Abstract: The invention provides a coating process for electrical steel sheet using a varnish composition, comprising the steps of a) applying at least one coating layer of a varnish composition onto the surface of the electrical steel sheet wherein the varnish composition comprises (A) 1 to 95 wt% of at least one resin comprising nucleophilic groups selected from the group consisting of OH, NHR, SH, carbonyl and CH-acidic groups, and electrophilic groups which can react with the above mentioned nucleophilic groups, wherein the resin is capable of transacylation in its main chain and/or side chain(s), (B) 5 to 75 wt% of at least one organic solvent and/or water, (C) 0 to 40 wt% of at least one resin different from (A), (D) 0 to 10 wt% of at least one customary additive, (E) 0 to 40 wt% of at least one pigment, filler and/or nano-scaled particle and/or monomeric and/or polymeric element-organic compound, wherein the wt% based on the total weight of the varnish composition, b) curing the applied at least one coating layer. Reduced energy consumption while curing the coating and reduced or no formaldehyde generation upon curing can be provided.
Title of the Invention
Coating Process with Self-Crosslinkable Composition for Electrical Steel Sheet

Field of the Invention
The present invention refers to a coating process for electrical steel sheet using a varnish composition based on new self-crosslinkable resin.

Background of the Invention
Electrical steel sheet varnishes to coat electrical steel and individual steel sheets are known. The coated electrical steel sheets can be assembled together by different technical means such as welding, clamping, interlocking, aluminium die casting or riveting to form a solid core for the use in electrical equipment, such as, transformers, generators and motors. The coatings provide electrical insulation between the metal sheets in core and should be able to meet the requirements of high surface insulation resistance, resistance to mechanical stress and corrosion and thermal stability.

JP 0733696, JP 2000345360 and EP-A 923 088 relate to enamels for coating electrical steel sheets wherein the enamels contain particles, such as, silica or alumina colloid particles. The compositions result in coatings having properties, such as, good scratch, blocking, chemical and corrosion resistance and high surface insulation ability. Such coatings have no bonding function and need additional means of bonding (welding, clamping, interlocking, aluminium die casting or riveting) to form a solid core.

There are some known coating systems in use for the coating of electrical steel sheets suitable for e.g. welding or punching application to form a solid core. In view of this, the core sheet varnish selection is frequently a compromise since there are occasions when a single coating will not fulfil all requirements. The known ranking classes of such
coatings, for example class C3, class C5, class C6 (registered as standards under AISI-ASTM A 976-03) show the different requirements of coatings in this field with regard to such properties. The coating may be only an organic mixture (C3 insulation type) or an organic/inorganic mixture of complex resins and chromate, phosphate and oxides (C5 and C6 insulation type).

C3 coatings based on organic resins, e.g., phenol, alkyd, acrylic and epoxy resin are used. The C3 coating will enhance punchability and is resistant to normal operating temperatures but will not withstand stress-relief annealing. In general, the C5 coating can be on the one hand a semi organic coating with very good punchability and good welding response and on the other hand a basically inorganic coating with organic resins and inorganic fillers, which has excellent welding and heat-resistance properties with good punchability. But C5 coatings generally based on chromate-, phosphate- or titanate-compounds, and they are therefore not environmental friendly, particularly with respect to the remaining carcinogenic level, or they can tend to hygroscopicity and insufficient annealing and corrosion resistance, or can show insufficient welding properties. C6 coatings are organic coatings with a high content of fillers approximately of 50 wt%.

The known systems are not able to combine different technical requirements, such as, welding, clamping, interlocking, punching, riveting, pressure resistance and thermal resistance to provide a high property profile standard.

EP-A 2152792 and EP-A 2222805 disclose varnishes for coating individual electrical steel sheets wherein the varnishes can comprise self-crosslinkable binder resins as co-binders which can be epoxy novolak systems and urethane and acryl modified epoxy resins. Such varnishes often have not an acceptable solid content for a given viscosity of the compositions.
Known are self-crosslinkable systems based on transesterification as crosslinking reaction for the manufacture of coatings for magnet wires, see for example DE1 445263, DE1 494452, DE1 645435, EP1 4421 8, EP616628 or US4446300. Such coatings do not meet the properties necessary for electrical steel, for example, because the wettability and the solid content / viscosity ratio is insufficient and because they are typically dissolved in phenol, cresol and other organic solvents which do not fulfil the strict environmental requirements that apply for standard core sheet varnishes.

