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TOOTHED BELT AND METHOD OF PRODUCTION THEREOF

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a toothed belt made of a thermoplastic elastomer, that can be used for power transmission, conveyance, etc. and a method of production of the same.

2. Description of the Related Art

Conventionally, a toothed belt made of rubber (for example, see Japanese Unexamined Patent Publication (Kokai) No. H11-182632 (pages 1 to 2, Fig. 1)) or a thermosetting polyurethane elastomer has been used for power transmission, conveyance, etc. The toothed belt has teeth and bottoms to engage with a pulley.

With the increasing sophistication of functions of equipment using belt mechanisms, cases have arisen where jumping resistance, durability, drive friction reduction, and response cannot be satisfied with current belt technology (in particular when the pitch of the teeth is small). Further, when the resin or elastomer is exposed at the surface sides of the teeth, the resin or elastomer is easily peeled off or detached during use, so there are problems such as abnormal noise, undesirable jumping performance and reduced durability.

SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide a toothed belt having superior jumping resistance, improved

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durability, reduced drive friction, and improved response, and in which abnormal noise is prevented, compared with conventional products (rubber belt or thermosetting polyurethane elastomer belt).

According to the present invention, there is provided a toothed belt which is characterized by being provided with a belt-body comprised of a thermoplastic elastomer having the advantages of both rubber and plastic (elasticity and strength), cord serving as a tensioning member, and a cover fabric covering the tooth surfaces of the belt. This thermoplastic elastomer having a copolymer that forms a hard segment in a crystalline phase and a soft segment in a non-crystalline phase, exhibits rubbery elasticity at room temperature, and is made plastic and can be shaped at a high temperature.

Since the toothed belt of the present invention is configured as explained above, it has superior jumping resistance, durability, response, etc. and resistance to seepage of the resin as well as reduced drive friction compared to a conventional rubber belt.

Here, the material of the cover fabric can be for example, nylon, polyester, aramid, cotton, PBO fiber, etc. Further, the material of the cord can be for example, polyester, glass fiber, aramid, steel, carbon fiber, PBO fiber, etc.

Preferably, the thermoplastic elastomer is a thermoplastic polyether ester elastomer. The thermoplastic polyether ester may be comprised of a copolymer of an aromatic polyester (crystalline

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phase (hard segment)) and an aliphatic polyether (non-crystalline phase (soft segment)). The hard segment may be an aromatic polyester with a high melting point, and is superior because of its high crystallization speed, high strength, heat deformation resistance, good moldability, chemical stability, and heat aging resistance. Further, the soft segment may be an aliphatic polyether with a low glass transition point, and is superior because of its flexibility, high impact absorption, and low-temperature properties. Further, it is possible to design an elastomer with a suitable ratio of hard segment to soft segment to take advantage at the above characteristics.

A toothed belt configured in this way has the advantages of quietness, impact resistance, impact resilience, low temperature flexibility, bending strength, environmental resistance (low out gas), and food sanitarness.

As a thermoplastic elastomer, a thermoplastic polyurethane elastomer can be used in the toothed belt. The thermoplastic polyurethane elastomer includes polyester types and polyether types, and is comprised of a soft segment and hard segment. The soft segment is comprised of polyethylene adipate, polybutylene adipate, other adipate esters (ADP), polycaprolactone (PCL), polycarbonate (PC), or other aliphatic polyester diols, polytetramethylene ether glycol (PTMG), polyethylene glycol (PEG), polypropylene glycol (PPG), or other aliphatic polyether diols, or other polyols (long chain diols). The hard segment is comprised

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of diisocyanate and a short chain diols.

When the soft segment is comprised of a polyester polyol such as a polyethylene adipate, a polybutylene adipate, other adipic acid esters (ADP), polycaprolactone (PCL), polycarbonate (PC), and other aliphatic polyester diols, a thermoplastic polyurethane elastomer having superior mechanical strength, heat resistance, abrasion resistance, and chemical stability is obtained. On the other hand, when the soft segment is polytetramethylene ether glycol (PTMG) or other polyether polyols, a thermoplastic polyurethane elastomer having superior water resistance and low-temperature properties is obtained. Further, for an MDI-based thermoplastic polyurethane elastomer using an aliphatic glycol chain extender for the hard segment, the cohesive density between chains falls as do the physical properties when the length of the chain extender is extended.

A toothed belt configured in this way has the advantages of being superior in abrasion resistance, durability, and back surface conveyability (due to high μ).

It is also possible to make the hardness of the thermoplastic elastomer about A70 to A95 (Duro meter hardness of JIS-K6253). A toothed belt configured in this way has the advantages of superior flexibility, durability, and high load performance.

In the present invention, the toothed belt is formed to prevent the thermoplastic elastomer from seeping out of the surface side of the belt teeth, from the locations where the weave of the

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cover fabric is spread. The exposed thermoplastic elastomer at the surface side of the belt, can easily peel off while the belt is running and be deposited at the bottom of the pulley which may cause poor engagement, deterioration in the jumping performance, reduced durability, and abnormal noise.

Further, another object of the invention is to provide a production method of the toothed belt mentioned above, in which the belt is resistant to seepage of resin from the belt tooth surfaces or resistant to molding defects.

That is, according to the present invention, there is provided a toothed belt production method, which is characterized by forming a preshaped article of a thermoplastic elastomer, placing the cover fabric, cord, and said preshaped article in a forming mold, press heating the assembly from the outside, and heating it from the inside of the mold at a temperature that exceeds the crystallization temperature of the thermoplastic elastomer and which is less than the melting point, for a certain time so as to form the teeth.

