A heat exchanger including at least one collecting tank for input and output of a first heat transfer medium, a plurality of plastic tubes receiving the first heat transfer medium from the at least one collecting tank and outputting the first heat transfer medium to the at least one collecting tank, and a plurality of metal heat exchange elements between the tubes and in heat exchange contact with the tubes and a second heat transfer medium. At least some of the heat exchange elements are incorporated in the tube walls, with wave crests and troughs embedded in furrows of the walls. The heat exchanger is manufactured by heating the heat exchange element to plasticize the tubes at least at the contact sites between the tubes and the heat exchange elements, and then producing intimate contact between the tube and the heat exchange element.
Fig. 6

SELECTIVE HEATING OF THE FIN ABOVE MELTING POINT 220°C OF PA 6.6

Fig. 7
HEAT EXCHANGER AND METHOD OF MANUFACTURING

CROSS REFERENCE TO RELATED APPLICATION(S)
[0001] Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT
[0002] Not applicable.

REFERENCE TO A MICROFICHE APPENDIX
[0003] Not applicable.

TECHNICAL FIELD
[0004] The present invention is directed toward heat exchangers, and particularly toward heat exchangers having plastic components.

BACKGROUND OF THE INVENTION AND TECHNICAL PROBLEMS POSED BY THE PRIOR ART
[0005] DE 33 02 150 A1 discloses one example of a heat exchanger having flat metal tubes and flat metal ribs having the contour of the openings corresponding to the flat tubes. One flat tube each is inserted through each opening of a stack of ribs so that a heat exchanger block is formed by a number of tubes that are passed through a stack of ribs. The heat exchanger also has side parts made of plastic and a bottom part viewed as a collecting tank, which also consists of plastic. The soldering process often required to produce heat exchangers is avoided by this structure, thereby advantageously allowing the significant energy requirements, related costs and environmental burdens of soldering processes to be avoided. However, the contact between the flat tubes and the heat exchanger elements is not particularly intensive in this structure, and therefore heat exchange is inhibited. An identical design of the heat exchangers with respect to the described features can also be found in DE 32 02 901 C2 and DE 32 10 114 C2.

[0006] DE 37 28 303 A1 discloses a heat exchanger having round tubes and heat exchange elements (flat or corrugated ribs) made of plastic, which were produced in one piece with the tubes. This heat exchanger can also be produced without soldering, but heat exchange efficiency is not ideal. WO 00/43722 A1 also teaches round tubes made of plastic, without heat exchange elements between the tubes, where the tubes run in close wave-like rows to increase heat transfer between the cooling air flowing around the tubes and the charge air flowing in the tubes by deflecting the cooling air several times. Heat exchange efficiency is not ideal with this structure either.

[0007] A heat exchanger that can have either metal or plastic tubes is described in EP 191 956 A1. The material to be used for the other components of the heat exchanger, especially for the heat exchange element, is not mentioned there, although it can be concluded from the configuration shown in the figures that it was produced from plastic. The heat exchanger has no collecting tanks but the heat exchanger block is situated in a housing and is traversed in cross-flow by the two heat exchange media. Its heat exchange efficiency is also not ideal.

[0008] The present invention is directed toward overcoming one or more of the problems set forth above.

SUMMARY OF THE INVENTION
[0009] In one aspect of the present invention, a heat exchanger is provided, including at least one collecting tank for input and output of a first heat transfer medium, a plurality of plastic tubes receiving the first heat transfer medium from the at least one collecting tank and outputting the first heat transfer medium to the at least one collecting tank, and a plurality of metal heat exchange elements between the tubes and in heat exchange contact with the tubes and a second heat transfer medium.

[0010] In one form of this aspect of the present invention, the tubes have walls, and at least some of the heat exchange elements are incorporated in the tube walls. In a further form, the corrugated ribs have wave crests and wave troughs, and the crests and troughs are embedded in the tube walls whereby the crests and troughs lie in furrows of the walls. In a still further form, the wave crests and wave troughs have protrusions which penetrate into the tube walls. In a yet further form, the protrusions pass through the tube walls.

