FORMING OF SHEET METAL


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15 Claims. (Cl. 153—48)

This invention relates to the forming of sheet metal by operations that give rise to considerable friction between the sheet metal and the former to which it is being shaped or the tools that assist in the shaping. Whereas in the stretch-wrapping of sheet metal, the sheet is first stressed in tension and then brought to the shape of the former with negligible relative movement between the contacting surfaces of the sheet and the former, in stretch-forming the sheet is applied to the former under no such tension but is stretched over the former so that it elongates when in contact with the former, and not only does the resultant friction increase the force for applied in the operation: it is a major factor in restricting stretch-forming as to type of sheet that can be used, the accuracy of forming and the shapes that can be produced. Again, drawing (particularly deep drawing) is accompanied by considerable friction as the sheet metal is drawn over the die to which it is held by a blankholder.

The increasing application of stainless steel sheet in the aircraft industry has emphasized the need to reduce the friction over the former in stretch-forming, and oil or grease is applied to the burnished surface of the usual cement or resin former after the surface has been sealed with a resin or the like. It can be shown that such treatments give a coefficient of friction between the former and the sheet of the order of 0.15 to 0.25, which relatively high value results in a substantial change in stress in the metal with increasing angle of lap over the former, and consequently in a serious limitation of the angle of lap that can be used.

According to the present invention, a process for shaping sheet metal by means of a former in which relative movement takes place between the contacting surfaces of the sheet and the former is carried out with the shaping surface of the former consisting of a solid substance that sharply and reversibly changes between the solid and the liquid state, and with the operating conditions resulting in superficial liquefaction of the substance to produce a liquid lubricating film of the substance itself next to the surface of the sheet. This production of a liquid film does not materially affect the shape of the former that is to be imparted to the sheet metal, and the film constitutes a lubricant yielding a very low coefficient of friction.

Ice is a particularly suitable substance, since, apart from assistance in effecting the superficial liquefaction readily deriving from the heat available in a sheet at normal room temperature, the pressure accompanying the forming operation itself encourages the change from solid to liquid state. In fact, it is possible to produce a superficial water film by the accompanying pressure alone, i.e., without relying on a temperature difference between the sheet and the ice constituting the forming surface. However, to avoid working at ice temperatures that are unduly critical, it is generally convenient to utilise the temperature difference available from a sheet worked at room temperature, or even to augment the sheet temperature somewhat before its application to the former or immediately on application to the former, as by subjecting it to infra-red radiation when it is on the former.

Other materials having a sharp, reversible change between the solid and liquid state at modest temperatures, and not prohibitive on account of cost, are acetophenone (melting point 20° C.), cyclohexanol (melting point 23° C.), and glacial acetic acid (melting point 16° C.), and these can be used with metal sheets at room temperature or as heated as indicated above. Such materials may be applied at a temperature that liquefies them and then allowed to set, e.g., simply by having the former cool enough.

However, ice has many advantages, including the free availability of water from which to form it, and the ease with which it may be dispersed after it has served its purpose, but particularly the simplicity with which the shaping surface may be formed. Thus, water mist may be sprayed on to a cooled former, to produce a thin coating, the surface of which corresponds closely to that of the former. Experience has shown that an ice layer in the range 1 mm. to 2 mm. in thickness is highly satisfactory. The lubricating water film has been found to produce a coefficient of friction of the low order of 0.03.

For materials with a low rate of strain hardening e.g., aluminum, the minimum and maximum stresses may be the yield stress or 1% proof stress and the ultimate stress respectively. For sheet materials with a high rate of strain hardening, e.g., stainless steel, the minimum stress may be required to differ from the ultimate stress by as little as possible as the conditions of forming will permit, to reduce to a minimum the spring-back of the sheet metal after it has been shaped to the former, and this result is achieved by the vastly improved lubrication provided by means of the invention. Again, for any given former, the ratio of maximum to minimum stress is so much reduced by means of the invention that materials with low elongation and high strain hardening rates can be used. Whatever the material, the reduction in this ratio by the low coefficient of friction of the order indicated above is of great benefit by giving more accurate forming. It has been found that the use of ice immediately makes available a substantial increase (about 5-fold) in the angle of lap for material of any given minimum and maximum stress, or, as improved above, extends the range of materials that can be effectively and accurately shaped on any given former.