In the method of production of a toothed belt, it is possible to press and heat the assembly from the outside and to heat it from the inside at a temperature that exceeds the crystallization temperature of the thermoplastic elastomer and which is less than the melting point for a certain time so as to control the fluidity of the thermoplastic elastomer. These temperature conditions can be maintained for a certain time for forming the teeth. That is,

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since it is possible to spend a certain amount of time for molding the belt in the state where the fluidity of the thermoplastic elastomer is controlled under the above specific molding temperature conditions, seepage of the thermoplastic elastomer from the interstices of the cover fabric to the belt tooth surfaces is prevented and further molding defects, and tip rounding where teeth cannot be completely formed, are also prevented.

Note that the molding temperature range, that is the temperature range that exceeds the crystallization temperature of the thermoplastic elastomer and which is less than the melting point is generally in a range from 125°C to 190°C.

It is possible to form the teeth by controlling the molding temperature and heating for a certain time so that the amount of flow of the thermoplastic elastomer becomes approximately 5×10^{-4} to 6×10^{-3} ml/sec (load 50 kgf/cm² and hole diameter and length of 1 mm x 1 mm).

If the molding temperature conditions are set so that the amount of flow of the thermoplastic elastomer is between about 5×10^{-4} and 6×10^{-3} ml/sec, a temperature range where the temperature exceeds the crystallization temperature of the thermoplastic elastomer and is less than the melting point, seepage of the resin from the interstices of the cover fabric to the belt tooth surfaces is prevented, as are molding defects of the belt (tip rounding where teeth cannot be completely formed) and therefore, the molding becomes more accurate.

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For measuring the amount of flow of the thermoplastic elastomer, the Flow Tester CFT-500 made by Shimadzu Mfg. etc. can be used. The test conditions are a load of 50 kgf/cm^2 , a preheating time of 100 seconds, a sectional area of a cylindrical plunger of 1 cm^2 , and a die hole diameter x length of $1 \text{ mm} \times 1 \text{ mm}$. Further, after reaching the set temperature (measurement temperature) and after preheating for 100 seconds (holding the same temperature for 100 seconds and making the entire sample the same temperature), a plunger is used to give a load of 50 kgf/cm^2 to the sample and the amount of flow of the sample per unit time flowing out from the hole of the die is measured.

It is preferable that the ratio of the filament denier of the cover fabric (weft/warp) is 0.5 to 3.0, the ratio of the yarn density (weft/warp) is 0.5 to 1.0, the elongation of the cover fabric for molding process is about 50 to 150% (at 50 mm width/2 kgf). Further, the cover fabric is preferably treated with resin or moisture-cure type urethane before molding.

By configuring the cover fabric in this way, the cover fabric is pressed against the flowing thermoplastic elastomer at the time of molding and even if stretched, the filaments are superposed and therefore opening of the interstices is reduced, hence seepage of the resin from the interstices of the cover fabric to the belt tooth surfaces is prevented and further molding defects of the belt (tip rounding where teeth cannot be completely formed) are also prevented. Therefore, the molding becomes more accurate.

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Further, by resin treatment or moisture-cure type urethane treatment, the bonding between the thermoplastic elastomer and the cover fabric becomes stronger.

Furthermore, according to the present invention, there is provided a toothed belt production method, which is characterized by arranging a cover fabric having elasticity, at the tooth-forming surface of a forming mold having tooth shapes, laminating a resin film that stretches together with the cover fabric, on the surface of the cover fabric contiguous with the forming mold, setting the melting point of the resin film higher than that of the thermoplastic elastomer as the belt-body material, and shaping a thermoplastic elastomer in a flowable state at a temperature less than its melting point in a forming mold.

With this method of production of a toothed belt, the resin film, laminated on the surface of the cover fabric which is contiguous with the forming mold, stretches along with the cover fabric, and has a higher melting point than the belt-body material. When the belt-body material is in a flowable state at a temperature less than the melting point of the resin and passes through the interstices of the cover fabric, the resin film having a higher melting point and not being in a molten state at this time will prevent the belt-body material from passing. Therefore, the belt-body material cannot seep out to the belt tooth surfaces, so it is not exposed at the surface sides of the belt teeth.

Further, the cover fabric and the resin film may be pressed

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against the flowing belt-body material when shaping the belt, and expand together until molded against the grooves of the forming mold, whereby a cover fabric layer and resin film layer of substantially the same thickness are formed. If the cover fabric layer forming the bottoms has uniform thickness, the pitch line becomes stable and the cord is protected, so the durability is improved.

The belt-body material can be heated after arranging a sheet shape material or other somewhat deformable fixed shape material on the forming mold, or can be converted to a flowable state (liquid resin or molten state) and fed to the forming mold from an extruder etc. It is also possible to make the flowable belt-body material pass through the interstices of the cover fabric and fuse with the resin film.

While shaping the belt, the resin film softens somewhat. By making the belt-body material pass through the interstices of the cover fabric and directly fuse with the resin film, after cooling, the belt-body material, cover fabric, and resin film can be strongly laminated with each other. It is also possible to use polyether ester as the belt-body material and use polyether ester resin film as the resin film.

