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METHOD OF FORMING SHEET MATERIAL

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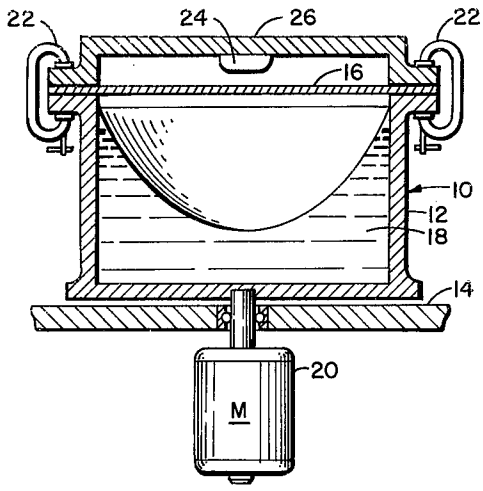


Fig. 1

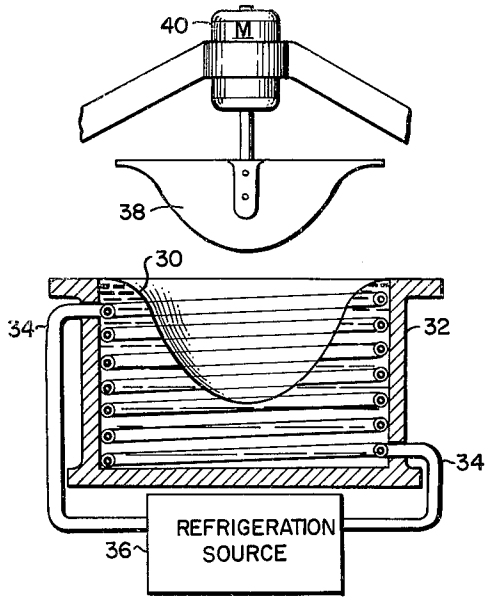
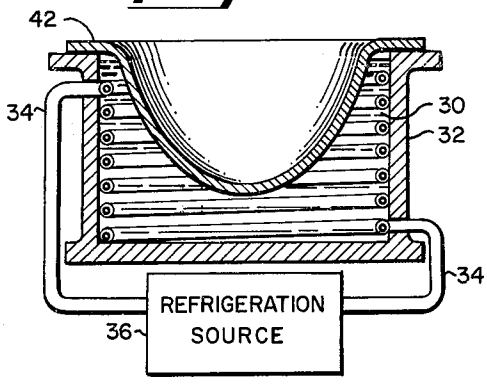


Fig. 2

Fig. 3



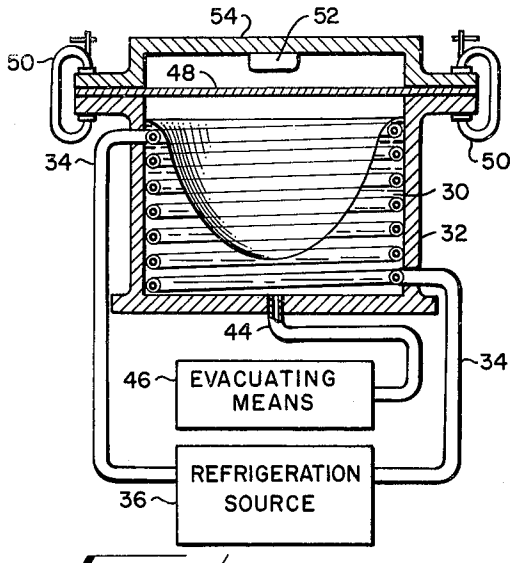


Fig. 4

INVENTOR.
IRVING LIEBERMAN
LOUIS ZERNOW

BY D. Gordon Angus

ATTORNEY

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METHOD OF FORMING SHEET MATERIAL

Irving Lieberman, Covina, and Louis Zernow, Glendora, Calif., assignors to Aerojet-General Corporation, Azusa, Calif., a corporation of Ohio

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This invention relates to a method and apparatus for forming sheet material and die construction. The primary object of this invention is to provide a method and apparatus for die construction and formation of sheet material which makes a substantial reduction in construction cost, including the man hours, the materials used, the weight, and skilled labor.

