NON-GALVANICALLY APPLIED NICKEL ALLOY

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ABSTRACT
Lead-free nickel phosphorous dispersion alloy present on a metallic substrate surface, obtainable by electroless deposition in an electrolyte which contains 4 to 7 g/l of nickel ions; 15 to 40 g/l of hypophosphite; at least one stabiliser; 5 to 400 mg/l of an alkylaryl oxydialkyl benzyl ammonium chloride or a partially fluorinated betaine; 50 to 60 g/l of a carboxylic acid-containing complexing agent A; 5 to 40 g/l of a carboxylic acid-containing complexing agent B different from A; 4 to 10 g/l of dispersed particles which differ from the composition of the nickel/phosphorus alloy; and contains no boric acid or borates, and articles coated therewith.
NON-GALVANICALLY APPLIED NICKEL ALLOY

[0001] The present invention relates to a lead-free nickel alloy produced chemically, i.e. electrolecless, with inclusions as well as to objects coated therewith.

[0002] Chemical nickel plating of metal surfaces is a process used frequently on an industrial scale to protect metals against corrosion and wear.

[0003] In general, a distinction is made between an electrolytic and an electrolecless deposition for the production of a nickel layer.

[0004] Electrolytic deposition — also known as galvanic deposition or coating — is a deposition reaction on the surface to be coated, which is brought about by the current introduced.

[0005] In the case of electrolecless deposition — also known as chemical deposition or coating — the formation of the layer is based on an autocatalysed process which is determined decisively by the electrochemical potentials of the reactants involved.

[0006] An electrolytic process for the production of a nickel layer is known e.g. from EP 0 218 845 A1 in which an electroplating tank is used which, apart from a cationic surfactant from the group of alkylaryl oxydiaryl benzyl ammonium chloride derivatives, necessarily contains boron acid or borates.

[0007] These layers thus obtained have the disadvantage that they exhibit a more than proportional layer build-up at the edges and a less than proportional layer build-up at indentations or undercutts. For this reason, these processes are not suitable for geometrically complex structural parts (carburetor bodies, fuel distributors for injection systems etc., for example) in which an even layer build-up in all areas is of decisive importance.

[0008] Also, it is not possible to coat such geometrically complex structural parts on the inside without the use of internal anodes. The use of internal anodes has the disadvantage of extremely difficult positioning: bores with a small diameter (less than 2 mm) cannot be coated by such processes using an internal anode.

[0009] Consequently, electrolecless processes have achieved greater industrial importance in the manufacture of functional (i.e. not exclusively decorative) nickel layers and/or nickel alloy layers. In order to achieve an improved protection against corrosion, it has proved necessary, to achieve a nickel/phosphorus alloy by adding suitable compounds to the aqueous electrolyte.

[0010] Pure nickel and phosphinate-containing electrolytes for chemical nickel plating require additional stabilisers to prevent spontaneous decomposition. Stabilisers adequate for industrial application has previously been achieved mainly by the addition of lead compounds. Stabilisers previously used as an alternative such as e.g. molybdenum compounds, cadmium or tin compounds exhibit a reduced effectiveness in comparison with lead.

[0011] Moreover, the addition of lead and cadmium is no longer acceptable from the points of view of environmental policy; against this background, it is understandable that the motor vehicle industry, for example, is no longer permitted to use lead-containing structural parts in view of the EU end-of-life vehicles directive in force at present.

[0012] An example of such a bath containing lead in principle for electrolecless nickel deposition is described in patent specification DE 3 421 646 C2. Apart from a metal salt of the above-mentioned type, a special sulphonium betaine is used as additional stabiliser.

[0013] According to WO 02/34964, an electrolyte is used for the production of a lead-free nickel alloy by means of an electrolecless process, which electrolyte does not contain any lead-containing stabiliser but a combination of an antimony compound and a bismuth compound.

[0014] This specially matched electrolyte is not suitable for the production of dispersion layers, in particular not of PTFE-containing nickel layers.

[0015] Such a necessary combination of antimony ions and bismuth ions in the electrolyte, however, is not universally suitable to stabilise electrolytes for the production of dispersion coatings. The production of PTFE-containing dispersion electrolytes with a combination of an antimony compound and a bismuth compound, in particular, leads to an unsatisfactory stability of the electrolyte. The disadvantage here is the fact that the bath becomes excessively stabilised after a short period.

