March 6, 1956 E. E. JONES 2,737,224

APPARATUS FOR FORMING SHEET METAL

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FIG. 1

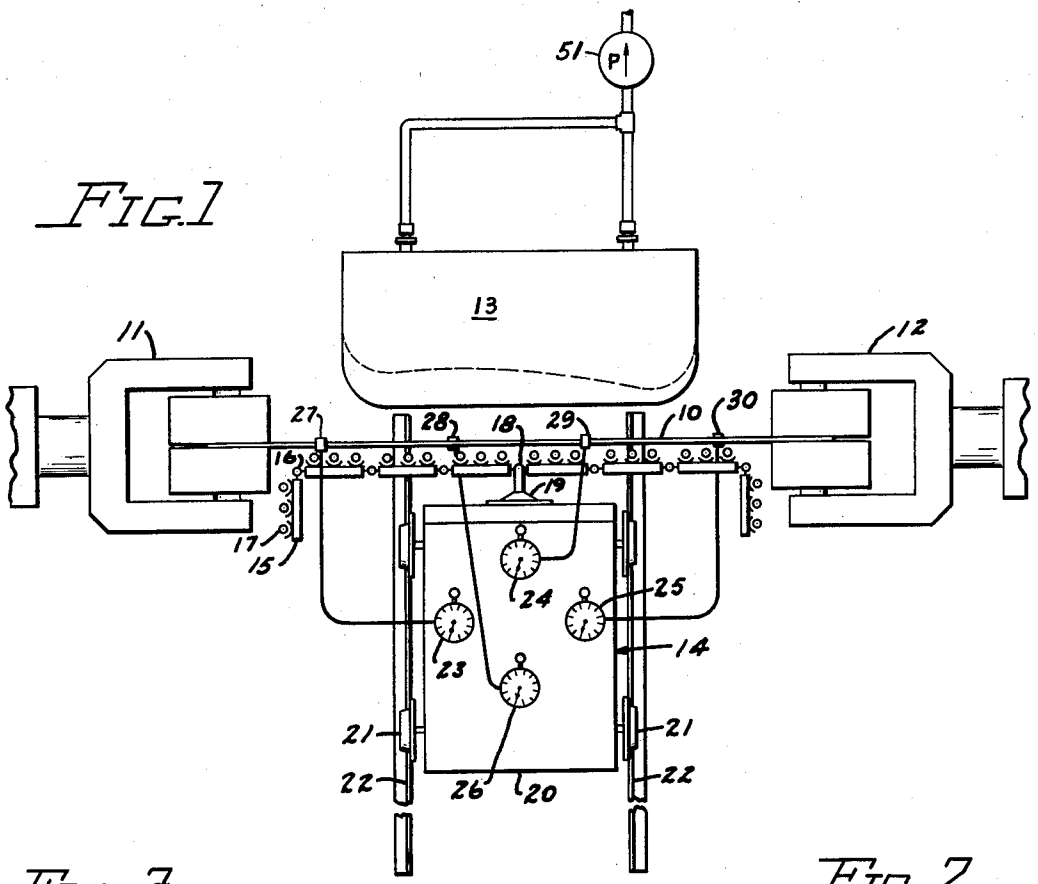


FIG. 3

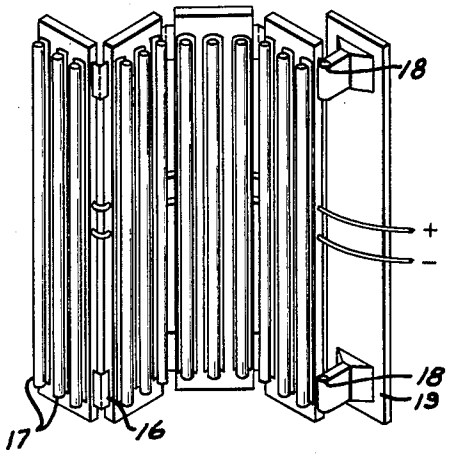
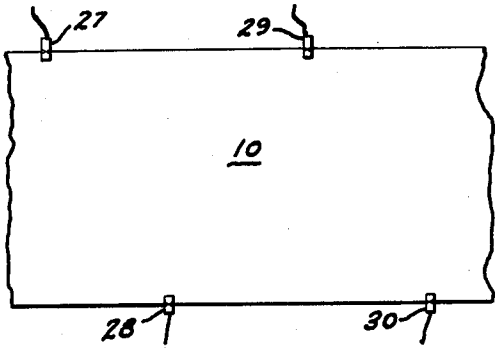