As the belt-body material, thermoplastic elastomer is preferable and various types of thermoplastic elastomers can be used. On the other hand, various types of resins or elastomers can be used as the resin film. Among these materials, using

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polyether ester resin for both components is preferable because a polyether ester resin has the superior high-temperature properties of a thermoplastic elastomer, high strength, and rubbery elasticity from a low temperature to a high temperature. Therefore, the usage temperature range is wide, the vibration absorption, oil- and water-proofness, and chemical stability are superior, and the meshing noise with the pulley is reduced, while the durability is good due to the low coefficient of friction. Further, it is also possible to use a liquid injection molding resin or elastomer as the belt-body material to form the belt using an injection-molding machine, or to use a thermoplastic elastomer to form a belt using an extruder.

In this method, a phenol resin layer, modified by an ingredient containing phenol having side chains with unsaturated bonds and/or a phenol carboxylic acid is formed at the outermost layer of the cover fabric. When configured in this way, the bondability between the cover fabric and the belt-body material comprised of the polyether ester resin is superior. Here, treatment by latex or treatment by RFL before forming the phenol resin layer on the cover fabric is effective for reducing the rubbing between the yarns of the cover fabric and improving the abrasion resistance of the cover fabric.

In this method, the cord are embedded and the outermost layer of the cover fabric is formed of a phenol resin layer modified by an ingredient containing phenol having side chains with

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unsaturated bonds, and/or a phenol carboxylic acid. If configured in this way, the bondability between the cord and the belt-body material comprised of the polyether ester resin becomes superior. Note that to increase the bond strength between the cord (glass fiber or aromatic polyamide fiber) and the belt body, the cord may in accordance with need be formed for example with a resorcinol-formaldehyde latex (RFL) layer or a resorcinol-formaldehyde latex (RFL) layer further formed with an overcoat layer superior in bondability with an RFL layer.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the description of the preferred embodiment of the invention set forth below together with the accompanying drawings, in which:

Fig. 1 is a sectional view of the toothed belt of a first embodiment of the present invention;

Fig. 2 is a perspective view explaining a sleeve of a toothed belt of the present invention;

Fig. 3 is a graph for explaining the relationship between resin fluidity and temperature;

Fig. 4 is a graph of the results of a grease resistance test;

Fig. 5 is a graph of the results of a drive friction test;

Fig. 6 is a schematic view showing the structure of a rotational accuracy tester;

Fig. 7 is a graph of the results of a rotation accuracy test;

Fig. 8 is a graph of the results of a response test;

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Fig. 9 is a graph of the results of a jumping test;
Fig. 10 is a graph of the results of an oil resistance test;
Fig. 11 is a graph of the results of a stationary position accuracy test;

Fig. 12 is a graph of the results of a durability test;
Fig. 13 is a sectional view of the toothed belt of a second embodiment of the present invention;

Fig. 14 is a view for explaining the production method of the toothed belt of the second embodiment;

Fig. 15 is a plan view for explaining the state of the interstices of the cover fabric; and

Fig. 16 is a view for explaining a conventional method of production of a toothed belt.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, the preferred embodiments of the present invention are described with reference to the attached drawings. Below, the first embodiment of the present invention will be explained with reference to the drawings.

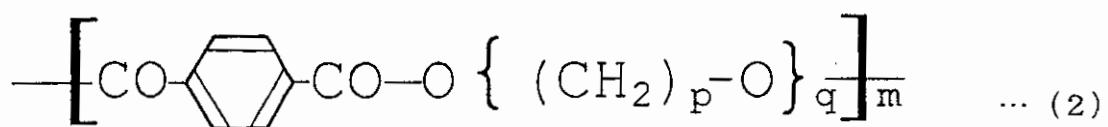
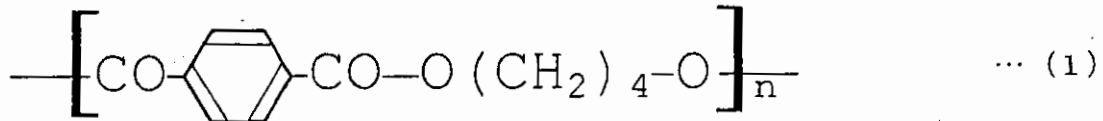
[First Embodiment]

Fig. 1 is a sectional view of the toothed belt 10 of the first embodiment of the present invention. The toothed belt 10 has belt-body material 15 forming the teeth, and a cover fabric 12 arranged at the surface of the toothed belt 10. Further, cord 16 acting as a tensioning member is embedded in the belt-body material 15.

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Next, the production method of the toothed belt made of a thermoplastic elastomer is explained. First, the thermoplastic resin is molded into a sheet-like preshaped article (resin sheet) by an extruder.

For the thermoplastic elastomer, use is made of a thermoplastic polyether ester elastomer and thermoplastic polyurethane elastomer. The thermoplastic polyether ester elastomer has a hard segment shown by the chemical formula (1) and a soft segment shown by chemical formula (2). For example, it is possible to use an elastomer having the brand name Pelprene made by Toyobo CO.LTD., or the brand name Hytrel made by DUPONT-TORAY CO.LTD., etc.



Further, for the thermoplastic polyurethane elastomer of the preshaped article, it is possible to use the elastomers of the brand name Miractran made by Nippon Miractran, or the brand name Elastran made by BASF Japan, etc.

As the material of the cord, for example it is possible to use polyester, glass fiber, aramid, steel, carbon fiber, PBO fiber,

etc.

