METHOD OF MAKING A CAN END

Filed June 22, 1967 2 Sheets-Sheet 1

Fig. 1

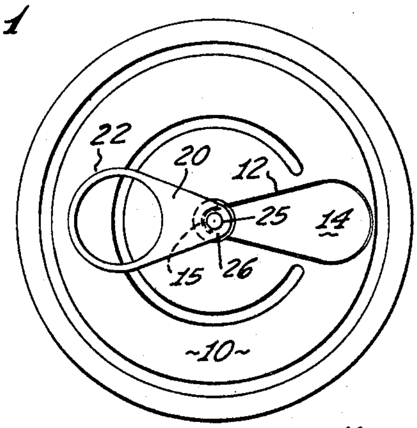

Fig. 2

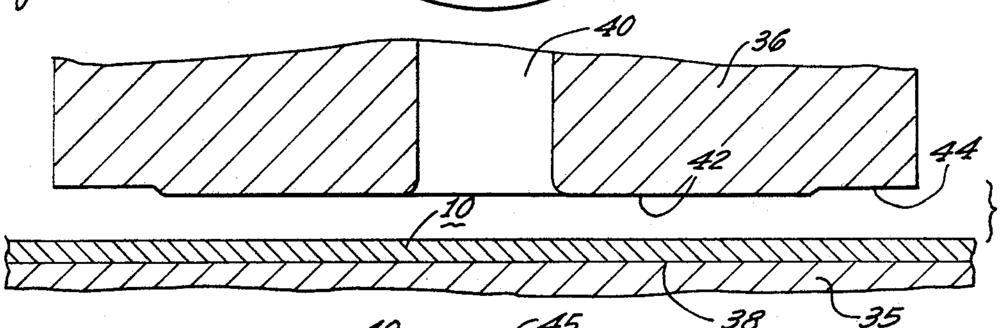

Fig. 3

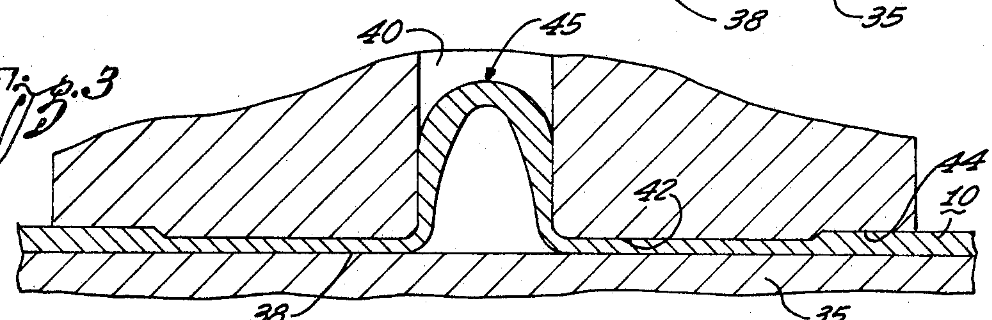

Fig. 4

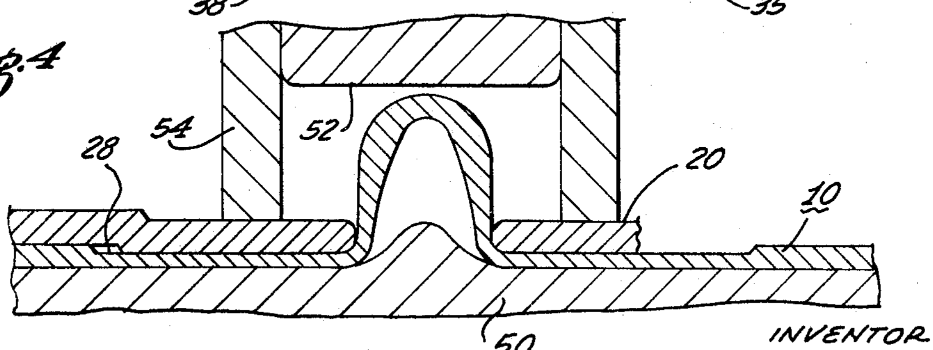

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Fig. 5

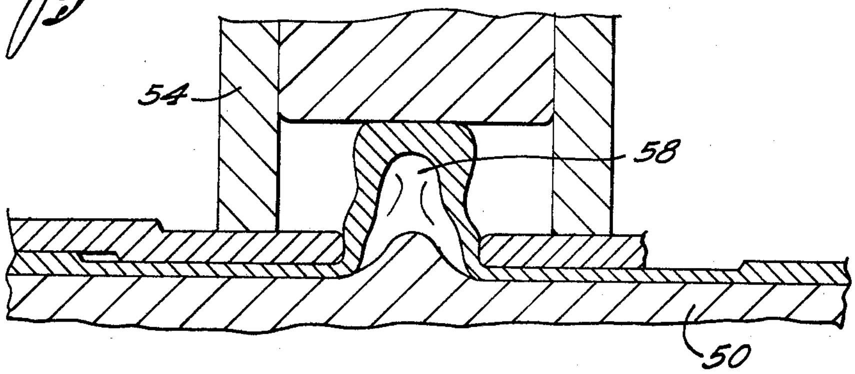


Fig. 6

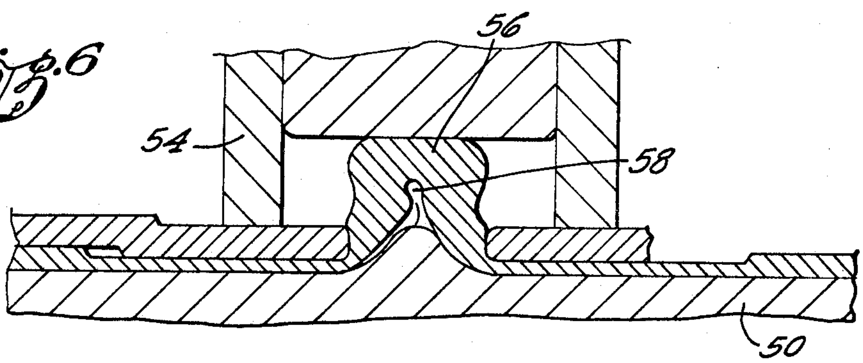
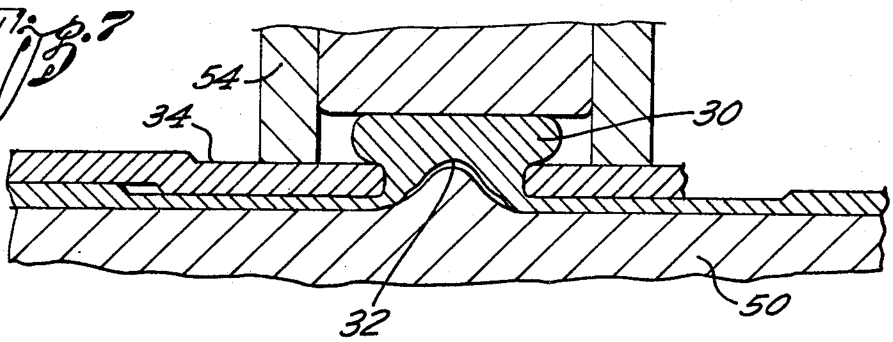


Fig. 7



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METHOD OF MAKING A CAN END

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U.S. Cl. 29—509 18 Claims

ABSTRACT OF THE DISCLOSURE

The invention relates to a method of forming a rivet in a tear strip of a can end integrally of the tear strip with the rivet extending through an aperture of a pull tab in overlapping engagement with the pull tab for anchorage of the pull tab to the can end. The rivet is initially formed by coining or squeezing the sheet material of the tear strip across its thickness in an annular zone with consequent extrusion of the sheet material radially inwardly of the annular zone.

Background of the invention

Broadly described the invention relates to a method of forming a joint between two members of deformable sheet material positioned face-to-face wherein one member has an aperture and a rivet of a preliminary hollow configuration is formed in the other member and then positioned to extend through the aperture of the one member, the final operation being to stake the preliminary rivet to form the final headed rivet.

The first commercially successful method of forming such a rivet in the tear strip of an easy opening can is set forth in the Fraze Patent 3,191,564. This method is characterized by the steps of, first, forming a dimple in the sheet metal of the tear strip of substantially larger than the desired rivet, second, reshaping the dimple to form a preliminary rivet of the cross section of the shank of the desired rivet, and, finally, staking the rivet to form the final rivet configuration. The staking operation is carried out by inserting a die into the hollow rivet to serve as an anvil and by then applying an axial impact force against the outer end of the preliminary rivet to squeeze and spread the transverse end wall of the rivet to form the head or bead of the final rivet.