FIG. 2



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FIG. 4

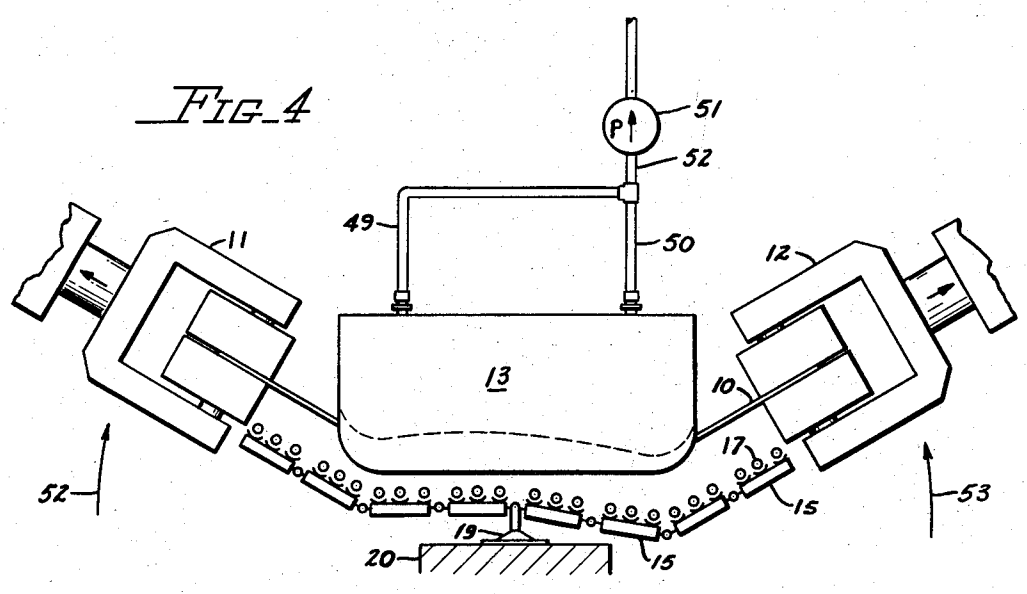


FIG. 5

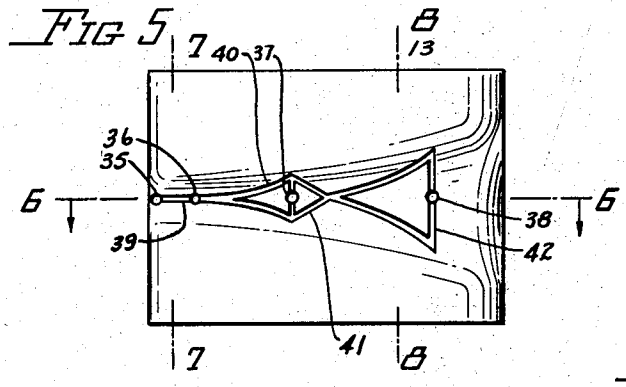


FIG. 7

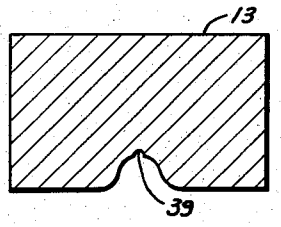


FIG. 6

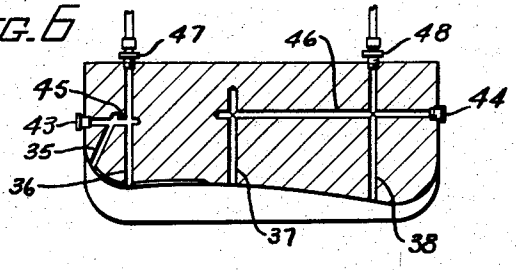
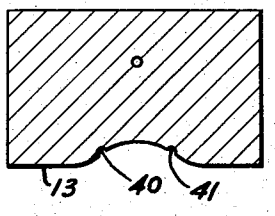


FIG. 8



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2,737,224

APPARATUS FOR FORMING SHEET METAL

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Application December 10, 1951, Serial No. 260,817

5 Claims. (Cl. 153—48)

This invention relates to the forming of single blanks of sheet metal into finished parts having irregular or compound and severe surface curvatures.

As is well known, aluminum alloy is the material commonly used for the manufacture of aircraft wing, body, and empennage skin sections. The alloys accepted as satisfactory for such use have certain definite limits of elongation, however, and the stretch-wrap forming of such sheet material to extreme curvatures has often necessarily exceeded these limits, resulting in scrappage of the parts. To obtain satisfactory parts, the manufacturer has had to make the skin sections smaller in size so that no single section would exceed the limit of elongation of the aluminum during forming. This practice has proven expensive due to the extra labor, dies, etc. required to accomplish the forming, and to the extra time and labor required to install the too numerous sections on the aircraft frame.

