

Oct. 28, 1958

H. L. WHEELER, JR

2,857,657

METHOD OF CONSTRUCTING A POROUS WALL

Filed Jan. 16, 1956

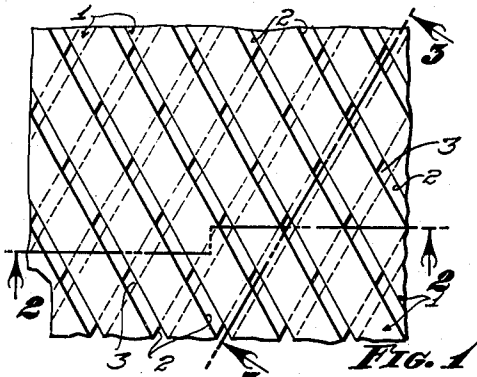


FIG. 1

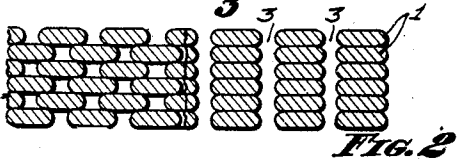


FIG. 2

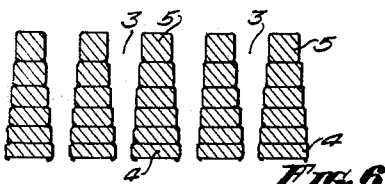


FIG. 6

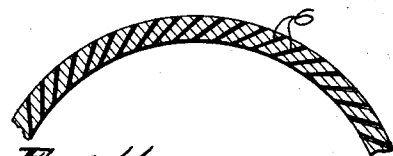


FIG. 11



FIG. 12



FIG. 16

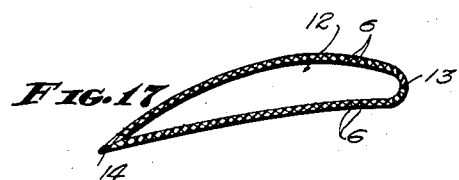


FIG. 17

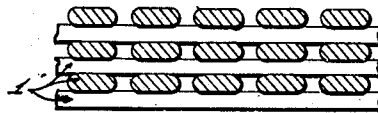


FIG. 3

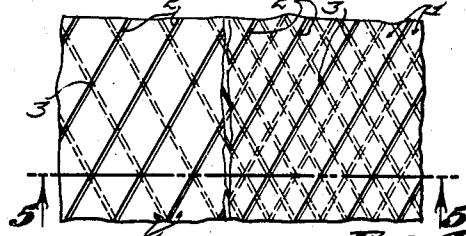


FIG. 4

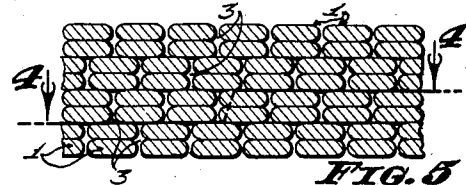


FIG. 5

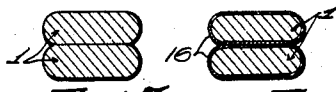


FIG. 7



FIG. 9

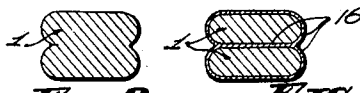


FIG. 8



FIG. 10

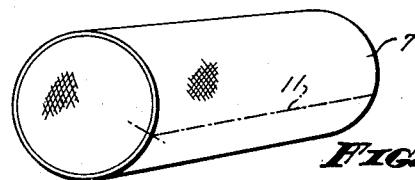


FIG. 13

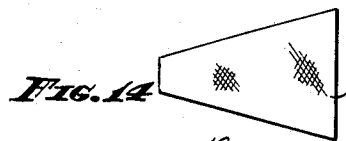


FIG. 14

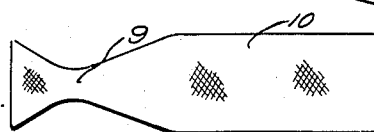


FIG. 15

INVENTOR.
HARRY L. WHEELER JR.