Although the former may be simply cooled in a chamber of appropriate temperature or by impinging a cooling jet of compressed gas on to it, it is preferable, particularly when ice is to be used, for the former to be capable of being continuously cooled internally by a coolant passing through tubes formed or embedded in the body of the former or forming part of the framework on which the former is supported.

By applying a layer on a former determining the general size and shape to which the sheet metal is to be formed, it is not necessary to finish the surface of the former with any high degree of smoothness, and this reduces the cost of preparing formers. Thus, a concrete former of the required profile may even have a somewhat rough surface to receive and hold the layer. The former provides the mechanical support for the layer. The surface of the layer, moreover, may be readily reconstituted, as by spraying between each forming operation.

In addition to stretch-forming, the invention is applicable to the drawing and deep drawing of sheet metal.

Several methods of applying the invention to the stretch-forming and deep drawing of sheet metal will
now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a part-sectional perspective view of apparatus for stretch-forming sheet metal to form the leading edge of an aircraft wing.

Figures 2 and 3 are diagrammatic sections showing the operation of the apparatus of Figure 1.

Figure 4 is a diagrammatic side elevation of the former of Figure 1.

Figure 5 is a diagram showing a cooling system for apparatus as in Figure 1.

Figure 6 shows the spraying of the former of Figure 1.

Figures 7 and 8 are part-sectional side views of apparatus for stretch-forming skin panels for aircraft, in two operational positions.

Figures 9 and 10 correspond to Figures 7 and 8, but illustrate a modification.

Figure 11 is a perspective view of a modified former suitable for use in the apparatus of Figures 7 to 10; and

Figure 12 is a diagram showing the application of the invention to the deep drawing of sheet metal.

In Figures 1 to 4, a concrete former has lengthwise passage 2 close to its curved surface to which sheet metal 3 is to be made to conform. The passages 2 may be formed directly in the concrete of the former 1, but preferably they are constituted by embedded piping, for which purpose plastic piping is particularly suitable. Such piping ensures that coolant does not seep through the concrete. Pipes 4 connect the passages 2 with an exchanger 6 (Figure 5) where the coolant is cooled by refrigerant circulated through pipes 7, 8 from a refrigerating machine 9. The exchanger 6 may serve more than one former 1, e.g., the former 1A, 1B connected in parallel to main coolant lines 10, 11. Valves 12, 12A, 12B are provided to enable the supplies to the respective formers to be controlled from the flow produced by the circulating pump 13.

Before the sheet 3 is applied to the former 1, the latter is sprayed, as shown in Figure 6, by nozzles 14 projecting from a pipe 15 shaped to the general curvature of the former and supplied with water by a flexible pipe 16. The pipe 15 is supported by carriages 17 guided by slots 18 in the base 19 of the apparatus, so that it can be moved over the length of the cooled former 1 as many times as may be necessary for the mist sprayed by the nozzles 14 to build up a layer of ice between 1 mm. and 2 mm. in thickness. The layer keys to the curved surface of the concrete former and conforms externally to the shape to be imparted to the sheet 3, offering a smooth surface to the sheet.

The sheet 3 is then applied to the former, its longitudinal edges being secured between inner clamps 20 secured to the base 19 and outer clamps 21 controlled by hydraulic cylinders 22. For clarity, the clamps 20, 21 and the cylinders 22 are omitted from Figure 6. The former 1, appropriately strengthened by suitable reinforcement (not shown), is supported by a strong backing plate 23 and a beam 24 operated by hydraulic cylinders 25, which urge the former 1 upward so that the sheet 3, with its edges held down by the clamps 20, 21, is stretched, relative movement taking place between the sheet and the former, to a greater degree along the sides of the former as the distance increases from the apex 26 towards the clamped edges. Under the pressure applied by the cylinders 25 and the relative movement of the sheet, the upper surface of the ice layer liquifies, and the automatically produced water, under pressure, acts as an interposed lubricant, with a very low coefficient of friction. The stretching tension applied by the cylinders 25 is thus made available to the sides of the sheet over the whole sides of the former, so that the sheet takes up shape of the former, with negligible spring-back when the clamps 20, 21 are released.

The former 1, being continuously cooled, the ice layer is maintained at the surface of the concrete, and is quickly restored to working thickness by further use of the nozzles 14 between removal of one sheet 3 and the application of the next. The sheets can be quickly applied and clamped, so that they may be previously stored, by 15° C. to 20° C. above ambient temperature, or heated after application to the former, e.g., by infrared radiation, to assist in the formation of the water film on the surface of the ice layer.