Summary of the Invention

The invention provides a coating process for electrical steel sheet using a varnish composition, comprising the steps of

a) applying at least one coating layer of a varnish composition onto the surface of the electrical steel sheet wherein the varnish composition comprises

(A) 1 to 95 wt% of at least one resin comprising nucleophilic groups selected from the group consisting of OH, NHR and SH, and electrophilic groups which can react with the above mentioned nucleophilic groups, wherein the resin is capable of transacylation in its main chain and/or side chain(s),

(B) 5 to 75 wt% of at least one organic solvent and/or water,

(C) 0 to 40 wt% of at least one resin different from (A),

(D) 0 to 10 wt% of at least one customary additive,

(E) 0 to 40 wt% of at least one pigment, filler and/or nanoscaled particle and/or monomeric and/or polymeric element-organic compound,
wherein the wt% is based on the total weight of the varnish composition (A) to (E) and wherein the amount of component (C) is smaller than the amount of component (A), and

b) curing the applied at least one coating layer.

The process according to the invention provides excellent adhesion of the coatings to the surface of the electrical steel sheet as well as high corrosion resistance of the coatings and good electrical insulation. The coatings provided by the process according to the invention show a high property profile standard combining the different technical requirements, such as, welding, clamping, interlocking, punching, riveting, high pressure and thermal resistance of electrical steel sheet coated with the composition according to the invention and of cores produced from these coated electrical steel sheet. Surprisingly, the varnish composition of the invention has a higher solid content for a given viscosity as the varnish compositions of prior art and, therefore, it provides a reduced energy consumption while curing the coating and, compared to standard core sheet varnishes, a reduced or no formaldehyde generation upon curing. It is possible to provide very thin coating layers in the range under 1 micrometer, in combination with excellent adhesion and corrosion resistance. The varnish composition of the process according to the invention is usable as one-component system.

**Detailed Description**

The features and advantages of the present invention will be more readily understood, by those of ordinary skill in the art, from reading the following detailed description. It is to be appreciated those certain features of the invention, which are, for clarity, described above and below in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any sub-combination.
In addition, references in the singular may also include the plural (for example, "a" and "an" may refer to one, or one or more) unless the context specifically states otherwise.

The application of the varnish composition by the coating process according to the invention proceeds, e.g., by spraying, rolling or dip coating onto the surface of one or both sides of the electrical steel sheet.

The surface of the electrical steel sheet may be coated or uncoated, pretreated or unpretreated prior to the application according to step a) of the process of the invention. The sheet may be pretreated, for example, by washing in order to remove soiling, grease and other deposits.

Preferably, pre-washed and uncoated electrical steel sheet is used, coated with the varnish composition according to the invention by applying at least one coating layer, preferably one coating layer, of the varnish composition onto the surface of the electrical steel sheet.

Subsequently the curing (also known as crosslinking) of the coating on the electrical steel sheet takes place by thermal curing under definite curing conditions, preferably, at temperatures providing a PMT (peak metal temperature) in the range of 180 to 260 °C, preferably 230 to 260 °C. The ambient curing temperatures, for example oven temperatures, can be, for example, in the range of 200 to 600 °C, preferred 300 to 450 °C, and the curing can be done in a time period of 10 seconds to 1 minute, preferably 10 to 40 seconds, more preferably 10 to 20 seconds. The necessary heat can be supplied, for example, in an oven, by means of induction heating, infrared (IR) radiation, near infrared (NIR) radiation and/or hot air.

After curing, parts can be punched out of the coated electrical steel sheet and can then be stacked and assembled to form a sheet core by technical means selected from the group consisting of welding, clamping,
interlocking, aluminium die casting or riveting, if necessary, by supply of heat and pressure. Welding is the preferred technical mean.

Therefore, the invention is also directed to a process for the production of electrical steel sheet core.

It is possible to apply the varnish composition according to the invention as a water-based or a solvent-based varnish composition.

