March 30, 1948. J. O. ARCHER ET AL 2,438,837

TOOL AND METHOD FOR DIMPLING

Filed Nov. 9, 1944

Fig-1

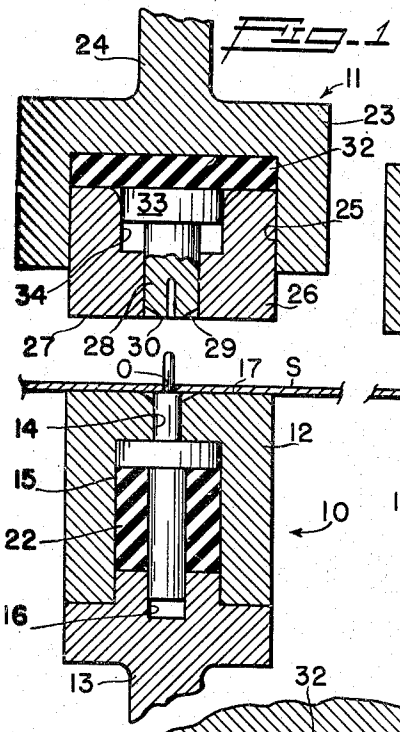


Fig-2

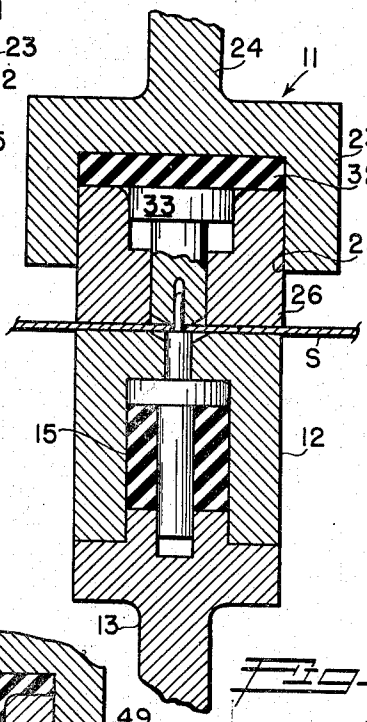


Fig-3

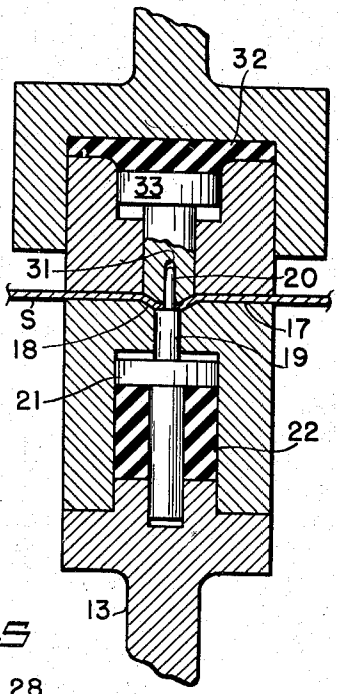


Fig-5

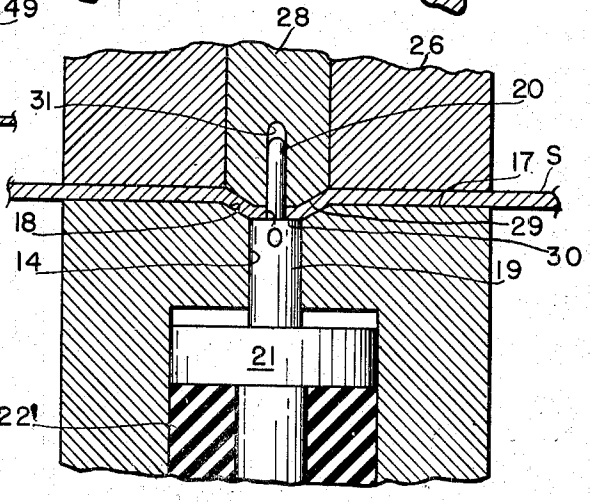


Fig-4

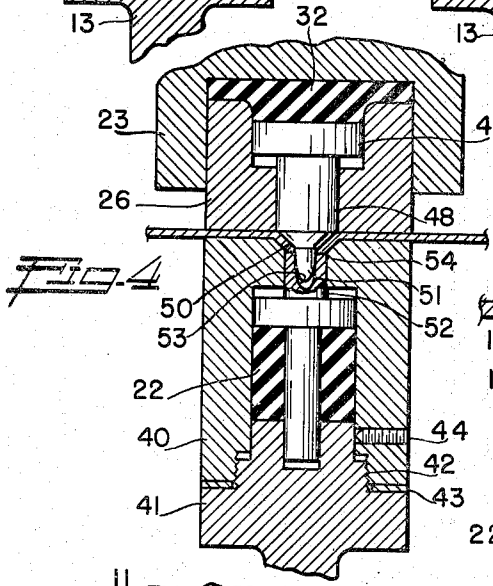
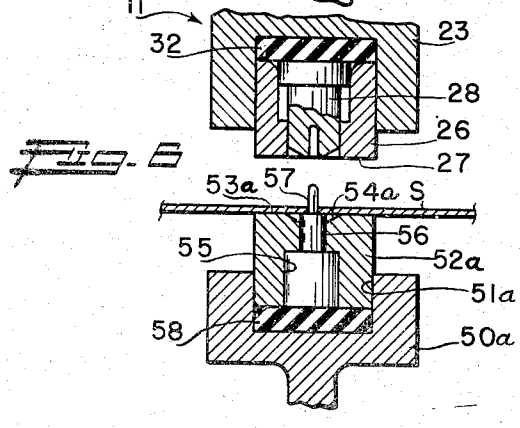


Fig-6



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TOOL AND METHOD FOR DIMPLING

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16 Claims. (Cl. 153—21)

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The invention relates to forming tools and methods, and relates more particularly to a tool and method for forming dimples at the rivet and screw receiving openings of metal sheets, and the like.

In the fabrication of various parts and structures, such as aircraft components, it is the common practice to provide dimples at the rivet receiving openings of sheet metal parts so that the heads of the rivets may lie flush with the surfaces of such parts. The dimpling is often a very critical operation in which the forming stresses approach the rupture values. Procedures and tools which satisfactorily dimple relatively soft metals or alloys, with only occasional cracking at the dimples, are not suitable where harder materials are to be dimpled. For example, the conventional tools employed to dimple 24S–T aluminum alloy sheets cannot be used to dimple sheets of high strength aluminum alloys such as 75S–T and 24S–T86 without excessive cracking of the metal at the dimples. To overcome this difficulty it has been proposed to "coin" or forge the metal within the dimple by employing a yieldingly supported ram in the die. As the load is applied, the ram, acting in conjunction with an opposing surface of the punch, compresses and forges the sheet material around the opening, preventing expansion of the opening and eliminating cracking of the material around the opening which would otherwise result from such expansion of the opening and forming of the dimple. The forging action also reduces stresses at the mouth of the dimple, produced by the dimple forming action, thereby preventing cracking at this point. This forging action is controlled by the substantially equal diameters of the punch and die, and during the final stages of the dimpling action the stresses which are set up during the initial stages of the forming are counteracted so that sharp, substantially stress-free dimples result. However, the forming of the metal coupled with the forging action obtained by the yieldingly supported ram, causes substantial warpage of the sheet, particularly where the dimpling operations are performed adjacent the margins of the sheets, which is the location of a great majority of dimpled openings. The warpage is believed to be due to the fact that the forging action reduces the total volume of the material in the dimple and forces some of the material into the surrounding sheet. This material displaced into the sheet around the dimple produces substantial distortion of the sheet. Such distortion is difficult to remedy and is the

