METHOD OF MANUFACTURING A REGENERATOR

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ABSTRACT

A regenerator made of wires cut from a band of metal and compressed into layers, and a method and apparatus for making such wires by urging a cutter against the surface of a moving metal band, and a method of making regenerators using such wires.

8 Claims, 8 Drawing Figures
METHOD OF MANUFACTURING A REGENERATOR

CROSS REFERENCE

This is a division of applicants co-pending application Ser. No. 849,415, filed Aug. 12, 1969 and now abandoned.

The invention relates to a regenerator particularly suitable for use in a hot-gas engine which contains filling mass of a material in the form of wire or band incorporated in a housing, the wires or bands extending at right angles to the direction of flow in the regenerator.

When the filling mass in the regenerator is in the form of wire material it is common practice to obtain this by a comparatively expensive drawing process. In this process the wire material serving as the starting material is drawn through a number of dies of successively decreasing bores, to the desired small transverse dimensions and only one wire of a large length is obtained per series of successively traversed dies. A number of methods are known to make a filling mass out of such a long wire. For example, from German Pat. specification No. 876,494 it is known to stack wire material in the form of gauze in a number of layers and to compress the resulting packet to a filling mass. It is furthermore known from U.S. Pat. specification No. 3,015,153 to cut the wire to pieces and arrange said pieces in a space. When material in the form of band is used, the same considerations hold good. The starting material normally traverses a number of rollers.

The drawing or rolling process described makes the filling mass comparatively expensive.

It is the object of the present invention to provide a regenerator the favourable properties of which, for example, high efficiency and low resistance to flow, are fully maintained and which is economically more attractive than the one described in the preamble. The regenerator of the above-described type according to the present invention is characterized in that the stratified filling mass is constructed from a number of wires or bands obtained exclusively by a cutting operation which per layer are mainly oriented in the same direction and extend mainly throughout the dimension of said layer viewed in the longitudinal direction of the relative wires or bands.

Actually it has been found that wires or bands having a large length with respect to the transverse dimensions can be manufactured in a good quality and in an extremely simple and cheap manner, by means of exclusively a cutting operation, from a piece of material and are particularly suitable for use as a filling mass of regenerators.

Moreover, several such wires or bands can be cut at a time with very simple means from one piece of material. In general said wires or bands may be situated already close to each other and then form a bundle from the place where they are cut out of the piece of material, the elements of said bundle being mutually aligned.

In order to cut a number of wires or bands simultaneously from one piece of material, for example, a chisel may be used having a number of separate cutting edges which are simultaneously operative on the piece of material.

In a favorable embodiment of the regenerator according to the invention, the layers from which the filling mass is constructed are situated at right angles to the direction of flow in the regenerator. As a result of this it is reached that the thermal conductivity of the filling mass in the direction of flow is comparatively small as a result of the comparatively low thermal contact between mutually engaging layers.

In a further favorable embodiment of the regenerator according to the invention, the main direction of the wires or bands situated in one layer encloses an angle with the main direction of the wires or bands situated in an adjacent layer. In this manner the contact surface between mutually engaging layers is again reduced so that on the one hand the thermal conductivity of the filling mass in the direction of flow is further reduced and on the other hand the contact surface of said mass with the flowing medium increased.

In a further favorable embodiment of the regenerator according to the invention the filling mass consists of a helically wound layer of material which is constructed from wires of bands extending in the longitudinal direction of said layer and oriented in the same direction.

A further favorable embodiment of the regenerator according to the invention is characterized in that the wires or bands consist of a metal and cohere together by sintering.

The invention furthermore relates to a method of manufacturing a regenerator filling mass for use in the above-described regenerator.

According to this method, several wires or bands having a large length are cut simultaneously from one piece of starting material by means of cutting tools, which wires or bands are oriented and combined to form a flat bundle of wires or bands mutually oriented in the same direction, after which one or more cut parts of said bundle are formed to a packet, while substantially maintaining the mutual orientation of the wires or bands in said bundle, the packet being then compressed and sintered.

The starting material may be, for example, sheet steel or steel band, while the cutting tools used may be, for example, cutting chisels each having one or more separate cutting edges simultaneously operative on the piece of material.

According to an embodiment of said method, the cut bundle pieces are formed to a packet by stacking.

Another embodiment of the method according to the invention is characterized in that one cut bundle piece is formed to a packet by folding in a zig-zag manner.

According to the invention it is also possible to wind one bundle piece helically to a packet.