As initially fabricated in mass production the shank of the Fraze rivet was of a diameter of approximately ¼", and since the rivet is employed at the leading end of the tear strip, the width of the leading end of the tear strip had to be greater than ¼". The initial function of the pull tab is to apply force to the leading end of the tear strip to initiate the rupture of the sheet metal and it was found that an excessive amount of force is required if the leading end of the tear strip is as wide as it must be to accommodate a rivet as large as ¼" in diameter.

The shank diameter of the Fraze rivet was then reduced to the minimum which is approximately ⅛". In the meantime another method of forming such a rivet of a shank diameter as small as ⅛" was developed as set forth in my copending application entitled "Metal Forming," Ser. No. 464,909, filed June 18, 1965.

The method of rivet formation set forth in my copending application is characterized by the forming of what may be termed a preliminary hollow rivet in one step by coining or squeezing the sheet material of the tear strip across its thickness in an annular zone to cause the formation of the preliminary rivet by extrusion of the sheet material radially inwardly of the annular coining zone. The resulting hollow preliminary rivet is then stacked in the same general manner as the Fraze rivet by employing an anvil die inside the hollow rivet in cooperation with an outer impact die to squeeze the transverse end wall of the rivet.

The reduction of the shank diameter to approximately ⅛" by both of these prior rivet forming methods makes possible corresponding reduction in the width of the leading end of the tear strip but the magnitude of the force required to initiate rupture of the metal is still too high and the problem is presented of still further reducing the diameter of the rivet.

It has been found that there are two inherent limitations in both of these prior art methods that preclude the production of a rivet of acceptable strength and reliability with a shank diameter substantially less than ⅛".

In the first place, the rivet must be hollow to permit the insertion of the anvil die for the staking operation the result being that the final rivet has a substantial void extending from the root end of the rivet throughout the length of the shank of the rivet and into the interior of the head of the rivet. Such a void has a disproportionate weakening effect when the rivet is greatly reduced in scale.

In the second place, the staking techniques employed in both of the rivet forming methods requires that the height of the preliminary rivet be limited to substantially the height of the final staked rivet. It has been found that adequate strength in a rivet of a shank diameter substantially smaller than ⅛" requires a great deal more material than is found in a preliminary hollow rivet that is substantially no higher than the height of the final staked rivet.

The present invention surmounts these two limitations by eliminating the necessity for insertion of an anvil into the preliminary rivet and by further teaching a staking technique that is applicable to an extruded preliminary rivet of a height that greatly exceeds the height of the desired final rivet configuration.

Summary of the invention

The invention is based on the discovery that increasing the extrusion of the metal to produce a preliminary rivet substantially higher than the desired final rivet, for example as much as twice as high, to provide a corresponding increase in material available for the final rivet results inherently in a preliminary rivet of a character that may be transformed into the desired greatly shortened staked configuration by the simple application of an axial impact force without the necessity of supporting the rivet internally. This discovery is surprising because at first thought it would seem that abruptly axially compressing such an elongated preliminary hollow rivet would simply squash the hollow rivet and spread the metal unduly to produce a final rivet having a head of excessive diameter on a weak shank.

The desired behavior of the elongated bubble in response to the axial impact force is explained by the fact that the longitudinal cross section of the elongated bubble is that of an inverted U with the two legs of the U diverging and with the metal tapering in thickness towards the two ends of the two legs, i.e., towards the root end of the rivet, the interior of the rivet flaring towards the root end. Thus the inner circumferential wall of the rivet inclines slightly inwardly to overhang the hollow interior of the rivet.

The fact that the metal wall of the preliminary rivet is of maximum thickness towards the outer end of the elongated configuration provides a solid body of metal to meet the impact force with consequent initial retardation of the spreading of the outer end of the preliminary rivet by the impact force. The progressive accumulation of metal in the shank region during the impact stroke progressively increases the resistance to axial displacement of metal into the shank region, however, with the desirable result that the radial spreading of the metal to form the final rivet head is accelerated at the end of the impact stroke. A further important result of the liberal provision of metal at the outer end of the greatly elongated preliminary rivet is that the resulting head of the staked rivet is solid metal instead of being formed by folded metal or being formed by a hollow circumferential bead.