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cause of the misalignment of the dimpled openings with openings in the substructure, and also causes poor mating of superimposed sheets and irregularities in the assembled sheets. Accordingly, while the tools employing forging rams at the dies form good, sharp dimples substantially devoid of cracks, such tools are not acceptable for general usage because of the sheet distortion caused by the forging action.

It is a general object of the present invention to provide a method and tool operable to form sharp radius, crack-free dimples in high strength aluminum alloy sheets, and the like, without deforming or distorting the sheets. The tool and method of the invention have all the advantages and capabilities of the forging-method tool above referred to, but completely avoid the accompanying distortion and warpage of the sheets.

Another object of the invention is to provide a dimpling tool employing a yieldingly supported ram in the die assembly to forge the metal around the opening in the sheet and thus obtain a true, sharp dimple free of cracks, which tool further embodies means to confine the effects of the forming and forging actions to the dimple itself to prevent stressing and distortion of the metal around the dimple. By isolating the forming and forging of the dimple from the remainder of the sheet, there is no possibility of warpage or distortion of the sheet as a whole even though the dimples may be formed adjacent the edge of the sheet.

Another object of the invention is to provide a dimpling tool of the character referred to embodying a double action dimpling punch having an annular clamping or pressure pad which contacts an annular area of the sheet around the zone to be dimpled, and serves to clamp the sheet against an opposing surface of the die prior to and throughout the forming and forging phases of the dimpling operation to thereby prevent distortion of the sheet as a whole by reason of displacement of material from the dimple into the sheet, or from other causes.

Another object of the invention is to provide a method and tool operable to form sharp radius dimples in high strength aluminum alloy sheets, etc., of such character that dimples of superimposed sheets may properly nest or fit one within the other without the necessity of altering the dimensions of the dimples in the subsheets or substructure. The walls of the dimples are uniform and are forged so that an unlimited number of sheets dimpled by the same tool may be accurately nested or engaged one upon the other.

