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April 3, 1973

C. S. JOHNSON ET AL

3,725,173

METHOD OF MAKING A PROTECTIVE DIVING SUIT

Filed Jan. 13, 1972

2 Sheets-Sheet 1

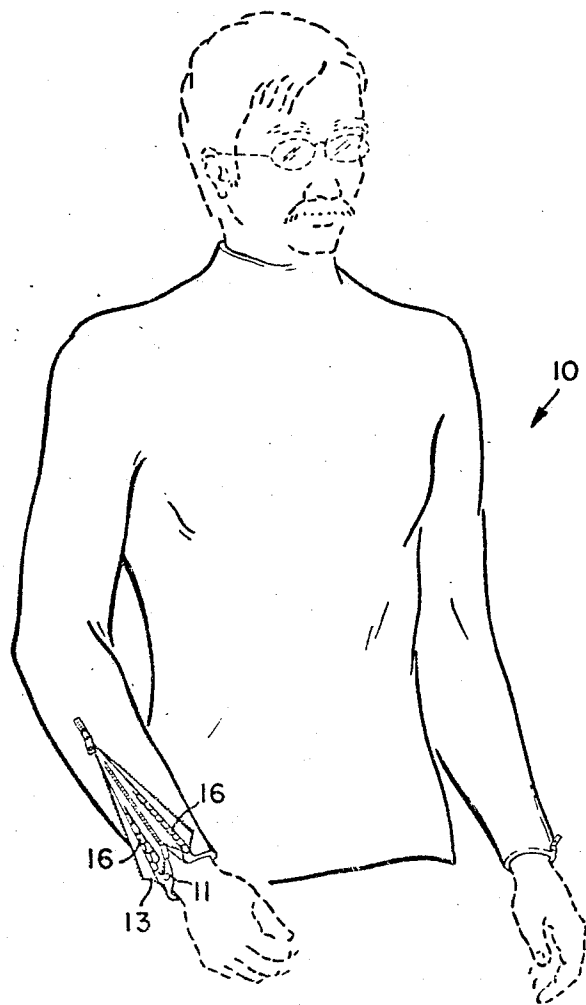


FIG. 1

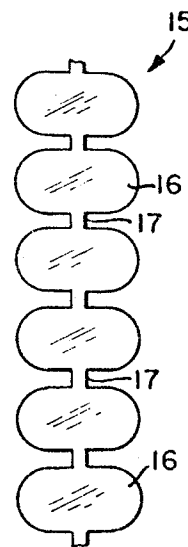


FIG. 2

TX 3590

X 3250

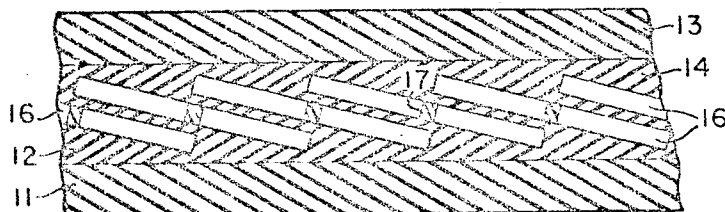


FIG. 1a

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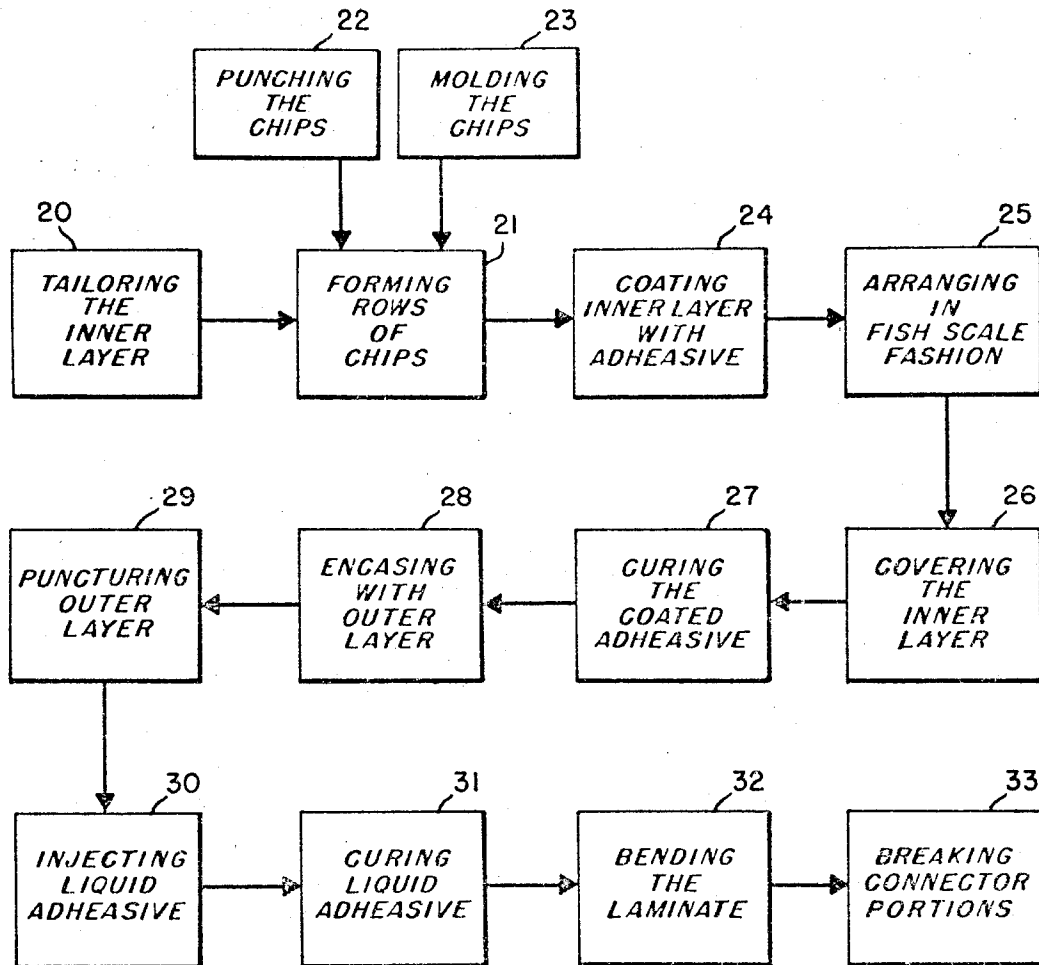


FIG. 3

1

3,725,173

METHOD OF MAKING A PROTECTIVE DIVING SUIT

Clarence S. Johnson and Arthur F. Langguth, San Diego, Calif., assignors to the United States of America as represented by the Secretary of the Navy

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7 Claims

ABSTRACT OF THE DISCLOSURE

A diving suit is fabricated to provide freedom of motion and protection from marine predators including a pair of neoprene sheets sandwiching a fish scale arrangement of overlapping plastic chips. Using a resilient adhesive to bond row after row of interconnected plastic chips onto the inner sheet of neoprene in the overlapping "fish scale like" arrangement provides a protective laminate. Covering the joined rows with the second neoprene sheet holds the suit together and reduces the possibility of snagging the chips' exposed edges. Holes are made in the outer neoprene sheet and a liquid resilient adhesive is injected to coat the chips and fill any voids created between the two sheets. After a sufficient drying time, the laterally arranged rows of plastic chips are bent and flexed along axes perpendicular to the rows to break the small connecting portions between adjacent chips. Thusly resiliently bonded and segmented, the layered diver armor provides protection yet retains a high degree of flexibility to prevent diver fatigue.

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

