Aug. 28, 1962 C. J. SWAIN 3,051,830

SHEET DIMPLING APPARATUS AND METHOD

Filed May 4, 1959

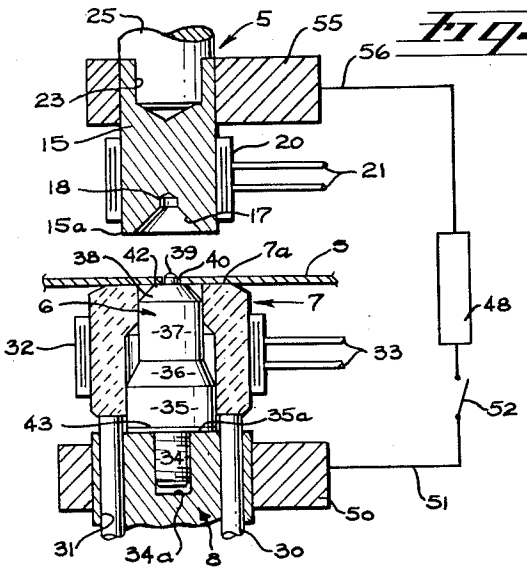


Fig. 1

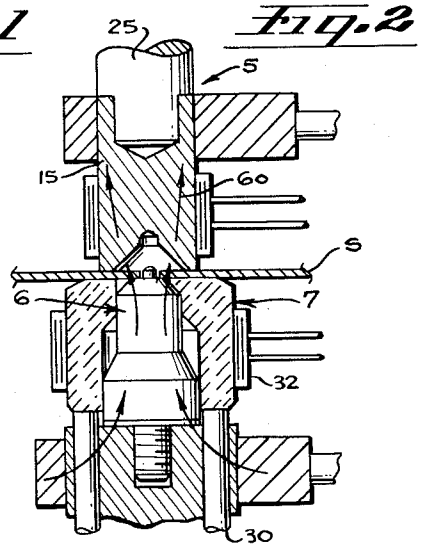


Fig. 2

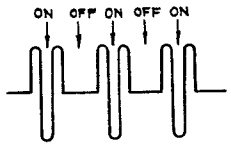


Fig. 5

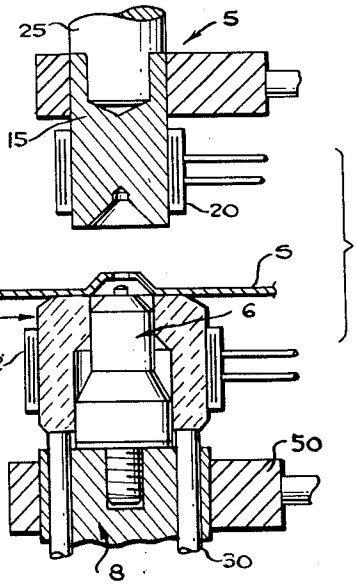


Fig. 4

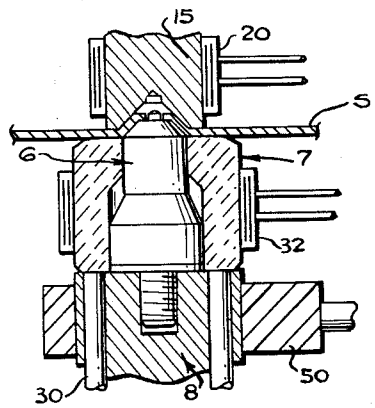


Fig. 3

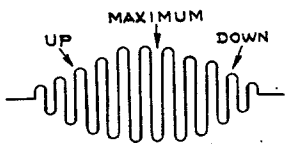


Fig. 6

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SHEET DIMPLING APPARATUS AND METHOD

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This invention has to do with apparatus for and method of forming or embossing dimples in worksheets, such as for the purpose of countersinking rivet or bolt heads. While my invention is especially useful in dimpling sheets for use in airplane construction, it is of course useful wherever dimpled sheets are required.

Airplane speeds have gradually increased as new and improved means of propulsion have been provided, and in order to be able to withstand the temperatures and stresses incident to such higher speeds, the air frames and air foils must be made of relatively high tensile-temperature resistant metals, such as alloys of titanium, corrosion-resistant steels, and the high temperature hot-worked die steels.

In dimpling worksheets made of the aluminum-type alloys heretofore more generally used, it has been possible to sufficiently heat the sheet by applying conduction heat through the dimpling tools.

