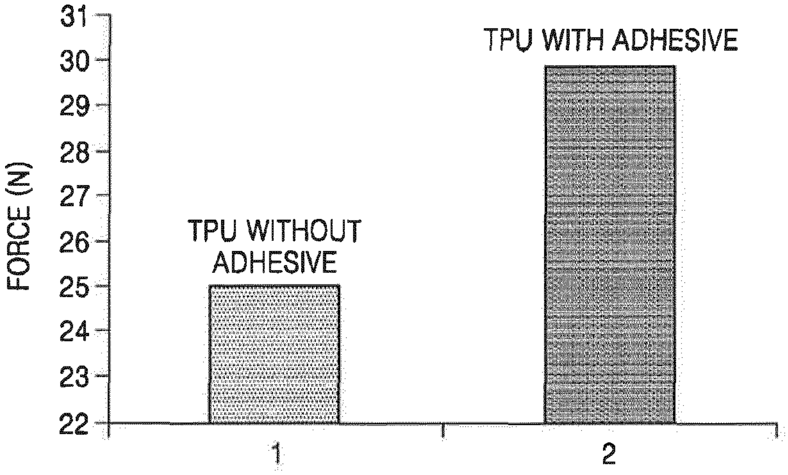

31
30
29
28
27
26
25
24
23
22
FORCE (N)
TPU WITHOUT ADHESIVE
TPU WITH ADHESIVE
1
2

FIG. 15

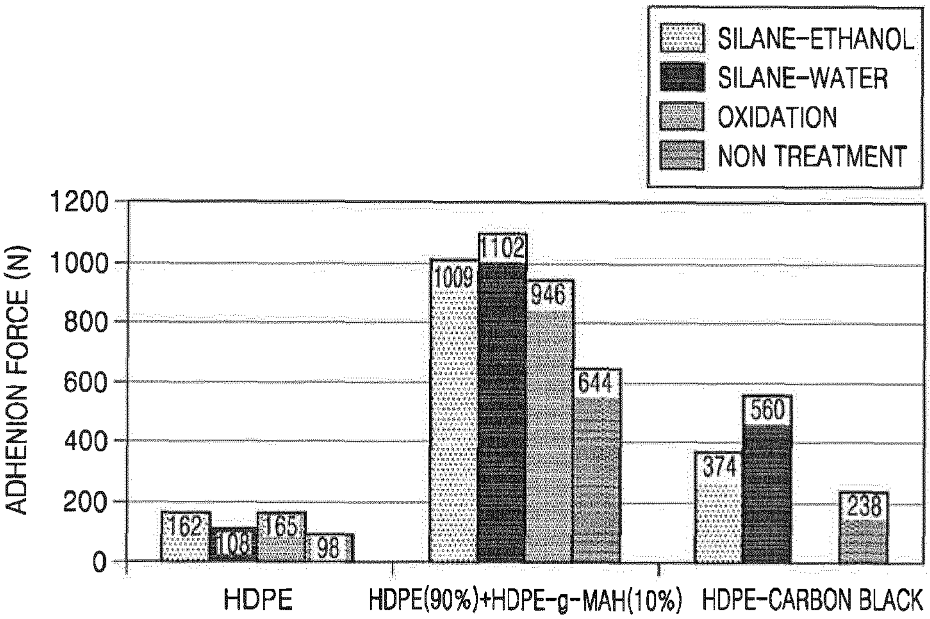

SILANE-ETHANOL
SILANE-WATER
OXIDATION
NON TREATMENT
ADHENION FORCE (N)
1200
1000
800
600
400
200
0
162
108
165
98
1009
1102
946
644
374
560
238
HDPE
HDPE(90%)+HDPE-g-MAH(10%)
HDPE-CARBON BLACK