The significance of the downward flare of the interior of the preliminary rivet is that the axial impact force tends to collapse the peripheral wall of the rivet radially inwardly. Thus the metal displace by the axial impact force is directed towards the interior of the preliminary rivet as the preliminary rivet progressively approaches the final staked configuration.

The axially applied impact force actually results in three kinds of metal displacement simultaneously, namely: radially outward flow at the outer end of the preliminary rivet to produce the final rivet head configuration; radially inward flow in the shank region below the progressively forming head to diminish the initial void in the rivet; and longitudinal or axial flow into the shank region of the final rivet configuration for further reduction of the initial void. The final result is a rivet in which the volume of metal greatly exceeds the volume of the void to result in a rivet as strong or stronger than conventional hollow rivets of larger diameter.

The degree to which the process approaches the creation of a solid metal rivet depends, of course, on the volume of metal that is extruded relative to the final overall rivet configuration and one factor which enters into the determination of this volume is the degree to which the sheet metal is thinned by the coining operation and another factor is the ratio between the outside diameter and the inside diameter of the annular coined area. Values for these two factors for different kinds of metal are selected to provide the elongation of the preliminary rivet that distinguishes the present invention from the prior art.

Brief description of the drawings

In the drawings, which are to be regarded as merely illustrative:

FIG. 1 is a plan view of a can end incorporating a preferred embodiment of the present invention;

FIG. 2 is a fragmentary sectional view on a larger scale showing a pair of coining dies ready to carry out the operation of extruding the metal to form the elongated preliminary rivet;

FIG. 3 is a similar view showing the completion of the rivet-forming extrusion operation;

FIG. 4 is a similar view showing a pair of staking dies ready to apply axial force to convert the preliminary rivet into the final rivet configuration;

FIG. 5 is a view similar to FIG. 4 showing the staking dies at an early stage in the staking operation;

FIG. 6 is a similar view showing the staking dies at a later stage in the staking operation; and

FIG. 7 shows the two staking dies at the completion of the staking operation.

Description of the preferred embodiment

The single embodiment of the invention selected for the present disclosure is by way of example only, it being understood that the factors involved may be widely varied within the scope of the underlying inventive concept.

FIG. 1 is a plan view of a can end or top **10** of a well known construction in which a continuous line of scoring **12** defines a tear strip **14** that tapers to a narrow leading end **15**. In a well known manner, the can end is offset to form an arcuate rib **16** to minimize the buckling of the sheet metal by the scoring operation.

A pull tab **20** having a ring-shaped handle **22** is attached to the leading end **15** of the tear strip **14** by a staked rivet **25** and the greatly reduced width of the leading end of the tear strip is made possible by the fact that the shank of the staked rivet is of a diameter substantially less than ⅛".

The base or root end of the shank of the rivet is surrounded by an annular coined zone **26** where the can top has been squeezed across its thickness to extrude the metal that forms the rivet. Preferably, as best shown in FIG. 4, the pull tab **20** is formed with an annular offset **28** which is dimensioned to seat in the annular coined zone **26** thereby to permit the tab to lie close against the coined metal.

In this particular embodiment of the invention, the final staked rivet has the overall configuration shown in FIG. 7. By overall configuration is meant the profile configuration, any void in the rivet being ignored. The final rivet shown in FIG. 7 is characterized by a rivet head **30** that is of solid metal over its entire transverse cross section. The rivet is further characterized by a relatively small void **32** of generally conical configuration at the root end of the shank of the rivet. In this instance the axial extent of the small void **32** falls short of the shear plane that is defined by the outer surface **34** of the surrounding portion of the pull tab **20** and therefore the shank of the rivet is of solid metal in that shear plane. It is apparent, however, that the conical void may actually intercept this shear plane without unduly weakening the rivet. For example, if the diameter of the void at the shear plane is as large as ⅓ of the diameter of the shank, over 85% of the cross section of the shank at the shear plane will be solid metal.

The first step in the fabrication of the rivet for attaching the pull tab **20** to the tear strip **14** is illustrated by FIGS. 2–4 wherein a lower die **35** supports the can top **10** and an upper coining die **36** cooperates with the lower die to extrude the metal to form a preliminary rivet. In this instance the lower die has a planar working face **38** but, as taught by my co-pending application, this working face need not be entirely planar. The upper die **36** has a central cylindrical cavity **40** surrounded by by an annular working face **42**, the working face being advanced or offset from a surrounding die face **44**. Preferably as may be seen in FIG. 3, the annular working face **42** is offset from the surrounding die face **44** in accord with the exact degree to which the metal is to be thinned by the coining operation so that at the end of the coining operation the outer die face **44** firmly abuts the adjacent portion of the pull tab that lies outside of the coined area.