Conventionally, garments worn as body armor have been used in a wide variety of applications. Heavily padded flack vests or more sophisticated protective garments using overlaid ceramics are routinely worn by aviators and ground troops. However, these types of body armor need not afford complete freedom of motion since the wearer is usually seated or otherwise partially stationary. More recently, attempts have been made to modify diving suits to include some sort of armor to protect the diver from rocks, coral, urchins or predacious marine creatures. Since the designs of the dry-land body armors usually have been quite bulky and restricts motion, adaption of these designs for marine application is not a sound practice since a diver must remain highly mobile to perform his tasks. One notable attempt at providing such an adaption suitable for diving is disclosed in the U.S. Pat. No. 3,284,806 to D. O. Prasser for his "Protective Garment." His garment employs layered neoprene on either side of a metallic mesh fabric, all bonded securely together. A reinforced garment also includes a plurality of small intermeshed rings bonded between the intermeshed layers for added protection. A diver clothed in such a garment necessarily must exert a considerable force to overcome the biasing force of the bonded metallic fabric and rings. The added exertion would quickly tire a diver and he would be incapable of sustained work. One other armor which might be adapted for use in a diver protective armor suit is disclosed in the U.S. Pat. No. 1,021,804 to A. M. Schneider for his "Armor." Schneider shows an interesting arrangement of small plates overlapping one another and carried within a suit coat. Quite readily his overlying plate arrangement could be modifiable to be

2

sandwiched between two layers of neoprene to provide a diver a certain degree of protection. Even if such a modification were attempted, however, Schneider's method of connecting interleaving the plates would overtax a diver's strength and premature fatigue would set in. That is to say, securing the individual plates at each corner creates an inflexible suit that would not stretch as a diver reaches and bends. Furthermore, such a suit assembled one plate at a time must cause greatly inflated fabrication costs. A need continues for a flexible suit of diver armor which does not unduly restrict motions nor is overly expensive.