It has long been known that certain magnesium alloys have limits of elongation several times greater than those of aluminum alloys, and that the heating of either material prior to forming will greatly reduce cracking and breakage during the forming operation. However, no practical method of stretch-wrap forming either material in the presence of heat has previously been introduced, and as a result the largest magnesium alloy sheet which any manufacturer has been able to form by the stretch-wrap method measured only 10 inches by 20 inches, and was of very fine gage.

It is the primary object of this invention to provide a practical apparatus for stretch-wrap forming magnesium and aluminum alloy sheet stock into finished parts having severe surface curvatures.

Another object is to provide an apparatus for stretch-wrap forming such sheet stock to severe curvatures without wrinkling, cracking, breaking, or work hardening the material, thus reducing the forming of unsatisfactory parts to a minimum.

Another object is to provide an apparatus which makes possible the severe stretch-wrap forming of sheets of magnesium and aluminum alloy as large as 50" by 100", and of heavy gage material.

A still further object is to provide one form of apparatus to aid in carrying out the method in a practical manner.

The invention, together with other objects, will be more clearly understood when the following description is read in connection with the accompanying drawings, in which:

Fig. 1 is a schematic plan view of one form of apparatus, and shows the forming die in position with relation to the work sheet to be formed, the work sheet being held in the jaws of a stretch forming machine;

Fig. 2 is a fragmentary plan view of a work sheet showing the anchoring and spacing of heat sensing elements thereon;

Fig. 3 is a fragmentary perspective view of radiant heating panels, showing mounting details;

Fig. 4 is a schematic plan view similar to Fig. 1, but shows the sheet stock actually being formed;

Fig. 5 is a front elevation of a preferred form of forming die, showing details of construction;

Fig. 6 is a sectional view of the die taken along line 6—6 of Fig. 5; and

Figs. 7 and 8 are lateral sectional views of the die taken along the lines 7—7 and 8—8 of Fig. 5.

At the present time magnesium sheet material is available to manufacturers in two forms, commonly identified as "H" magnesium and "A" magnesium. H-condition magnesium is roll hardened, and is used in making parts which will be subject to high stresses and strains. It is difficult to form, and I have found that if its temperature is maintained above 325° F. for a period of more than 12 minutes, it begins to anneal, that is, it begins to soften and lose strength, making it unfit for use in forming parts which must withstand high stresses and strains. The temperature of 325° F. will be referred to hereinafter as the "critical forming temperature." I have also found that if H-condition magnesium is allowed to drop below 280° F. during severe forming, or if it is formed too fast, the sheet stock work hardens and becomes so brittle that it cracks or breaks before the forming operation is completed, causing the formed part to be scrapped as useless. While H-condition magnesium sheet can be formed satisfactorily if it is maintained within a temperature range of 280° F. to 325° F., I have established that the optimum temperature range is 300° F. to 310° F.

A-condition magnesium is magnesium which has already been annealed. It is much easier to form than H-condition magnesium, but does not have the strength characteristics of H-condition sheet. It cannot, therefore, be used in forming parts which are required to withstand high stresses and strains. I have found that if A-condition magnesium sheet is formed at a temperature above 325° F., it stretches and "flows" excessively, causing wrinkles, tends to cool in spots during the forming operation, loses strength, and as a result forms unsatisfactory parts. On the other hand, if it is severely formed at a temperature below 240° F., it work hardens and cracks or breaks. The optimum range for severely forming A-condition magnesium sheet, as established by my own experiments, is from 300° F. to 310° F.

Method in general

Based on the above determinations, the method employed in connection with the apparatus disclosed generally includes the steps of preheating the forming die to a temperature approximating the critical forming temperature of the magnesium sheet, placing the sheet stock to be formed in a position closely adjacent the preheated die, uniformly heating that portion of the sheet stock which is to be formed to a temperature just below its critical forming temperature, and forcing the sheet stock into contact with the forming surface of the die, and allowing sufficient time for the sheet stock to set against the die surface, then removing the formed sheet and trimming it to form the finished part.

Apparatus in general

Referring to Fig. 1 of the drawings, the magnesium work sheet is designated by the numeral 10, the two sheet gripping jaws of the stretch forming machine are designated by the numerals 11 and 12, the forming die by the numeral 13, and the heating unit assembly by the numeral 14. It is not thought necessary to illustrate or describe the details of construction of the stretch forming machine because such machines are in common use, and their construction and operation is well understood by those familiar with this art.