The at least one resin of component A) is a self-crosslinking resin comprising nucleophilic group(s) selected from the group consisting of OH, NHR and SH, and comprising electrophilic group(s) which can react with the above mentioned nucleophilic group(s), wherein the resin is capable of transacylation in its main chain and/or in its side chain(s). The resin of component (A) can be used in amounts of 1 to 95 wt%, preferably 5 to 60 wt%, based on the total weight of the varnish composition.

The transacylation can be achieved by reacting the mentioned nucleophilic group(s) of the resin of component (A) with the mentioned electrophilic group(s) of the resin of component (A).

Examples of the resin of component (A) are poly(meth)acrylates, polyurethanes, alkyd resins, epoxy resins, polyester amides/imides, unsaturated polyesters and/or polyester imides, silicon resins, polyolefines, polyvinyl alcohols, polytitanesters, as such known at a skilled person, comprising the above mentioned groups wherein the resin is capable of transacylation in its main chain and/or side chain(s).

Preferred nucleophilic groups are OH and/or SH.

Examples of electrophilic group(s) are carbon atoms bound via double-bond to oxygen atoms such as those in esters and/or amides.

Preferred electrophilic groups are glycol monoester groups (monoester groups of 1,2-diols) such as groups of monoesters of ethylene glycol, propylene glycol, hexylene glycol, and monoesters of terminal diols such as 1,3-propane diol, 1,4-butane diol, neopentyl glycol, hexane diol.
Preferred resins of component (A) are polyurethanes and/or polyesters comprising the above mentioned nucleophilic and electrophilic group(s) wherein the resins are capable of transacylation in their main chain and/or side chain(s).

As component (A) polyurethanes, for example, aliphatic polyurethanes, can be used having an acid value (mg KOH/g solid resin) in the range of 18 to 33 and a hydroxyl value (mg KOH/g solid resin) in the range of 100 to 170, comprising the above mentioned groups wherein the resins are capable of transacylation in their main chain and/or side chain(s). The number average molar mass Mn of those polyurethanes can be, for example from 13000 to 25000. Preferably, those polyurethanes carry terminal or side chain glycol monoester groups.

All the number average molar mass Mn data stated in the present description are determined or to be determined by gel permeation chromatography (GPC; divinylbenzene-cross-linked polystyrene as the immobile phase, tetrahydrofuran as the liquid phase, polystyrene standards) determined according to ISO 13885-1 standard.

The term hydroxyl value stated in the present description is defined as the number of mg of potassium hydroxide (KOH) which is equal to the number of mg acetic acid for acetalizing of 1 g of the resin, determined according to DIN 53240.

The term acid value stated in the present description is defined as the number of mg of potassium hydroxide required to neutralize the acid groups of the resin, according to DIN EN ISO 2114.

Furthermore, as component (A) polyesters can be used, including polyesters with heterocyclic nitrogen-containing rings, for example, polyesters with imide, hydantoin, benzimidazole, isocyanurate, amide and/or amide imide structures condensed into the molecule, comprising the above mentioned groups wherein the resins are capable of transacylation in their main chain and/or side chain(s).
The polyesters as such are, in particular, condensation products of polybasic aliphatic, aromatic and/or cycloaliphatic carboxylic acids and the anhydrides thereof, polyhydric alcohols and, in the case of imide-containing polyesters, amino group-containing compounds, optionally, with a proportion of monofunctional compounds, for example, monohydric alcohols, as known by a skilled person.

Preferred carboxylic acids and/or anhydrides are phthalic acid, isophthalic acid, terephthalic acid, adipic acid, the reaction product of 1 mol of 4,4'-diaminodiphenylmethane and 2 mols of trimellitic anhydride, and/or dodecanoic diacid and/or the anhydrides of the mentioned acids.

The carboxylic groups may also be incorporated into the polyesters by transesterification of esters of the above mentioned polybasic carboxylic acids.

Also hydroxyfunctional carboxylic acids such as 12-hydroxy stearic acid or dimethylol propionic acid may be used.

Preferred polyhydric alcohols are 1,2-diols such as ethylene glycol, propylene glycol, hexylene glycol, 1,3-propane diol, reaction products of polyaddition reactions of ethylene oxide and/or propylene oxide, 1,6-hexane diol, neopentyl glycol, trimethylol propane and tris(hydroxyethyl)isocyanurate (THEIC).

1,2-diols such as ethylene glycol and propylene glycol are preferred, and they are at the same time suitable to generate glycol monoester groups suitable for the transacylation in the main chain and/or in side chain(s) of such polyesters.