[0016] Such nickel dispersion layers, however, are being increasingly used in high performance structural parts such as parts of locks, valves, rotary ducts, valve anchors, moveable pistons, complex geometrical fuel conducting parts in the motor vehicle industry.

[0017] Involved in this case is the production of a metal layer by an electrolecless process with simultaneous inclusion of solids which are present in the electrolyte in the dispersed form.

[0018] Depending on the application, these solids are slip additives (e.g. PTFE, graphite, spherical aluminium oxide, encapsulated MoS2, etc.) or hard materials (diamond, corundum, cubic BN etc.)

[0019] A serious problem during the manufacture of these layers is posed by the regular incorporation of the solids into the metal matrix. Non-homogeneous dispersion layers lead to premature and/or undesirable local wear and tear which, depending on the field of application, may present a considerable safety risk (e.g. hydraulic cylinders in the aircraft industry).

[0020] One possibility for manufacturing such a nickel dispersion layer is described in U.S. Pat. No. 4,997,688 A1. It involves a process for electrolecless nickel coating in which an electrolyte is used which, apart from the nickel cations and phosphinate anions, contains a mixture of a non-anionic surfactant with a cationic, anionic or amphoteric surfactant.

[0021] The addition of this combination of surfactants to the hypophosphate-containing electrolytes has the disadvantage that the useful life of the electrolyte is dramatically shortened, for example in the case of the incorporation of finely divided PTFE. This reduction of the useful life is attributable, among other things, to the formation of orthophosphate or nickel phosphate crystals and the formation of decomposition products of the surfactant mixture added. Moreover, a decomposition of the bath can be observed, depending on the test conditions.

[0022] In addition, the nature of the surface is uneven which promotes the early abrasion of these dispersion layers.

[0023] Moreover, these nickel dispersion layers are produced using convention nickel/phosphorus electrolytes which contain either lead or a combination of tin with cadmium as stabiliser.

[0024] For this reason, there have been increased efforts in the recent past not to use emulsifiers or surface-active substances in hypophosphate-containing electrolytes for electrolecless nickel plating of PTFE-containing dispersion layers.

[0025] From U.S. Pat. No. 6,273,943, an electrolyte for the electrolecless deposition of a nickel/PTFE dispersion layers is known which exhibits a quaternary perfluoroalkyl ammonium halide and a lead compound as stabiliser.

[0026] Apart from the decisive disadvantage of the necessary use of lead, perfluorocetyl sulphonyl (PFOA), an extremely toxic and bioaccumulative compound, is formed as intermediate product during the production of perfluoralkyl ammonium halides.
The object of the present invention is the provision of a lead-free nickel/phosphorus dispersion coating present on a metallic substrate surface, which coating permits a homogeneous layer build-up (in particular at the edges, in indentations and undercuts) even on geometrically complex structural parts with functional inclusions.

In this connection, as homogeneous an incorporation of the particles into the nickel alloy matrix as possible is to be guaranteed.

This coating is to be suitable in particular for geometrically complex structural parts which can be subjected to high mechanical and friction stresses and, moreover, exhibit low tolerances.

Finally, these nickel alloy layers should be obtainable by electrodeposition in an electrolyte which is characterised by comparatively long useful lives.

This object is achieved according to the invention by way of a lead-free nickel/phosphorus dispersion alloy present on a metallic substrate surface, obtainable by electrodeposition in an electrolyte containing

- 4 to 7 g/l of nickel ions;
- 15 to 40 g/l of hypophosphite;
- at least one stabiliser;
- 5 to 400 mg/l of an alkylaryl oxydialkybenzyl ammonium chloride or a partially fluorinated betaine;
- 50 to 60 g/l of a complexing agent A containing carboxylic acid;
- 5 to 40 g/l of a complexing agent B different from A (e.g. or preferably dicarboxylic acid);
- 3 to 10 g/l of dispersed particles which differ from the composition of the nickel/phosphorus alloy; and
- no boric acid or borates

the data relating to the composition of the electrolyte as a whole.

In this respect, it should be noted that the electrolyte does not contain cadmium either.

By means of the lead-free nickel/phosphorus dispersion alloy according to the invention, it is possible for the first time to provide geometrically complex structural parts such as e.g. carburetor bodies, fuel distributors for injection systems etc with a homogeneous layer build-up of a coating that can be subjected to a high level of friction, in particular at the edges, in indentations and undercuts.