FIG. 16

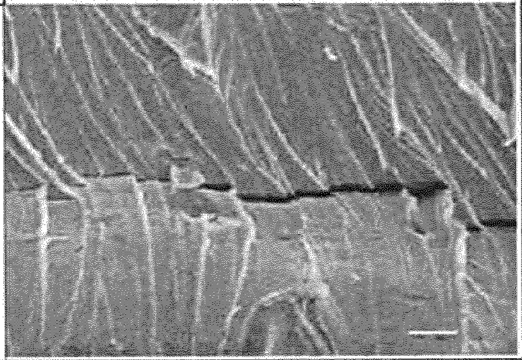
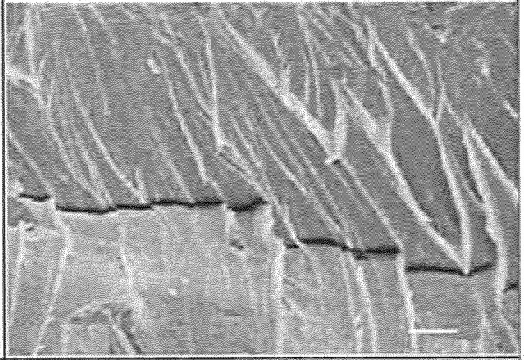
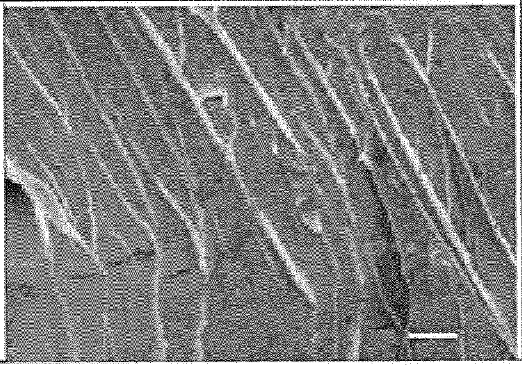
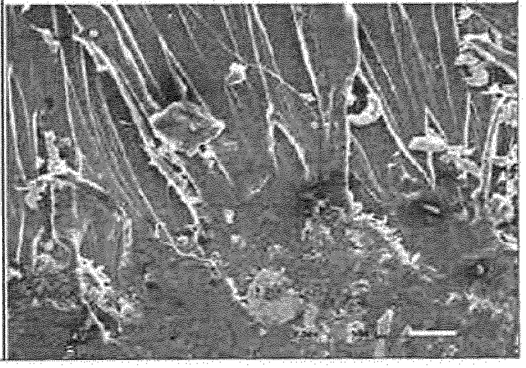
SAMPLES	0.3MM TPU (TPU AND ARAMID)	0.475MM POLYESTER (POLYESTER AND ARAMID)
BEFORE PLASMA TREATMENT		
AFTER PLASMA TREATMENT		