Furthermore, poly(meth)acrylates may also be used as component (A) comprising the above mentioned groups wherein the resins are capable of transacylation in their main chain and/or side chain(s). For example, poly(meth)acrylates may carry mono ester groups of 1,2-diols, for example by incorporation of hydroxyethyl(meth)acrylate into the poly(meth)acrylate backbone, as known by a person skilled in the art.
The term (meth)acrylic stated herein is respectively intended to mean acrylic and/or methacrylic.

The production of the at least one resin of component (A) is known as such at a person skilled in the art and from the specialist literature, see, for example, Behr, "Hochtemperaturbestandige Kunststoffe" Hanser Verlage, Munich 1969; Cassidy, "Thermally Stable Polymers" New York: Marcel Dekker, 1980; Frazer, "High Temperature Resistant Polymers" New York: Interscience, 1968; Mair, Kunststoffe 77 (1987) 204.

Due to its chemical structure according to the invention as described above component (A) itself is able to form stable thermosetting films, without the use of any additional crosslinking resin(s).

The at least one resin of component (A) may comprise nano-scaled particles which are chemically bound into the resin structure of component (A).

The nano-scaled particles as such typically have an average particle size in the range of 1 to 300 nm, preferably in the range of 2 to 80 nm. These are, for example, inorganic nano-scaled particles based on compounds, such as, SiO$_2$, Al$_2$O$_3$, TiO$_2$, boron nitride, silicon carbide.

The nano-scaled particles can be, for example, compounds based on an element-oxygen network comprising elements from the series consisting of silicon, zinc, aluminium, tin, boron, germanium, gallium, lead, the transition metals and the lanthanides and actinides, in particular, from the series consisting of silicon, titanium, zinc, yttrium, cerium, vanadium, hafnium, zirconium, nickel and/or tantalum. Usable particles are, e.g., colloidal solutions or dispersions of such particles, like silica, aluminum oxide, titanium oxide, preferably, colloidal silica, which are commercially available from, e.g., Nyacol$®$ Corp., Grace Davison (Ludox$®$ colloidal silica in water), Nissan Chemical. The surface of the element-oxygen network of the particles can be modified with reactive organic groups, as described, for example, in EP-A 1166283, to be able to react with reactive groups of
the resin of component (A) to be chemically bound into the resin structure of component (A). Examples of suitable reactive particles are Aerosil products from Degussa AG, preferably Aerosil® R 100-8000. The surface of the element-oxygen network of the particles can also be partially modified with non-reactive groups.

The nano-scaled particles can be chemically bound in the resin structure of component (A) by chemical reaction of component (A) with the nano-scaled particles. Depending on the chemical nature of component (A) and the nano-scaled particles as mentioned above various chemical reactions are possible, for example, transesterification reaction, polymerisation reaction, addition reaction, condensation reaction.

The at least one resin of component (A) may comprise the mentioned nano-scaled particles in amount of 0 to 40 wt%, preferably 0 to 20 wt%, the wt% based on the total weight of component (A).

As component (B), the composition comprises at least one organic solvent and/or water, in amounts of 5 to 75 wt%, preferably 10 to 70 wt%, based on the total weight of the varnish composition. Examples of organic solvents are aromatic hydrocarbons, N-alkyl pyrrolidones, aliphatic and/or aromatic esters, ketones, aliphatic carbonates, cresols, phenols, xylenols, aliphatic alcohols, aliphatic ethers, monoothers of aliphatic diols.

If water is used in component (B), the at least one resin of component (A) may contain additional carboxylic or sulfonic acid functionalities which are neutralized by bases in order to achieve compatibility with or dispersability in water, as known at a person skilled in the art. Examples for such bases are sodium hydroxide, potassium hydroxide, magnesium hydroxide, lithium hydroxide, primary, secondary and tertiary amines such as triethylamine, dibutylamine, hexylamine, dimethylisopropylamine, diamines such as hexamethylene diamine, aminoalcohols such as ethanolamine, triethanolamin, N,N-dimethylethanolamine, N,N-dimethylisopropanolamine etc. If the amines
are already used as condensation components during the preparation of
the at least one resin (A), as such known at a person skilled in the art, no
further neutralization by bases may be necessary.