The material of the cover fabric can be, for example, nylon, polyester, aramid, cotton, or PBO fiber, etc. Further, when making the ratio of the filament denier of the cover fabric (weft/warp) 0.5 to 3.0, making the ratio of the yarn density (weft/warp) 0.5 to 1.0, making the elongation of the cover fabric about 50 to 150% (at 50 mm width/2 kgf), and making the cover fabric treated with resin or moisture-cure type urethane in advance of molding, the cover fabric is pressed against the flowing thermoplastic elastomer at the time of molding. Therefore, even if stretched, the filaments are superposed and opening of the interstices is prevented, hence seepage of the resin from the interstices of the cover fabric to the belt tooth surfaces is prevented and molding defects of the belt (tip rounding, where teeth cannot be completely formed) are also prevented. Therefore, the molding becomes more accurate. Further, the bonding between the thermoplastic elastomer and cover fabric becomes stronger.

The cover fabric having elasticity, the cord, and the preshaped article are assembled in a metal mold having teeth and this assembly is covered by a rubber bag. The assembly is then press heated from the outside of the rubber bag to a pressure of 500 to 3000 KPa at a temperature of 70 to 200°C, and heated from the inside of the mold for a certain time to a temperature exceeding the crystallization temperature of the thermoplastic elastomer (differing depending on grade of resin) and less than the melting

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point (differing depending on grade of resin). The molding temperature range is from a temperature exceeding the crystallization temperature of the thermoplastic elastomer to a temperature less than the melting point. This differs depending on the grade of the resin, but is generally in a range from 125°C to 190°C.

At the time of molding, the molding temperature is set to be in the temperature range of the temperature exceeding the crystallization temperature of a thermoplastic elastomer and less than the melting point, so as to enable an amount of flow of the thermoplastic elastomer of approximately 5×10^{-4} to 6×10^{-3} ml/sec (load 50 kgf/cm² and hole diameter and length of 1 mm x 1 mm), and the assembly is also heated from the inside of the mold for a certain time. Setting the flow amounts of thermoplastic elastomers to be in the range of about 5×10^{-4} to 6×10^{-3} ml/sec by controlling temperatures, enables the belt to be correctly formed without seepage of the resin to the belt tooth surfaces or tip rounding, where the teeth cannot be completely formed.

At the end of the heat press molding, the assembly is cooled and removed from the mold to obtain the toothed belt sleeve (see Fig.2). The sleeve of the toothed belt 1 has teeth 2 and bottoms 3 engaging with the pulley etc. After this, the sleeve is cut to a certain width to obtain a toothed belt (timing belt).

(Examples of Thermoplastic Elastomers)

Next, examples showing the setting of the flow amount of the

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thermoplastic elastomers, are explained with Fig. 3 and Table 1.

Fig. 3 shows a graph of the relationship between the fluidity of the resin and the temperature. In the graph, TPEE-A and TPEE-B are thermoplastic polyether ester elastomers (made by Toyobo CO.LTD., brand name Pelprene), while TPEE-C and TPEE-D are also thermoplastic polyether ester elastomers (brand name Hytrel made by DUPONT-TORAY CO.LTD.). Further, TRU-A is a thermoplastic polyurethane elastomer (brand name Elastran made by BASF Japan), while TRU-B and TRU-C are also thermoplastic polyurethane elastomers (brand name Miractran made by Nippon Miractran).

Table 1 shows the relationship between the type of resin and the belt moldability. (The cover fabric and the cover fabric E are explained later in Table 2.)

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[Table 1]

Types and Moldability of Resins

Resin	Molding temp. (°C)	Fluidity of resin (ml/s)	Seepage	Tip rounding	Overall evaluation
TPEE-A	125	4.20E-04	No	Yes	X
TPEE-A	130	5.54E-03	No	No	O
TPEE-A	135	1.03E-02	Yes	No	X
TPEE-B	140	1.24E-03	No	No	O
TPEE-B	145	3.95E-03	No	No	O
TPEE-C	150	6.20E-04	No	No	O
TPEE-C	155	3.30E-03	No	No	O
TPEE-D	165	1.62E-03	No	No	O
TPEE-D	170	5.43E-03	No	No	O
TPU-A	180	3.53E-03	No	No	O
TPU-B	180	2.57E-03	No	No	O
TPU-C	185	1.85E-03	No	No	O
TPU-C	190	6.14E-03	Yes	No	X
TPU-C	195	9.12E-03	Yes	No	X

Cover Fabric E

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First, in the case of TPEE-A, when the molding temperature was set at 130°C, the amount of flow was 5.54×10^{-3} ml/sec (load of 50 kgf/cm² and hole diameter x length of 1 mm x 1 mm) or in the range of about 5×10^{-4} to 6×10^{-3} ml/sec. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding, where the teeth cannot be completely formed.

Next, in the case of TPEE-B, when the molding temperature was set at 140°C, the amount of flow was 1.24×10^{-3} ml/sec while when set at 145°C, the amount of flow was 3.95×10^{-3} ml/sec or in the range of about 5×10^{-4} to 6×10^{-3} ml/sec. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

Next, in the case of TPEE-C, when the molding temperature was set at 150°C, the amount of flow was 6.02×10^{-4} ml/sec while when set at 155°C, the amount of flow was 3.30×10^{-3} ml/sec or in the range of about 5×10^{-4} to 6×10^{-3} ml/sec. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

Next, in the case of TPEE-D, when the molding temperature was set at 165°C, the amount of flow was 1.62×10^{-3} ml/sec while when set at 170°C, the amount of flow was 5.43×10^{-3} ml/sec or in the range of about 5×10^{-4} to 6×10^{-3} ml/sec. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

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Next, in the case of TPU-A, when the molding temperature was set at 180°C, the amount of flow was 3.53×10^{-3} ml/sec or in the range of about 5×10^{-4} to 6×10^{-3} ml/sec. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

Next, in the case of TPU-B, when the molding temperature was set at 180°C, the amount of flow was 2.57×10^{-3} ml/sec or in the range of about 5×10^{-4} to 6×10^{-3} ml/sec. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

Finally, in the case of TPU-C, when the molding temperature was set at 185°C, the amount of flow was 1.85×10^{-3} ml/sec or in the range of about 5×10^{-4} to 6×10^{-3} ml/sec. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

(Examples of Cover Fabrics)

Examples showing different filament denier weft/warp ratios, yarn density weft/warp ratios, and amount of elongation of cover fabrics are explained with reference to Table 2. Table 2 shows the relationship between the type of cover fabric and the moldability (for the resin, the above TPEE-B was used and the molding temperature was set at 145°C).