In their fully coated state, these structural parts have a tolerance of ±3 µm with a total layer thickness of 10-12 µm.

Depending on the particles used, it is possible to achieve a roughness depth and/or functional surface characteristics which are specifically matched to the corresponding application.

As a result of the components necessarily present in the electrolyte in line with the main claim for the production of the coating according to the invention, a homogeneous incorporation of the particles into the nickel alloy matrix is guaranteed. In this way, a wide variety of particle forms, e.g. agglomerates, individual particles or particles of different geometries, can be distributed homogeneously, something that can be easily depicted by way of a metallographic micrograph.

Finally, the useful life of the electrolyte used for the electrodeposition of a dispersion layer according to the invention having incorporated silicon carbide particles may be a useful life of up to 10 MTO (metal turn over—i.e. metal throughput based on the electrolyte used, in litres).

The term “metallic substrate surface” should be understood to mean also synthetic resin surfaces which are activated first of all by means of processes known to the expert and subsequently nickel plated.

Metallised synthetic resin surfaces which are produced using a mechanical microstructurisation are particularly preferred and disclosed in WO 2004/092436 A2 and WO 2004/092256 A1, for example.

A common layer thickness of this nickel/phosphorus dispersion alloy of between 3 and 30 µm is sufficient to increase the abrasion resistance, to improve the sliding and friction properties and to provide anti-adhesion properties. Depending on the type of particles used, energy transferring functional layers can also be produced.

A preferred embodiment of the nickel/phosphorus dispersion alloy according to the invention is achieved if the components of nickel, phosphorus and particles are evenly distributed in the alloy layer.

The term “evenly” means here and subsequently a distribution typical of the alloy and function of the corresponding components in the nickel matrix. By way of this homogeneous distribution, a uniform structure is achieved in the alloy such that the mechanical and functional properties of this layer are constant even within narrow tolerance ranges.

The carboxylic and dicarboxylic acids known for the production of the usual nickel/phosphorus electrolytes are used as complexing agents A.

Lactic acid and malonic acid are particularly preferred as complexing agent A; succinic acid is preferably used as complexing agent B.

A simple example of an alkylaryl oxydialkybenzyl ammonium chloride is benzalkonium chloride with the formula

or the formula

\[
\text{CH}_3\begin{array}{c}
\text{CH}_3 \\
\text{CH}_3
\end{array}\begin{array}{c}
\text{CH}_3 \\
\text{CH}_3
\end{array}\begin{array}{c}
\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2
\end{array}\begin{array}{c}
\text{CH}_3 \\
\text{CH}_3
\end{array}\]
in which X represents a chlorine atom. Such compounds are sold by Clariant, for example, under the trade name of HYAMIN® 1622.

Further simple examples of alkylaryl oxydialkyl benzyl ammonium chlorides are benzalkonium chloride (N-silky-N,N-dimethyl-N-benzyl ammonium chloride with a C12_C14 or C18_C24 alkyl radical) and methyl dodecyl benzyl tri- methyl ammonium chloride. Benzalkonium chlorides are sold by Clariant, for example, under the trade name of HYAMIN® 3500.

Those compounds can be used as possible partially fluorinated betaine, for example; which are sold by Clariant under the trade name of FLUOWET® CA.

In a preferred embodiment of the invention, the electrolyte contains; as stabiliser; at least 10 mg/l of antimony ions and maximum 1.5 mg/l of bismuth ions.

This addition of antimony and bismuth, however, is not essential—it is thus possible to use only stabilisers based on tin (II) compounds, for example.

Particularly preferably, the electrolyte contains, as stabiliser; 10-150 mg/l of antimony ions and 0.01-1.5 mg/l of bismuth ions.

By selecting the stabilisers according to this embodiment, it is possible to achieve very high levels of storage stability of the electrolyte. For an electrolyte with SiC as particles, it is possible by way of this choice to achieve useful lives of up to 10 MTO (metal turn over—i.e. metal throughput based on the electrolyte used, in litres) and it is possible to achieved useful lives of 3 MTO and more for an electrolyte for the production of a nickel phosphorus-PTFE dispersion layer.

According to a further embodiment of the present invention, the electrolyte additionally contains a non-ionic surfactant. The non-ionic surfactant selected from the group of partially fluorinated or non-fluorinated surfactants is particularly preferred. The term “partially fluorinated surfactants” should be understood to mean all surface-active substances not exhibiting perfluorinated radicals. The term “non-fluorinated surfactants” should be understood to mean all surface-active substances not exhibiting fluoride atoms.