Preferably, 50 to 100 wt% of component (B) is water, based on the
total weight of component (B).

As component (C), the varnish composition according to the
invention may additionally comprise at least one resin different from (A), in
amounts of 0 to 40 wt%, preferably 0 to 20 wt%, based on the total weight
of the varnish composition. Examples are resins known at a person skilled
in the art as cross-linking agents, for example, phenolic resins, melamine
resins, blocked isocyanates, epoxides, depending on the kind of resin of
component (A). Also, at least one other resin can be used as component
(C), in order to obtain special properties of the entire coating composition,
for example, to increase the speed of cross-linking or to increase the
resistance against organic solvents. Those resins can be polyurethane
resins, poly(meth)acrylate resins, partially or fully hydrolyzed polymers
generated by copolymerization of maleic anhydride and (meth-)acrylic acid
as well as possibly other co-monomers capable of radical polymerization
such as styrene and (meth)acrylic esters, polyester resins, polyester imide
resins, polyamide imide resins, polyimide resins, polyamide resins, epoxy
resins, phenolic resins such as novolaks or resols, melamine resins,
polycarbonate resins, alkyd resins, polymeric carboxylic acids,
unsaturated polyester resins, and/or urethane acrylates, polymethacrylic
imide, polyimides, polybismaleimide imides, polyether imides,
polybenzoxazine diones, polyhydantoins, polyvinylformals,
polyvinylacetals, epoxy novolak resins, epoxy hybrid resins, for example,
urethane modified epoxy resins, acryl-modified epoxy resins and epoxy
esters and/or masked isocyanates.

The amount of component (C) is smaller than the amount of
component (A) in the varnish composition of the invention.
Preferably, no component (C) is used in the varnish composition of the invention.

At least one customary additive known at a person skilled in the art can be used as component (D) in the varnish composition of the invention, in amounts of 0 to 10 wt%, preferably 0.1 to 10 wt%, based on the total weight of the varnish composition. Examples are extenders, plasticising components, accelerators, for example metal salts, substituted amines, catalysts, such as, tetrabutyl titanate, isopropyl titanate, cresol titanate, triethanolamine titanate, the polymeric forms thereof, zirconates, such as n-propyl zirconate, triethanolamine zirconate, dibutyl tin dilaurate, zinc salts such as zinc acetate, initiators, for example, photo initiators, heat-responsive initiators, stabilisers, for example, hydroquinones, quinones, alkylphenols, alkylphenol ethers, defoamers and flow control agents.

As component (E) the varnish composition of the invention comprises at least one pigment, filler and/or nano-scaled particle and/or monomeric and/or polymeric element-organic compound, in a range of 0 to 40 wt%, preferably 0.1 to 30 wt%, based on the total weight of the varnish composition.

Example of pigments and/or fillers are known at a skilled person, for example, fillers based on SiO₂, Al₂O₃, TiO₂, Cr₂O₃, BaSO₄, colour-imparting inorganic and/or organic pigments, such as, titanium dioxide or carbon black and effect pigments, such as, metal flake pigments and/or pearlescent pigments, in amounts of 0 to 40 wt%, preferably 0 to 30 wt%, based on the total weight of the varnish composition of the invention.

Further, nano-scaled particles can be used as component (E) which are not covalently part of component (A) as described above, in amounts of 0 to 25, preferably 0 to 15 wt%, based on the total weight of the varnish composition of the invention. Those nano-scaled particles are particles as described above hereto for component (A).
The varnish composition may also comprise at least one monomeric and/or polymeric element-organic compound as component (E), in amounts of 0 to 40 wt%, preferably 0 to 30 wt%, more preferably 0.1 to 30 wt%, based on the total weight of the varnish composition of the invention. Examples of polymeric organo-element compounds include inorganic-organic hybrid polymers of the type mentioned, for example, in DE-A 198 41 977. Examples of monomeric organo-element compounds include ortho-titanic acid esters and/or ortho-zirconic acid esters containing residues such as, nonyl, cetyl, stearyl, of triethanolamine, of diethanolamine, of acetylacetone, of acetoacetic ester, tetraisopropyl, cresyl, butyl, as well as titanium tetralactate, hafnium compounds and silicon compounds, for example, hafnium tetrabutoxide and tetraethyl silicate and/or various silicone resins. The varnish composition useable for the process according to the invention is a composition preferably consisting of