It will be obvious to those skilled in the art that the thinning of the metal of the can top may be accomplished by depressing the lower face of the can top instead of the upper face or by depressing both faces of the can top simultaneously.

As shown in FIGS. 3 and 4, the result of the radial extrusion of the metal by the coining operation is the formation of a preliminary rivet **45**, the axial dimension of the preliminary rivet relative to its diameter being much greater than taught by the prior art. In the disclosure of my copending application, the axial dimension of the preliminary rivet is substantially less than its outside diameter whereas in FIG. 3 the axial dimension of the preliminary rivet **45** is substantially more than its outside diameter. It is the additional metal gained by the added height of the preliminary rivet that makes possible the degree to which the final rivet approaches a solid metal structure.

The second and final step is the stacking of the preliminary rivet in the manner shown in FIGS. 4 to 7 by a lower supporting die **50** and an upper impact die **52** in cooperation with an annular pressure pad **54**. The pressure pad holds the pull tab **20** snug against the coined zone of the can top **10** with ample space inside the pressure pad for radial expansion of the head portion of the preliminary rivet as the impact die descends to form the final rivet configuration.

The previously mentioned conical void **32** in the root end of the rivet shank is created by slightly curtailing the volume of extruded metal relative to the overall volume of the final rivet configuration and preferably by further providing the lower supporting die **50** with a conical forming boss **55**. It has been found that such a conical void close to the level of the surrounding portion of the can top does not unduly weaken the rivet and obviously the permissible void desirably reduces the volume of metal that must be extruded to form the rivet.

A further and important advantage of providing the conical forming boss **55** is that the boss cooperates with the surrounding circumferential wall of the aperture of the pull tab **20** to restrict the path of radially outward flow from the rivet configuration into the surrounding coined zone of the can top as the impact die completes the formation of the final rivet.

In those instances where greater strength is desired in the root end of the rivet shank, the forming boss **55** may be omitted and more metal may be extruded to result in a substantially solid metal staked rivet. In such an instance the pressure exerted by the pressure pad **54** may be raised to a sufficient magnitude to prevent any significant reverse radial flow of metal into the annular coined zone as the upper impact die approaches the end of its stroke.

Comparison of FIG. 5 with FIG. 4 shows how the effect of the initial impact of the upper die tends to buckle the circumferential wall of the preliminary rivet radially inwardly because of the downwardly flared internal configuration of the rivet. Concurrently with the inward buckling effect of the impact die is the effect of the impact die in crowding the metal downwardly to thicken the circumferential wall of the rivet. As indicated in FIG. 6, the combined result of these two simultaneous effects is that the circumferential wall of the rivet "grows" in thickness radially inward towards the axis of the rivet and at the same time the transverse end wall **56** "grows" in thickness. Thus the stage of the rivet-forming operation represented by FIGS. 5 and 6 is characterized by progressive radial and longitudinal shrinking of the initial axial void **58**.

In the final stage of the staking operation represented by FIGS. 6 and 7 the axial void **58** shrinks towards the final configuration of the conical void **32**. At the same time the accumulation of metal in the shank region of the rivet abruptly increases the resistance to metal flow into that region with consequent desirable final acceleration of the radial spreading of the metal to form the final rivet head **30**.

Generalizations for guidance in practicing the invention may be made by expressing the volume of metal extruded into the die cavity **40** in terms of multiples of the thickness of the sheet metal stock of the can top. A disk of this thickness and of the diameter of the initial rivet is initially available in the rivet area for the formation of the preliminary rivet and the volume of additional metal to be extruded into the rivet area for completion of the rivet may be expressed in terms of a number of additional disks of the thickness of the sheet metal stock.