Another object of the invention is to provide a dimpling tool of the character mentioned in which the modulus of the yieldable actuating means for the forging plunger may be varied or adjusted at will to obtain the proper forging action when dimpling material of given characteristics.

A further object of the invention is to provide a simple, inexpensive dimpling tool and a rapid, commercially practical dimpling method of the character above referred to.

Other objects and features of the invention will be readily understood from the following detailed description of typical preferred forms of the invention wherein reference will be made to the accompanying drawings in which:

Figure 1 is a vertical sectional view of the die and punch assemblies of one form of the invention showing the parts in the idle positions and illustrating certain portions in side elevation;

Figure 2 is a view similar to Figure 1 showing the pressure ring of the punch assembly in engagement with the sheet;

Figure 3 is a view similar to Figure 1 showing the parts in the final actuated positions;

Figure 4 is a fragmentary vertical sectional view of another form of the invention illustrating a means for adjusting the resilient plunger supporting means;

Figure 5 is an enlarged fragmentary detailed sectional view showing the active parts in the final operative positions; and,

Figure 6 is a vertical sectional view of another form of the invention.

The tool and method of the invention are adapted to dimple the openings of sheets and like parts of various materials and configurations. In the drawings we have illustrated typical forms of the invention suitable for dimpling openings in aluminum alloy sheets, and the like, it being understood that the tools are capable of modification to adapt them for given uses and that the invention is not to be construed as limited to the particular details herein set forth.

The tool of Figures 1 to 3 inclusive comprises a die assembly 10 and a punch assembly 11. The two units or assemblies may be designed for use in any selected or appropriate machine suitable for carrying out the dimpling operations. The assemblies 10 and 11 are related for relative movement so that the active parts may be moved into and out of engagement with the sheet S or other work. It will be assumed that the die assembly 10 remains stationary and that the punch assembly 11 is moved downwardly and then upwardly with respect to the die assembly to perform the dimpling operation and to restore the parts to their original relationship. The die assembly 10 is shown as being the lower unit of the tool and the punch 11 is illustrated as being the upper assembly, it being apparent that this relationship may be reversed if desired.

The die assembly 10 comprises a holder 12 provided at its lower end with a reduced shank 13, or other appropriate means for facilitating its mounting or attachment in the machine. A central vertical opening 14 enters the holder 10 from its upper end and joins an internal chamber or opening 15 of larger diameter. The opening 15 is preferably cylindrical and extends longitudinally within the holder 12. The holder 12 may be constructed in two sections to facilitate the provision of the openings 14 and 15, the sections normally being in rigid connection with one another. A central vertical socket 16 is provided in the bottom wall of the opening 15. In the form of the invention being described, the body or holder 12 of the die assembly presents an annular upwardly facing surface 17 at its upper end for engagement by the work or sheet S. While the surfaces 17 and 27 are shown as being normal to the longitudinal axis of the tool, it is to be understood that either one or both of these surfaces may be given a small angle or curvature to be slightly conical or spherical and thus compensate for spring-back of the sheet S following the dimpling operation. The surface 17 may be annular and of substantial area.

The die recess 18 of the tool occurs in the surface 17 at the mouth of the opening 14. The recess 18 is frusto-conical, having an annular wall which slopes downwardly and inwardly from the surface 17 to the wall of the central opening 14. This sloping wall constitutes the die surface for assisting in shaping the dimple. In accordance with the invention, it may not be necessary to provide a radius where the recess 18 joins the flat surface 17 because the forging action assures the production of sharp, effective dimples without cracking at this point. It is to be understood that the dimensions and configuration of the die recess 18 may be varied in different applications of the invention.

The die assembly 10 further includes a plunger or ram 19 operable in the openings 14 and 15 and engageable with the sheet S around its opening O to "coin" or forge the material of the dimple. The ram 19 slidably operates in the opening 14 and has a flat normal upper end for acting on an annular area of the sheet around the opening O. A reduced stem or pilot 20 extends upwardly from the end of the ram 19 to engage in the opening O of the sheet S to assure the correct concentric disposition of the dimple with respect to the opening. The end of the pilot 20 may be rounded to readily enter the opening O. The ram 19 continues downwardly through the opening 15 and its lower end portion is slidably guided in the socket 16. A flange or piston 21 is provided on the ram 19 to operate in the enlarged opening 15 of the holder 12. The piston 21 is rigid with the ram 19 and is engageable with the upper wall of the opening 15 to limit the upward travel of the ram.