SUMMARY OF THE INVENTION

The invention is directed to providing a protective diving suit and a method of fabrication including an inner layer of neoprene having successive rows of interconnected plastic chips layered and resiliently bonded in place in a "fish scale like" fashion. An outer layer of neoprene covers the bonded rows and a liquid resilient adhesive is injected through small punctures in the outer neoprene layer to cover the layered rows and fill voids between them and the outer neoprene layer. After drying, the laterally reaching rows, now bonded in place, are flexed in a direction perpendicular to their direction of alignment to break small interconnecting portions previously holding the aligned adjacent plastic chips together. Thusly flexed and broken, the interlayered rows of chips are free for independent motion as a diver performs his tasks.

It is a prime object of the invention to provide a suit of protective diving armor.

Another object is to provide a method for fabricating a superior protective suit of diving armor.

Still another object is to provide a suit of diving armor allowing nearly unrestricted motion by a diver.

A further object is to provide a protective diving suit fabricated at low cost.

These and other objects of the invention will become more readily apparent from the ensuing specification when taken with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric depiction partially in section of the preferred form of the invention.

FIG. 1a is a cross sectional representation of the laminate.

FIG. 2 is a top view of an interconnected row of chips.

FIG. 3 is a schematic representation of the method of fabricating the protective diving suit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, the top half of a diving suit 10 fabricated in accordance with the disclosed inventive concept includes as principal components an inner layer of neoprene rubber 11 having a conventional zipper sewn and bonded in place along the wrist and lower arm portion and a slightly larger outer layer of neoprene rubber 13 similarly mounting a conventional zipper. The inner and outer neoprene layers are selected from a variety of commercially available materials each possessing the capabilities of entrapping a homogeneous mass of bubbles to ensure insulation and warmth for a diver as well as having a satisfactory elasticity and durability to allow donning and removal of the suit. Optionally, the inner surface of the inner layer carries a popular nylon elastic material to facilitate putting the suit on and taking it off and the outer surface of the outer layer similarly is equipped to guard against tearing and ripping on sharp objects.

The unique features of this invention are attributed to the inclusion of rows 15 of armor-like chips and their manner of resilient connection to the inner and outer

layers. Each row consists of a plurality of essentially elliptically shaped chips 16 each joined to an adjacent chip by a small connector portion 17. A material most suitable for construction of the rows is a flat sheet of polycarbonate or a similar plastic material having approximately a $\frac{1}{16}$ inch thickness.

One method of forming the rows calls for a suitably shaped punch repeatedly being driven through the sheet to make the interconnected row. An equivalent method of row fabrication calls for molding the rows of interconnected chips and connectors by pouring a heated plastic material into an appropriately shaped mold. In either event, a row of chips is formed which materially contributes to the commercial success of the invention since fabrication time and assembly costs are greatly reduced using the interconnected rows of chips.

In prototype models the chips were dimensioned from $\frac{1}{16}$ inch thick stock having elliptical configurations measuring $\frac{1}{2}$ inch across the minor axis and approximately $\frac{3}{4}$ inch across the major axis. In the alternative, larger or smaller scales are used to provide a lesser or greater degree of flexibility. However, the $\frac{1}{2} \times \frac{3}{4}$ size chips have been found to be a practical size to work with since they allow a sufficient degree of flexure in the diving suit yet keep the number of rows of chips within practical limits for efficient assembly.

First, an inner layer of a flexible material, for example, the neoprene rubber widely used in diving suits is cut and tailored 20 to fit a diver. Next, a plurality of rows of interconnected chips are formed 21 either by punching 22 of by molding 23 in the manner outlined above.

Following the formation of the rows of chips by either of the disclosed methods, the outer surface of the inner layer is coated 24 with a layer of coating 12 resilient liquid adhesive. The adhesive is chosen from one of a goodly variety of commercially available adhesives, one industrial adhesive having sufficient strength and resiliency is a preferable type and is marketed under the trademark "Scotch Grip" No. 4693 by the 3M Company of St. Paul, Minn.

Now the chips are arranged 25 in a fish scale pattern with adjacent parallel rows partially overlapping each other. Preferably, the arranging or orientation of the scales should generally define a circumferential circular containment of a limb as opposed to running longitudinally down the arm, for example, to allow a greater degree of flexure. By merely visualizing the scale arrangement on a fish where the scales cover its body, the same relative alignment of the scales and their orientation is practiced as the rows are arranged.

After the fish scale configuration has been followed to such a degree as to effect the covering 26 of the desired area of the inner sheet, coated adhesive 12 is cured 27 to resiliently hold the rows of interconnected chips on the inner layer. Such a resilient interconnection allows flexure of inner layer 11 as a diver bends and also permits the relative motion between overlapped rows of chips as the suit is bent along axes parallel to the rows' orientation.