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[Table 2]

Types and Moldability of Cover Fabrics

Cover Fabric	Ratio of denier of filaments (weft/warp)	Ratio of yarn density (weft/warp)	Elongation	Treatment	Seepage	Tip rounding	Overall Evaluation
A	1.00	0.59	28	Resin	Yes	Yes	×
B	3.80	0.63	48	Resin	No	Yes	×
C	2.67	0.63	61	Resin	No	No	○
D	2.67	0.63	58	RFL	Yes	No	×
E	0.95	0.65	63	Resin	No	No	○
F	0.95	0.65	68	Urethane	No	No	○
G	0.95	0.38	51	Resin	No	Yes	×
H	0.95	0.98	131	Resin	No	No	○
I	0.95	0.98	162	Urethane	Yes	No	×
J	0.95	0.98	136	RFL	Yes	No	×
K	0.46	0.98	142	Resin	Yes	No	×
L	0.71	1.60	180	Resin	Yes	No	×

Resin: TPEE-B

Molding temperature: 145°C

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As shown in Table 2, for example in the case of the cover fabric C, the ratio of the weft filament denier to the warp denier (weft/warp) was set to 2.67, and the ratio of yarn density (number) (weft/warp) was set to 0.63. Thus the cover fabric was manufactured in such a manner to elongate 61% at 50 mm width/2 kgf, and was then subjected to a resin treatment. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

Next, in the case of the cover fabric E, the ratio of filament denier (weft/warp) was set to 0.95, the ratio of yarn density (number) (weft/warp) was set to 0.65, the elongation of the cover fabric was 63% (at 50 mm width/2 kgf), and resin treatment was performed. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

Next, in the case of the cover fabric F, the ratio of filament denier (weft/warp) was set to 0.95, the ratio of yarn density (number) (weft/warp) was set to 0.65, the elongation of the cover fabric was 68% (at 50 mm width/2 kgf), and moisture-cure type urethane treatment was performed. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

Next, in the case of the cover fabric H, the ratio of filament denier (weft/warp) was set to 0.95, the ratio of yarn density (number) (weft/warp) was set to 0.98, the elongation of the cover fabric was 131% (at 50 mm width/2 kgf), and resin treatment was

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performed. It was possible to correctly form the belt without seepage of the resin to the belt tooth surfaces or tip rounding.

(Examples of Test Results)

The evaluation test results of a small pitch toothed belt of the present invention will be explained next. The pitch size of the toothed belt was 2 mm.

Example 1 and Example 2 toothed belts were produced using the already explained molding conditions. Example 1 was made of a thermoplastic polyether ester elastomer (brand name Hytrel 3046), while Example 2 was made of a thermoplastic polyether ester elastomer (brand name Hytrel 4057 made by DUPONT-TORAY CO.LTD.). Then, a toothed belt of a Comparative Example 1 was produced from an castable polyurethane (thermosetting polyurethane elastomer).

The toothed belts were completely immersed in grease for a grease resistance test. As shown by the graph of the results of Fig. 4, the belts of Examples 1 and 2 featured smaller rates of change in dimensions (width and thickness) compared with the Comparative Example 1 and were therefore superior.

Example 3, Example 4, and Example 5 toothed belts were produced using the already explained molding conditions. Example 3 was made of a thermoplastic polyether ester elastomer (brand name Hytrel 4057 made by DUPONT-TORAY CO.LTD.), Example 4 was made of a thermoplastic polyether ester elastomer (brand name Hytrel G3548L), and Example 5 was made of a thermoplastic polyether ester elastomer (brand name Hytrel 3046).

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A Comparative Example 2 toothed belt was produced from hard type chloroprene rubber, a Comparative Example 3 toothed belt was produced from soft type chloroprene rubber, and a Comparative Example 4 toothed belt was produced from an castable type thermosetting polyurethane elastomer.

A drive friction test was conducted using the torque difference between the drive side and the driven side as the drive friction. As shown by the graph of the results of Fig. 5, the belts of Examples 3, 4, and 5 feature the same drive torque compared with Comparative Examples 2, 3, and 4 despite the hardness of the belt being higher and the thickness of the belt being greater. They also feature a smaller drive friction while improving the durability of the belt, and were therefore superior.

An Example 6 Toothed belt was produced using the already explained molding conditions and a thermoplastic polyether ester elastomer (brand name Hytrel 4057 made by DUPONT-TORAY CO.LTD.). The toothed belt of the Comparative Example 5 was produced from chloroprene rubber and a rotational accuracy test was conducted as follows.

As shown in Fig. 6, as the tester, a rotational accuracy tester (a non-contact speed unevenness meter LV-203 made by Mitsubishi Electric for measurement of the rotational speed) was used. The belt size was 318-2GT-10, the cover fabric was 3A, the cord was 40:0 at 200D/1, the pulley size was P14/P14 (the same specifications as those for the durability test), the rotational

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speed was 200 min^{-1} (266666 pps 1/160 drive), and the installation tension was 28.05N (standard).