However, for several reasons, such condition heating has been found to be inadequate in dimpling sheets made of the relatively high tensile-temperature resistant alloys. For instance, conduction heaters capable of producing the required high temperatures are not available, and the tool-steels of which the dimpling tools are made do not have the thermal-mechanical perimeters required for the dimpling cycle, and the thermal conduction properties of some elevated temperature airframe structure materials are not compatible with thermal gradient requirements in the metals.

While electrical resistance heating has been attempted in efforts to meet the problem, such attempts have been largely unsuccessful because the heating occurs throughout such a substantial area of the sheet that objectionable sheet warpage occurs. Also, such attempts have been unsuccessful for the further reason that they have produced objectionable thermal shocks and arcing.

While my dimpling apparatus and method are useful and advantageous in forming dimples in all types of metal sheets, it is a more particular objective of my invention to provide novel method and apparatus by which dimples may be formed in sheets composed of relatively high tensile temperature resistant alloys and the like without experiencing the shortcomings and undesirable results of previous attempts to dimple such sheets.

More particularly it is an object of my invention to provide apparatus and method by which electrical resistance heating is effectively confined substantially to the restricted immediate area of the dimple.

It is another object to provide novel apparatus and method for carrying out resistance heating a restricted area of a worksheet preparatory to dimpling, by the application of a low-voltage high amperage current for an extremely short period.

While I shall point out in the appended claims the features and combinations which I consider to be new, I shall now, for the purpose of enabling those skilled in the art to practice my invention, describe presently preferred apparatus and procedures, for which purpose I shall refer to the accompanying drawing in which:

FIG. 1 is a view, partly in medial longitudinal section and partly in side elevation, showing the parts of my apparatus in their relative positions at the commencement of the operation;

FIG. 2 is a view like FIG. 1 except that it illustrates the relative positions of the parts in another stage of the operation;

FIG. 3 is a view like FIG. 1 except that it shows the relative positions of the parts in another stage of the operation;

FIG. 4 is a view similar to FIG. 1 except that it shows the position of the parts after the dimple has been formed and stripped from the punch and die;

FIG. 5 diagrammatically illustrates an input current control pattern for a pulsating current; and

FIG. 6 is a diagram illustrating an up-down slope current control pattern.

Referring now to the drawing, the numeral 5 generally designates the female die element, 6 generally designates the punch element, 7 generally designates the punch pad, and 8 generally designates the anvil post cap in which the bottom end of the punch is stationarily secured. A typical metal worksheet is denoted by the letter S.

The die element 5 comprises a cylindrical die body 15 having a conoidal dimple-forming recess 17 at whose apex there is a cylindrical cavity 18 for the reception of the pilot pin of the punch, to be described. An electrical conduction heater 20 embraces the body 15 and wires 21 for electrically energizing the heater are connected into the heater and to a source, not shown. The top end portion of the body 15 has an upwardly opening recess 23 to receive the reduced end portion of a fluid pressure actuated ram 25.

The punch pad 7, which surrounds and telescopes relative to the punch element, has an annular flat top end 7*a* and is supported upon circumferentially spaced pins or plungers 30 which are reciprocated, through corresponding bores 31 in the anvil post cap, by means of a conventional fluid pressure actuated piston, not shown; the bottom ends of the pins 30 bearing against the said piston. Thus the punch pad is yieldable pressure-loaded to resist being forced downwardly by pressure exerted by the ram-actuated die body. An electrical conduction heater 32 embraces the punch pad and current for energizing the heater is supplied through wires 33 connected into the heater and to a source, not shown.

The punch 6 has a relatively small diameter bottom end portion 34 threadedly engaged in a recess 34*a* in the anvil post cap. Adjoining the portion 34, the punch has major diameter portion 35 providing a downwardly facing annular shoulder 35*a*, above which the punch tapers at 36 to an upper cylindrical portion 37. The top end portion of the punch presents a frusto-conical surface 38 from the center of which projects an axially disposed pilot pin portion 39, which preferably is of less diameter than the pilot hole 40 in the worksheet S. The frustum of the punch portion 38 provides a flat annular shoulder 42 immediately surrounding the pilot pin. It is my preference to interpose a silver shim 43 between the shoulder 35*a* and the top face of the anvil post cap, for better electrical conduction.

The anvil post cap 8 and the punch are made of electrically conductive material, such as tool steel. However, the surrounding and contacting punch pad 7 is made of electrically non-conductive material, such, for instance, as alumina or a suitable ceramic. Also, the die body 15 is composed of electrically conductive metal, such as tool steel.