According to another embodiment of the method, the packet is first compressed to approximately 50 percent of its original volume, then normalized in a reducing atmosphere, after which the packet is further compressed until the desired space factor is obtained after which it is sintered. By normalizing the packet only after it has been compressed to approximately 50 percent of its original volume, a lower amount of pressure is sufficient to compress the packet to the desired space factor.

Starting from steel wire or band, normalizing can be carried out, for example, at approximately 650°C in a hydrogen atmosphere. Sintering may in that case be effected, for example, at approximately 1,100°C. Owing to the sintering, the coherence of the filling mass is maintained during operation of a regenerator in a hot-gas engine while said filling mass can be handled more readily.
According to the invention it is also possible to compress the packet in a mould which, together with a die, encloses the packet on all sides. Due to this enclosure on all sides, the filling mass during compression cannot be forced away at right angles to the direction of compression so that said mass remains homogeneously divided in the packet.

In order that the invention may be readily carried into effect, it will now be described in greater detail, by way of example, with reference to the accompanying drawings.

FIG. 1a diagrammatically shows a device with which several wires can be cut simultaneously, in this case at two places, from one piece of material, which wires are guided over guide rollers and combined to form a strip of wires which are mutually oriented in the same direction.

FIGS. 1b and 1c diagrammatically show how several strips of wires, which wires are simultaneously cut from one piece of material at several places, are combined to form a flat bundle of wires which are mutually oriented in the same direction.

FIGS. 2, 3 and 4, successively show how a flat bundle of wires which are mutually oriented in the same direction are formed to a packet by cutting to pieces and stacking, by folding in a zig-zag manner and by helically winding, respectively.

FIG. 5 shows a mould and a die in which a packet to be compressed is arranged.

FIG. 6 shows an embodiment of the regenerator according to the invention.

Refracting now to FIG. 1, reference numeral 1 denotes a metal band, for example steel band, moving in the direction of the arrows via rollers 2 and 3. The driving mechanism of the device and the further control of the supply and conveyance of the metal are not shown.

A toothed chisel 4 is provided in a holder (not shown) and the teeth of which are operative with their cutting edges parallel to the metal band, cuts a number of wires situated substantially in a flat plane from one surface of the metal band at the area where the same engages the roller 2 with its other side. The number of cut wires is determined by the number of teeth on the chisel 4. The transverse dimensions of the wire are determined by the tooth dimensions and by the depth of incision hereof in the band of material. In this manner it is possible to cut several wires simultaneously in a simple and cheap manner.

The wires 5 cut by the chisel 4 are guided through grooves of a guide roller 6, so that they maintain their mutual orientation.

The part of the metal band operated by the chisel 4 shows a surface having grooves and in between ridges extending in the direction of transportation of the band. A further flat chisel 7 which is also held in a holder (not shown) cuts a second series of wires 8 situated substantially in a flat plane from the ribbed surface of the metal band at the area where the same engages the roller 3 with its side remote from the chisel, so that the band again obtains a flat surface.

By choosing the mutual distance and dimensions of the teeth of the chisel 4 and the depth of incision of the two chisels 4 and 7 to be equal, it is reached that the wires cut by said chisel have the same transverse dimensions and each wire has at least one generally flat side due to the flat surface on the metal band remaining after each flat chisel cut.

The wires 8 cut by the chisel 7 are transported in grooves of a guide roller 9, so that they remain mutually orientated.

The wires from the guide rollers 6 and 9 are combined at the area of the roller 10 to form a strip 11 of mutually oriented wires.

By arranging several combinations of a toothed and a flat chisel successively in the transporting device of the band, several strips of wires can be obtained and combined simultaneously to form a flat bundle of mutually oriented wires. This is shown in FIGS. 1b and 1c in which the same reference numerals are used for corresponding components. The strips of wires 11 formed by wires from the guide rollers 6 and 9 are combined to a flat bundle in a flat funnel 12.

Of course it is also possible to combine the wires which were simultaneously cut from several metal bands, to form one or more flat bundles of mutually orientated wires.

As a starting material for cutting the wires sheet metal, for example, sheet steel, may also be used.

Starting from the resulting flat bundle of mutually oriented wires, there are several possibilities for composing a packet.

For example, the bundle of wires may be cut to pieces and the cut bundle pieces be formed to a packet by stacking. This is shown in FIG. 2 in which for reasons to be explained below the main direction of the wires situated in one layer consisting of a bundle piece encloses an angle, in this case 90°, with the main direction of the wires situated in an adjacent layer.