In this way, it is possible to obtain an improved, (i.e. more homogeneous) nickel phosphorus dispersion layer since the use of an additional non-ionic surfactant is achieved in the case of preventing an undesirable agglomeration in the electrolyte and simultaneously makes a contribution to keeping the non-soluble components of the electrolyte in suspension.

Thus, a longer useful life of the electrolyte is guaranteed by this embodiment.

The dispersed particles may be selected in a preferred embodiment of the present invention from the group of silicon carbide, corundum, diamond, cubic boron nitride, spherical aluminium oxide and boron tetracarbide, those particles being particularly preferred which are non-metallic and have a hardness of more than 1,000 HV.

The nickel phosphorus dispersion alloys obtained according to this preferred embodiment are particularly suitable for providing the coated substrates with resistance to abrasion, protection resistance to wear and increased friction to guarantee tight-fitting connections or the desired surface structure. In this way, the substrate can be provided with functional properties which are precisely matched to the requirements of its application. Thus rough surface structures with typical functional inclusions are achieved in the case of a nickel phosphorus dispersion layer with incorporated silicon carbide particles, which, in tight fitting connections, achieve friction values of μ~0.50 and more (for comparison; the friction value in a dry steel contact amounts to only μ=0.15).

In another, also preferred, embodiment, the particles exhibit friction-reducing properties and are selected from the group of polytetrafluoroethylene, molybdenum sulphide, molybdenum disulphide, hexagonal boron nitride, tin sulphide and graphite.

The nickel phosphorus dispersion layers obtainable according to this embodiment must also be selected according to the functional requirements of the resulting structural part. Thus, excellent friction-reducing properties are achieved by incorporating PTFE particles into the nickel phosphorus matrix. Only by way of this special composition of the electrolyte according to the present invention is it possible to provide a lead-free and cadmium-free system which guarantees a stability sufficient also for the production of nickel phosphorus PTFE alloys and good surface properties. As a result of the complex interaction of all the components involved regarding the stability of the electrolyte and the good deposition rates, it had previously not been known to provide electrolytes containing polytetrafluoroethylene which do not depend on lead-containing or cadmium-containing stabilisers.

A further advantage of the embodiment according to the invention is the fact perfluorinated cationic or non-ionic surfactants are dispensed with. For electrolytes containing polytetrafluoroethylene, in particular, perfluorinated cationic and non-ionic surfactants had previously been mainly used since these alone had been suitable to provide the PTFE particles with the charge necessary for migration and co-deposition. The production of these fluorinated cationic and non-ionic surfactants, however, takes place via a toxic intermediate stage (“perfluorocycyl sulphonyl”) with a bioaccumulation potential such that these have been removed by manufacturers from their production programme worldwide. This development has led to a search for new methods in order to be able to continue produce PTFE-containing nickel phosphorus dispersion alloys without having to use the fluorine-containing cationic surfactants no longer available. It is precisely this application, however, which is possible with nickel phosphorus PTFE dispersion alloy of the present invention in a manner which takes into account all framework conditions imposed by environmental and health policies.

The nickel phosphorus dispersion alloys according to the present invention can be used as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry with improved sliding friction properties, in particular for parts of locks, valves, rotary ducts, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

The individual process steps for the production of a chemically produced nickel alloy by electroleoless metal deposition in an aqueous electrolyte are known in principle. This applies in particular to selecting suitable compounds for the nickel cations and phosphate ions. In addition, it is known to the expert which additives, stabilisers, complexing agents or other additives are additionally necessary for a corresponding nickel alloy.
However, these parameters are not critical for the application of the process according to the invention. For this reason, this basic knowledge is not dwelled on in detail, instead reference should be made to the textbook “Einführung in die Galvanotechnik (Introduction into electroplating technology)” by Bernhard Gaida, E. Leuze Verlag.

In the process according to the invention, the proportion of nickel cations in the electrolyte may amount to 4 to 7 g/l, based on the sum total of the components of nickel and phosphorus present in the aqueous electrolyte.

The proportion of phosphinate ions in the electrolyte may be between 15 and 40 g/l, based on the weight ratio of phosphorus to the sum total of the components of nickel and phosphorus present in the aqueous electrolyte.