The lower side of the piston 21 is engaged by a resilient supporting or actuating means. While the character of the resilient means may be varied, we prefer to employ rubber, rubber composition or synthetic rubber of the required shore hardness as the resilient element of the die assembly. Thus in the drawings a resilient body 22 of rubber, or the like, occupies that portion of the opening 15 below the piston 21. The resilient body 22 is preferably of such volume that it is under a selected compression between the piston 21 and the bottom wall of the opening 15 when the ram 19 is in its normal unactuated position of Figure 1. Accordingly, the resilient body 22 normally holds the ram 19 in its fully raised position. When the ram 19 is in this unactuated position, its upper end occupies substantially the same plane as the upper surface 17 of the holder 12. When we employ the term "resilient body" it is to be construed as contemplating any resilient element or unit yieldingly supporting the ram 19 for its forging operation to be later described.

The punch assembly 11 includes a holder 23 provided at its upper end with a stem 24 of reduced diameter for facilitating its mounting in the machine. A cylindrical socket 25 of substantial

diameter enters the lower end of the holder 23 and slidably receives a pressure sleeve or ring 26. The pressure ring extends downwardly beyond the end of the holder 23 and may have a plain flat lower surface 27, normal to the longitudinal axis of the tool, for engaging the sheet S. As above described, the surface 27 may be slightly conical or spherical. The outside and inside diameters of the surface 27 substantially conform to the corresponding diameters of the surface 17 of the die holder. The upper end of the pressure ring 26 is spaced from the upper wall of the socket 25.

The punch assembly 11 further includes a punch 28 slidably operable in the opening of the pressure ring 26. The punch 28 is an elongate cylindrical member having an outside diameter substantially equal to the largest diameter of the die recess 18. The lower end of the punch 28 presents an annular frusto-conical surface 29 complementary to the wall of the recess 18 to constitute the shaping or forming surface of the punch assembly. The punch surface 29 may have substantially the same angle as the wall of the opening 18. In this form of the invention a flat annular surface 30, normal to the longitudinal axis of the plunger 28, occurs within the punch surface 29. This annular surface 30 acts on the sheet S in a zone immediately surrounding the opening O to assist in bringing about the forging action to be later described. A central opening or socket 31 extends upwardly from the surface 30 to receive the pilot 20.

In accordance with the invention, the punch assembly 11 is double acting; that is, the pressure pad or ring 26 is first actuated against the sheet S to confine a zone of the sheet around the area to be dimpled and the punch 28 is then actuated to form the dimple while said area or zone remains confined. To accomplish this double action a body 32 of flowable material is provided in the socket 25 to transmit movement and actuating pressures to the ring 26 and punch 28. The upper end of the ring 26 is exposed for full engagement by the material 32 and a head 33 may be provided on the upper end of the punch 28 to present an extensive area for engagement by the material. The head 33 is in the nature of a piston-like flange slidably operating in a counterbore or socket 34 in the upper end of the pressure ring 26. The nature of the material 32 may vary considerably and practically any selected material capable of flowing under pressure may be employed. A stiff grease or similar "semi-liquid" may be used, or a mass of flowable comminuted material may be employed. It is desirable to use a material that has good flow characteristics and that will not break down with extended use. Cured rubber of about 40 Shore hardness may be successfully employed as the actuating material 32. Such material has the ability to return to its normal volume and configuration when relieved of pressure. The body of material 32 preferably completely occupies the socket 25 above the ring 26 and punch head 33. The edge or corner of the pressure ring 26 occurring where the wall of the socket 34 joins the end of the upper ring may be rounded off to permit free flow of the material 32 into the socket.

The method of the invention will be described in connection with the operation of the tool disclosed above. The sheet S previously provided with the opening O is arranged between the die and punch assemblies so as to have the pilot 20 engaged in its opening O. The die and punch means may be employed in individual sets or in gangs. Where a gang of the units is used, a plurality of openings O may be simultaneously dimpled. Figure 1 illustrates the normal or idle positions of the die and punch assemblies and shows the pressure ring 26 spaced clear of the pilot 20 to allow ready engagement of the sheet S on the die assembly. When the sheet S has been properly positioned the machine, with which the die and punch set is associated, is put into operation to produce relative movement between the die and punch assemblies.

When the punch assembly is in its idle condition the body of flowable material 32 holds the pressure ring 26 in the extended position. The initial phase of downward movement of the punch holder 23 brings the lower end of the ring 26 into engagement with the sheet S. This engagement limits the downward travel of the ring and as the holder 23 continues to move downwardly, the material 32 is compressed between the upper wall of the socket 25 and the upper end of the ring 26. The material 32, acting under compression, transmits downward pressure from the holder 23 to the ring 26 and the ring is pressed against the sheet S with considerable force. This results in an annular area of the sheet, spaced around the opening O, being confined or gripped between the end surface 27 of the ring 26 and the end surface 17 of the die holder 12. Figure 2 of the drawings shows the pressure sleeve 26 in its active position in engagement with the sheet S. Continued downward movement of the holder 23 increases the pressure exerted on the annular zone of the sheet surrounding the die recess 18 and while this pressure may reach a high value, it never attains the yield point of the sheet S.