Heretofore, in the formation of sheet material for various apparatus such as rocket missile motors and the like, the usual procedure was to form dies by conventional die sinking methods. This involved the use of expensive machinery, specialized equipment, and the services of highly paid die makers and die sinkers. The castings which are made by prior methods tended toward excessive weight and the loss of expensive materials in machining was large. As the size of the sheet materials increased to something comparable to the size of an automobile or extremely large rocket missiles, the weight of the die and the amount of material to be used in the die became astronomical. Some common approaches to solving these problems in the past have been the use of relatively inexpensive low melting alloys and the like. However, these alloys must still be machined which does take time and money and, although the material was recoverable, the mere weight of the die became a detriment for large scale fabrication.

In accordance with our present invention we overcome many of the undesired features of conventional die construction methods and processes for forming sheet materials. Briefly, our invention includes the use of a liquid as one component of a die. In one embodiment of our invention, liquid is placed within a container and rotated to form a contour in the liquid surface and thereafter the sheet material is forced into engagement with the liquid surface acting as a forming element and a hydraulic cushion. In another embodiment of our invention, the liquid in the solidified condition is used as a die component, which allows the liquid to be shaped into any configuration desired.

One feature of our present invention is the ease in repairing the solidified liquid in the surface of the die after damage has occurred. Additional liquid may be poured upon the damaged surface and solidified, and thereafter the surface may be scraped or formed to the desired shape.

Other features and advantages not specifically enumerated above will be apparent after consideration of the following detailed description and the appended claims. The preferred forms which the invention may assumed are illustrated in the accompanying drawings:

FIG. 1 is a longitudinal cross section of a die and sheet material ready to be formed therein according to one embodiment of our present invention;

FIG. 2 is a longitudinal cross section of a die having yet another embodiment of our present invention in which a solidified liquid is shown as a die component with a scraper in position to form the surface of the solidified liquid;

FIG. 3 is a longitudinal cross section of a die embodying the second embodiment of our present invention in which a core or mold is used to form the surface of the solidified liquid; and

FIG. 4 is a longitudinal cross section of a die having a sheet material thereon ready to be formed by a conventional explosive forming method.

Before explaining the present invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

Referring to the drawings, FIG. 1 shows the die **10** constructed according to this invention. The die **10** comprises a hollow container **12** adapted to be attached (by means not shown) to a floor or base **14** such that the die may be adequately supported during the formation of the sheet material **16**.

Container **12** has positioned therein a liquid **18** which may be water, however any liquid may be used, which is in the fluid state at room temperature. Obviously, such things as water soluble oils may be placed in the water to prevent corrosion of the surrounding metallic parts in the immediate vicinity of the liquid.

A means are used for providing a shape on the surface of the liquid such as the parabola shown in FIG. 1. In the present embodiment, a motor **20** is attached to the bottom portion of the container **12** but is used merely as an example and not as a limitation. Such things as mixers or other rotary devices may be placed in contact with the container or placed directly within the liquid **18** to give it a desired shape. By varying the speed of the motor **20** or placing baffles in the container the surface of the liquid **18** can be changed as it is rotated by the motor **20**.

The sheet material **16**, shown in FIG. 1, is fixedly attached at its periphery to the top of the container **12** by a plurality of clamps **22**, which are shown schematically. The sheet material is retained at its periphery to prevent wrinkles from forming as compressive forces are subjected on the periphery of the sheet material during the forming operation. It is considered within the contemplation of this invention to merely place the sheet material upon the top of the container without restriction and allow the forming to take place in any manner. Such things as gauges and guides may be used on the top of container **12** to keep the sheet material in position as the formation takes place.

Any type of means for forcing the sheet panel into engagement with the surface of the liquid may be used. For example such things as a male punch as used with conventional dies, rubber pads, or an explosive forming operation may be used as a forcing means. The embodiment as shown in FIG. 1 is best adapted to the explosive forming operation which is illustrated therein.