BY

Lyons & Lyons

ATTORNEYS

1

2,857,657

METHOD OF CONSTRUCTING A POROUS WALL

Harry L. Wheeler, Jr., La Canada, Calif., assignor to California Institute Research Foundation, Pasadena, Calif., a corporation of California

Application January 16, 1956, Serial No. 559,153

8 Claims. (Cl. 29—156.8)

My invention relates to constructing a porous wall, and is a continuation-in-part of my previous application Serial No. 335,670 filed February 9, 1953 for Porous Wall Construction and Method of Manufacture. Included in the objects of my invention are:

First, to provide a method of constructing a porous wall wherein the wall may be made tubular in form or tapered or arranged to form a venturi throat or nozzle or which may be reformed from such initial shapes into asymmetrical form or cut and reformed into a sheet.

Second, to provide a method of constructing a porous wall wherein the pore spaces may be accurately controlled so that not only is the wall of uniform porosity, but the size, direction, and tortuousness of the pore spaces may be accurately predetermined so as to meet specific needs; that is, the pores may be normal to the wall surface, inclined, varying in area, or of a labyrinth nature.

Third, to provide a method of constructing a porous wall whereby the wall may have a controlled variation in porosity to predetermine relative flow of fluids within different areas.

Fourth, to provide a method of constructing a porous wall wherein one or more layers of wires are wrapped about a mandrel and heated to fuse the said metal.

With the above and other objects in view as may appear hereinafter, reference is directed to the accompanying drawings in which:

Figure 1 is a greatly exaggerated, fragmentary plan view showing one form of porous wall constructed in accordance with my method.

Figure 2 is an idealized, sectional view thereof, taken through 2—2 of Figure 1.

Figure 3 is a similar sectional view thereof, taken through 3—3 of Figure 1.

Figure 4 is an exaggerated, fragmentary, sectional view showing successive layers of a porous wall constructed in accordance with my method.

Figure 5 is a transverse, sectional view thereof through 5—5 of Figure 4.

Figure 6 is an exaggerated, sectional view similar to Figure 2 by showing a modified form of my porous wall constructed in accordance with my method in which the porosity varies between the two surfaces of the wall construction.

Figure 7 is a diagrammatical view showing my porous wall in the process of construction in which two layers of wire comprising my forming layers of the porous wall are shown in juxtaposition before heating.

Figure 8 shows these wires as they bond together in the course of heating.

Figure 9 is a fragmentary, sectional view similar to Figure 7 showing the wires coated or plated.

Figure 10 is a similar view showing the coated wires after heating wherein the coating of adjacent wires is fused together.

Figure 11 is a fragmentary, sectional view indicating diagrammatically an arrangement of pore spaces tending to induce tangential flow of fluid.

2

Figure 12 is a diagrammatical, sectional view of a porous wall constructed in accordance with my method as it appears when flat and arranged with the pore spaces sloping relative to the surfaces of the wall construction.

Figure 13 is a perspective view of a porous wall cylinder constructed in accordance with my method.

Figure 14 is a diagrammatical view of a cone constructed in accordance with my method.

Figure 15 is a similar diagrammatical view showing a venturi nozzle and rocket motor combustion chamber constructed in accordance with my method.

Figure 16 illustrates diagrammatically in cross-section a turbine blade constructed in accordance with my method.

Figure 17 is a diagrammatical, sectional view showing a modified form of turbine blade utilizing the tangential pore arrangement represented in Figures 11 and 12.

In the exercise of my invention, I wind one or more fine wires on to a mandrel having the shape of the finished object or a shape from which the finished object can be developed. Essentially such a mandrel is a figure of revolution such as a cylinder, cone, or more complex shape such as a venturi throat or an approximation of a figure of revolution such as an ellipse or a polygon or an asymmetrical figure of positive curvature. By controlling the manner in which the wire is wound on the mandrel and by controlling the cross-section of the wire itself, a porous wall may be constructed, the porosity of which may be both uniform, or, if desired, nonuniform, or graduated, but in any case the pore arrangement is predictable to a close degree.

The wire is wound on a mandrel capable of withstanding the bonding temperature of the material comprising the wire. Thus the mandrel may be formed of ceramic material or formed of metal and coated with a ceramic material. After the wire has been wound to form a plurality of laminations, the mandrel, with the wire thereon, is subjected to heating temperatures causing the contacting surfaces of the laminations of wire to bond together.