The body of flowable material 32 transmitting the downward pressure for the actuation of the pressure ring 26, as described above, is partially displaced from between the upper end of the ring and the top wall of the socket 25 to flow downwardly into the socket 34. The material 32 displaced into the socket 34 forces the punch 28 downwardly, serving to transmit the downward movement and pressure from the holder 23 directly to the punch. Thus, as the holder 23 travels downwardly, the punch 28 is forcibly moved against the sheet S to form the dimple. The opening 31 receives the pilot 20 as the punch moves downwardly. The punch surface 29, acting in conjunction with the upper surface of the sheet S and the wall of the die recess 18, shapes or forms the dimple. It is to be observed that this forming of the dimple occurs while a substantial annular zone of the sheet S, surrounding the area of the dimple, remains confined or compressed between the pressure ring 26 and the surface 17 of the die holder.

During the forming of the dimple, the portion of the sheet material immediately surrounding the opening O is engaged by the flat end surface 30 of the punch and is pressed against the flat upper end of the forging ram 19. This more or less limited portion of the sheet is gripped between the opposite flat surfaces of the punch and ram to be subjected to compression and forging. The body of yieldable material 22 under the ram piston 21 offers a high resistance to downward movement of the ram, and during the dimple forming phase of the operation, the cooperating surfaces of the punch and ram acting on the limited portion of the sheet material surrounding the opening O, forge the material to counteract the stresses set up by the forming action. As the dimple is shaped or formed, there

is a drawing action tending to stretch the upper section or layer of the material of the dimple. This stretching sets up tensile stresses which, unless counteracted, weaken the material and cause cracks to develop. The forging action of the ram 19 and surface 30 of the punch counteracts or corrects this "drawing" or "thinning" at the mouth of the dimple and produces a radial outward flow of the material in the dimple to effectively counteract substantially all excessive stresses. The forging action also prevents enlargement of the opening O, thinning of the dimple wall, and over stressing of the sheet material at the periphery of the dimple. The radial outward flow of material caused by the forging of the metal supplies material to prevent over stressing and cracking of the sheet at the angle occurring at the mouth of the dimple.

As shown in Figure 3, the ram 19 retracts to some extent during the dimpling and forging operations, but the yieldable material 22 permits such retraction only after the material of the sheet around the opening O has been subjected to the desirable high compression and forging. The tool may be constructed so that the material 22 offers the required degree of resistance to ram movement to adapt the tool for the dimpling of given materials or classes of materials. The resisted retraction of the ram 19 is important as it assures the desirable compression and forging of the material in the dimple and yet allows full action of the die and punch surfaces in the forming of the dimple. The forging action just described is effective in preventing cracking and over stressing of the dimple, even in the case of high strength aluminum alloys which are subject to cracking when conventional dimpling methods are used.

The confining or clamping under pressure of the annular zone of the sheet S immediately surrounding the dimple area prevents stressing of the sheet beyond the dimple itself. It is to be noted that the compressive force exerted on the annular zone of the sheet around the area being dimpled prevents stressing of the sheet itself as a result of the dimple forming action as well as the dimple forging action. The confining or clamping pressure increases with the forming and forging pressures, and when the latter are at their maximum values the clamping pressure is also at its greatest value to effectively resist stressing of the sheet beyond the dimple area. Accordingly, the sheet S is not distorted or warped as a result of the dimpling operation, even in instances where the dimples are formed at openings adjacent the edge of the sheet.

At the completion of the dimpling operation, the punch holder 23 moves upwardly to disengage the punch 28 and pressure ring 26 from the sheet. This frees the sheet S for removal from the tool. Upon such retraction of the punch assembly, the body of elastic material 22 returns to its original configuration restoring the ram 19 to its normal idle position. In a like manner, the pressure ring 26 and punch 28 return to their normal relative positions.

The dimples formed by the tool in Figures 1, 2 and 3 are such that it may be necessary to redrill the openings O to remove the material within the inner margins of the dimples. The form of the invention illustrated in Figure 4 is such that there is no material remaining within the dimple at the completion of the dimple forming operations and the wall of the opening and the inner margin of the dimple coincide. The punch assembly of Figure 4 includes the holder 23, the pressure ring 26 and the body 32 of flowable material all as above described. In this form of the invention the punch 48 slidably operates in the opening of the ring 26 and has a head 49 slidably engaged in the counterbore 34 to be acted upon by the material 32. The lower end of the punch 48 has a frusto-conical surface 50 which operates in conjunction with the recess 18 of the die to form the dimple. We have shown a pilot 51 on the lower end of the punch 48, it being understood that the pilot may be carried by the ram of the die assembly as in Figures 1, 2 and 3. Where the pilot 51 is carried by the punch 48 the surface 50 surrounds the root of the pilot.