For purposes of adapting the present invention as illustrated in FIG. 1 to such things as the explosive forming operation, a means for suspending an explosive charge is used to position the explosive charge **24** above the sheet material **16**. In the present embodiment, a bridge-like support **26** is placed upon the die **10** and the charge **24** is attached thereto at approximately the geometric center of the sheet material **16**. Other devices such as ropes or strands may be used to suspend the explosive charge above the sheet material. The operation of the explosive forming process is given in detail in our copending patent application Serial No. 829,904, filed July 27, 1959 and assigned to the same assignee as the present application.

In operation, the invention as illustrated in FIG. 1 starts with the deposition of liquid **18** within the container **12** to a desired height. The means for providing a shape to the surface of the liquid in the container such as the motor **20** is operated at a particular speed to give a wave form to the surface of the liquid. Sheet material **16** is attached to the top of the container **12** by a plurality

of clamps 22 or conversely it is merely placed upon the top of the container. A means for forcing the sheet material into engagement with the liquid surface is actuated, as for example charge 24 is detonated creating an explosive shock wave to force the sheet material 16 into engagement with the liquid 18 and forming it into a desired shape which will be approximately the shape of the liquid surface.

Another embodiment of the present invention is illustrated in FIGS. 2, 3, and 4. In this embodiment, a liquid 30 in the solid state is used as a die component and is retained by the container 32. A means for solidifying the liquid 30 is either placed within the container 32 in direct contact with the liquid or may be placed exteriorly of the container 32. As an example, a plurality of refrigeration coils 34 attached to a refrigeration source 36, such as a conventional refrigerator, may be used to solidify the liquid 30. Other conventional refrigeration means such as Dry Ice may be used to solidify the liquid.

The choice of the liquid is dependent upon the desired characteristics of the liquid in the solid state. For most operations, a suitable liquid would be water since it is extremely cheap and available although it may be modified to gain strength or change its effect upon adjacent components. For instance fresh water or brine may be used, or the water may be strengthened by any inert material used such as sand, sawdust, straw, or the like. These additives substantially increase the compressive strength of the frozen water. Other additives which may be added to the water are such things as water soluble oil and other corrosive preventatives. There is a great multitude of liquids which have properties very similar to water and those especially which have a freezing point near 0° C. are especially attractive for use in the subject invention. By way of example such liquids may be either used singly or in combination with other liquids, compounds, or emulsions. Further by way of example, the following liquids are listed as acceptable liquids which may be used in the present invention: ethanol, methanol, diethyl ether, trimethylamine, phenylamine, piperidine and triethylene glycol.

After solidification of the liquid 30 within a container 32, a means for shaping the surface of the solidified liquid is used to duplicate the shape of the finished sheet material in the solidified liquid. In FIG. 2, a rotating scraper 38 is used as a shaping means and is powered by the motor 40 for lowering into the surface of the solidified liquid.

The second means for shaping the surface of the solidified liquid is illustrated in FIG. 3. In this case, a mold or core 42 is either floated or forced into the surface of the liquid 30 and retained in that position until the liquid is solidified by the refrigeration means. After the liquid has solidified, the core or mold is removed and the surface of the liquid is finished. A parting compound may be placed between the mold or core to expedite removal. Ultimately, it may be desirable for specific applications to permit the contoured mold to remain in the solidified liquid to act as a shell against which the blank will be formed.

Other conventional methods may be used to shape the surface of the solidified liquid such as conventional die sinking methods. For instance, the liquid may be solidified with a completely flat surface. Thereafter a chisel or handscraper may be used to form the shape on the surface of the liquid. The shaping process is certainly variable and its choice is somewhat determinative of the particular shape which is desired. It should be apparent in the above description that the shape of the solidified liquid may be either symmetrical or nonsymmetrical, or cylindrical or of any other geometry.

Referring now to FIG. 4, a channel 44 may be provided in the bottom of the solidified die component and attached to an evacuating means 46, such as a vacuum pump. The means 46 will prevent air from being trapped in the die component as the sheet material is being pressed into the cavity.

The sheet material 48 is placed upon the top of the container 32 and attached thereto by clamps 50, which are shown schematically in FIG. 4. The sheet material 48 may be formed by using a means for forcing the material into engagement with the surface of the solidified liquid in much the same manner as discussed in the embodiment illustrated in FIG. 1.