It is also possible to form a bundle piece to a packet by folding in a zig-zag manner which is shown in FIG. 3, in which case the main direction of adjacent layers is substantially the same.

FIG. 4 shows how a bundle piece is helically wound to form a packet.

In order to obtain a filling mass of the desired space factor, a packet manufactured in the above described manner is compressed preferably in a mould. The filling mass is subsequently sintered.

FIG. 5 shows a mould 13 in which a packet 14 is provided which is compressed by means of a die 15. The packet is surrounded on all sides by the mould and the die. It is possible, to compress the packet to the desired high space factor in one operation with the die 15. According as the deformation of the packet progresses, the required amount of pressure will increase. By first compressing the packet to approximately 50 percent of its original volume and then normalizing in a reducing atmosphere, a low amount of pressure is sufficient to compress the packet, which is halved in volume, to the desired space factor. This provides the advantage that a less heavy and cheaper press may be used.

When the packet consists of steel wire, normalizing can take place at approximately 650° C, for example, in a hydrogen atmosphere. Sintering of the compressed packet in that case may be carried out at a temperature of approximately 1,100° C.

As a result of the sintering a good coherence of the wires is obtained, so that the packet can easily be machined further, for example, turned on a lathe, and the coherence of the filling mass used as the regenerator of, for example, a hot-gas engine is maintained.

The filling mass obtained in the manner described, is then provided in a regenerator housing in such manner that the wires from which the stratified filling mass is
constructed extend at right angles to the direction of flow in the regenerator. As a result of this it is reached that the thermal conductivity of the filling mass in the direction of flow is low.

A further reduction of the thermal contact in the direction of flow can be obtained by stacking the layers in such manner that the main direction of the wires in one layer encloses an angle with the main direction of the wires in an adjacent layer. This is shown in Fig. 2 in which, as already described above, the chosen angle is 90°. Thus, the contact surface of the filling mass with the flowing medium is at the same time increased and hence the heat transfer between them is improved and a higher homogeneity is ensured.

The filling mass can be held in the regenerator housing for example, by providing perforated plates or metal gauzes at the two open ends of the housing and securing them to the edges of the housing.

Fig. 6 shows an embodiment of the regenerator according to the invention. The filling mass 16 which is constructed from layers in the manner as shown, for example, in Fig. 2, is accommodated in a housing 17.

On the front and rear sides of the housing the filling mass is covered by a metal gauze 18 which is secured to the wall of the housing throughout its circumference by means of a frame 19 and screws 20. The cylindrical filling mass can be obtained by starting from a sintered filling mass in the form of a rectangular block and turning said block on a lathe. The block shape can easily be obtained by taking the stack of bundle pieces forming a packet as shown in Figs. 2 and 3, respectively, as a basis.

It is obvious from the above that the invention provides a regenerator which is economically very attractive and can be manufactured as described in a comparatively cheap and simple manner and which has proved to possess good regenerator properties.

What is claimed is:

1. A method of manufacturing regenerator filling mass comprising the steps, moving a metal band axially, cutting from the surface of the band at least one continuous wire, by urging a cutter against said moving surface, stripping each cut wire from the band, disposing a plurality of said cut wires into a layer while maintaining a generally mutually parallel orientation of the wires, compressing the wires in said layer, and sintering said compressed layer.

2. A method according to claim 1 comprising the steps of initially compressing said layer of wires to approximately 50 percent of its initial volume, normalizing the compressed layer in a reducing atmosphere, and further compressing the layer, before sintering same.

3. A method according to claim 1 comprising forming said layer in a zig-zag manner prior to compressing same.

4. A method according to claim 1 comprising cutting the layer into segments and stacking said segments prior to compressing same.

5. A method according to claim 2 wherein the layers comprise steel wire, the normalizing is at approximately 650° C in an atmosphere such as hydrogen, and said sintering is at a temperature of approximately 1,100° C.

6. A method of manufacturing regenerator filling mass comprising the steps, moving a metal band axially, cutting from the surface of the band at least one continuous wire, by urging a cutter against said moving surface, stripping each cut wire from the band, disposing a plurality of said cut wires into a layer while maintaining a generally mutually parallel orientation of the wires, and disposing a plurality of said layers into overlying relationship.

7. A method according to claim 6 wherein the cutter has a plurality of teeth and the step of cutting comprises urging all said teeth simultaneously against said surface, and thus cutting a plurality of wires, and leaving corresponding grooves and ridges.

8. A method according to claim 7 comprising cutting of wires with a first cutter, and cutting a different plurality of wires from the ridges in the band with a second cutter spaced from the first cutter.