The die assembly of Figure 4 includes means whereby the forging pressures may be readily adjusted to adapt the tool for the forming of dimples in sheet materials having different physical characteristics. The die holder is made up of two sections 40 and 41 adjustably threaded together at 42. The holder is generally of the same configuration as the above described holder 12 and carries the ram 52 and the resilient material 22. Shims 43 are preferably engaged between opposing surfaces of the threadedly connected holder sections 40 and 41. The shims 43 may be adjusted in thickness to regulate the initial volume of the resilient body 22 so as to offer the required forging pressure for the particular material being worked upon. A set screw 44, or the equivalent, may be employed to retain the sections 40 and 41 in their relative adjusted positions.

The ram 52 operates in the opening 14 of the die holder to have its upper end exposed for the forging of the metal of the dimple. Where the pilot 51 is carried by the punch 48, a vertical opening 53 enters the upper end of the ram 52 to receive the pilot. The forging surface 54 of the ram is annular and is in surrounding relation to the mouth of the opening 53.

When the machine carrying or embodying the tool of Figure 4 is operated, the pressure ring 26 presses the sheet S against the surface 17 of the die holder to confine or clamp an annular area of the sheet surrounding the zone to be dimpled. As in the previously described form of the invention, this confining of the sheet continues throughout the several phases of the operation and the pressure increases in value as the forming and forging pressures increase. The punch surface 50 and the recess 18 form the dimple and the ram 52 supported or actuated by the yielding material 22 forges the material of the dimple to counteract the effect of the stresses set up therein. It is to be observed that the annular surface 54 of the ram 52 acts upon the material of the dimple immediately surrounding the opening in the sheet. This material is compressed or forged between the ram surface 54 and the lower portion of the punch surface 50. The resultant forging action prevents enlargement of the opening in the sheet, which would otherwise accompany forming of the dimple, and also counteracts the stresses set up in the inner portion of the dimple which might produce cracks in the dimple. The forging action of the opposed ram surface 54 and punch surface 50 also effects an outward material flow in the dimple to counteract stresses in the peripheral portion of the dimple. The forming of the dimple may set up tensile stresses at or ad-

jacent the dimple mouth and the outward material flow produced by the above described forging action prevents cracking of the material at or adjacent the periphery of the dimple. Thus the forging action permits the formation of a sharp dimple devoid of a radius at its periphery.

In Figure 6 we have illustrated a tool in which both the die assembly and the punch assembly embody pressure rings for confining the area of the sheet around the zone to be dimpled. The punch assembly 11 may be the same as in Figures 1, 2 and 3 and corresponding reference numerals are applied to its several parts. The holder 50*a* of the die assembly has a socket 51*a* in its upper end slidably receiving a pressure ring and die member 52*a*. The member 52*a* presents a flat upper surface 53*a* of the same dimensions as the surface 27 of the pressure ring 26 and the die recess 54*a* is formed in the upper end of the pressure ring and die member. A central vertical opening 55 is provided in the member 52*a* and is counterbored from its inner end. The forging ram 56 is slidable in the opening 55 and has a flat upper end surface for the forging operation. A suitable pilot 57 may extend from the upper end of the ram. The ram has a portion of enlarged diameter slidably operating in the counterbore of the opening 55. A body 58 of elastic flowable material is arranged in the bottom of the socket 51*a* to support the member 52*a* and ram 56. The body of material 58 is capable of flowing into the counterbored opening 55 when compressed by downward pressure exerted on the member 52*a*.

In the operation of the tool of Figure 6 the sheet is engaged on the surface 53*a* to have the pilot 57 pass through its opening O and the punch assembly 11 is moved downwardly by the machine. This downward movement brings the pressure ring 26 against the sheet so that an annular zone of the sheet is gripped between the ring and the surface 53*a* of the member 52*a*. As the punch assembly continues to move downwardly, the pressure ring and die member 52*a* retracts slightly under downward pressure and the body of material 58 is obliged to partially flow into the counterbored opening 55. This results in upward relative movement of the ram 56. The forging action is substantially the same as above described and serves to supply material radially in the dimple to counteract stresses therein and to maintain uniform wall thickness throughout the dimple. During the dimple forming and forging phases a substantial annular zone of the sheet S remains confined or gripped between the surfaces 27 and 53 to prevent stresses from developing in the sheet S outside of the dimple itself. Accordingly, there can be no warping or deformation of the sheet as a result of the dimpling operation.

Having described only typical forms of the invention, we do not wish to be limited to the specific details herein set forth, but wish to reserve to ourselves any variations or modifications that may appear to those skilled in the art or fall within the scope of the following claims.

We claim:

1. A dimpling tool comprising two elements, one a die assembly the other a punch assembly, one element being movable toward the other, the die assembly having a work engaging surface and a dimple depression, a punch on the punch assembly for forming a dimple in said depression and having a forging surface for engaging the work within the dimple, a yieldingly supported ram on the die assembly opposing the forging surface whereby the material at the inner margin of the dimple is forged, and a pressure member on the punch assembly for clamping the work against said surface to resist flow of the material of the work in the area around the dimple during the forming of the dimple and the forging of said material.

