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MANUFACTURE OF INFLATED METAL PRODUCTS

Filed Nov. 7, 1966

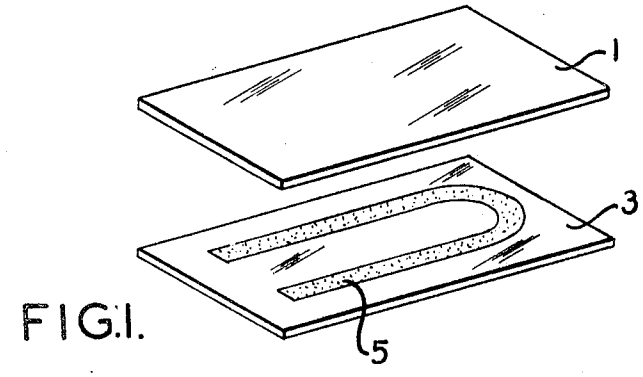


FIG.1.

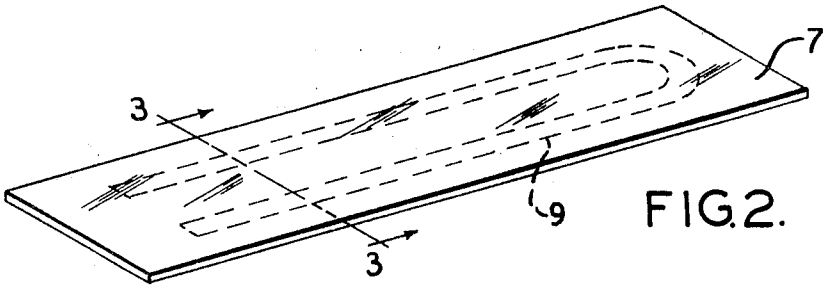


FIG.2.

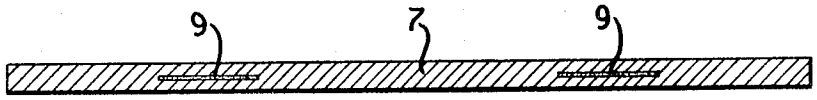


FIG.3.

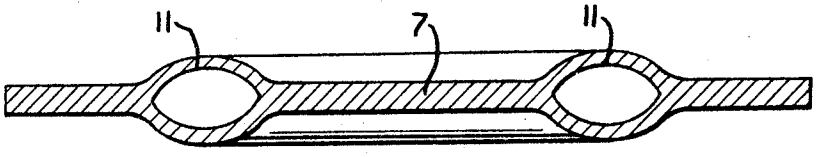


FIG.4.

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MANUFACTURE OF INFLATED METAL PRODUCTS

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U.S. Cl. 29—157.3 4 Claims

ABSTRACT OF THE DISCLOSURE

A pair of steel sheets with a stop-off pattern therebetween are interfacially bonded. The pattern is composed of finely divided aluminum in a dried rinsable carrier. Aluminum is inert with respect to hydrogen. The sheets in bonded condition with the stop-off pattern therebetween are immersed in an acid solution saturated with hydrogen sulphide. As a result, atomic hydrogen will form in the solution in equilibrium with molecular hydrogen. The atomic hydrogen at the faces of the sheets will penetrate them and enter the discontinuity formed by the stop-off material. Here it reforms molecular hydrogen with generation of pressure to inflate the composite substantially throughout the stop-off area. After providing suitable openings in the inflation the finely divided aluminum and its rinsable carrier are flushed out. The process may be accelerated by employing the composite as a cathode in the solution operating as an electrolyte in an electric circuit applied through it.

Among the several objects of the invention may be noted the production of an inflated composite metal product from sheets, strips or the like which is an improvement upon prior methods for producing such inflated products in that the process of inflation can be carried out without extraneous fluid pumps and with low-cost equipment operating at or near room temperature. Other objects and features will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the elements, steps and sequence of steps, features of construction and manipulation, and arrangements of parts which will be exemplified in the constructions and methods hereinafter described, and the scope of which will be indicated in the following claims.

In the accompanying diagrammatic drawings, in which one of various possible embodiments of the invention is illustrated,

FIG. 1 is an exploded view of two sheets prepared for bonding;

FIG. 2 is a view illustrating the prepared sheets of FIG. 1, rolled and bonded to form a composite sheet;

FIG. 3 is an enlarged cross section taken on line 3—3 of the composite shown in FIG. 2; and

FIG. 4 is a view similar to FIG. 3 but showing the composite in inflated condition.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

Hereinafter the term "sheet" will be understood to comprehend appropriate plates, strips or other areas of metal useful for carrying out the invention.

Inflated products made from bonded metal sheets sandwiching a stop-off pattern have in some cases been made and inflation accomplished by introducing fluid under pressure into the pattern area from costly extraneous pumps which have been troublesome to connect. In other cases the pattern has been made of iron oxide and inflated in the stop-off area by introducing hydrogen through the sheets into the stop-off area to convert the iron oxide

to iron and steam, the latter forming the desired inflation according to the pattern. This latter process required high temperatures on the order of 1800° F. or so in a comparatively costly furnace containing an atmosphere of hydrogen, disassociated ammonia or the like. By means of the present invention inflation is accomplished at comparatively low temperatures without extraneous pumps, high temperature furnaces and the like.

A steel surface in the presence of moisture and hydrogen sulphide reacts as follows:

$$Fe+H_2S=FeS+2H \quad (A)$$

The atomic hydrogen (H) is capable of penetrating into various metals including steel. Since atomic hydrogen H tends to assume the molecular state H_2, on reaching any discontinuity in the metal the atomic hydrogen recombines to form molecular hydrogen with the concomitant generation of a comparatively high pressure. This phenomenon is employed in carrying out my invention.