As shown by the graph of the results of Fig. 7, the Example 6 belt exhibited a smaller rate of fluctuation in rotation of the driven pulley compared with the Comparative Example 5 belt and therefore was superior.

An Example 7 toothed belt was produced using the already explained molding conditions. A thermoplastic polyether ester elastomer (brand name Hytrel 4057 made by DUPONT-TORAY CO.LTD.) was used. A Comparative Example 6 toothed belt was produced from an castable type thermosetting polyurethane elastomer.

For a response test, the rotating pulley was stopped and the amount of displacement of the residually vibrating driven pulley was measured. As shown by the graph of the results of Fig. 8, the Example 7 belt exhibited a smaller overshoot and faster attenuation of vibration compared with the Comparative Example 6 belt and was therefore superior.

Example 8, Example 9, and Example 10 toothed belts were produced using the already explained molding conditions. Example 8 was made of a thermoplastic polyether ester elastomer (brand name Hytrel 4057 made by DUPONT-TORAY CO.LTD.), Example 9 was made of a thermoplastic polyether ester elastomer (brand name Hytrel G3548L), and Example 10 was made a thermoplastic polyether ester elastomer (brand name Hytrel 3046).

A Comparative Example 7 toothed belt was produced from hard

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type chloroprene rubber, a Comparative Example 8 toothed belt was produced from soft type chloroprene rubber, and a Comparative Example 9 toothed belt was produced from a castable thermosetting polyurethane elastomer.

Further, a belt was set on the tester and rotated at a constant speed, then the torque of a hysteresis brake was gradually raised for a jumping test. As shown by the graph of the results of Fig. 9, the Example 8, 9, and 10 belts exhibited a higher jumping torque than Comparative Examples 7, 8, and 9 and were therefore superior.

Next, a large pitch toothed belt was produced and tested for performance as follows. The pitch size of the toothed belt was 9.525 mm.

An Example 11 toothed belt was produced using a thermoplastic polyether ester elastomer (brand name Hytrel 4057 made by DUPONT-TORAY CO.LTD.) under the already explained molding conditions. Further, a Comparative Example 10 toothed belt was produced from chloroprene rubber.

The belts were immersed in machine oil for one week, then the belt dimensions and hardness were measured for an oil resistance test. As shown by the graph of the results of Fig. 10, this Example belt 11 featured a smaller change in hardness and change in belt dimensions compared with the Comparative Example 10 and was therefore superior.

An Example 12 toothed belt was produced using a thermoplastic polyether ester elastomer (brand name Hytrel 4057 made by

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DUPONT-TORAY CO.LTD.) under the already explained molding conditions. Further, a Comparative Example 11 toothed belt was produced from chloroprene rubber.

A stationary position accuracy test was conducted by a tester as shown at the top left in Fig. 11. As shown by the graph of the results in Fig. 11, the Example belt 12 featured a smaller amount of displacement. The displacement comprised of the rotational angle on the pulley with respect to the load converted to offset on the pitch line, and was smaller compared with the Comparative Example 11, therefore, the Example belt was superior.

An Example 13 toothed belt was produced using a thermoplastic polyether ester elastomer (brand name Hytrel 4057 made by DUPONT-TORAY CO.LTD.) under the already explained molding conditions. Further, a Comparative Example 12 toothed belt of was produced from chloroprene rubber.

The belts were wound around pulleys and tested for durability by giving them a certain rotational speed and a certain load. As shown in the graph of the results of Fig. 12, the Example belt 13 featured a greater number of flexes compared with the Comparative Example 12 under the same test conditions, and was therefore superior.

In this embodiment, setting molding temperature to be within the range between the crystallization temperature and the melting point of the thermoplastic elastomer prevents seepage of the resin to the belt tooth surfaces and tip rounding. Therefore, the present

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embodiment provides a toothed belt with superior jumping resistance, durability, and response as well as reduced drive friction compared to conventional products.

[Second Embodiment]

Below, the second embodiment of the toothed belt and its method of production will be explained with reference to the drawings.

Fig. 13 is a sectional view of the toothed belt 10 of the second embodiment. The difference from the first embodiment is that a resin film 20 is provided on the surface of the cover fabric 12. The resin film 20 functions as a sealant for the molding, and a barrier for the toothed belt after production.

Next, the method of production of the toothed belt of the second embodiment is explained. As shown in Fig. 14A, Fig. 14B, and Fig. 14C, in the method of production of the toothed belt, a cover fabric 12 having elasticity is arranged at the tooth-forming surface of a forming mold 17 having tooth shapes, and a resin film 20 is laminated in advance on the surface of the cover fabric 12. Cord 16 is arranged next to the cover fabric 12 which is near the tooth-forming surface of the forming mold 17. In the drawing, reference 19 indicates a rubber bag for shaping. For the molding, the resin film 20 stretches together with the cover fabric 12, being contiguous with the forming mold 17.

The resin film 20 is set to a melting point higher than the belt-body material 15. Polyether ester resin is used as the

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belt-body material 15, while polyether ester resin film is used as the resin film 20.

Further, when the belt-body material 15 is in a flowable state at a temperature less than the melting point of the resin film 20, it can be shaped in the forming mold 17. When the interstices 18 of the cover fabric 12 (see Fig. 15A) for the shaping are stretched and expanded due to the pressure of the belt-body material 15 (see Fig. 15B), the belt-body material 15 passing between the cords 16, from the belt back surface and seeps out from the interstices 18 of the cover fabric 12 and then fuses with the resin film 20.