(A) 1 to 95 wt% of at least one resin comprising nucleophilic groups selected from the group consisting of OH, NHR and SH, and electrophilic groups which can react with the above mentioned nucleophilic groups, wherein the resin is capable of transacylation in its main chain and/or side chain(s),

(B) 5 to 75 wt% of at least one organic solvent and/or water,

(C) 0 to 40 wt% of at least one resin different from (A),

(D) 0 to 10 wt% of at least one customary additive,

(E) 0 to 40 wt% of at least one pigment, filler and/or nano-sized particle and/or monomeric and/or polymeric element-organic compound,
wherein the wt% is based on the total weight of the varnish composition (A) to (E) and wherein the amount of component (C) is smaller than the amount of component (A).

The varnish composition useable for the process according to the invention is a composition more preferably comprising

(A) 5 to 60 wt% of at least one resin comprising nucleophilic groups selected from the group consisting of OH, NHR and SH, and electrophilic groups which can react with the above mentioned nucleophilic groups, wherein the resin is capable of transacylation in its main chain and/or side chain(s),

(B) 10 to 70 wt% of at least one organic solvent and/or water,

(C) 0 to 20 wt% of at least one resin different from (A),

(D) 0.1 to 10 wt% of at least one customary additive,

(E) 0.1 to 30 wt% of at least one pigment, filler and/or nano-scaled particle and/or monomeric and/or polymeric element-organic compound,

wherein the wt% is based on the total weight of the varnish composition (A) to (E) and wherein the amount of component (C) is smaller than the amount of component (A).

The composition according to the invention may be produced by simply mixing the individual components together. For example, it is possible to produce a resin dispersion by mixing the at least one resin of component A) with water. The further components are then added, for example, with stirring, to produce a stable dispersion, optionally, with input of heat and dispersing agents. It is also possible to produce a mixture of the at least one resin with the organic solvent. The further components are then added, e.g., by stirring.
Water and/or organic solvents as component (B) are added in a quantity such that a non-volatile content of, for example, 20 to 60%, preferably 25 to 50%, is obtained for the finished varnish composition of the invention.

The application of the composition by the process according to the invention proceeds, e.g., onto the surface of one or both sides of the electrical steel sheet as one or more coating layers, preferably as one coating layer, with a dry layer thickness of, for example, 0.1 to 30 μm, preferably, 0.2 to 20 μm, per layer.

In particular, the composition according to the invention is suitable as a single-layer application.

The following examples are intended to illustrate the invention in greater detail. All parts and percentages are on a weight basis unless otherwise indicated.

**Examples**

**Example 1**

**Preparation of Resin of Component (A) (Resin 1)**

600 parts of tris(hydroxyethyl)isocyanurate, 885 parts of trimellitic anhydride and 430 parts of ethylene glycol were heated to 120°C. After addition of 2 parts of transesterification catalysts the mixture was heated to 180°C and water was distilled off until an acid value of 72mgKOH/g has been reached. At 165°C, 345 parts of triethanolamine were added. After further cooling to 130°C, 350 parts of methoxypropanol and 1400 parts of water were added. The pH value has been adjusted to 8.5 using dimethylethanolamine. The obtained resin solution had a solid content (non-volatile content) of 49% (conditions of solid content determination: 1h, 180°C) and a viscosity of 300mPas (25°C) (DIN53211).

**Example 2**

**Preparation of Resin of Component (A) (Resin 2)**
1050 parts of tris(hydroxyethyl)isocyanurate, 1540 parts of trimellitic anhydride, 745 parts of ethylene glycol and 600 parts of triethanolamine were heated to 120°C. After addition of 4 parts of transesterification catalysts the mixture was heated to 210°C and water was distilled off until an acid value of <5mgKOH/g has been reached. After cooling to 140°C, 595 parts of phthalic anhydride were added, followed by an exothermal reaction. After cooling to 140°C, 700 parts of methoxypropanol and 2770 parts of water were added. The pH value has been adjusted to 8,7 using dimethylethanolamine. The obtained resin solution had a solid content (non-volatile content) of 52% (conditions of solid content determination: 1h, 180°C) and a viscosity of 480mPas (25°C) (DIN5321 1).