For example, a final rivet of the general overall configuration shown in FIG. 7 may be analyzed in terms of stock thickness as follows: a solid cylinder of the diameter of the rivet shank and of the overall axial dimension of the finished rivet may be in a particular instance equivalent to 3.4 thicknesses of the sheet metal stock. The peripheral bead of the final rivet head may be, for example, equivalent to one additional thickness to give a total requirement of 4.4 thicknesses for a solid rivet of the final overall configuration. Since one thickness of metal already exists in the rivet area, the metal to be extruded to form the solid rivet is equivalent to 3.4 thicknesses. If the forming boss **55** is employed to provide the conical void **32** in the root end of the rivet shank, the amount of metal may be reduced by approximately ⅔ of a thickness to reduce the total extrusion requirement to a

volume equivalent to 2.75 thicknesses of the sheet metal stock.

As heretofore indicated, two of the factors in the extrusion operation that determine the number of thicknesses or sheet metal stock that are added to the initial thickness in the rivet area are the ratio between the outside diameter and the inside diameter of the annular coined area and the percentage of reduction of the stock thickness by the coining operation. The wide range of choice that may be made in the magnitudes of these two factors may be understood from the following theoretical tabulation:

Ratio of the outside diameter of the annular coined zone to the diameter of the preliminary rivet	Ratio of the area of the coined zone to the area of the preliminary rivet	Percent of reduction of the stock thickness in the annular coined zone to extrude 3.4 thicknesses of metal to produce a solid rivet of a configuration shown in Fig. 7 without a conical void in the root end of the rivet	Percent of reduction of the stock thickness in the annular coined zone to extrude 2.75 thicknesses of metal to produce a rivet of the configuration shown in Fig. 7 with the conical void in the root end of the rivet shank
2.5:1	5.25	65% (residual 35%)	52% (residual 48%).
3:1	8.0	42% (residual 58%)	34% (residual 66%).
4:1	14.8	23% (residual 77%)	18% (residual 82%).
5:1	23.7	15% (residual 85%)	12% (residual 88%).

The first consideration in deciding the values to be selected for these two factors is the minimum residual thickness in the annular coined zone that is necessary for adequate strength of the can top. When this consideration is determined, there is a wide choice of ratios for extruding the required volume of metal without thinning the metal beyond the permitted limit. Which ratio is used is a matter of judgment based on the properties of the particular metal that is used for the can top. The properties of the metal may permit a long path of radially inward metal flow with relatively light coining of the sheet metal or on the other hand may permit a shorter path with deeper coining to extrude the same amount of metal. In all instances, however, the practice of the invention will be distinguished from the disclosure of my co-pending application by the height of the preliminary rivet being substantially greater than the height of the final rivet configuration and by the ratio of the height of the preliminary rivet to its diameter being at least 0.75 and preferably at least approximately 1.00. In all instances the volume of metal in the preliminary rivet will be more than 50% of the volume of the overall configuration of the final staked rivet. Preferably the final rivet is at least 75% metal and in the example shown in FIG. 7 where the rivet is solid metal except for the small conical void, the final rivet is approximately 85% metal. In addition, as heretofore pointed out, the new rivet has a solid metal head and is at least largely solid metal across the shear plane immediately below the rivet head.

Up to this point, the only factors that have been considered with reference to the magnitude of the rivet extrusion are the ratio between the outside diameter and the inside diameter of the annular coined area and the percentage of reduction of the stock thickness by the coining operation. A third factor, however, arises from the fact that the coining operation not only extrudes metal radially inwardly to form the preliminary rivet but also extrudes metal radially outward to thicken the surrounding sheet metal stock. The third factor, then, is the percentage of the extrusion that is radially inward.

The percentage of the extrusion that is radially inward varies with the properties of the sheet metal, the degree to which the sheet metal is thinner by the coining operation, the inside diameter of the coined area, and the ratio between the outside diameter and the inside diameter of the coined area. As for the inside diameter of the coined area, i.e. the diameter of the extruded rivet, more work is required to extrude a given volume of metal into a die cavity of small diameter than is required to force the given volume into a die cavity of larger diameter. Thus if the inside diameter of the coined area is reduced to a relatively small dimension, either the degree of coining of the metal or the outside diameter of the coined area must be increased to avoid reducing the volume of metal that is extruded to form the hollow rivet.