While the wire may have a wide variety of cross-sectional configurations such as circular, rectangular, or ellipsoidal cross-section, it has been found that a relatively flat wire is advantageous. For example, a wire flattened to a thickness-to-width ratio of two-to-one. This may be accomplished by running the wire between rollers either prior to winding or in the course of winding the wire on the mandrel. The flat configuration provides a maximum area over which the successive laminations of wire are in pressure contact and thus insures an adequate area bonded by heating.

The cross-section or area of the wire varies with the intended use and the size of the mandrel on which it is wound. The larger the mandrel the more coarse the wire which may be used. However, in any case extremely fine wire may be used. For example, wire two thousandths in diameter, flattened to one thousandth in thickness has been used with success.

It has been found feasible first to pre-bond the wire while on the mandrel, then remove the mandrel, subject the porous wall formed by the wire to mechanical pressure, and then rebond. Also, the wire may be wound in cylindrical form as shown in Figure 13 and then slit lengthwise, flattened into a sheet, and passed between rollers, this being done after a preliminary bonding.

As mentioned hereinbefore, the wire may be wound on itself to produce a wide variety of porous conditions. Perhaps the simplest form involves winding the wire at a uniform rate back and forth over a rotating cylinder. By controlling the relative rate of rotation and feed, the succeeding laminations of the wire may be stacked in such a way that vertical pores may be formed. Thus, as shown

3

in Figures 1, 2, and 3, the wire strands 1 may be wound to form channels 2 parallel to each other and to the surfaces of the wall thus formed. If the wires are laid uniformly, they may define ports 3 which extend normal to the two surfaces of the resulting cylinder or other figure of revolution. The porosity is controlled by the closeness with which the wires are wound.

The manner in which the wire may be fed on to the rotating mandrel may be so regulated that succeeding layers do not place the ports in alignment. Thus, as shown in Figure 4, if the succeeding layers are staggered, the ports 3 are not connected except through the channels 2. The result is that a multiplicity of labyrinth passages are formed, which, however, may be uniformly spaced and quite predictable in character. This type of construction is particularly suitable for porous walls to be used as filters.

It is sometimes desirable that the porosity of the resulting structure vary from one side to the other. This may be accomplished by altering the cross-sectional configuration of the wire as succeeding laminations are wound on the mandrel. This may be done as the wire is wound by gradually or intermittently changing the adjustment of the flattening rollers through which the wire passes. Thus, the first laminations of the wire may be flat, as indicated by 4 in Figure 6, and succeeding layers rendered less flat until the final layer may be square or round as indicated by 5 in Figure 6.

It is, of course, not necessary, in order to have relatively straight pore spaces, that these pore spaces be normal to the surfaces of the finished wall. By proper control of the rate of the feed, the succeeding laminations of wire may be displaced slightly so that the resulting pore space is essentially tangential as indicated by 6 in Figures 11 and 12. In this regard, it will be observed that in forming a cylinder the axes of the pore spaces may be tangential as well as provided with a slope directed toward one end or the other of the cylinder.

As indicated hereinbefore, the mandrel on which the porous wall is formed may take the shape of the finished object, providing such object is a figure of revolution, or an approximation thereof such as an ellipse or polygonal.

Figure 13 illustrates a cylindrical form 7; Figure 14 a conical form 8; and Figure 15 a more elaborate form which represents a nozzle 9 and a chamber 10 of a rocket motor. In this regard, by varying the rate of progress of the wire as it is being wrapped, the resulting porosity may be varied so that, for example, in the construction of a rocket motor, greater porosity may be provided at the regions in which greater introduction of fluid is desired.

It is possible to cut a porous wall cylinder after bonding so as to form a flat sheet. Such sheet may then be reformed. For example, in Figure 13, the cylinder may be cut along the line 11 and formed into a flat sheet. The sheet may be cut to form the two sides of a turbine blade 12 and the sides welded together at the leading and trailing edges as indicated by 13 and 14. If this is done, the pore spaces may have the essentially tangential alignment 6 referred to in regard to Figures 11 and 12. It is not necessary, however, to cut the cylinder or other generated shape. Instead such member may be pressed into the desired final shape. In this case, a turbine blade 15 is indicated in Figure 16 which is without seams or welds.