The former could be cooled in a refrigerated chamber and moved in continuous condition to the stretch-forming apparatus, either receiving the ice-forming spray when in operative position, as described above, or prior to reaching its location in the apparatus. Again, the former may be cooled by impingement on its surface of a jet of a gas compressed sufficiently to produce a temperature substantially below normal ambient expansion. Yet again, the former may comprise a block of ice, or layer of ice of substantial thickness, formed to the desired shape, in which case, internal cooling may be used to maintain the frozen condition for as long as may be necessary.

In Figures 7 and 8, a skin-stretching former 27, which may have a double curvature, as shown by the former 28 in Figure 11, has coolant passages 29 close inside its upper surface over which a sheet 30 is to be stretched, pipes 31, 32 connecting the passages to a circulating system as in Figure 5. The former 27 is supported by a bed 33 adjustable as to height by screw jacks 34. Clamps 35 closed by hydraulic cylinders 36 are mounted on heads 37 rocking with hydraulic cylinders 38 about pivots 39 adjustable as to height by screws 40, further screws 41 enabling the heads 37 and cylinders 38 to be rocked to bring the clamps 35 into position to grip the edges of the sheet 30 where these project in continuation of the curvature of the former in one dimension. The clamps forming to the curvature in the other dimension. The cylinders 38 pull the edges of the sheet 30 in opposite directions, so producing surface liquefaction of an ice layer formed on the former 27 as the sheet moves relatively to the surface of the layer, much as explained with reference to Figures 1 to 6. The sheet 30 is thus stretched over the whole area of the former 27, because of the interposition of the water as a lubricant of very low coefficient of friction, and thus has negligible spring-back upon the clamps 35 being released.

In Figures 9 and 10, a former 42 with cooling passages 43 and feed pipes 44, 45 much as in Figures 7 and 8, is supported and operated by a hydraulic cylinder 46. Clamps 47, closed by hydraulic cylinders 48, and pulled by hydraulic cylinders 49, rock freely with the cylinders 49 about pivots 50, adjustable for height by screws. With a sheet 51 to be formed into a skin panel applied over an ice layer on the former 42 and secured at its edges by the clamps 47, upward pressure on the former by the cylinder 46 while the cylinders 49 apply tension cause the ice layer to liquify superficially as the sheet moves relatively to the surface of the layer, and the protruding edges of the sheet are pulled about the edges 52 of the former, which is particularly advantageous in some cases for minimizing spring-back of the stretched skin panel on its release from the clamps 47.

In Figures 7 to 10, at least one of the mountings for the clamps 35 and 47 may be adjustable with respect to the former, as shown by the carriages 53 and securing holes 54 in the base 55 of the apparatus.

In Figure 11, a former 58 of metal or other hard nonporous material has an open coolant passage 56 covered by a plate 57, forming the operative surface of the former, with an interposed gasket 58, so that coolant fed by pipes 59, 60 flows under the plate 57 to enable an ice layer to be formed in it.

In Figure 12, a forming die 61 with cooling passages 62 close to its upper surface (including the curved surface 63 leading to the die opening 64) has an ice layer formed on that surface, after which a sheet metal blank 65 held to the die by a clamping ring 66 is pressed through the opening 64 by a deep-drawing punch 67, the
pressure of which combined with the relative movement of the blank over the surface of the die as it is transformed from the flat into the desired deep-drawn article, liquidizes the ice layer superficially to provide a continuous lubricating film of water. Because of the substantial crushing forces arising, the temperature of the die should be somewhat lower than that of the sheet-stretching dies described above, so that the colder thin layer of ice can withstand those forces.

What we claim is:

1. Stretch-forming process for sheet metal, comprising cooling a former just below the freezing point of water, spraying the surface of the former with water to form a layer of ice on the surface, applying to the surface a sheet of metal at room temperature, and stretch-forming the sheet, so that a water film is produced by melting of the surface of the ice layer by the temperature difference between the sheet and the ice.

2. Stretch-forming process for sheet metal, comprising cooling a former below the freezing point of water, spraying the surface of the former with water to form a layer of ice on the surface, applying to the surface a sheet of metal to be stretched and effecting the stretch-forming with the sheet somewhat heated to assist in the production of a water film by melting the surface of the ice layer.