In the present embodiment, there is illustrated an explosive charge 52 which is suspended above the sheet material by the support 54 and located approximately in the geometrical center of the sheet material 48. Upon detonation of charge 52, the sheet material 48 is forced into the die cavity and into contact with the solidified liquid. As discused above, the clamps may be deleted and merely a gauge may be used to align the sheet material 48 on the container. Also, as discussed above, other means for forcing the sheet material into contact with the die component may be used.

In the event the solidified liquid has been shattered or partially damaged in the forming process, additional liquid may be poured upon the surface of the solidified liquid and thereafter solidified. The surplus solidified liquid is scraped away and smoothed into a shape consistent with the former shape of the die component.

It should be understood that the term "sheet material" as used herein covers any metal or nonmetal material in either sheet or other forms which are capable of being formed by ordinary means.

It will be recognized that many variations within the scope of this invention may suggest themselves to a person skillful in the art and that the invention should not be limited except in accordance with the scope of the appended claims.

We claim:

1. A method of forming sheet material comprising: filling a container with a material that is in liquid form at room temperature and atmospheric pressure, solidifying the liquid material, shaping a surface of the solidified liquid material into a configuration similar to a shape desired in the sheet material, placing the sheet material over the container, and forcing the sheet material into engagement with the shaped surface of the solidified liquid material.

2. A method of forming sheet material comprising: filling a container with a material that is liquid at room temperature and atmospheric pressure, solidifying the liquid material, shaping a surface of the solidified liquid into a configuration similar to a shape desired in the sheet material, placing the sheet material over the container, restricting the peripheral movement of the sheet material, and forcing the sheet material into engagement with the shaped surface of the solidified liquid material.

3. A method of forming sheet material comprising: filling an open top container with a material that is in the liquid state at room temperature and atmospheric pressure, solidifying the liquid material, scraping the surface of the solidified liquid material to shape the surface into a configuration similar to the shape desired in the sheet material, positioning the sheet material over the container, positioning an explosive charge over the sheet material, and detonating the explosive charge to force the sheet material into engagement with the shaped surface of the solidified liquid material.

4. Apparatus for forming sheet material comprising: a container having a material in liquid form at room temperature and atmospheric pressure therein above which a sheet to be formed is adapted to be positioned, means operably associated with said container for solidifying the liquid material with its surface in a particular shape, and means in association with said container and disposed above the liquid material for applying force in at least one direction toward the liquid material when solidified, said force applying means being adapted to push a sheet disposed in proximity thereto between the force applying means and the solidified liquid material into engagement with the shaped surface of the solidified material

to form the sheet into generally the same configuration of the shaped surface of the solidified material.

5. Apparatus as defined in claim 4, further including means on said container for restricting peripheral movement of the sheet to be formed and being adapted to be attached thereto.

6. A method of making a temporary die component for use in forming sheet material comprising: filling a container with water, freezing the water, and shaping the top surface of the frozen water in the container into a configuration similar to a shape desired in the sheet material to be formed.

7. A method of making a temporary die component for use in forming sheet material comprising: filling a container with water, freezing the water, and scraping the top surface of the frozen water in the container to shape the top surface of the frozen water into a configuration similar to a shape desired in the sheet material to be formed.

8. A method of making a die component for use in forming sheet material comprising: filling a container with water, maintaining a mold having a surface configuration similar to a shape desired in the sheet material on the surface of the water so as to cause the surface of the water to conform to the surface of the mold in contact therewith, freezing the water with the mold in place, and removing the mold to expose the surface of the frozen water shaped thereby.

9. A method of forming sheet material comprising: filling a container with water, freezing the water, shaping a surface of the frozen water into a configuration similar to a shape desired in the sheet material, placing the sheet material over the container, and forcing the sheet material into engagement with the shaped surface of the frozen water.

10. A method of forming sheet material comprising: providing a container with a supply of water, maintaining a mold having a surface configuration similar to a shape desired in the sheet material on the surface of the water so as to cause the surface to conform to the surface of the mold in contact therewith, solidifying the water with the mold in place, removing the mold to expose the surface of the solidified water shaped thereby, placing the sheet material over the container, and forcing the sheet material into engagement with the shaped surface of the solidified water.

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WILLIAM J. STEPHENSON, *Primary Examiner.*