[0011] In another form of this aspect of the present invention, the tubes are extruded flat tubes. In a further form, the tubes are multi-chamber tubes.

[0012] In still another form of this aspect of the present invention, the heat exchange elements are corrugated ribs. In a still further form, the ribs are produced from one of the group consisting of an aluminum sheet and a non-ferrous heavy-metal sheet.

[0013] In yet another form of this aspect of the present invention, the heat exchange elements are flat ribs having protruding fins with the ends of the fins incorporated in walls of the tubes.

[0014] In still another form of this aspect of the present invention, metal internal inserts are in the plastic tubes.

[0015] In another aspect of the present invention, a method of producing a heat exchanger such as described above is provided, with the tubes and heat exchange elements assembled in a heat exchanger block, comprising the steps of (1) heating the heat exchange element to plasticize the tubes at least at the contact sites between the tubes and the heat exchange elements, and (2) producing intimate contact between the tube and the heat exchange element.

[0016] In one form of this aspect of the present invention, the heating step is accomplished by an electrical induction current.

[0017] In another form of this aspect of the present invention, the heat exchange elements are corrugated ribs with wave crests and wave troughs and, during the heating step, heat input is concentrated on the wave crests and wave troughs.

[0018] In still another form of this aspect of the present invention, cooling within the tubes is accomplished during the heating step. In a further form, the cooling is accomplished by compressed air in the tubes.
BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 is a front view of a heat exchanger embodying the present invention;

[0020] FIG. 2 is an enlarged cross-sectional view of a corner of the heat exchanger of FIG. 1;

[0021] FIG. 3 is a view of the tube ends of the heat exchanger;

[0022] FIG. 4 is another cross-section through the FIG. 1 heat exchanger, running through one of the ribs;

[0023] FIG. 5 is an enlarged cross-sectional view of one of the tubes according to one embodiment of the present invention;

[0024] FIG. 6 is an illustration of the joining of a corrugated rib and a flat tube according to the present invention;

[0025] FIG. 7 is a cross-sectional view of a wall of a flat tube and an associated corrugated rib in another embodiment of the present invention;

[0026] FIG. 8 is a cross-sectional view of a tube and associated rib according to another embodiment of the present invention;

[0027] FIG. 9 is a top view of a curved heat exchange block according to an embodiment of the present invention;

[0028] FIG. 10 is an exploded view of a tube and a heat exchanger element having protrusions according to an embodiment of the present invention;

[0029] FIG. 11 is a view from the side of FIG. 10 showing the heat exchanger element and protrusion;

[0030] FIGS. 12 and 13 illustrate another embodiment of the present invention with another heat exchanger element;

[0031] FIG. 14 is a schematic illustrating the production of a heat exchanger core according to the present invention; and

[0032] FIG. 15 is a cross-sectional view of yet another flat tube and heat exchanger element combination with which the present invention may be used.

DETAILED DESCRIPTION OF THE INVENTION

[0033] Heat exchangers 20 variously embodying the present invention are illustrated in the Figures. Such heat exchangers 20 can be advantageously used, for example, in a vehicle as a radiator, a charge air cooler or an oil cooler, but it should be understood that heat exchangers incorporating the present invention may advantageously be used in other applications as well.

[0034] As is apparent from FIG. 1, the heat exchanger has a heat exchanger block 22 assembled from flat tubes 26 and heat exchange elements (corrugated ribs 28). The flat tubes 26 are a suitable, for example, one with the designation PA 6.6 which has proven to be particularly suitable in heat exchangers in the aforementioned area of application. Extruded flat tubes are prescribed as the flat tubes 26 of the illustrated example, with the corrugated ribs 28 produced from sheet aluminum (though brass or copper or nonferrous heavy-metal sheets are other suitable alternatives) such as are already known and available. It should be understood, however, that the term "tube" according to the present invention may mean essentially all forms and designs of lines in which a medium can flow and exchange heat with a medium flowing outside of the line. Moreover, it should also be understood that corrugated ribs in the present context includes all wave-like heat exchange elements, regardless of the design of the individual waves, wavelength, wave height, etc. For example, so-called rectangular plates also could be considered to be corrugated ribs for the purpose of this application.