In this method of production of a toothed belt, the resin film 20 is set to a melting point higher than the belt-body material 15 and is laminated on the tooth-forming surface of the cover fabric 12 (see Fig. 14A). Even if the belt-body material 15 passes through the interstices 18 of the cover fabric 12 (see Fig. 15B) from the back surface during shaping, the resin film 20 can fuse with the belt-body material 15 and prevent it from reaching to the tooth surface (see Fig. 14C). That is, the resin film 20 having a higher melting point and not being in the molten state during the molding, prevents the belt-body material 15 from passing.

Therefore, the seepage of the belt-body material 15 to the belt tooth surfaces (see Fig. 16 showing seeped belt-body material 21) is prevented, so there are the advantages that the material is not exposed at the surface sides of the belt teeth. Due to this,

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since there is no state of unbalance between portions where the belt-body material 15 is exposed and portions where it is not, the occurrence of abnormal noise can be suppressed compared with previous belts, and the jumping performance and durability can be improved.

Further, since the structure is one where the surface of the cover fabric 12 at the tooth surface of the toothed belt produced is laminated with a layer of a resin film 20, it is possible to prevent oil, water, etc. from the belt tooth side, from penetrating the resin film 20 layer. Therefore, the dimensional stability of the belt becomes superior, and the lifetime becomes long.

It is possible to use various types of resins or elastomers as the belt-body material 15, but when a polyether ester resin is used, there are the advantages of the superior high-temperature properties of a thermoplastic elastomer, high strength and rubbery elasticity being exhibited from a low temperature to a high temperature, the temperature range for usage temperature being wide, improved vibration absorption, improved oil- and water-proofness, superior chemical stability, reduced meshing noise with the pulley, and increased durability due to the low coefficient of friction.

Note that as the belt-body material 15, it is also possible to use a liquid castable resin or elastomer to form the belt with an injection-molding machine or use a thermoplastic elastomer to form the belt with an extruder.

(Example 1 of Toothed Belt Production)

Next, the production of the toothed belt of the present embodiment is explained.

A Nylon cover fabric 12 (toothed cloth) was laminated with a resin film 20 (Hytrel film) having a melting point higher than the belt-body material 15 (Hytrel sheet) and cut to predetermined dimensions and bonded (called "cover fabric jacket").

The cover fabric 12 was treated with latex and treated with RFL, then the outermost layer was formed with a phenol resin layer having side chains with unsaturated bonds. Note that instead of a phenol resin layer, it is also possible to form a phenol resin layer modified by an ingredient containing a phenol carboxylic acid.

A cover fabric jacket was covered over the tooth-forming surface at the outer surface of the forming mold 17 so that the resin film 20 (Hytrel film) contacted the mold surface of the forming mold 17, then glass cord 16 was wound spirally around the outer surface.

The outermost layer of the cord 16 was formed with a phenol resin layer having side chains with unsaturated bonds. Further, to increase the bond strength between the cord 16 and the belt-body, an RFL layer was formed on the cord 16, then an overcoat layer superior in bondability with an RFL layer was formed.

An ordinary temperature belt-body material 15 (Hytrel sheet) was wound around the cord 16 and fastened by adhesive tape. Release

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paper was wound on the belt-body material 15 (Hytrel sheet) and fastened by adhesive tape, then the assembly was inserted into an shell bag, placed in a vulcanization pot, and heated and pressed to form a belt slab. The heating temperature was set to be equal to or higher than the melting point of the belt-body material 15 (Hytrel sheet) and lower than the melting point of the resin film 20 (Hytrel film). The pressure and the heating time were set so that the belt-body material 15 flowed and the belt teeth were completely formed.

That is, the belt-body material 15 (Hytrel sheet) was arranged in advance in the forming mold 17 together with the cover fabric 12 covered and laminated with the resin film 20, and the cord 16 in the state of the resin sheet not being heated. Then the belt-body material 15 was pressed and heated starting at room temperature and reaching the molding temperature, at the time of shaping. Therefore, the belt-body material 15 was plasticized to achieve a flowable state and form the belt teeth.

This being so, the resin film 20 (Hytrel film) laminated on the cover fabric 12 stretched together with the stretching of the cover fabric 12 at the time of shaping and the cover fabric 12 covered with the resin film 20 formed the belt tooth surfaces at the time of formation of the belt teeth.

After the end of shaping, the forming mold 17 was immediately water cooled to close to room temperature. The forming mold 17 was taken out from the shell bag and the molded slab removed from

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the forming mold by a de-molding device. The molded slab was grinded at the back surface by a slab grinder to remove the release paper and match with a predetermined belt thickness, then printed on and cut to obtain a toothed belt.

The obtained toothed belt therefore became, in order from the surface of the belt teeth, a resin film 20 layer, a cover fabric 12 layer impregnated with the belt-body material 15, and the belt-body material 15 (with cord 16). That is, due to the resin film 20, the belt-body material 15 was prevented from seeping out to the belt tooth surfaces, and the cover fabric 12 covered with the resin film 20 was formed on the belt tooth surfaces.

(Example 2 of Toothed Belt Production)

Another example of the toothed belt production is mentioned below.

A Nylon cover fabric 12 (toothed cloth) was laminated with a resin film 20 (Hytrel film) having a melting point higher than the belt-body material 15 (Hytrel sheet) and preformed by a preforming apparatus (not shown) so that the belt tooth surface side became the Hytrel film 20 (called a "preformed cover fabric").