FIG. 17

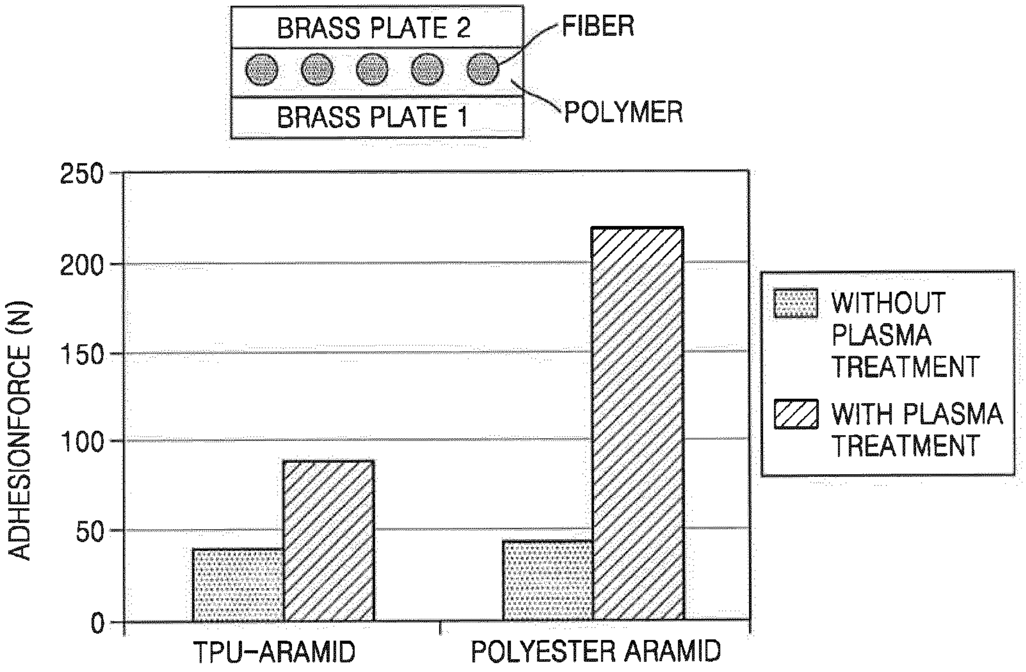
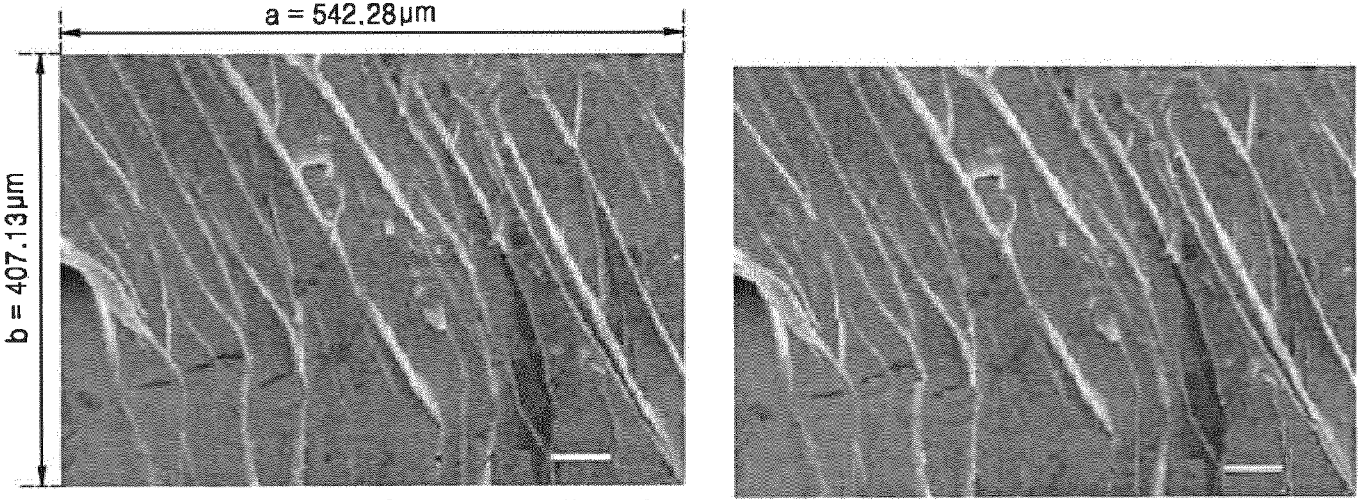

BRASS PLATE 2
BRASS PLATE 1
FIBER
POLYMER
ADHESIONFORCE (N)
250
200
150
100
50
0
TPU-ARAMID
POLYESTER ARAMID
WITHOUT PLASMA TREATMENT
WITH PLASMA TREATMENT