[0035] The heat exchanger of the illustrated embodiment has two collecting tanks 30 and 32 arranged on opposite ends 36 of the flat tubes 26. The collecting tanks 30, 32 as illustrated are inlet and outlet collecting tanks, although it will be understood by those skilled in the art that in some applications a single tank could serve as both the inlet and outlet. In versions (not shown) with only one collecting tank, a partition divides the collecting tank into an inlet and outlet collecting tank part and, in such cases, only one so-called deflection tank can be situated on the opposite end 36 of flat tube 26 or the ends 36 of flat tubes 26 can be closed, in which case the flat tubes 26 then advantageously have at least one internal partition. If a deflecting tank is provided, the partition in the tubes can be dispensed with, so that some tubes of the heat exchanger block are allocated to the inlet collecting tank part and other tubes to the outlet collecting tank part.

[0036] In accordance with the present invention, the collecting tanks 30, 32 may also advantageously consist of plastic. The ends 36 of the flat tubes 26 may be inserted into openings of the collecting tanks 30, 32 or into openings of tube bottoms that are part of the collecting tanks 30, 32, with a suitable stable and tight fastening therebetween provided by, for example, by welding or gluing (FIG. 2). The heat exchanger 20 may also have side plates 38 on opposite sides lying against the outermost corrugated ribs 28, with the plate ends connected to the collecting tanks 30 and 32 such as is known in the art.

[0037] As clearly shown in FIGS. 2 and 5, part of the corrugated ribs 28 are embedded or incorporated in the wall 40 of the flat tubes 26. The wave crests 44 and the wave troughs 46 even pass through the walls 40 of adjacent flat tubes 26, with the walls 40 perforated slit-like. It should be appreciated that, with this practical example, the tightness of the connections of wave crest 44 or wave trough 46 to wall 40 should be carefully controlled since a coolant is situated within the flat tubes 26 which must not leak through the connections. If necessary, good heat-conducting adhesives can also be used.

[0038] Cooling air freely flows through the corrugated ribs 28 perpendicular to the plane of the drawing in FIG. 1. Passage of the corrugated ribs 28 through walls 40 can be present almost over the entire depth of corrugated ribs 28 or flat tubes 26 in the direction of cooling air flow, or protrusions 48 which penetrate the wall 40 of flat tubes 26 can be formed on the wave crests 44 and wave troughs 46 of the corrugated ribs 28. Further, the front and rear edges lying in the direction of the depth of corrugated ribs 28 may be advantageously aligned in order to ensure better sealing to the interior of flat tubes 26. FIGS. 10 and 11 show a practical example with protrusions 48 on the wave crests 44 and wave troughs 46.
In FIG. 5, arrows pointing from the bottom up in the interior of flat tube 26 show the coolant flowing in direct contact with the wave crests 44 and wave troughs 46 of the corrugated ribs 28 so that very good heat exchange efficiency is achieved. This should direct contact with the metal particularly advantageous given that the tubes 26 consist of plastic, which is generally known to have lower heat conductance than metal, whereby the direct contact allows heat transfer to the metal ribs 28 without any insulating effect from the plastic walls 40. The arrows in FIG. 5 illustrate that flow of the coolant is disturbed by the inward extending parts of the corrugated ribs 28, whereby heat exchange efficiency is additionally influenced in a positive way.

A heat exchanger of the described type is a distinct progress relative to the prior art in almost any relation, both in terms of cost-effective production and in terms of excellent heat exchange efficiency. The heat exchanger also has a comparatively limited weight and may be readily adapted to different applications (i.e., the necessary design changes can be converted to a specific product with relatively limited expense).

The flat tubes 26 according to the practical example in FIG. 3 are multi-chamber tubes produced, for example, by an extrusion method. Two separation joints 56 in each flat tube 26 form three chambers, with the wall thickness "s" (see FIG. 5) of the flat tube 26 advantageously lying in a range well below 1 mm. Any suitable manufacturing methods for plastic tubes are able to make the tubes with such wall thicknesses, including methods able to make smaller wall thicknesses than by extrusion, may be advantageously used in producing the present invention. The wall thickness "s" of the corrugated ribs 28 may advantageously lie in the range from one tenth or even one hundredth of a millimeter.