The preformed cover fabric was cut and bonded to match with the number of teeth and tooth width of the forming mold 17. It was placed over the tooth-forming surface of the outer circumference of the forming mold 17, and was temporarily fastened so that there was no slip at the seams. Then the glass cord 16 was wound spirally around the forming mold 17.

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Ordinary temperature belt-body material 15 (Hytrel sheet) was wound over the cord 16 and held by adhesive tape. Release paper was wound over the belt-body material 15 (Hytrel sheet) and was held by adhesive tape, then the assembly was inserted into a shell bag and heated and pressed to form a belt slab.

The heating temperature was set to be equal to or higher than the melting point of the belt-body material 16 (Hytrel sheet) and less than the melting point of the resin film 20 (Hytrel film). The pressure and the heating time were set so that the resin flowed and the belt teeth were completely formed.

After the end of formation, the forming mold 17 was immediately cooled by water to close to room temperature. The forming mold 17 was removed from the shell bag and the molded slab was released from the forming mold 17 by a de-molding device. The molded slab was grinded at its back by a slab grinder to remove the release paper and match with a predetermined belt thickness, then was printed and cut to obtain a toothed belt.

According to this method, since the cover fabric 12 and the resin film 20 (Hytrel film) are not stretched much at all, there are the advantages that it is possible to reduce the variations in the yarn density of the cover fabric 12, and the thickness of the resin film 20, etc. Further, the performance of the product is good, as is the durability.

In this embodiment, a resin film 20 having a melting point higher than that of a belt-body material 15 is laminated on a cover

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fabric 12. The molding temperature is set to be between the melting point of the resin film 20 and that of the belt-body material 15. Therefore, seeping out of the belt-body material 15 can be prevented by the rigid resin film 20 although the belt-body material 15 has fluidity. There is no state of unbalance between portions where the belt-body material is exposed and portions where it is not. The occurrence of abnormal noise can be suppressed compared to conventional belts, and the jumping performance and durability can be improved.

Finally, it will be understood by those skilled in the art that the foregoing description is of preferred embodiments of the device, and that various changes and modifications may be made to the present invention without departing from the spirit and scope thereof.

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CLAIMS

1. A toothed belt having tooth surfaces, comprising:
a belt-body comprised of a thermoplastic elastomer;
a cord embedded in said belt-body to serve as a
tensioning member; ~~and~~
a cover fabric that covers said tooth surface; and
wherein the hardness of said thermoplastic elastomer
is in the range of A70 to A95 (Duro meter hardness of JIS-
K6253).
2. A toothed belt according to claim 1, wherein said
thermoplastic elastomer is a thermoplastic polyether ester
elastomer.
3. A toothed belt according to claim 1, wherein said
thermoplastic elastomer is a thermoplastic polyurethane
elastomer.
4. A method of production of a toothed belt, comprising:
forming a preshaped article of a thermoplastic
elastomer;
assembling a cover fabric, cord, and said preshaped
article in a forming mold to form an assembly;
press heating said assembly from the outside of said
forming mold; and
heating said assembly from the inside of said forming
mold at a molding temperature exceeding the
crystallization temperature of said thermoplastic
elastomer and less than the melting point of said
thermoplastic elastomer for a sufficient time to form
teeth on a surface of said assembly.
5. A method of production of a toothed belt according to
claim 4, wherein said teeth are formed by setting said

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molding temperature and heating for a sufficient time so that the amount of flow of said thermoplastic elastomer is in the range from 5×10^{-4} to 6×10^{-3} ml/sec. (load 50 kgf/cm² and hole diameter and length of 1 mm x 1 mm).

6. A method of production of a toothed belt according to claim 4, wherein the ratio of filament denier of weft/warp of said cover fabric is 0.5 to 3.0, the ratio of the yarn density of weft/warp is 0.5 to 1.0, and said cover fabric is treated with resin or moisture-cure type urethane before forming an assembly, and said cover fabric has elongation of approximately 50 to 150% (at 50mm width / 2kgf) of original length.

7. A method of production of a toothed belt, comprising:
affixing a resin film that stretches together with a cover fabric, and has a higher melting point than that of a belt-body material, to a surface of said cover fabric contiguous with a forming mold that has a tooth-forming surface;

arranging said cover fabric having elasticity on said tooth-forming surface;

winding a cord on said cover fabric; and

shaping said belt-body material in a flowable state at a temperature less than said melting point using said forming mold.

8. A method of production of a toothed belt according to claim 7, wherein, in the shaping step, said flowable belt-body material passes through the weave of the cover fabric and fuses with said resin film.

9. A method of production of a toothed belt according to claim 7, wherein, before the affixing step, a phenol resin layer, modified by an ingredient containing phenol that

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has side chains with unsaturated bonds and/or a phenol carboxylic acid, is formed on the outermost layer of said cover fabric.

10. A method of production of a toothed belt according to claim 7, wherein, before the winding step, a phenol resin layer, modified by an ingredient containing phenol that has side chains with unsaturated bonds and/or a phenol carboxylic acid, is formed on the outermost layer of said cord.

11. A method of production of a toothed belt according to claim 7, wherein said belt-body material is comprised of polyether ester, and said resin film is comprised of polyether ester.

12. A toothed belt according to claim 1, wherein said toothed belt is produced by the method of claim 4.

13. A toothed belt according to claim 1, wherein said toothed belt is produced by the method of claim 7.