2. A tool for forming a dimple around an opening in a work piece comprising two units related for relative movement, one a die having a dimple recess, the other a punch assembly including a dimple forming punch operable in conjunction with said recess to form a dimple in the work piece around said opening, means on the units for clamping an area of the work piece around the dimple to resist flow of the material of the work piece in said area while the dimple is being formed, and means on the die and punch for forging the material of the work piece immediately surrounding said opening during the forming of the dimple, the last named means including a yieldingly supported ram carried by the die for acting on the work piece around said opening.

3. A tool for forming a dimple around an opening in a work piece comprising two units related for relative movement, one a die having a dimple recess, the other a punch assembly including a dimple forming punch operable in conjunction with said recess to form a dimple in the work piece around said opening, means on the units for clamping an area of the work piece around the dimple to resist flow of the material of the work piece in said area while the dimple is being formed, and means on the die and punch for forging the material of the work piece immediately surrounding said opening during the forming of the dimple, the last named means including a forging surface on the punch for acting on the work piece, and a yieldingly supported ram carried by the die and opposing said forging surface.

4. A tool for forming a dimple around an opening in a work piece comprising two units related for relative movement, one a die having a dimple recess, the other a punch assembly including a dimple forming punch operable in conjunction with said recess to form a dimple in the work piece spaced around said opening, means for forging the material of the work piece immediately surrounding the opening during the forming of the dimple to counteract the stresses set up in the dimple, said means including a surface on the punch and a yieldingly supported ram carried by the die, said punch surface and ram being engageable with the opposite surfaces of the work piece around the opening, and a pressure pad on one unit for clamping the zone of the work piece surrounding the area being dimpled against the other unit to prevent stressing of the work piece around the dimple.

5. A dimpling tool for forming a dimple in a work piece having an opening comprising relatively movable die and punch assemblies having surfaces for forming a dimple in the work piece spaced around said opening upon movement of one assembly toward the other, work piece engaging parts on the assemblies for forging the material of the portion of the work piece being dimpled and which immediately surrounds said opening during substantially the entire period of forming of the dimple to counteract the effect of the stresses set up in the dimple and to prevent enlargement of the opening as a result of

said forming of the dimple, yieldable means mounting at least one of said work piece engaging parts on its respective assembly, and means on the assemblies for acting on the work piece in a zone surrounding the area being dimpled to prevent stressing of the work piece as a result of said forming of the dimple and said forging of the material surrounding the openings.

6. A dimpling tool for forming a dimple in a work piece having an opening comprising relatively movable die and punch assemblies having surfaces for forming a dimple in the work piece around said opening upon movement of one assembly toward the other, parts on the assemblies for acting on and forging the inner portion of the work piece being dimpled which immediately surrounds said opening during substantially the entire action of the die and punch in forming the dimple to counteract the stresses set up in the dimple and to prevent enlargement of the opening as a result of said forming of the dimple, a yieldable element for transmitting force between at least one of said assemblies and its said part, and means on the assemblies for acting on the work piece in a zone surrounding the area being dimpled to prevent stressing of the work piece as a result of said forming of the dimple and said forging of the material, the last named means comprising a yieldingly supported pressure ring on one assembly for pressing the work piece against the other assembly.

7. A dimpling tool for forming a dimple in a work piece having an opening comprising relatively movable die and punch assemblies having surfaces for forming a dimple in the work piece around said opening upon movement of one assembly toward the other, parts on the assembles for acting on and forging the inner portion of the work piece being dimpled which immediately surrounds said opening during substantially the entire action of the die and punch in forming the dimple to counteract the stresses set up in the dimple and to prevent enlargement of the opening as a result of said forming of the dimple, yieldable elements for transmitting force between said assemblies and their respective forging parts, and means on the assemblies for acting on the work piece in a zone surrounding the area being dimpled to prevent stressing of the work piece as a result of said forming of the dimple and said forging of the material, the last named means comprising opposing yieldingly supported pressure members on the assemblies for pressing against the opposite sides of said zone.

8. A dimpling tool for forming a dimple in a work piece having an opening comprising relatively movable die and punch assemblies having surfaces for forming a dimple in the work piece around said opening upon movement of one assembly toward the other, means on the assemblies for forging the material of the work piece immediately surrounding said opening to counteract the stresses set up in the dimple and to prevent enlargement of the opening as a result of said forming of the dimple, said means including a surface portion on one assembly for acting upon one side of the work piece around said opening, a ram carried by the other assembly for acting upon the other side of the work piece around said opening, and means yieldingly resisting movement of said ram relative to said other assembly, and means on the assemblies for acting on the work piece in a zone surrounding the area being dimpled to prevent stressing of the work piece as a result of said forming of the dimple and said forging of the material surrounding the opening.

