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(54) Sheathed reinforcing wire.

(57) Reinforcing wire of nickel or nickel alloy for instance, for structures such as pipes and containers for the process industry, which in view of their working conditions consist of particular materials which, however, have an inadequate strength and/or dimensional stability at high working temperatures. In order to protect this reinforcing wire it is built up coaxially from a core wire, providing the reinforcement, a barrier layer of ceramic and a thin metal sheath.

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Sheathed reinforcing wire

The invention relates to a sheathed reinforcing wire, in particular for structures which in view of their working conditions, such as temperature and medium, consist of certain materials, but which materials have a per se inadequate strength and/or dimensional stability at high working temperature.

Examples of structures of this type are pipes and containers for the process industry and nuclear energy, but also moulds, in particular extrusion moulds.

In the said pipes and containers very aggressive media and high temperatures and pressures are often used. In view of this pipes and containers of this type are often constructed of nickel or a nickel-based alloy or of other heat- and medium-resistant materials. At very high temperatures, however, many of these materials lose their strength and dimensional stability. Problems of this type may occur, for example, in extrusion moulds in which very high pressures are generated and into which the material to be extruded flows. There therefore exists for these structures temperature and pressure limits which are determined by the material of the structures, as a result of which their application is subject to limitations, whereas they could, in view of the properties of, for example, nickel or nickel alloy, withstand much higher temperatures and more aggressive media. This means that structures of this type cannot be ideally utilised, even if the material is extremely suitable for certain working conditions.

A pipe structure consisting of a nickel alloy is already known which, as a result of the use of a reinforcing wire of molybdenum, can work at much higher internal pressure and higher temperature than without the reinforcing wire, as a result of which the efficiency of the process in the pipe is considerably increased. By using the said reinforcing wire the temperature can be increased from 900°C to 1,300°C and the pressure from 200 to 300 kPa.

It has emerged, however, that under certain circumstances the molybdenum of the reinforcing wire is attacked, as a result of which its strength decreases. At high temperature molybdenum will, for example in the presence of oxygen, oxidise to volatile molybdenum trioxide, as a result of which it becomes brittle and vaporises. At these high temperatures molybdenum may in addition diffuse into the material of the structure in which it is incorporated as a reinforcing wire and with which it is in close contact. Oxygen residues which may still be present locally after manufacture may again result in molybdenum trioxide. The molybdenum may in addition form metallic compounds which have completely different properties with the material of the surrounding structure. The material of this structure may also diffuse into the molybdenum.

The abovenamed unfavourable factors may be present separately, but also in combination, as a result of which their degenerative influence on the reinforcing wire in general increases considerably as the metal temperatures rise.

The things mentioned limit the use of the reinforcing wire and consequently the use of the said beneficial materials for the pipes, containers and moulds, etc.

The abovenamed drawbacks are now eliminated by the reinforcing wire according to the invention which has the characteristic that the reinforcing wire is successively built up coaxially from a core wire, which provides the reinforcement, a barrier layer of ceramic and a thin metal sheath.

The ceramic may possess the form of a powder in an extremely compressed state, but it can also be applied by means of per se known physical or chemical vacuum deposition processes, in which case the said coating will possess in general a crystalline structure, as a result of which an adequate density is also obtained, which in the case of a coating may approach 100%. A vacuum deposited coating of this type must have a minimum thickness of approx. 10 µm. In the case of moulded ceramic powder the density will in general be in the range of 60 to 80%.

The core wire preferably consists of molybdenum, tantalum or niobium, or of other materials with high heat resistance and a low coefficient of expansion, but with the drawback that they readily oxidise, diffuse and vaporise at high working temperatures, while they do not of themselves form any protective oxide skin.

The sheathed reinforcing wire according to the invention is protected against these disadvantageous effects by the barrier layer of ceramic so that it is not sensitive or is sensitive to a much lesser extent to the abovenamed negative influencing factors.

The ceramic powder, which may in particular consist of Al_2O_3, SiC, Si_3N_4 or $MoSi_2$ or mixtures thereof, may be applied to the core wire in diverse manners.

In one manufacturing process a flat strip of the sheath material, for example consisting of a nickel-based alloy such as inconel, is bent into a tube closed along a seam around the core wire in a continuous drawing process, such as is known in the manufacture of electrical wires and cables, by means of a former. Immediately before the bending into a tube, the ceramic powder is fed onto the metallic strip in a quantity such that, when the strip is bent into a tube, the ceramic powder is firmly pressed together and compressed. The seam of this closed tube is then sealed by welding, for example by means of a laser beam. After this the reinforcing wire thus formed can be reduced in diameter by means of further drawing processes, as a result of which the ceramic powder is compressed still further.

The quantity and compression of the ceramic powder depends on the expected working conditions in which the reinforcing wire will be used. The thickness and also the compression of the ceramic powder must be such that no oxygen can penetrate to the core wire and the material of the core wire cannot diffuse to the outside, while material from the surrounding structure can also not reach the core wire by diffusion. The ceramic powder must, in addition, have a high degree of purity, in particular there must be no materials present therein such as metals with which the metal of the core wire may form harmful compounds or metallic elements which may diffuse into the core wire. The thickness of the protective ceramic layer is also determined by the additionally necessary bends which the wire must be able to undergo when applied as reinforcing wire in or on a structure to be reinforced.