Example 3
Preparation of Varnish Composition (Varnish 1)

100 parts of water, 3600 parts of Resin 1 and 6 parts of a dispersing additive were charged during agitation and homogenized. Then 20 parts of carbon black, 900 parts of a titanium dioxide pigment and 4350 parts of a barium sulfate filler were charged and dispersed for 20 minutes. After that, the mixture was homogenized in a pearl mill for 20 minutes. After milling, 85 parts of an aqueous modified silicate, 610 parts of Resin 1 and 320 parts of water were charged, and this mixture was homogenized by proper stirring for 20 minutes. The resulting varnish had a solid content (non-volatile content) of 77,0% (conditions of solid content determination: 2h, 120°C ) and a viscosity of 175s (DIN5321 1, DIN4 cup, 20°C).

Example 4
Preparation of Varnish Composition (Varnish 2)

Charge 95 parts of water, 3450 parts of Resin 2 and 6 parts of a dispersing additive during agitation and homogenize. Then charge 20 parts of carbon black, 860 parts of a titanium dioxide pigment and 4150 parts of a barium sulfate filler and disperse for 20 minutes. After that, homogenize mixture in a pearl mill for 20 minutes. After milling, charge
600 parts of an aqueous modified silicate, 585 parts of Resin 2, 150 parts of flow additives and 90 parts of triethanolamine and homogenize this mixture by proper stirring for 20 minutes. The resulting varnish has a solid content (non-volatile content) of 77.5% (conditions of solid content determination: 2h, 120°C) and a viscosity of 148s (DIN53211, DIN4 cup, 20°C).

**Example 5**

**Preparation of Electrical Steel Sheet with Varnish 1**

Varnish 1 was applied onto an M800* electrical steel sheet (0.5mm thickness) as one-layer-coating and cured for 20 seconds at an oven temperature of 300°C (peak metal temperature: approx. 210°C). After curing the dry layer thickness is 5µm. *kind of steel according to EN 10106-2007

**Example 6**

**Preparation of Electrical Steel Sheet with Varnish 2**

Varnish 2 was applied at the same manner and conditions as described in Example 5.

**Comparative Example**

**Preparation of Electrical Steel sheet with commercially available Varnish Voltatex® 1151E**

Voltatex® 1151E (commercially available resin, DuPont) was applied at the same manner and conditions as described in Example 5.

**Test Results**

The test results of the electrical steel sheets coated with the varnish compositions of Example 5, 6 and Comparative Example can be found in Table 1.
<table>
<thead>
<tr>
<th>Test</th>
<th>Standard</th>
<th>Example 5</th>
<th>Example 6</th>
<th>Comparative Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosscut adhesion</td>
<td>DIN EN ISO 2609</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Chemical resistance*: Acetone</td>
<td>DuPont internal*</td>
<td>&gt;30 d.r.**</td>
<td>&gt;30 d.r.**</td>
<td>&gt;30 d.r.**</td>
</tr>
<tr>
<td>Chemical resistance*: Ethanol</td>
<td>DuPont internal*</td>
<td>&gt;30 d.r.**</td>
<td>&gt;30 d.r.**</td>
<td>&gt;30 d.r.**</td>
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<tr>
<td>Chemical resistance*: Water</td>
<td>DuPont internal*</td>
<td>&gt;30 d.r.**</td>
<td>&gt;30 d.r.**</td>
<td>&gt;30 d.r.**</td>
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<td>Bend test (cylindrical mandrel)</td>
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<td>Breakdown voltage</td>
<td>DIN VDE 303 part 21</td>
<td>48 V/μπι</td>
<td>49 V/μπι</td>
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<td>Surface insulation resistance</td>
<td>EN 10282</td>
<td>&gt;1000 Qcm²/la mella</td>
<td>&gt;1000 Qcm²/la mella</td>
<td>&gt;1000 Qcm²/la mella</td>
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<td>Formaldehyde emission during curing</td>
<td>qualitative</td>
<td>No</td>
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* The chemical resistance is tested using a small portion of cotton wool, which is soaked with the respective solvent and then rubbed on the coated steel. A rubbing movement back and forth is counted as one double rub. The test result is the number of double rubs until the coating shows first damages.