A copper electrode or terminal member 50 embraces the anvil post cap and is connected to an electrical source 48 by a suitable insulated conductor 51 through a control switch 52. Also, a copper electrode or terminal member 55 embraces the die body 15 and is connected to said source by a suitable insulated conductor 56.

The electrodes are energized by a low-voltage high amperage electrical current, and for this purpose I have

found that the voltage should be from ½ to 32 volts while the amperage should be 250–3000 amperes. The voltage and amperage may be varied according to the material of the sheet S. For instance, for a typical precipitation hardening thermal and corrosion resistant steel alloy (15–7 MO) of .016" thickness, a voltage of 5.8 volts and an amperage of from 900–1000 amperes would be used. Inasmuch as the punch pad 7 is electrically non-conductive, the introduction of the electrical current to the worksheet occurs only throughout the area of the sheet which is in contact with the annular shoulder 42.

The function of the punch pad 7 is to insure proper electrical contact of the sheet with the punch and die elements and to insure proper clamping of the worksheet during the dimpling cycle, as well as to minimize sheet warpage by inhibiting flow of metal from the dimpled area radially outwardly therefrom into the surrounding sheet area, or inwardly from the surrounding sheet area into the dimpled area.

The punch pad is yieldable pressure-loaded through the pins 30, to insure that the pad will not yield prematurely in the course of the dimpling operation. The length of the punch pad 7 is equal to the distance from the bottom end of the major diameter portion 35 of the punch to the base of the frusto-conical portion 38 of the punch, and the distance between the bottom end of the punch pad and the top end of the anvil post cap defines the extent to which the punch pad may be depressed in the course of a dimple-forming operation.

The die body 15 is moved towards and away from the punch assembly by means of the fluid pressure actuated ram 25.

Conventional pressure control mechanisms, not shown, are employed to insure the proper pressures against the worksheet during the various stages of the dimple-forming operation.

Also, the switch 52 is of a type enabling meticulous control of the current through the punch and die elements and the portion of the sheet S to be embossed.

The purpose of using the conduction heater 32 is to preheat the punch pad 7 above ambient temperature, to relieve thermal shock on the pad force due to application of the resistance heating current. The purpose of using the conduction heater 20 is to preheat the die body 15 above ambient temperature, to reduce conduction of heat from the dimpled area to the die body, and to minimize thermal gradients in the dimpled area.

In a typical operation, the punch pad may be preheated to a temperature of 300° F., and the die body to a temperature of 600–800° F.

In a typical operation, the worksheet S, with pilot hole 40 previously drilled therein, is placed against the flat top end of the punch pad 7 with the pilot pin 39 substantially centered in the rivet hole 40 (FIG. 1).

Then, in the first stage of the operation, the ram 25 moves the die body downwardly to the position of FIG. 2, so that sufficient pressure is exerted to form a firm contact between the worksheet, the bottom end surface of the die body, and the shoulder or frustum 42 of the punch. As soon as the desired firm contact is established the switch 52, controlling the resistance heating current through the apparatus, is actuated to close the circuit through the electrodes 50, 55. The effect of thus closing the circuit is to apply resistance heating to the portion of the worksheet in which the dimple is to be formed, which is the portion surrounded by the die body surface 15*a*. This stage of the operation occupies a very short period, typically only approximately 3 to 120 cycles of a 60-cycle current, which is sufficient to heat the sheet area to be embossed to a state of ductility, at the end of which period the switch 52 is operated to open the circuit. Immediately, further ram pressure is applied to move the parts into the position of FIG. 3, in which position the dimple D has been formed and coined in that portion of the sheet which has previously been conditioned by the resistance heating.

During the application of ram pressure to move the parts from the position of FIG. 2 to the position of FIG. 3, it will be observed that the die body will have depressed the punch pad against the resistance of the pressure-loaded pins 30 until the bottom end of the punch pad 7 engages the top of the fixed anvil post cap 8. The final coining of the dimple occurs as the punch pad reaches the latter position, which is the limit of its downward movement.

In the final stage of the operation, the ram is actuated to lift the die pad to the position of FIG. 4, allowing the pressure load of the pins 30 to move the punch pad upwardly to strip the dimple from the portion 38 of the punch. After the dimple is thus embossed, the pilot hole 40 is drilled to the diameter of the rivet to be used.