As illustrated in FIGS. 8 and 9, the flat tubes 26 may, where desired, advantageously be formed with conical broad sides 60 and increasing wall thicknesses rather than parallel sides. The use of such flat tubes 26 permits the heat exchanger to be curved with a contour, rather than a flat heat exchanger block 22.

FIG. 8 also illustrates another concept, wherein the penetration depth T of the corrugated ribs 28 into the wall 40 of the flat tube 26 is correspondingly deeper with increasing wall thickness "s" of the flat tube 26. Of course, a flat heat exchanger block 22 can also be produced in this manner, where the intended thermodynamic effects can be achieved by the fact that the channels between the flat tubes 26 through which the cooling air flows narrow or widen in the direction of cooling airflow. Narrowing or widening of the channel can be recognized in FIG. 8 in that the "free" height of the corrugated rib 28 on the left side is less than on the right side. The penetration depth T on the left is therefore greater than on the right. Moreover, it will be appreciated that a second identically arranged flat tube 26 in the upper end FIG. 8 would result in a channel which is narrower on the left than on the right.) The flow rate of the cooling air is therefore altered and, as desired, affects the pressure loss in the cooling air.

Cuts 64 are schematically shown in FIGS. 7 and 8 in the flanks 66 of the corrugated ribs 28 and also in other heat exchange elements 28 in order to ensure increased turbulence in the cooling air and therefore more efficient heat exchange. According to the practical example of FIG. 7, no perforations are present through the wall 40 of the flat tube 26, although the wall thickness is advantageously and significantly reduced to improve contact. A wave crest 44 or wave trough 46 is arranged in a furrow 68 formed in the tube walls.

FIGS. 12 and 13 illustrate other heat exchange elements 28 having a flat surface 70 from which fins 72 point in the opposite direction protrude from surface at tight spacing. FIG. 12 is a cross-sectional view of the heat exchanger block 22 showing the narrow sides of only two flat tubes 26. FIG. 13 shows the section through the top of FIG. 12 from which the longitudinal direction of the flat tubes 26 is consequently seen. Both Figures illustrate only features necessary to understand the basic structure disclosed therein.

FIG. 15 shows a practical example which is similar to FIG. 13 in terms of the view, wherein each flat tube 26 is formed from two plates 76 with two rods 78 extending along the longitudinal edges of the plates 76. In this embodiment, the corrugated rib 28 penetrates the plate 76, and the flanks of corrugated rib 28 is provided with cuts 64. The heat exchanger of FIG. 15 also includes a metal insert 80 (made of, e.g., aluminum sheet) within each flat tube 26. The insert 80 can also be incorporated in the plates 76 of the flat tubes 26, in this case from the inside. Such designs are particularly advantageous for air-cooled charge air coolers. It should be appreciated that while the internal inserts 80 are shown here in connection with flat tubes 26 formed from plates 76 and rods 78, they are not restricted to use with such tubes 26. Further, it should be appreciated that the depiction in FIG. 15 is purely schematic.

