

DESCRIPTION

Heat Transfer Pipe

The present invention relates to a heat transfer pipe comprising a pipe element and a number of ribs arranged around the outer circumference of the pipe element and extending outwards. Furthermore, the invention relates to a heat accumulator comprising at least one such heat transfer pipe.

Various heat accumulators are currently known which differ from one another with regard to their construction and their mode of operation. Sensitive heat accumulators use the tangible heat or the heat capacity of a material. They change the temperature level of the storage material when loading and unloading. Latent heat accumulators use, for example, the enthalpy of reversible thermodynamic state changes of a storage medium, in particular the phase transition from solid to liquid and vice versa. When loading the heat accumulator a phase change material provided in the latter is melted. During the melting process the phase change material absorbs a large amount of heat energy in the form of the fusion heat. Due to the reversibility of this process the phase change material gives off this amount of heat again when solidifying. A similar principle is followed by so-called thermochemical heat accumulators which use the enthalpy of reversible chemical reactions, such as for example absorption and desorption processes based upon chemisorption.

When loading a heat accumulator heat must be transferred to the storage medium. For this purpose so-called heat transfer pipes can be used by means of which heat is transferred indirectly from a medium flowing through to the storage medium. Heat transfer pipes comprise a pipe element for guiding the medium through. In order to increase the heat transfer surface outwardly extending ribs are normally arranged around the outer circumference of the pipe element. The ribs can be formed integrally with the pipe element, they can be in metallic contact with the pipe element, or they are connected metallicity to the pipe element by a solder or weld connection.

With the integral design the ribs are produced around the outer circumference of the pipe element for example with the aid of a rolling process. However, this integral design is disadvantageous in that the pipe element and the ribs must be made of the same material, due to which the requirements for high temperature stability on the inside and high heat conductivity on the outside can not be fulfilled optimally. Bimetal pipes do not have this advantage, but due to the different heat expansions of the components can only be used within a restricted temperature range. In this case the pipe element and rib materials can accordingly not be chosen arbitrarily. Moreover, the configuration possibilities for the rib geometry are restricted by the production process. Therefore in particular the rib diameter that can be produced by a rolling process is too small.

As an alternative to the integral configuration, the ribs can be fastened onto the outer circumference of the pipe element in the form of separate components. For example it is known to provide annular elements in the form of metal sheets defining ribs that are arranged around the outer circumference of the pipe element, whereupon the pipe can be widened from the inside in order to secure the annular element on the pipe element. However, a poor thermotechnical connection of the pipe element and ribs is achieved here. The maximum temperature for use is also restricted. Moreover, the wall thickness of the pipe element is limited in that it must be allowed to widen to the desired degree.

Furthermore, annular elements of the type described above or also ribs in the form of strips of metal sheet or the like can be soldered or welded to the outer circumference of the pipe element. The compatibility of the solder must be guaranteed here however.

Depending on the production method the currently available heat transfer pipes differ therefore as regards the maximum temperature for use, the possible configurations as regards the rib geometry, the maximum wall thickness of the pipe element, the quality of the thermotechnical connection

between the pipe element and the ribs, the compatibility of the materials to the pipe element and the ribs, and the compatibility of the solder and weld materials.

Proceeding from this prior art it is an object of the present invention to provide a heat transfer pipe of the type specified at the start wherein the configuration of the rib geometry, in particular of the rib diameter, the maximum temperature for use, the maximum wall thickness of the pipe element as well as the materials of the pipe and of the ribs can be chosen arbitrarily, a good thermotechnical connection between the pipe element and the ribs needing to be produced.