Diver comfort has been enhanced by leaving the areas of the armpits and the crotch free of the scales to prevent chafing. These areas are adequately protected by merely tucking the limbs against the body. Another area where the rows of chips are not needed is on the diver's back since this area is covered by a heavy metal compressed cylinder usually worn by other than hard hat divers.

At this point, the suit could be donned and worn by a diver and would afford a considerable degree of protection from sharp objects and marine predators. There is minimal resistance to motion by the diver as he bends his arms or moves through the water due to the cured resilient coating 12 on inner layer 11 and chip rows 15.

When exposing a suit having the uncovered areas, the routine abuse all diving equipment suffers, the scales tended to snag and broke loose. It was found to be most expedient to protect

the exposed layers of chips by encasing 28 the chip-inner layer laminate with an outer layer 13 of neoprene rubber. If the encasing outer layer is cut to hold the laminate in slight compression, an acceptable unitized diving armor is provided at this point. But, as a diver repeatedly flexes his limbs and body, the outer layer crawls and slides on the inner layer and chips to expose the rows of chips and to bind at the joints.

Remedying this bothersome situation merely requires puncturing 29 outer layer 13 with a number of small holes. Through the punctures, a liquid resilient adhesive 14 of the type identified above, is injected 30 between the two layers to coat the rows of chips and the inner surface of outer layer 13. Some of the injected adhesive finds its way between overlapping sections of chips 16, see FIG. 1a. As a consequence, the chips are resiliently joined to one another to further unitize the diving suit after a sufficient curing 31.

The curing, usually no more than the passage of time in a relatively dry warm area, transforms the liquid adhesive to a cured plastic, elastic state to hold the laminate resiliently together. Flexure between the rows of chips and the outer layer across coating 14 follows in the same manner as disclosed with respect to the flexure across coating 12. If needed, the curing process is expedited by forcing warm air through the punctures.

The rows of interconnected chips placed in the fish scale arrangement result in a substantial assembly-time savings, greatly reducing the cost per unit while providing a flexible diving armor as will be presently explained. After the resilient coatings 12 and 14 of the laminate have cured, the suit is taken in-hand and bent 32 along axes intersecting, or preferably perpendicular to, the orientation of the rows of chips. If the laminate is bent far enough into an acute angle, there is a breaking 33 of small connector portions 17 joining adjacent chips 16.

After the breaking, individual chips are capable of relative independent motion with respect to the adjacent chips and a high degree of lateral as well as longitudinal flexure by the laminate is possible. The independent motion by each chip is owed to its being nonrigidly connected to adjacent chips while being resiliently held in place with respect to the inner and outer layers and to the overlapping chips by the resilient coatings 12 and 14.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings, and, it is therefore understood that within the scope of the disclosed inventive concept, the invention may be practiced otherwise than specifically described.

What is claimed is:

1. A method of making a protective diving suit comprising:
 - a) tailoring an inner sheet of a flexible material to conform to the contours of the body;
 - b) forming rows of flat rigid chips each chip connected to its adjacent chip by a portion of reduced area;
 - c) covering said inner sheet with said rows of flat rigid chips;
 - d) encasing said rows in an outer sheet of a flexible material cooperating therewith to form a laminate including said inner sheet, said rows, and said outer sheet; and
 - e) bending said laminate along axes intersecting the direction of orientation of said rows of flat rigid chips breaking the reduced area portions to allow a degree of independent motion by individual chips as the suit is flexed to minimize resistance to motion.
2. A method according to claim 1 in which said forming includes punching a series of interconnected essentially elliptically-shaped disks from a plastic sheet.
3. A method according to claim 1 in which said forming includes molding a series of interconnected essentially elliptically-shaped disks from a heated plastic material.
4. A method according to claim 1 in which said covering includes arranging rows parallel to one another with

5

adjacent rows partially overlapping each other in a fish-scale-like fashion.

5. A method according to claim 4 further including:
 coating said inner sheet with a liquid adhesive prior to
 said covering and arranging the rows and
 curing said liquid adhesive to hold said rows on said in-
 ner sheet. 5
6. A method according to claim 5 further includes:
 puncturing said outer sheet after said rows have been
 encased to release trapped air and to allow said outer 10
 sheet to more closely contact said rows.
7. A method according to claim 6 further including:
 injecting a resilient liquid adhesive through the punc-
 tures in said outer sheet and
 curing said resilient liquid adhesive to resiliently bond 15
 said chips to said outer sheet.

6

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DOUGLAS J. DRUMMOND, Primary Examiner

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2—2.1; 161—404