9. A dimpling tool for forming a dimple in a work piece having an opening comprising relatively movable die and punch assemblies having surfaces for forming a dimple in the work piece spaced around said opening upon movement of one assembly toward the other, means on the assemblies for forging the material of the work piece immediately surrounding said opening to counteract the stresses set up in the dimple and to prevent enlargement of the opening as a result of said forming of the dimple, said means including a surface portion on one assembly for acting upon one side of the work piece around said opening, a ram carried by the other assembly for acting upon the other side of the work piece around said opening, and resilient means yieldingly resisting movement of said ram relative to said other assembly, and means on the assemblies for acting on the work piece in a zone surrounding the area being dimpled to prevent stressing of the work piece as a result of said forming of the dimple and said forging of the material surrounding the opening.

10. A dimpling tool for forming a dimple in a work piece having an opening comprising relatively movable die and punch assemblies having surfaces for forming a dimple in the work piece spaced around said opening upon movement of one assembly toward the other, means on the assemblies for forging the material of the work piece immediately surrounding said opening to counteract the stresses set up in the dimple and to prevent enlargement of the opening as a result of said forming of the dimple, said means including a surface portion on one assembly for acting upon one side of the work piece around said opening, a ram carried by the other assembly for acting upon the other side of the work piece around said opening, and resilient means yieldingly resisting movement of said ram relative to said other assembly, and means on the assemblies for acting on the work piece in a zone surrounding the area being dimpled to prevent stressing of the work piece as a result of said forming of the dimple and said forging of the material surrounding the opening.

11. A dimpling tool for forming a dimple in a work piece having an opening comprising relatively movable die and punch assemblies having surfaces for forming a dimple in the work piece spaced around said opening upon movement of one assembly toward the other, means on the assemblies for forging the material of the work piece immediately surrounding said opening to counteract the stresses set up in the dimple and to prevent enlargement of the opening as a result of said forming of the dimple, said means including a movable ram carried by one assembly for acting on one side of the work piece around said opening and opposing the dimple forming surface of the other assembly, yielding means for resisting movement of the ram in a direction away from the work piece, and means for adjusting the resistance offered by the yielding means, and means on the assemblies for acting on the work piece in a zone surrounding the area being dimpled to prevent stressing of the work piece as a result of said forming of the dimple and said forging of the material surrounding the opening.

12. A dimpling tool for forming a dimple in a work piece having an opening comprising relatively movable die and punch assemblies having

surfaces for forming a dimple in the work piece spaced around said opening upon movement of one assembly toward the other and means on the assemblies for forging the material of the work piece immediately surrounding said opening to counteract the stresses set up in the dimple and to prevent enlargement of the opening as a result of said forming of the dimple, said means including a movable ram carried by one assembly for acting on one side of the work piece around said opening and opposing the dimple forming surface of the other assembly, yielding means for resisting movement of the ram in a direction away from the work piece, and means on the assemblies for acting on the work piece in a zone surrounding the area being dimpled to prevent stressing of the work piece as a result of said forming of the dimple and said forging of the material surrounding the opening.

13. The method of dimpling a work piece which comprises resisting material flow in the work piece in directions outwardly from the area thereof to be dimpled by clamping an annular zone of the work piece around the area to be dimpled, then acting on the outer portion of said area to shape a dimple therein while said zone is thus confined, and acting on the inner portion of said area to forge the material thereof and cause a radially outward material flow in said area during at least the initial and major phases of said shaping of the dimple.

14. The method of dimpling a work piece which comprises the steps of acting on an annular area of the work piece to shape a dimple therein, reducing stressing of said annular area by forging the material of the inner portion of said area during at least the major phases of shaping of the dimple to cause a radially outward material flow in said area, and counteracting stressing of the work piece around said area as a result of said shaping and forging by clamping a zone of the work piece around said area during said shaping and forging to resist material flow therein.

15. The method of dimpling a work piece having an opening which comprises dimpling an annular area of the work piece around said opening by acting on said area with forming tools, acting on the portion of said area which immediately surrounds said opening with forging tools during at least the initial and major phases of said dimpling of said area to cause radially outward material flow in the area being dimpled, and resisting material flow in the work piece around said area as a result of said dimpling and forging by subjecting the work piece around said area to compressive forces during said dimpling and forging.

16. The method of dimpling a work piece having an opening which comprises resisting material flow in the work piece in directions outwardly from the area around the opening and which is to be dimpled by subjecting an annular zone of the work piece around said area to compressive forces, then forming a dimple in said area around said opening by acting on said area with forming tools while said compressive forces are maintained on said annular zone, and acting on the portion of said area immediately contiguous to said opening, during substantially the entire step of forming the dimple, to forge the material in said portion and cause a radially outward material flow in said area being dimpled.

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