The proportion of alkylaryl oxycarboxyl benzylic ammonium in the electrolyte may be between 0.01 and 0.4% by weight, in particular between 0.1 and 0.2% by weight, based on the sum total of the components of nickel and phosphorus present in the aqueous electrolyte.

The sum total of the proportions described above of the components present in the electrolyte is usually 100% by weight.

The following examples serve to illustrate the invention:

Test methods:

The determination of the useful life (in MTO-metal-turn-over) takes place via wet chemical titration on a nurexid indicator as consumption in g/l of nickel.

The value is calculated from the quantity of nickel ions which can be added to the finished electrolyte without the electrolyte having to be replaced. It is based on the total quantity of nickel in the electrolyte bath.

The determination of the homogeneous distribution of the PTFE particles takes place via a metallographic micrograph of the coated steel sheet. It is characterised by determining the percentage proportion of the distribution of the particles incorporated into the nickel/phosphorus matrix.

EXAMPLE 1

Into a 1 l glass beaker, 500 ml of fully demineralised water are introduced and the following compounds are added with stirring:

30 g/l of nickel sulphate (NiSO₄·6H₂O)
35 g/l of sodium phosphinate (NaH₂PO₄·2H₂O)
30 g/l of malonic acid
30 g/l of succinic acid
0.5 mg/l of bismuth methane sulphonate (Bi(OS (O₂CH)₂)
1.5 g/l of antimony chloride
10 m/l of tetrafluoroboric acid (50%)
100 mg/l of allyl thiourea
370 mg/l of cationic perfluorinated fluorine surfactant “FT 754” from 3M
7 g/l of PTFE dispersion Zonyl® 3807 from DuPont
15 mg/l of non-ionic surfactant “FSN-100” from DuPont

The layer thickness achieved is 5 μm.

EXAMPLE 2

(According to the Invention):

Comparative example 1 is repeated, though with the following electrolyte composition:

25 g/l of nickel sulphate (NiSO₄·6H₂O)
35 g/l of sodium phosphinate (NaH₂PO₄·2H₂O)
35 g/l of lactic acid (synthetic)
30 g/l of succinic acid
0.5 mg/l of bismuth tartrate
1.5 g/l of antimony chloride
0.5 mg/l of potassium o-ethyl dithiocarbonate
195 mg/l of Hyamin® 1622 from Lonza
7 g/l of PTFE dispersion Zonyl® 3807 from DuPont
15 mg/l of non-ionic surfactant “FSN-100” from DuPont

The pH of the electrolyte is adjusted to 4.5 by adding a 25% aqueous ammonia solution. The layer thickness achieved is 5 μm.

EXAMPLE 3

(According to the Invention):

25 g/l of nickel sulphate (NiSO₄·6H₂O)
35 g/l of sodium phosphinate (NaH₂PO₄·2H₂O)
35 g/l of lactic acid (synthetic)
30 g/l of succinic acid
0.5 mg/l of bismuth tartrate
1.5 g/l of antimony chloride
0.5 mg/l of potassium o-ethyl dithiocarbonate
725 mg/l of Fluowet® CA from Clariant
7 g/l of PTFE dispersion Zonyl® 3807 from DuPont
15 mg/l of non-ionic surfactant “FSN-100” from DuPont

The layer thickness achieved is 5 μm.

EXAMPLE 4

(According to the Invention):

30 g/l of nickel sulphate (NiSO₄·6H₂O)
40 g/l of sodium phosphinate (NaH₂PO₄·2H₂O)
40 g/l of lactic acid (synthetic)
5 g/l of succinic acid
8 g/l of malic acid
1 g/l of citric acid
10 g/l of sodium acetate
5 g/l of ammonium sulphate
75 ppm of Sn as tin(lI) sulphate
725 mg/l of Fluowet® CA from Clariant
7 g/l of PTFE dispersion Zonyl® 3807 from DuPont
15 mg/l of non-ionic surfactant “FSN-100” from DuPont

The layer thickness achieved is 5 μm.
The electrolyte behaviour “not stable” means essentially the formation of a foreign seed in the electrolyte during the layer formation process.

The electrolyte behaviour “hardly stable” means the formation of a foreign seed in the electrolyte after one hour during the layer formation process.

The electrolyte behaviour “stable” means no foreign seed formation in the electrolyte during the layer formation process.

Table I clearly shows improved properties of the nickel alloy dispersion layers according to the invention in comparison with those of the state of the art.