In order to achieve this object the present invention provides a heat transfer pipe of the type specified at the start, wherein the annular segments are formed encompassing the ribs on the pipe element and fastened to one another with a spring-elastic clamping device, in particular in the form of at least one spring-elastic clamp element, in particular on two annular segments respectively forming a half shell. The provision of a number of annular segments encompassing the pipe element and fastened to one another with a spring-elastic clamping device makes it possible to use materials with different expansion coefficients for the pipe element and to use the ribs at high maximum temperatures of use. Due to their spring elasticity the clamping device always guarantees good thermal contact between the pipe element and the annular segments, and accordingly a good thermotechnical connection between the pipe element and the ribs because it reacts flexibly to thermal material expansions. With the design of the clamping device in the form of at least one spring-elastic clamp element extending in the longitudinal direction of the heat transfer pipe the thermal contact between the pipe element and the annular segments is moreover constant over the length of the annular segments. Furthermore, the configuration of the ribs, in particular the rib diameter, can be chosen substantially arbitrarily.

The maximum wall thickness of the pipe element is in no way restricted either. According to one configuration of the present invention the clamp element(s)

is/are formed from spring steel. Accordingly, thermally caused expansions or shrinkage can be flexibly absorbed so that a very good thermotechnical connection of the pipe element and the annular segments is always guaranteed.

According to one configuration of the present invention each clamp element is a flexible part comprising a base section and two clamp sections to be extended over one another from opposite sides of the base section, end sections preferably splayed apart from one another adjoining the clamp sections and acting as a push-on aid, for example while pushing onto a clamping bar formed on the annular segments. Accordingly each clamp element has a substantially omega-shaped cross-section.

The annular segments are preferably in the form of extrusion moulded profiles, the ribs extending in the longitudinal direction of the pipe element. The extrusion moulding constitutes on the one hand an inexpensive production method. On the other hand the cross-section of the ribs is constant in the longitudinal direction of the heat transfer pipe, and when used within a heat accumulator this allows free volume expansion of the storage material in the longitudinal direction of the heat transfer pipe. Accordingly, thermomechanical stresses caused by the volume expansion of the storage material can be eliminated or at least reduced. This is particularly significant with latent heat accumulators because the phase change materials used in the latter undergo a large volume expansion in the phase change from solid to liquid or vice versa.

Preferably the geometry of the pipe element and that of the annular segments are matched to one another such that the annular segments rest with substantially their entire surface against the pipe element. In this way good heat transfer from the pipe element to the annular segments is guaranteed.

In order to increase the rib surface area the latter advantageously have branches.

According to one configuration of the present invention the annular segments have clamping bars which are encompassed by the clamp elements. The clamping bars are form-matched to the clamp elements here so that the clamp elements are easy to fit and a secure hold of the annular segments against the pipe element with good contacting is guaranteed.

The annular segments are preferably produced from an aluminium alloy or from unalloyed aluminium, in particular from alloys of aluminium groups 1xxx, 3xxx and 6xxx. These materials have shown to be particularly advantageous.

The pipe element can be a welded or a drawn pipe element.

The pipe element is preferably produced from steel or stainless steel.

Furthermore, the present invention provides a heat accumulator comprising at least one heat transfer pipe of the type specified above, in particular a latent heat accumulator or a sensitive accumulator or a thermochemical heat accumulator.

In the case of a latent heat accumulator, the storage material surrounding the heat transfer pipe is a phase change material, particularly salts or salt mixtures, in particular alkali metal nitrates, such as for example NaNO_3 or KNO_3 - NaNO_3 , nitrites, sulphates, carbonates, chlorides, hydroxides, bromides, thiocyanates and fluorides or combinations of the latter, in particular anhydrous salts with a melting temperature of above 120°C or salt hydrates with a maximum phase transformation up to 200°C .

Preferably, the at least one heat transfer pipe is disposed substantially vertically within the heat accumulator so as in this way to enable free volume expansion of the phase change material in the vertical direction within the heat accumulator during the phase change from solid to liquid or vice versa.

Further features and advantages of the present invention are described below using one embodiment of a heat transfer pipe according to the invention with reference to the attached drawings. These show as follows:

- Fig. 1** a perspective view that shows a heat transfer pipe according to one embodiment of the present invention;
- Fig. 2** a side view of the heat transfer pipe shown in Figure 1 which shows the face side of the latter; and
- Fig. 3** a diagram that shows the temperature developments over a plurality of melting/solidifying cycles.