During the actual embossing and coining of the dimple there is a considerable buildup of the ram pressure, which firmly confines the area of the sheet immediately around the dimple between the flat annular top end surface 7*a* of the punch pad and the annular bottom end surface 15*a* of the die body 15, thus restricting radial metal flow in the sheet and thus reducing metal growth which might cause warpage.

Also, inasmuch as the resistance heating occurs only for such a short period and within such a highly restricted area, sheet warpage which might otherwise result from the heating and cooling of the sheet is maintained at a minimum. While, of course, there is some limited conduction heating of the sheet radially outwardly from the resistance heated area, that is not sufficient to produce any appreciable warpage of the sheet.

The flow path of the current which produces the resistance heating is indicated by the arrows 60 in FIG. 2.

In using my apparatus and method to dimple some sheets, I have found it advantageous to use a pulsating current by employing a control pattern as shown in FIG. 5 instead of a uniform current; while in dimpling other sheets I have found it advantageous to use an up-down slope input current control of the type diagrammatically illustrated in FIG. 6. While it is my preference to use alternating current, a direct current may be used.

I claim:

1. In apparatus for embossing a dimple in an electrically resistant metal sheet, the combination including a pair of opposed, relatively axially movable, electrically conductive elements presenting opposed conforming frusto-conical sheet embossing surfaces arranged to receive therebetween the portion of said sheet to be occupied by said dimple, fluid actuated means for moving one of said elements towards the other, sheet clamping members associated with and immediately circumscribing the embossing surfaces of said respective elements for clamping therebetween the portion of said sheet immediately circumscribing the portion thereof to be occupied by said dimple, one of said members being carried by one of said elements and the other of said members being fluid pressure loaded to yield in response to relative axial movement of one of said elements towards the other, and at least one of said members being electrically non-conductive, electrode means conductively attached to said members and means for introducing a relatively low voltage-relatively high amperage electrical current to said electrode means.

2. The combination of claim 1 which additionally includes conductive heating means conductively attached to each of said elements.

3. In apparatus for embossing a dimple in an electrically resistant metal sheet immediately around a rivet-receiving hole therein, the combination including an electrically conductive die element having an outer end portion presenting a frusto-conical sheet-embossing surface and having a pilot pin-receiving aperture at the frustum of said surface, an electrically conductive punch element having at its outer end a frusto-conical sheet-embossing surface, a pilot pin carried by said punch and projecting

centrally from the frustum of said last-named surface and being of smaller diameter than the said hole in said sheet, the frustum of said last-named embossing surface presenting a flat, annular surface surrounding the said pilot pin, fluid actuated means for moving one of said elements towards the other, an anvil post cap having an axial bore, said punch having a reduced diameter inner end portion engaging in said bore, a silver shim interposed between said punch and said anvil post cap in position surrounding said reduced diameter inner end portion of said punch, said die element having an annular flat sheet clamping surface immediately surrounding the outer end of its sheet-embossing surface, an annular pad of electrically non-conductive material surrounding said punch element and having an annular flat sheet clamping surface opposed to said first-mentioned sheet-clamping surface, fluid actuated means normally yieldably urging said pad towards said first-mentioned clamping surface, conduction heaters carried by said respective elements in heat conductive relationship thereto, electrode means carried by and conductively connected to said respective elements, and means for introducing a relatively low voltage-relatively high amperage electrical current to said electrodes.

4. The method of embossing a dimple around a rivet hole in a limited region of an electrically resistant metal sheet positioned between opposed electrically conductive dimple forming elements, which consists of maintaining clamping pressure on a limited annular zone of said sheet immediately circumscribing said region, rendering said region ductile by electrical resistance heating by introducing thereto through said elements a relatively low voltage-relatively high amperage electrical current while insulating one surface of said zone of said sheet from

said current, and then embossing said region to form a dimple therein while continuing to maintain said clamping pressure on said zone.

5. The method of claim 4 wherein said electrical current is subjected to up-down slope input control.

6. The method of embossing a dimple around a rivet hole in a limited region of an electrically resistant metal sheet positioned between opposed electrically conductive dimple forming elements, which consists of maintaining clamping pressure on a limited annular zone of said sheet immediately circumscribing said region, rendering said region ductile by electrical resistance heating by introducing thereto through said elements a relatively low voltage-relatively high amperage electrical current while insulating one surface of said zone of said sheet from said current, stopping the introduction of said current after said region has been rendered ductile, and then embossing said region to form a dimple therein while continuing to maintain said clamping pressure on said zone.

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