As for the ratio between the outside diameter and the inside diameter of the coined area, it has been found that up to a certain point increasing the ratio increases the volume of extruded metal but beyond that point the extruded volume drops. Thus for a particular metal coined to a particular degree, there is an optimum ratio between the outside diameter and the inside diameter of the annular coined area. In a series of tests with an aluminum alloy of the character that is commonly employed for can lids wherein the inside diameter of the coined area was 1/16" to produce a preliminary of 1/16" diameter, and the metal was reduced in thickness by 42% from a starting thickness of .0146, the optimum ratio of the outside diameter to the inside diameter of the annular coined area was found to be 4.6:1. At this optimum ratio of the height of the extruded preliminary rivet was .075 but when the ratio was reduced to 4.4:1 the height was reduced to .063 and when the ratio was increased to 4.8:1 the height was reduced to .072.

In a second series of tests where the sheet metal was reduced in thickness by 38% from a starting thickness of .0088 it was found that the optimum ratio was again 4.6:1, the height of the extruded rivet being .066. Reducing the ratio to 4.4:1 reduced the height of the extruded rivet to .057 and increasing the ratio to 4.8:1 reduced the height of the extruded rivet to .064.

My description in specific detail of the selected embodiment of the invention will suggest various changes, substitutions and other departures from any disclosure within the spirit and scope of the appended claims.

I claim:

1. In the process of forming a rivet of a given final overall configuration in a first member of sheet material with the shank of the rivet extending through an aperture of a second member and with the head of the rivet engaging the outer surface of the second member for anchoring the second member to the first member,

which process includes the step of squeezing the sheet material of the first member across its thickness in a zone of generally annular configuration to extrude the sheet material radially inwardly of the annular zone into a central axially extending space to form a hollow preliminary rivet of substantially the diameter of the shank of the final rivet configuration,

and which process includes the later steps of positioning the preliminary rivet in the aperture of the second membe and then deforming the preliminary rivet to form the final rivet in engagement with the second member,

the improvement comprising:

selecting the dimension for the annular zone and the degree to which the sheet material is to be squeezed to leave a residual thickness in the annular zone adequate for the required strength for the first member and to extrude sufficient material to form a hollow preliminary rivet of substantially greater axial dimension than said final configuration and having an axial dimension equal to at least approximately 75% of its diameter and comprising a volume of solid material equivalent to substantially more than 50% of the volume of said given final overall configuration; and

reforming the hollow preliminary rivet to said final configuration by applying axial force to the outer end of the preliminary rivet while the preliminary rivet extends through said aperture without internally supporting the hollow preliminary rivet against axial compression thereby reducing the void in the hollow preliminary rivet and displacing material into the shank region of the final configuration to add strength to the shank of the final rivet and to form a substantially solid rivet head in engagement with the second member.

2. An improvement as set forth in claim 1 in which the outside diameter of the annular zone relative to the inside diameter and the degree to which the sheet material is squeezed are selected to form a hollow preliminary rivet of an axial dimension at least as large as its diameter.

3. An improvement as set forth in claim 1 in which the outside diameter of the annular zone relative to its inside diameter and the degree to which the sheet materail is squeezed are selected to form a hollow preliminary rivet of an axial dimension substantially greater than its diameter.

4. An improvement as set forth in claim 1 in which the sheet material of said first member is of a given stock thickness and in which the ratio between the outside diameter and the inside diameter of the annular zone is at least 2.0 and the degree to which the metal is squeezed in the annular zone is sufficient to extrude a volume of material equivalent to a solid cylinder of the diameter of the shank of the final rivet configuration and of an axial dimension at least as great as twice the given stock thickness.

5. An improvement as set forth in claim 4 in which said ratio and said degree are sufficient to extrude material equivalent to a solid cylinder of the diameter of the shank of the final rivet configuration and of an axial dimension between 2 and 3.5 times the given stock thickness.

6. An improvement as set forth in claim 1 in which the diameter of the preliminary rivet is substantially 1/16" and the ratio between the outside diameter and the inside diameter of the annular zone is between 3.4:1 and 6.0:1.

7. An improvement as set forth in claim 1 in which the diameter of the preliminary rivet is substantially 1/8" and the ratio between the outside diameter and the inside diameter of the annular zone is between 2 and 3.