Figures 1 and 2 show a heat transfer pipe 10 according to one embodiment of the present invention. The heat transfer pipe 10 comprises a pipe element 12, two annular segments 16 and 18 forming ribs 14, 15 and which respectively form a half shell disposed around the outer circumference of the pipe element 12 and surrounding the latter, and two clamp elements 20 with which the annular segments 16 and 18 are fastened to one another and held on the pipe element 12.

The pipe element 12 is a steel pipe with a circular lateral surface as viewed in cross-section. The annular segments 16 and 18 are respectively in the form of extrusion moulded profiles made of an aluminium alloy so that they have a constant cross-section in the longitudinal direction L. The geometry of the pipe element 12 and that of the annular segments 16 and 18 are matched to one another so that the annular segments 16 and 18 respectively lie with substantially their entire surface with an annular segment section 22 and 23 having a circular segment-shaped cross-section against the lateral surface of the pipe element 12. On the free ends of the annular segment sections 22, 23 respectively radially outwardly projecting clamping bars 24, 25 are formed which are encompassed by the clamp elements 20. In order to guarantee a secure seat of the clamp elements 20 the clamping bars 24, 25 are respectively provided on their free ends with snap tabs 26, 27. The ribs 14,

15 of the annular segments 16 and 18 have a plurality of branches by means of which the surface area of the ribs 14, 15 is increased.

The clamp elements 20 are flexible parts produced from spring steel comprising a base section 28 and two clamp sections 30 and 32 to be extended over one another from opposite sides of the base section 28, against which end sections 34 and 36 splayed apart from one another and which serve as a push-on aid rest.

In order to fit the heat transfer pipe 10 shown in Figures 1 and 2 the annular segments 16 and 18 are laid with their annular segment sections 22, 23 around the lateral surface of the pipe element 12. The four clamp elements 20 are then pushed onto the clamping bars 24, 25 formed on the annular segments 16 and 18 so that the annular segments 16 and 18 are fastened to one another and held by pressure against the pipe element 12. In this state the annular segment sections 22, 23 of the annular segments 16 and 18 lie with substantially their entire surface against the lateral surface of the pipe element 12.

The configuration of the heat transfer pipe 10 shown in Figures 1 and 2 is advantageous in that by providing a number of annular segments 16 and 18 surrounding the pipe element 12 and fastened to one another with clamp elements 20, the use of materials with different expansion coefficients for the pipe element 12 and the ribs 14, 15 at high maximum temperatures of use is made possible, such as in the present case steel for the pipe element 12 and an aluminium alloy for the ribs 14, 15. Moreover, the clamp elements 20 always guarantee a good thermal contact between the pipe element 12 and the annular segments 16 and 18, and accordingly a good thermotechnical connection between the pipe element 12 and the ribs 14, 15 because they can react flexibly to thermal material expansions. Furthermore, the configuration of the ribs 14, 15 can substantially be chosen arbitrarily, and this applies in particular to the outer diameter of the ribs 14, 15. The maximum wall thickness of the pipe element 12 is in no way restricted either.

Figure 3 shows the results of a series of tests which was carried out with a heat transfer pipe 10 of the type shown in Figures 1 and 2. For this purpose the heat transfer pipe 10 was inserted into a latent heat accumulator (not detailed). 1,070 g sodium nitrate with a melting temperature of 306 °C was used as a phase change material. The heat was introduced and removed via the heat transfer pipe 10 by means of air cooling and electrical heating. The quality of the connection produced with the aid of the clamp elements 20 between the pipe element 12 and the annular segments 16 and 18 was determined over 115 melting/solidifying cycles. One cycle was sub-divided here into four consecutive phases as follows:

- 1) isothermal heating at 280 °C for 3 hours;
- 2) implementation of a temperature jump from 280 °C to 330 °C;
- 3) isothermal heating at 330 °C for 3 hours; and
- 4) implementation of a temperature jump from 330 °C to 280 °C.