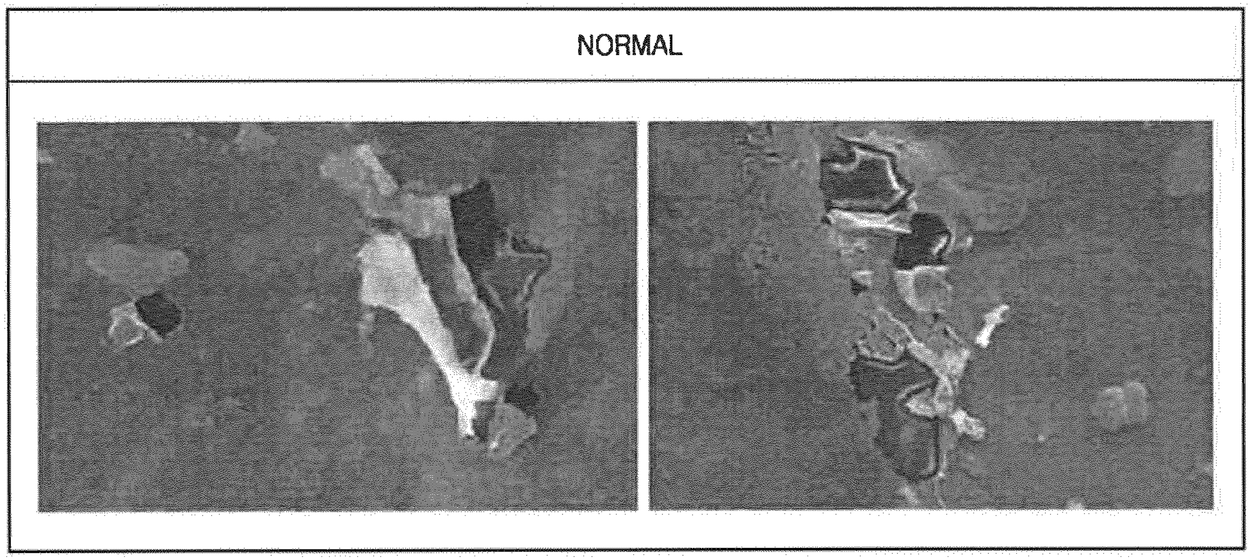
FIG. 18



TOTAL LENGTH OF VOID = 102.76μm

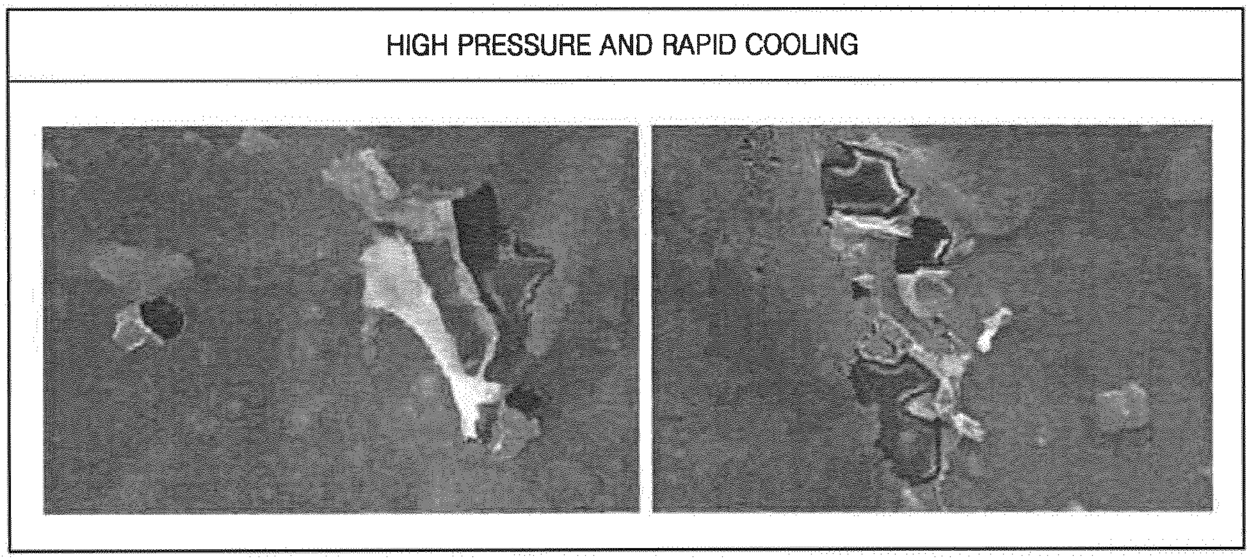
TOTAL ADHESION INTERFACE LENGTH = 630.83μm