In conjunction with the Figures already explained, FIG. 14 shows a more detailed view of an advantageous production method in which the plastic flat tubes 26 and heat exchange elements 28 are combined into a heat exchanger block 22. The heat exchanger block 22 is shown roughly in the center of FIG. 14, with the metal heat transfer elements 28 heated by an induction current as indicated by the bundle of arrows 84. The walls 40 of the plastic flat tubes 26 are plasticized by heat input at least on the contact sites between the wall 40 and the heat exchange elements 28 whereby they are temporarily converted to a slightly doughy state. This process of plastification can be controlled, for example, by simultaneously supplying compressed cooling airflow through flat tubes 26 while heating the heat exchange elements 28. During production, a corresponding ratio between cooling airflow inside the tubes 26 and heat input into the outer corrugated ribs 28 may be advantageously maintained or adjusted in order to optimize the contact therebetween. In addition, a proportioned force is deliberately applied in the direction of the two arrows 86 against the left and right of heat exchanger block 22 whereby intimate contact is established between the tubes 26 and the heat exchange elements 28. The connections between the flat tubes 26 and the heat exchange elements 28 after completion of the process and a cooling time, appear approximately as shown in FIG. 7 and described previously. No perforations on walls 40 are present, and consequently there are no problems with respect to sealing, although it should be appreciated that it would be within the scope of the present invention to otherwise form the connections such as previously described, including the connection of FIG. 5 in which the heat exchange elements 28 pass through wall 40 and reach.
the interior of flat tubes 26, and the connection of FIGS. 10 and 11 in which protrusions 48 deeply penetrate walls 40 to ensure intense connection.

[0048] It should also be understood that the production method can initially produce individual subblocks of the subsequent heat exchanger block 22 (e.g., a heat exchange element 28 and one or two tubes 26), with the heat exchange element or elements 28 heated and joined to the tube or tubes during production of the subblocks. Matching subblocks can then, as described, be assembled (also by heating) into an entire heat exchanger block 22 at the seams of the subblocks of the heat exchange elements 28. Moreover, the heat exchanger block 22 can also be produced by assembling tubes 26 and heat exchange elements 28 in alternation individually. In this case, each individual-added heat exchange element 28 is heated and joined to one or two tubes 26. Such production may be achieved without having to use a soldering method to produce the heat exchanger.

[0049] Still other aspects, objects, and advantages of the present invention can be obtained from a study of the specification, the drawings, and the appended claims. It should be understood, however, that the present invention could be used in alternate forms where less than all of the objects and advantages of the present invention and preferred embodiment as described above would be obtained.

1. A heat exchanger, comprising:
   at least one collecting tank for input and output of a first heat transfer medium;
   a plurality of plastic tubes receiving said first heat transfer medium from said at least one collecting tank and outputting said first heat transfer medium to said at least one collecting tank; and
   a plurality of metal heat exchange elements between said tubes and in heat exchange contact with said tubes and a second heat transfer medium.

2. The heat exchanger of claim 1, wherein said tubes have walls, and at least some of said heat exchange elements are incorporated in said tube walls.

3. The heat exchanger of claim 2, wherein said corrugated ribs have wave crests and wave troughs, and said crests and troughs are embedded in said tube walls whereby the crests and troughs lie in furrows of the walls.

4. The heat exchanger of claim 3, wherein said wave crests and wave troughs have protrusions which penetrate into the tube walls.

5. The heat exchanger of claim 4, wherein said protrusions pass through the tube walls.

6. The heat exchanger of claim 1, wherein said tubes are extruded flat tubes.

7. The heat exchanger of claim 6, wherein said tubes are multi-chamber tubes.

8. The heat exchanger of claim 1, wherein said heat exchange elements are corrugated ribs.

9. The heat exchanger of claim 8, wherein said ribs are produced from one of the group consisting of an aluminum sheet and a non-ferrous heavy-metal sheet.

10. The heat exchanger of claim 1, wherein said heat exchange elements are flat ribs having protruding fins with the ends of said fins incorporated in walls of the tubes.

11. The heat exchanger of claim 1, further comprising metal internal inserts in the plastic tubes.

12. A method of producing a heat exchanger according to claim 1 with said tubes and heat exchange elements assembled in a heat exchanger block, comprising the steps of:
   heating the heat exchange element to plasticize the tubes at least at the contact sites between the tubes and the heat exchange elements; and
   producing intimate contact between the tube and the heat exchange element.

13. The method of claim 12, wherein said heating step is accomplished by an electrical induction current.

14. The method of claim 12, wherein said heat exchange elements are corrugated ribs with wave crests and wave troughs and, during said heating step, heat input is concentrated on said wave crests and wave troughs.

15. The method of claim 12, further comprising cooling within the tubes during said heating step.

16. The method of claim 15, wherein said cooling is accomplished by compressed air in said tubes.

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