The metal comprising the wire is determined by the use for which the porous wall is intended. Thus, steel, copper, titanium, molybdenum wires, as well as alloys, to mention only a few, may be employed to meet specific conditions. Still further as shown in Figures 9 and 10, the wire may be plated or otherwise coated as indicated by 16.

In this case, the bonding temperature need only be high enough to fuse the coating material. For example, a copper-plated steel wire would thus be capable of

4

being bonded or fused at a lower temperature than unplated steel wire.

It should be observed that the wire is wound under tension so that a firm physical contact is maintained between succeeding laminations of the wire. It is this contact pressure which insures adequate bonding between the laminations in the course of heating.

As pointed out above, the wire is wound under high tension and, as a result, high radial pressure is exerted between the wires at the point of crossing and that tension exists in the completely wound structure while it is still on the mandrel. The initial bonding is accomplished by heating the wound wire while still on the mandrel and the pressure exerted by wire tension provides the required pressure for effecting a secure bond at the temperatures employed. After the structure is removed from the mandrel and compressed to a finer dimension, the portions of the wires adjacent the initial bond are deformed and the area of contact between the wires is extended or increased. Since the wire is actually deformed and still tightly wound, pressure exists between the wire surfaces at the extended areas of contact and the final heating results in bonding the wires, by heat and the existing pressure, to provide the required bond. During the compression of the porous wall after removal from the mandrel, the wires of the laminations are forced closer together, thus producing passages of even smaller dimension than existed at the finish of the shaping and permits construction of porous walls with extremely fine passageways therethrough and permits accurate control of the uniformity and porosity of the product.

As has been indicated hereinbefore, the spacing between individual convolutions of wire and the relative position of the wires comprising succeeding convolutions makes possible the construction of a porous wall having precisely the selected porosity and resistance to flow; that is, with a given porosity the resistance to flow may be increased or decreased, depending on the relation between succeeding laminations of the wire.

Whether a single wire or a multiplicity of wires are used, the winding pitch is such that the wires of succeeding layers cross at a substantial angle with the result that the resulting wall structure, for example, the cylinder shown in Figure 13, will have favorable strength longitudinally as well as circumferentially.

If a single wire is used, it follows that many traverses of the wires are required before the space between succeeding convolutions of the wire may be filled and a lamination completed.

This, of course, results in crossing of the wires at periodic points along the figure of revolution. Any increase in thickness along these points is eliminated after bonding by pressing or running the wall structure between rollers. It, of course, follows that in winding the wire back and forth across the mandrel, the pitch must change to zero and reverse at each end with the result that there is a "build-up" at the extremities of the figure of revolution. If the resulting decrease in porosity in these end regions is objectionable in the final production, these portions may be trimmed off after sintering. However, in many cases these ends will be welded or otherwise secured to other members, and the lack of porosity and correspondingly increased density and strength is advantageous.

It is necessary, of course, that the ends of the porous wall figure wound on the mandrel remain in place and not shift axially. If the winding pitch angle is less than 20°, the frictional contact between the wire and the mandrel is sufficient to prevent axial shifting of the wire.

However, in winding the wire at pitch angles greater than 20° it is necessary to pass the wire as a chord across the end of the mandrel. The location of the chord path is such that the angle formed by the subtended arc has a value equal to twice the pitch angle. By so winding the ends of the figure forming the porous

5

wall, the pitch angle may be 60° or, if desired, even more. A 45° pitch angle will give the resulting porous wall figure equal strength in a longitudinal and a circumferential direction. If greater than 45° pitch angle is used, the strength in a longitudinal direction is made greater than in a circumferential direction. Thus the strength characteristics of the porous wall may be adjusted to meet particular needs. For example, a turbine blade may need greater longitudinal strength; whereas a high pressure filter may need greater circumferential strength.

While it is not necessary to wind over the end of the mandrel or over a shoulder thereon if the pitch angle is less than 20°, it has been found that the uniformity is improved if this is done, particularly in the winding of large diameter figures.