FIG. 19A



AVERAGE AREA: 2698.57 μm^2

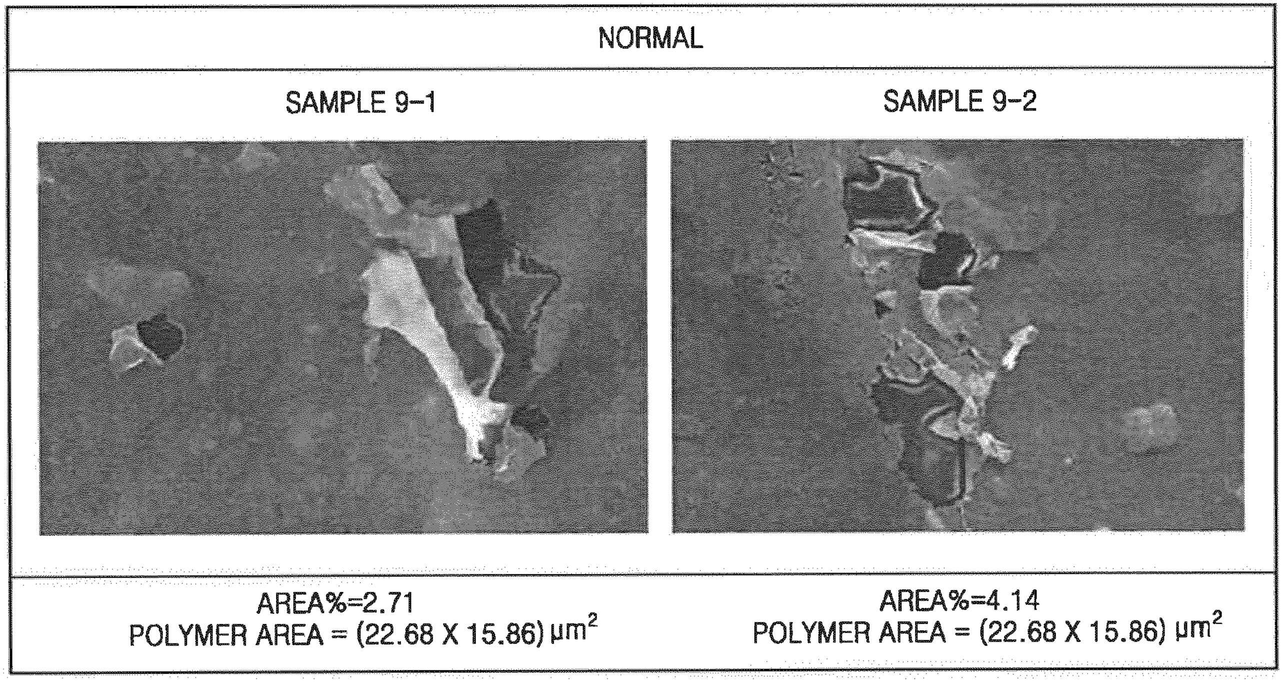
FIG. 19B



HIGH PRESSURE AND RAPID COOLING

AVERAGE AREA: 173.78μm^2

FIG. 20A



NORMAL

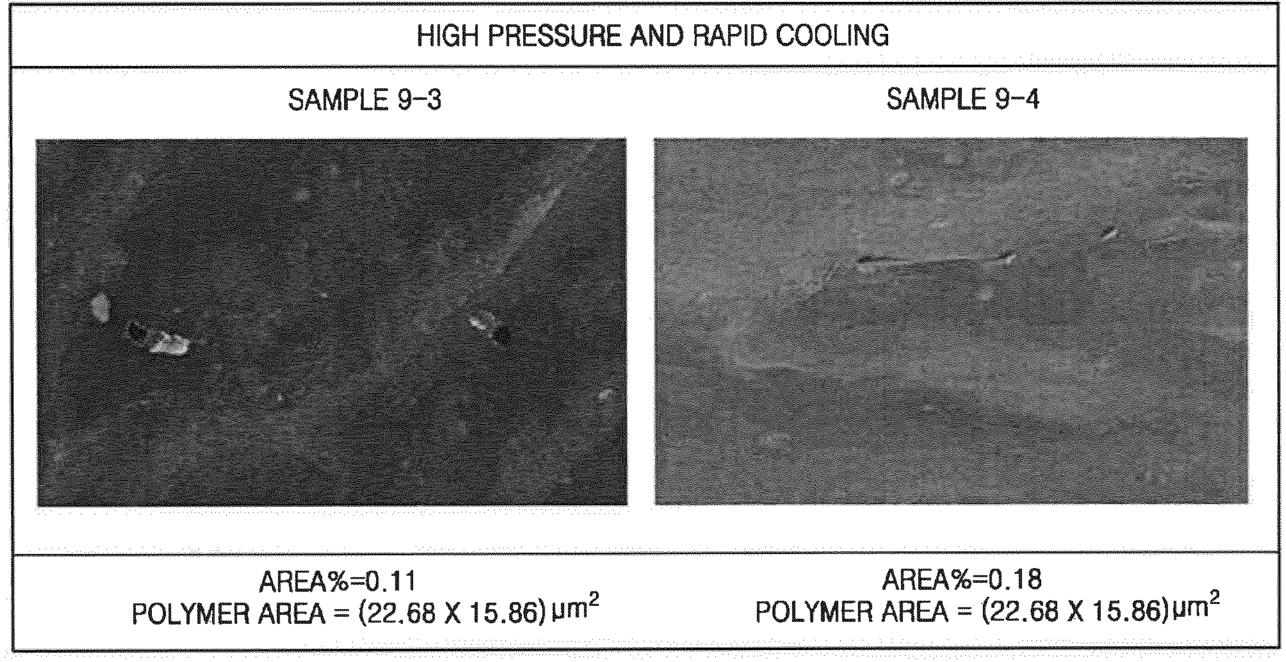
SAMPLE 9-1

SAMPLE 9-2

AREA%=2.71
POLYMER AREA = (22.68 X 15.86) μm^2

AREA%=4.14
POLYMER AREA = (22.68 X 15.86) μm^2

FIG. 20B



HIGH PRESSURE AND RAPID COOLING

SAMPLE 9-3

SAMPLE 9-4

AREA%=0.11
POLYMER AREA = (22.68 X 15.86) μm^2

AREA%=0.18
POLYMER AREA = (22.68 X 15.86) μm^2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2016/001522

A. CLASSIFICATION OF SUBJECT MATTER

D07B 1/12(2006.01)i, D07B 5/00(2006.01)i

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)
D07B 1/12; D07B 1/16; H01B 9/00; D06M 11/45; D07B 1/06; C08L 23/16; D07B 1/10; C08L 23/08; D07B 5/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: polymer, material, filament, fiber, adhesion, steel, plasma, air gap, filler

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2011-0107797 A (NV BEKAERT SA.) 04 October 2011 See abstract; paragraphs [0017], [0019], [0087], [0093]-[0094], [0114]; claims 1, 5; and figure 2.	1-10,12-13
Y		11,14
Y	KR 10-2012-0007469 A (MANUEL RODRIGUES DOLIVEIRA SA. & FILHOS, S. A.) 20 January 2012 See paragraph [0025]; and claim 3.	11
Y	US 4670349 A (NAKAGAWA, Mikio et al.) 02 June 1987 See column 8, lines 40-46.	14
A	KR 10-2009-0009723 A (NEXANS) 23 January 2009 See paragraphs [0021]-[0027]; and figures 2-4.	1-14
A	KR 10-2005-0026689 A (NV BEKAERT SA.) 15 March 2005 See claims 1-8.	1-14

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search 25 OCTOBER 2016 (25.10.2016)	Date of mailing of the international search report **31 OCTOBER 2016 (31.10.2016)**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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