** d. r. = double rubs

The test results of the coatings based on Varnish 1 and Varnish 2 show that no formaldehyde emission during curing is observed, and very good coating properties can be provided.
Claims

What is claimed is

1. A coating process for electrical steel sheet using a varnish composition, comprising the steps of
   a) applying at least one coating layer of a varnish composition onto the surface of the electrical steel sheet wherein the varnish composition comprises
      (A) 1 to 95 wt% of at least one resin comprising nucleophilic groups selected from the group consisting of OH, NHR and SH, and electrophilic groups which can react with the above mentioned nucleophilic groups, wherein the resin is capable of transacylation in its main chain and/or side chain(s),
      (B) 5 to 75 wt% of at least one organic solvent and/or water,
      (C) 0 to 40 wt% of at least one resin different from (A),
      (D) 0 to 10 wt% of at least one customary additive,
      (E) 0 to 40 wt% of at least one pigment, filler and/or nano-scaled particle and/or monomeric and/or polymeric element-organic compound,
   wherein the wt% is based on the total weight of the varnish composition (A) to (E) and wherein the amount of component (C) is smaller than the amount of component (A), and
   b) curing the applied at least one coating layer.

2. The coating process according to claim 1 wherein the varnish composition comprises
(A) 5 to 60 wt% of at least one resin comprising nucleophilic groups selected from the group consisting of OH, NHR and SH, and electrophilic groups which can react with the above mentioned nucleophilic groups, wherein the resin is capable of transacylation in its main chain and/or side chain(s),

(B) 10 to 70 wt% of at least one organic solvent and/or water,

(C) 0 to 20 wt% of at least one resin different from (A),

(D) 0.1 to 10 wt% of at least one customary additive,

(E) 0.1 to 30 wt% of at least one pigment, filler and/or nano-scaled particle and/or monomeric and/or polymeric element-organic compound,

wherein the wt% is based on the total weight of the varnish composition (A) to (E) and wherein the amount of component (C) is smaller than the amount of component (A).

3. The coating process according to claim 1 and 2 wherein the resin of component (A) comprises OH and/or SH as nucleophilic groups.

4. The coating process according to claims 1 to 3 wherein the resins of component (A) are polyurethanes and/or polyesters comprising the nucleophilic groups and the electrophilic groups wherein the resins are capable of transacylation in their main chain and/or in their side chain(s).

5. The coating process according to claims 1 to 4 wherein applying one coating layer of the varnish composition onto the surface of the electrical steel sheet.
6. The coating process according to claims 1 to 5 wherein the curing takes place at temperatures providing a PMT (peak metal temperature) in the range of 180 to 260 °C.

7. The coating process according to claims 1 to 6 wherein the ambient curing temperatures are in the range of 200 to 600 °C and the curing is done in a time period of 10 seconds to 1 minute.

8. A process for the production of an electrical steel sheet core by punching out parts of the coated electrical steel sheet after curing according to the coating process of claims 1 to 7, stacking and assembling the parts to form a sheet core by technical means selected from the group consisting of welding, clamping, interlocking, aluminium die casting and riveting.

9. The process according to claim 8 wherein technical mean is welding.

10. An electrical steel sheet coated with the coating process according to claims 1 to 7.

11. An electrical steel sheet core produced from electrical steel sheets coated with the coating process according to claims 1 to 7.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. C08G63/685 C09D167/00 H01B3/30 H01F1/18

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)
C08G C09D H01B H01F

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

Electronic data base consulted during the international search (name of data base and, where practically, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>X</td>
<td>WO 2009/079540 AI (DU PONT [US]; BOEHM FRANK-RAINER [DE]; HERM MICHAEL [DE]; FROSCHAUER B) 25 June 2009 (2009-06-25) cited in the application on page 5, line 23 - page 6, line 28 page 9, lines 4-7; claims 1,2,4,7-12</td>
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<td>X</td>
<td>WO 2007/019434 AI (DU PONT [US]; BOEHM FRANK-RAINER [DE]; HERM MICHAEL [DE]) 15 February 2007 (2007-02-15) claims 1,2,4,9,11; examples 1-5</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) on which the document is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means of publication
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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"A" document member of the same patent family

Date of the actual completion of the international search
26 March 2013

Date of mailing of the international search report
05/04/2013

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016

Authorized officer
Kratzschmar, Ulrike
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