1. Lead-free nickel phosphorus dispersion alloy present on a metallic substrate surface, obtainable by electroless deposition in an electrolyte containing 4 to 7 g/l of nickel ions; 15 to 40 g/l of hypophosphite; at least one stabiliser; 5 to 400 g/l of an alkylaryl oxydialkyl benzyl ammonium chloride or a partially fluorinated betaine; 50 to 60 g/l of a complexing agent A containing carboxylic acid; 5 to 40 g/l of a complexing agent B different from A containing carboxylic acid; 4 to 10 g/l of dispersed particles which differ from the composition of the nickel phosphorus alloy; and no boric acid or borates the data relating to the composition of the electrolyte as a whole.

2. Nickel alloy according to claim 1 characterised in that the electrolyte contains, as stabiliser, at least 10 mg/l of antimony ions and maximum 1.5 mg/l of bismuth ions.

3. Nickel alloy according to claim 2 characterised in that the electrolyte contains, as stabiliser, 10-150 mg/l of antimony ions and 0.01-0.5 mg/l of bismuth ions.

4. Nickel alloy according to claim 1 characterised in that the electrolyte additionally contains a non-ionic surfactant.

5. Nickel alloy according to claim 4 characterised in that the non-ionic surfactant is selected from the group of partially fluorinated or non-fluorinated surfactants.

6. Nickel alloy according to claim 1 characterised in that the particles are selected from the group of silicon carbide, corundum, diamond, cubic boron nitride, spherical aluminium oxide and boron tetracarbide.

7. Nickel alloy according to claim 1 characterised in that the particles are non-metallic and exhibit a hardness of more than 1,000 HV.

8. Nickel alloy according to claim 1 characterised in that the particles exhibit friction-reducing properties and are selected from the group of polytetrafluoroethylene, molybdenum sulphide, molybdenum disulphide, hexagonal boron nitride, tin sulphide and graphite.

9. Use of a nickel alloy according to claim 1 as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry with improved sliding friction properties, in particular for parts of locks, valves, rotary ducts, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

10. Nickel alloy according to claim 2 characterised in that the particles exhibit friction-reducing properties and are selected from the group of polytetrafluoroethylene, molybdenum sulphide, molybdenum disulphide, hexagonal boron nitride, tin sulphide and graphite.

11. Nickel alloy according to claim 3 characterised in that the particles exhibit friction-reducing properties and are selected from the group of polytetrafluoroethylene, molybdenum sulphide, molybdenum disulphide, hexagonal boron nitride, tin sulphide and graphite.

12. Nickel alloy according to claim 4 characterised in that the particles exhibit friction-reducing properties and are selected from the group of polytetrafluoroethylene, molybdenum sulphide, molybdenum disulphide, hexagonal boron nitride, tin sulphide and graphite.

13. Nickel alloy according to claim 5 characterised in that the particles exhibit friction-reducing properties and are selected from the group of polytetrafluoroethylene, molybdenum sulphide, molybdenum disulphide, hexagonal boron nitride, tin sulphide and graphite.

14. Use of a nickel alloy according to claim 2 as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry with improved sliding friction properties, in particular for parts of locks, valves, rotary ducts, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

15. Use of a nickel alloy according to claim 3 as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry with improved sliding friction properties, in particular for parts of locks, valves, rotary ducts, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

16. Use of a nickel alloy according to claim 4 as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry with improved sliding friction properties, in particular for parts of locks, valves, rotary ducts, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

17. Use of a nickel alloy according to claim 5 as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry with improved sliding friction properties, in particular for parts of locks, valves, rotary ducts, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

18. Use of a nickel alloy according to claim 6 as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry.
with improved sliding friction properties, in particular for parts of locks, valves, rotary duets, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

19. Use of a nickel alloy according to claim 6 as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry with improved sliding friction properties, in particular for parts of locks, valves, rotary duets, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

20. Use of a nickel alloy according to claim 7 as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry with improved sliding friction properties, in particular for parts of locks, valves, rotary duets, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

21. Use of a nickel alloy according to claim 8 as wear-resistant surface, in particular in the motor vehicle industry and in engineering, particularly preferably as parts of locks for door closure systems and functional components for fuel metering systems or as surface in the motor vehicle industry with improved sliding friction properties, in particular for parts of locks, valves, rotary duets, valve anchors, moveable pistons and other moveable parts in the motor vehicle industry and in engineering.

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