In another manufacturing process a relatively thick, short reinforcing wire with ceramic powder applied around it and an outer sheath in the form of a coaxial cylinder with a likewise relatively large diameter is subjected to a drawing process in which the assembly thus obtained in successively fed through drawing dies with increasingly smaller diameter until the assembly finally has the desired outer diameter. In this drawing process the ceramic powder will also be considerably compressed.

The above manufacturing methods can of course also be used if the ceramic is applied by means of.the physical and chemical vacuum deposition processes mentioned. The coating thus obtained will in general have a crystalline structure, which guarantees a good sealing of the parts with respect to each other.

The reinforcing wires according to the invention may be embedded in the structure to be reinforced, but they may also be applied, for example, on the outside around a pipe or container or mould, for example wound, woven or braided. The distances between the mutual reinforcing wires in this woven structure or braiding work depend of course on the desired strength of the structure. As a result of the protective layer of the reinforcing wire these reinforcements can now also be applied on the side of the structure in which the media occur which would have a very aggressive action on the bare reinforcing wire.

If the reinforcing wire is embedded, the space between the wound or braided wires will preferably be filled up with suitable metal powder, for example nickel powder with a grain size less than 50 µm which is compressed under pressure to 60% or more. (A density of 100% corresponds to the specific gravity of the pure metal.) If the reinforcing wire is embedded, consideration can also be given to a structure in which the said wires are applied to the outside, for example wound as mentioned above, and in which a thin metal sheath is moulded around the said wires which does not per se contribute to the strength of the structure. In this case the space between the separate sheathed reinforcing wires will also preferably be filled with the said metal powder.

The thickness of the core wire of the reinforcing wire according to the invention depends on the stress to be taken up by the said wire, i.e. on the degree to which the structure must be reinforced. The wire may of course be thinner if the braiding work is closer.

A test wire according to the invention which was sucessfully tested had a total final thickness of 3 mm. The core wire had a thickness of 1.2 mm, while the seam-welded outer sheath was 0.3 mm thick. These dimensions were achieved after a drawing process. For this purpose the sheathed reinforcing wire had a thickness of 3.2 mm after the bending of a metal strip around the core wire in the manner previously described and the sealing of the seam by welding. With this thickness the ceramic powder was already so compressed that it could not fall loosely out of the space between the core wire and the sheath.

It is self evident that the invention is not limited to the special reinforcing wires described above but that modifications and amplifications are possible without going beyond the scope of the invention. The cross-section of reinforcing wire will in general be round, but it may also be elliptical. The same applies of course to the core wire. The reinforcing wires according to the invention can be manufactured to any desired length and applied in or on the structures to be reinforced.

Claims

1. Sheathed reinforcing wire, in particular for structures which have an inadequate strength and/or dimensional stability at high temperature, characterised in that the reinforcing wire is successively built up coaxially from a core wire, which provides the reinforcement, a barrier layer of ceramic and a thin metal sheath.

2. Sheathed reinforcing wire according to Claim 1, characterised in that the ceramic consists of a powder in an extremely compressed state.

3. Sheathed reinforcing wire according to Claim 1, characterised in that the ceramic consists of a coating with an in general crystalline structure which is applied by means of physical vacuum deposition processes (PVD) or chemical vacuum deposition processes (CVD).

4. Sheathed reinforcing wire according to one of the Claims 1, 2 or 3, characterised in that the core wire consists of material with a high heat resistance and a low coefficient of expansion.

5. Sheathed reinforcing wire according to Claim 4, characterised in that the core wire consists of molybdenum, tantalum or niobium.

6. Sheathed reinforcing wire according to Claim 2, characterised in that the ceramic powder consists of Al_2O_3, SiC, Si_3N_4 or $MoSi_2$ of adequate purity or mixtures thereof.

7. Sheathed reinforcing wire according to Claim 6, characterised in that the coating has a minimum thickness of approx. 10µm.

8. Sheathed reinforcing wire according to one of the preceding claims, characterised in that the thin metal sheath consists of material which is resistant to high working temperatures and the medium to which the core wire is not resistant.

9. Sheathed reinforcing wire according to one of the preceding claims, characterised in that the thin metal sheath consists of nickel or a nickel-based alloy.

10. Sheathed reinforcing wire according to Claim 8 or 9, characterised in that the thin metal sheath consists of a metal strip bent into a tube and seam-welded.

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EUROPEAN SEARCH REPORT

Application number

EP 85 20 1675

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	DE-B-2 454 620 (KRAFTWERK UNION) * Whole document *	1,2,4-7	H 01 B 3/10 B 21 C 37/04
Y	GB-A- 983 023 (THE INTERNATIONAL NICKEL CO.) * Claim 1; page 2, lines 60-64 *	1,2,4-7	
A	EP-A-0 003 370 (VEREINIGDE BUIZENFABRIEKEN) * Abstract; figures 2a,2b *	10	
A	DE-B-1 298 680 (PHYSICAL SCIENCES CORP.)		
A	US-A-3 109 053 (AHEARN)		**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
A	US-A-3 222 219 (SAUNDERS et al.)		H 01 B B 21 C B 05 D F 16 L
A	EP-A-0 015 621 (KONINKLIJKE MAATSCHAPPIJ "De Schelde")		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14-12-1985	ASHLEY G.W.

CATEGORY OF CITED DOCUMENTS

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