The temperature progressions T_1 , T_{10} , T_{30} , T_{80} and T_{115} (the index corresponds to the cycle number) in Figure 3 show that the time until there is total introduction of the heat with a jump from 280 °C to 330 °C at the time “5 minutes” (phases 2 and 3) is kept almost constant over the number of cycles. After approx. 35 minutes there is a state of equilibrium with all measurements. In this state the flow of heat on the lateral surface of the pipe element 12 is almost 0. Therefore the results show that the contact resistance between the pipe element 12 and the annular segments 16 and 18 is practically unchanged over 115 melting/solidifying cycles.

CLAIMS

1. A heat transfer pipe (10) comprising a pipe element (12) and a number of ribs arranged around the outer circumference of the pipe element (12) and extending outwards (14, 15), **characterised in that** annular segments (16, 18) are formed encompassing the ribs (14, 15) on the pipe element (12) and fastened to one another with a spring-elastic clamping device, in particular on two annular segments (16, 18) respectively forming a half shell.
2. The heat transfer pipe (10) according to Claim 1, **characterised in that** the clamping device has at least one spring-elastic clamp element (20).
3. The heat transfer pipe (10) according to any of the preceding claims, **characterised in that** the clamp elements (20) are produced from spring steel.
4. The heat transfer pipe (10) according to Claim 2 or 3, **characterised in that** each clamp element (20) is a flexible part comprising a base section (28) and two clamp sections (30, 32) to be extended over one another from opposite sides of the base section (28), end sections (34, 36) preferably splayed apart from one another adjoining the clamp sections (30, 32) and acting as a push-on aid.
5. The heat transfer pipe (10) according to any of the preceding claims, **characterised in that** the annular segments (16, 18) are in the form of extrusion moulded profiles, the ribs (14, 15) extending in the longitudinal direction of the pipe element (12).
6. The heat transfer pipe (10) according to any of the preceding claims, **characterised in that** the geometry of the pipe element (12) and that of the annular segments (16, 18) are matched to one another such that the annular segments (16, 18) rest with substantially their entire surface against the pipe element (12).

7. The heat transfer pipe (10) according to any of the preceding claims, **characterised in that** the ribs (14, 15) have branches.
8. The heat transfer pipe (10) according to any of Claims 2 to 7, **characterised in that** the annular segments (16, 18) have clamping bars (24, 25) which are encompassed by the clamp elements (20).
9. The heat transfer pipe (10) according to any of the preceding claims, **characterised in that** the annular segments (16, 18) are produced from an aluminium alloy or from unalloyed aluminium, in particular from alloys of aluminium groups 1xxx, 3xxx and 6xxx.
10. The heat transfer pipe (10) according to any of the preceding claims, **characterised in that** the pipe element (12) is a welded or a drawn pipe element.
11. The heat transfer pipe (10) according to any of the preceding claims, **characterised in that** the pipe element (12) is produced from steel or from stainless steel.
12. A heat accumulator comprising at least one heat transfer pipe (10) according to any of the preceding claims, in particular a latent heat accumulator or a sensitive accumulator or a thermochemical heat accumulator.
13. The heat accumulator according to Claim 12, **characterised in that** the storage material surrounding the heat transfer pipe is a phase change material, in particular in the form of salts and salt mixtures, in particular alkali metal nitrates, nitrites, sulphates, carbonates, chlorides, hydroxides, bromides, thiocyanates and fluorides or combinations of the latter, in particular anhydrous salts with a melting temperature above 120 °C or salt hydrates with a maximum phase transformation temperature of up to 200 °C.

14. The heat accumulator according to either of Claims 12 or 13,
characterised in that the at least one heat transfer pipe (10) is arranged
substantially vertically within the heat accumulator.

Key to Fig. 3

Elektrische Leistung vom luftgekühlten Stab [W]

= electrical power of the air-cooled bar [W]

Zeit [min] = time [mins]