Heating unit

The heating unit includes a series of upright panels **15** hinged to each other along their side edges, as indicated at **16**. To the face of each panel there is secured a plurality of upright resistance heating elements **17**. The elements on each panel are electrically connected to each other in parallel and the panels are electrically connected in series, so that all the elements on any one panel may be disconnected from the circuit if desired. The assembled panels **15** are pivotally mounted at **18** on a supporting standard **19**. To facilitate moving the panel assembly into a desired location with relation to the work sheet, the standard **19** may be mounted on the free end of a hydraulically actuated plunger, similar to the manner in which the jaws **11** and **12** are mounted, or it may be mounted on a traveling carriage **20**, as shown. In this instance the carriage is fitted with wheels **21** which are guided by tracks **22**.

Heat unit control

Carriage **20** also carries a plurality of combination temperature indicating and automatic circuit breaking instruments **23**, **24**, **25**, and **26**, which are respectively connected to thermocouples **27**, **28**, **29**, and **30**. These thermocouples are removably clipped into heat conducting contact with the work sheet **10** in spaced relation, so that each thermocouple may sense the temperature of a substantially equivalent area of the work sheet, as clearly shown in Fig. 2. The instruments **23** to **26** inclusive are respectively provided with electric signal bulbs **31**, **32**, **33**, and **34**. The instruments are connected in the heating circuit in parallel so that any one of them may independently break the heating circuit if the work sheet temperature in the region sensed by its particular thermocouple exceeds a predetermined degree. When the heating circuit is broken by any particular instrument, its respective signal bulb will light, apprising the operator which instrument broke the circuit, and indirectly, which region of the sheet stock has reached the desired temperature. The radiant heating panels adjacent that region may then be spaced a little farther from the sheet stock, and when the temperature of that particular region has dropped to a predetermined temperature, the instrument will close the circuit and all panels will resume heating. The instruments may be set to make and break the circuit at desired temperatures. If all instruments are set to break the heating circuit at 310° F., for instance, and the circuit is broken during heating of the sheet, and all signal bulbs light, the operator may assume that all regions of the work sheet have been heated to a temperature of 310° F. This may be verified by reading the individual instrument dials, the hands of which indicate the temperatures sensed by the respective thermocouples.

Forming die

The type of die which I prefer to use, and which aids materially in carrying out the process of this invention, differs from conventional stretch-wrap forming dies in having provisions for evacuating the space between the forming surface and the adjacent work sheet surface during forming. As illustrated in Figs. 5 and 6, suitably located air passages **35**, **36**, **37** and **38** are drilled through the die body. Their open ends are interconnected along the forming surface of the die by narrow superficial grooves **39**, **40**, **41**, and **42**, which are located to distribute air pressure along the curved forming surface as evenly as possible. Threaded plugs **43** and **44** close the ends of blind interconnecting ducts **45** and **46**. Threaded adapters **47** and **48**, seated in the rear face of the die connect all the air ducts with conduits **49** and **50** (Fig. 4), which in turn are connected to vacuum pump **51** by duct **52**. It should be noted that the die block itself may be made either of plastic material or of Kirksite or any other suitable metal.

The forming process

If a metal die is to be used, the die is preheated, as in an oven, to a temperature within the critical forming range of the sheet stock. This range is 240° F. to 325° F. for A-condition sheet and 280° to 325° F. for H-condition. Preferably the die is heated to 325° F. or just below that figure. The die is then anchored in position adjacent the jaws of the stretch forming machine. The sheet stock is mounted in the jaws **11** and **12** as shown in Fig. 1. The heating unit is then moved toward the sheet stock, the heating panels **15** are positioned approximately equidistant from that intermediate portion of the sheet which is actually to be formed. The heating circuit to the radiant heating elements is closed, and the sheet is uniformly preheated to a temperature within its critical forming range, as above, but preferably between 300° F. and 320° F. The jaws **11** and **12** are then moved by the operator toward the positions shown in Fig. 4. This jaw movement "wraps" the sheet into contact with the die forming surface, and simultaneously places the sheet under a very considerable tension. Shortly after the edges of the sheet stock have contacted the edges of the die forming surface, and before the sheet has been placed under the maximum intended forming tension, the operator places the vacuum pump **51** in operation. Air is thus evacuated from the space between the sheet stock and the die forming surface. Atmospheric pressure, acting on the outer surface of the sheet then begins to force the sheet toward the die forming surface, and this atmospheric pressure prevents longitudinal wrinkles from forming in the sheet due to the tension being applied by the jaws.