While the method herein described is intended primarily for the forming of porous wall structures of metal wire, it may be used to wind wire coated with a fusible plastic material, or for that matter wire formed entirely of plastic material, providing the nature of the mandrel permits fusing together or bonding of the wire at the cross points.

Having thus described certain embodiments and applications of my invention, I do not desire to be limited thereto, but intend to claim all novelty inherent in the appended claims.

I claim:

1. A method of forming porous wall structures characterized by: forming a figure of revolution by helically winding wire under tension about a mandrel having a surface of material incapable of fusing with said wire, to form at least four successive laminations having spaced parallel wires therein, winding said wire successively in opposite directions whereby each wire crosses underlying wires in mutual bearing contact therewith; initially bonding said laminations by heat and pressure while on said mandrel and while their wires are in bearing contact with the wires of adjacent laminations to fuse said wires together; removing said figure of revolution from the mandrel; compressing said figure to reduce the thickness thereof, to reduce the size of the spaces between wires, and to extend the area of contact between the wires; and thereafter again heating said laminations to fuse said wires together throughout the extended areas of contact therebetween.

2. A method of forming porous wall structures as set forth in claim 1 which is further characterized by: directly superimposing the wires of alternate laminations whereby radially directed pore spaces are defined by a plurality of laminations.

3. A method of forming porous wall structures as set forth in claim 1 which is further characterized by: offsetting the wires of successive laminations having the same direction of pitch whereby the pore spaces formed between a plurality of laminations define axes disposed in acute angular relation to the surfaces of said laminations.

4. A method of forming porous wall structures as set forth in claim 1 which is further characterized by: staggering the location of the wire comprising a plurality of laminations thereby to produce labyrinth pore spaces through said laminations.

5. A method as defined in claim 1 including the step

6

of slitting said figure of revolution longitudinally and flattening the same after removal from said mandrel and wherein said step of compressing said laminations is performed by passing said flattened figure between rollers.

6. A method of forming porous turbine blades characterized by: forming a figure of revolution by winding wire under tension about a ceramic coated mandrel to form successive laminations, the wires of successive laminations being wound in traversing directions whereby the wires thereof cross and are in mutual bearing contact; initially bonding said laminations by heat and pressure while on said mandrel and with their wires in bearing contact with the wires of adjacent laminations to fuse said wires together; removing said figure of revolution from said mandrel; compressing said figure to reduce the thickness thereof, to reduce the size of the spaces between wires, and to increase the area of bearing contact between the crossed wires of successive laminations; and again heating said laminations to fuse said wires together at the increased area of bearing; and deforming said figure of revolution into the profile of a turbine blade.

7. A method of forming porous hollow asymmetrical body characterized by: forming a figure of revolution by winding wire under tension about a mandrel to form successive laminations, the wires of successive laminations being wound in traversing directions whereby the wires thereof cross and are in mutual bearing contact; initially bonding said laminations by heat and pressure while on said mandrel and with their wires in bearing contact with adjacent laminations to fuse said wires together; removing said figure of revolution from said mandrel; compressing said laminations to reduce the thickness of said figure and the size of the spaces between wires while also increasing the area of bearing contact between the crossed wires of successive laminations; and again heating said laminations to fuse said wires at said increased areas of contact; and deforming said figure of revolution into the profile of an asymmetrical body.

8. A method of forming a porous wall structure characterized by: helically wrapping wire under tension on a ceramic-coated mandrel to form successive laminations of wire, at a pitch angle not greater than twenty degrees, the pitch angle of successive laminations being in opposite direction wherein the wires cross at a multiplicity of points; initially bonding said laminations by heat and pressure while said figure is intact on said mandrel to effect at least a partial fusion of said wires at their points of contact; removing said bonded figure from said mandrel; compressing said figure to reduce the thickness thereof, to reduce the size of the spaces between wires, and to extend the area of contact between wires; and thereafter again heating said laminations to fuse said wires together throughout the extended areas of contact therebetween.

References Cited in the file of this patent

UNITED STATES PATENTS

1,198,349	Heany	Sept. 12, 1916
1,644,728	Jahnke	Oct. 11, 1927
1,714,989	Schlaich	May 28, 1928
2,100,159	Curstadt	Nov. 23, 1937
2,351,152	Schick	June 13, 1944