3. Stretch-forming process as in claim 1, wherein the sheet is heated before its application to the ice-surfaced former.

4. A stretch-forming process for sheet metal, comprising the steps of: providing a former with a shaping surface layer of ice, stretching a sheet of the metal over the former, and superficially liquidifying the surface of the ice layer to and maintaining it in the liquid state during the stretch-forming, thus providing a lubricating film of water next to the surface of the sheet.

5. A stretch-forming process for sheet metal, comprising the steps of: cooling a former below the freezing point of water, spraying the surface of the former with water to form a layer of ice on said surface, applying to the former a sheet of metal to be stretch-formed, stretching the sheet upon the former, and lubricating the sheet with a film of water by superficially melting the surface of the ice layer while stretch-forming.

6. A stretch-forming process for sheet metal, comprising the steps of: cooling a former below the freezing point of water, spraying the surface of the former with water to form a layer of ice approximately 1 to 2 mm thick on said surface, applying to the surface a sheet of the metal to be stretch-formed and stretch-forming the sheet, and lubricating the sheet with a film of water by superficially melting the surface of the ice layer during stretch-forming.

7. A process for shaping sheet metal, comprising the steps of: providing a former with a shaping surface layer of ice, imparting relative movement between contacting surfaces of a sheet of the metal and of the former, and superficially melting the surface of the ice layer during the shaping of the metal to produce a lubricating water film next to the surface of the sheet.

8. A process for shaping sheet metal, comprising the steps of: providing a former with a shaping surface layer of a solid substance that undergoes a solid-liquid phase change at a substantially constant temperature, said substance being selected from the group consisting of ice, acetoephonene, cyclohexanone, and glacial acetic acid, imparting relative movement between contacting surfaces of the metal and the former, and superficially bringing the surface of the layer to and maintaining it in the liquid state during the shaping of the metal to provide next to the surface of the metal a liquid lubricating film of low coefficient of friction.

9. A process for stretch-forming sheet metal by means of an internally cooled former, comprising the steps of: cooling the former to below the freezing point of water by circulating a coolant therethrough, spraying the shaping surface of the former with water to produce a layer of ice, stretch-forming a sheet of the metal upon the former with the surface of the ice layer superficially liquefied to provide a lubricating film of water adjacent said sheet, and respraying the former to reconstitute the ice layer after removal of the stretch-formed sheet.

10. Stretch-forming process as in claim 9 including heating the sheet of metal to above room temperature before its application to the former.

11. A drawing process for metal, comprising the steps of: providing a die with a shaping surface layer of ice, forcing metal into the die, and superficially liquidifying the surface of the ice layer to provide a lubricating film of water as the metal is forced through the die.

12. A drawing process for metal, comprising the steps of: internally cooling a die, spraying the die with water to produce a shaping surface layer of ice, forcing the metal into the die, and superficially liquidifying the surface of the ice layer during the shaping of the metal to provide a liquid lubricating film of low coefficient of friction.

13. A process for shaping sheet metal with a former, comprising the steps of: providing a former with a shaping surface layer of solid acetoephonone, pressing a sheet of the metal into contact with the surface of the former while imparting relative movement between the contacting surfaces of the sheet and former, and superficially liquidifying the surface of said layer during the shaping of the metal to provide a liquid lubricating film next to the surface of the sheet.

14. A process for shaping sheet metal with a former, comprising the steps of: providing a former with a shaping surface layer of solid cyclohexanone, pressing a sheet of the metal into contact with the surface of the former while imparting relative movement between the contacting surfaces of the sheet and former, and superficially liquidifying the surface of said layer during the shaping of the metal to provide a liquid lubricating film next to the surface of the sheet.

15. A process for shaping sheet metal with a former, comprising the steps of: providing a former with a shaping surface layer of solid glacial acetic acid, pressing a sheet of the metal into contact with the surface of the former while imparting relative movement between the contacting surfaces of the sheet and former, and superficially liquidifying the surface of said layer during the shaping of the metal to provide a liquid lubricating film next to the surface of the sheet.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,952,294

Graham E. Beverley et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 65, for "substantial" read -- substantially --.

Signed and sealed this 11th day of April 1961.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

ARTHUR W. CROCKER
Acting Commissioner of Patents