If H-condition magnesium is being formed, and especially if the forming is severe, the relative positions of the heating panels **15** should be changed as the forming proceeds, to aid in maintaining the temperature of the sheet **10** at around 310° F. Also the forming should be done in steps, that is, only slight tension should be applied to the sheet at first. Then the jaws **11** and **12** should be moved only a short distance in the direction of the arrows **52—53**. Then partial vacuum applied, then additional tension, etc. If A-condition magnesium is being formed, this step by step forming is not ordinarily necessary, because A-condition sheet is more plastic than H-condition sheet within a temperature range of 300° F. to 320° F. Furthermore, with A-condition material it is often possible to omit the step of heating the sheet during forming, at least so long as the die temperature is above 280° F.

By observation the operator can determine when the sheet is in firm contact throughout the die forming surface. After allowing a short time for the sheet to "set," pump **51** is reversed and air is forced between the sheet and the forming surface. The jaws are actuated to release the sheet, and are then returned to their normal positions to receive the next sheet. With one pre-heating of the die to 325° F., more than 50 parts have been formed before the die temperature dropped below the critical forming range. If a plastic die is used, the preheating of the die can be eliminated. This is true because a plastic die is practically non-conductive, and there is very little loss of heat from the sheet during the time the two are in contact. This is especially true if the sheet is heated during forming.

Having described the invention with sufficient clarity to enable those familiar with this art to practice it, I claim:

1. Apparatus for severely forming magnesium alloy sheet stock comprising: a fixed negative forming die; a pair of sheet gripping jaws, one near each end of said die, and movable laterally and longitudinally with relation to the die for wrapping the sheet into contact therewith; means for evacuating air from the die cavity; a carriage movable toward and away from the die forming surface;

a radiant heating unit mounted on and movable with said carriage, said unit including a plurality of articulated radiant heating panels movable with relation to each other to vary their spacing from the die forming surface; means for energizing said panels to provide radiant heat; heat conducting means connectible to a plurality of spaced points along the sheet to be formed; and means connected to said heat conducting means and to the panel energizing means, and responsive to the heat conducting means for controlling the panel energizing means.

2. Apparatus for severely forming magnesium alloy sheet stock comprising: a forming die; work sheet gripping means for supporting a work sheet along and adjacent the die forming surface; means for effecting relative movement between the die and gripping means to stretch-wrap a sheet against the die forming surface; a plurality of juxtaposed relatively movable radiant heating panels supported along and adjacent a sheet held in said gripping means and independently movable toward and away from said sheet; means for supplying heat energy individually to said panels; area heat sensing means attachable at spaced locations to said sheet and connected to the heat energy supplying means for controlling the heat energy supplied to the panels individually in response to changes in temperature of individual areas of the sheet as sensed by the sensing units.

3. Apparatus for severely forming magnesium alloy sheet stock comprising: a forming die; work sheet gripping means for supporting a work sheet along and adjacent the die forming surface; means for effecting relative movement between the die and gripping means to stretch-wrap the sheet against the die forming surface; a battery of individually controllable area heating units supported along and adjacent a work sheet held in said gripping means; area heat sensing means attachable in spaced locations to a work sheet held in said gripping means, and connected respectively to said heating units for selectively controlling the temperatures of the respective heating units in response to changes in the temperatures of the sheet areas as sensed by the respective sensing units.

4. The apparatus described in claim 3, and means for evacuating air from between the die forming surface and a work sheet being formed thereon.

5. Apparatus for severely forming magnesium alloy sheet stock comprising: a forming die; work sheet gripping means supporting a work sheet adjacent the die forming surface; means for effecting relative movement between the die and the work sheet gripping means to stretch-wrap the sheet against the die forming surface; a battery of individually controllable area heating units; movable means supporting said units along and adjacent a work sheet gripped in said gripping means; area heat sensing means attachable in spaced locations to a work sheet supported in said gripping means; and means controlled by said heat sensing units for selectively supplying heat energy to the respective heating units in response to changes in temperature of the sheet areas as sensed by the respective sensing units.

References Cited in the file of this patent

UNITED STATES PATENTS

1,457,772	Forsyth	June 5, 1923
2,123,683	Oeckl	July 12, 1938
2,377,946	Leary	June 12, 1945
2,442,338	Borkland	June 1, 1948

FOREIGN PATENTS

431,095	Great Britain	July 1, 1935

OTHER REFERENCES

The disclosure on pages 24 through 29 in the Journal of the Aeronautical Sciences, volume 8, No. 1, November 1940.

The disclosure on pages 980 and 981 of the 1948 edition of the Metals Handbook, published by the American Society for Metals.