Referring now more particularly to the drawings, there is shown at numerals **1** and **3** a pair of clean sheets of steel on one of which is located a stop-off pattern **5**. If desired, the pattern may be applied in two registrable parts, one on each inside face of a sheet. This pattern may be of any appropriate shape, the U-shape shown being simply illustrative. The pattern **5** is composed of finely divided aluminum which may be applied in a suitable adhering slurry, the liquid constituents of which dry after application. Other methods may be employed for emplacing the pattern such as by painting on an adhering rinsable substance on a dry sheet, sifting on finely divided aluminum, some of which sticks on the substance and the remainder being shaken from the dry plate. The substance is then permitted to dry. Appropriate rinsable adhering substances are known to those skilled in the art. Other methods for emplacing the aluminum will suggest themselves to one skilled in the art. The choice of aluminum depends upon its inertness. Other inert finely divided materials may be used.

Next the sheets **1** and **3** in a clean state are brought together, sandwiching the pattern **5**. The sheets are then rolled down with a suitable reduction in their thicknesses with resulting elongation to form a composite sheet **7** which is elongated in the direction of rolling, as illustrated in FIG. 2. In the rolling process the pattern **5** elongates to the form **9**. The reduction is made under conditions to bring about solid-phase green-bonding as taught in U.S. Patents 2,691,815 and 2,753,623. The green-bonding occurs throughout the interfacial contact between the sheets **1** and **2**, with the exception of the area occupied by the elongated stop-off pattern **9**, which forms a discontinuity in the bonded metal composite. In planning the shape of the extended pattern **9** to be obtained in the composite **7**, the applied pattern **5** is made to have a shape suitably foreshortened in the direction of rolling. After completion of the green-bonding step the green bonds may in the known manner be improved by sintering at a suitable temperature to improve the bonds. As a result, there will be produced a solid-phase bonded composite **7** such as shown in FIG. 3 in which the pattern **9** of inert aluminum particles is embedded.

Next the composite strip **7** is exposed to a moist or wet environment containing hydrogen sulphide (H_2S). Such an environment may consist of a water solution of 2.5% hydrochloric acid (HCl), 1% sulphuric acid (H_2SO_4), saturated with hydrogen sulphide (H_2S). The solution is placed on the steel surface by dipping the composite **7** therein. According to reaction (A) atomic hydrogen (H) is formed. The solution needs be only at or near room temperature, which is one advantage of the

process. The atomic hydrogen will then penetrate through the steel and reach the unbonded patterned discontinuity **9** which is formed by the inert aluminum. Upon entering this discontinuity the atomic hydrogen recombines to form molecular hydrogen in the discontinuity **9** with a buildup of pressure to inflate the composite **5** as illustrated in FIG. 4. The inflations are indicated at numeral **11**.

The process may be accelerated by making the composite **7**, when in the uninflated condition shown in FIG. 3, a cathode in a pool of electrolyte formed of the solution of hydrochloric acid, sulphuric acid and hydrogen sulphide and connecting an electric circuit through the electrolyte and the cathode. This produces more atomic hydrogen on the surface of the composite **7** than is obtained by the exclusively chemical reactions above described.

After inflation, the resulting product may be segmented, drilled or otherwise opearted upon to produce connections with the interior of the inflation **11** for circulating any desired heating or cooling fluid so as to function as a heat exchanger or the like. The aluminum particles in the finished tubulation in the composite can be readily removed by circulating a rinsing material therethrough. The result is a tube-in-sheet product, the inside tubular surfaces of which are substantially free of any of the stop-off material.

While steel is preferred as the material of sheets **1** and **3**, other metals may be used through which hydrogen readily penetrates. Also, while aluminum has been specified as the inert stop-off material for the pattern **9**, it will be understood that other inert finely divided materials may be used, the function of the stop-off material being simply to form the discontinuity in the composite **7** in which conversion occurs of atomic to molecular hydrogen. While solid-phase bonding such as above set forth is preferred for bonding, it will be understood that other bonding means may be used, provided that the resulting bonds are strong enough to prevent separation of the sheets **1** and **3** except at the discontinuities afforded by patterns of stop-off material such as **9**.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions and methods without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. The process of making an inflated composite metal product comprising applying to at least one of a pair of metal sheets a pattern of stop-off material which is inert with respect to hydrogen, interfacially contacting said sheets with said pattern sandwiched therebetween, bonding the interface between the sheets exclusive of said pattern to form a bonded composite sheet, said stop-off material forming a discontinuity in the composite, placing said composite sheet in an environmental fluid containing atomic hydrogen and molecular hydrogen in equilibrium whereby atomic hydrogen becomes located on a surface of the composite and passes through the metal of the composite into the discontinuity formed by said pattern, said atomic hydrogen in the discontinuity converting to molecular hydrogen to generate pressure to form an inflation in the composite in the general form of said pattern.

2. The process according to claim **1** wherein the sheets forming the composite are steel and the said material forming the pattern is finely divided aluminum adhered to at least one of the sheets by rinsable material, and including the step of opening the inflation and rinsing the aluminum and rinsable materiol therefrom.

3. The process according to claim **2** wherein said environmental fluid consists of a water solution of approximately 2.5% hydrochloric acid, 1% sulphuric acid, said solution being saturated with hydrogen sulphide.

4. The process according to claim **3** including the step of forming an electrolytic pool of said solution, placing the composite as a cathode in said pool, and esablishing an electric circuit through said pool and cathode.

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