8. In the process of forming a rivet of a given final overall configuration in the first member of sheet material with the shank of the rivet extending through an aperture of a second member and with the head of the rivet engaging the outer surface of the second member for anchoring the second member to the first member,

which process includes the step of squeezing the sheet material of the first member across its thickness in a zone of generally annular configuration to extrude the sheet material radially inwardly of the annular zone into a central axially extending space to form a hollow preliminary rivet of substantially the diameter of the sank of the final rivet configuration,

and which process further includes the later steps of positioning the preliminary rivet in the aperture of the second member and then deforming the preliminary rivet to form the final rivet in engagement with the second member,

the improvement comprising:

selecting the dimension for the annular zone and the degree to which the sheet material is to be squeezed to leave a residual thickness in the annular zone adequate for the required strength for the first member and to extrude sufficient material to form a preliminary rivet of substantially greater axial dimension than said final configuration and having a large axial void and having an axial dimension at least as great as approximately 75% of its diameter and to give the preliminary rivet the longitudinal cross-sectional configuration of an inverted U with the thickness of the two legs of the U tapering towards the ends of the legs and with the interior configuration of the preliminary rivet progressively increasing in diameter towards the root region of the rivet sank with the inner circumferential wall of the preliminary rivet overhanging the interior of the rivet;

applying an axial impact force directed against the outer end of the preliminary rivet to reduce the axial dimension of the preliminary rivet without internally supporting the preliminary rivet against axial compression for the purpose of deforming the rivet into engagement with the second member to simultaneously cause three kinds of flow of the material of the preliminary rivet, namely:

radially inward flow into the axial void;

axial flow into the axial void combining with the radially inward flow to thicken the circumferential wall to diminish the volume of the void in the shank of the final rivet configuration; and

radially outward flow of material at the outer end of the axially diminishing rivet to form the head of the final rivet configuration.

9. An improvement as set forth in claim **8** in which the outside diameter of the annular zone relative to the inside diameter and the degree to which the sheet material is squeezed are selected to form a hollow preliminary rivet of an axial dimension at least as large as approximately 75% of its diameter.

10. An improvement as set forth in claim **8** in which the outside diameter of the annular zone relative to its inside diameter and the degree to which the sheet material is squeezed are selected to form a hollow preliminary rivet of an axial dimension at least as large as approximately its diameter.

11. An improvement as set forth in claim **8** in which the sheet material of said first member is of a given stock thickness and in which the ratio between the outside diameter and the inside diameter of the annular zone is at least 2.5 and the degree to which the metal is squeezed in the annular zone is sufficient to extrude a volume of material equivalent to a solid cylinder of the diameter of the shank of the final rivet configuration and of an axial dimension at least as great as twice the given stock thickness.

12. In the process of forming a hollow rivet of a given overall configuration in a first member of sheet material of a given stock thickness with the shank of the rivet extending through an aperture of a second member and with the head of the rivet engaging the outer surface of the second member for anchoring the second member to the first member,

which process includes the step of squeezing the sheet material of the first member across its thickness to a residual thickness in a zone of generally annular configuration to extrude the sheet material radially inwardly of the annular zone into a central axially extending space to form a hollow preliminary rivet of substantially the diameter of the shank of the final rivet configuration,

and which process includes the later steps of positioning the preliminary rivet in the aperture of the second member and then deforming the preliminary rivet to form the final rivet in engagement with the second member,

the improvement comprising:

employing a pair of dies for movement towards each other to a given minimum space of the two dies to carry out the squeezing operation,

one of said dies having a central cavity of substantially the cross section of the sank of the final rivet, said one die having an advanced working face around the cavity of a diameter at least two times the diameter of the cavity to form said annular zone of the first member,

said minimum spacing of the two dies in the area of said working face being sufficiently less than said stock thickness to extrude into the die cavity sufficient material to form a hollow preliminary rivet of an axial dimension at least as large as approximately 75% of the cross dimension of the cavity and comprising a volume of material substantially more than 50% of the volume of the final profile configuration of the rivet reforming the hollow preliminary rivet to said final rivet by applying axial force to the outer end of the preliminary rivet while the preliminary rivet extends through said aperture without internally supporting the hollow preliminary rivet against axial compression thereby reducing the void in the hollow preliminary rivet and displacing material into the shank region of the final rivet to add strength to the shank of the final rivet and to form a substantially solid rivet head in engagement with the second member.

13. An improvement as set forth in claim **12** in which a second pair of dies is employed to shape the preliminary rivet to said final rivet configuration,

one of the dies of said second pair having a leading face to cooperate with the other die of the second pair to subject the outer end of the preliminary rivet to an axial impact force,

the other die of said second pair of dies having a boss in alignment with the interior of the preliminary rivet, the boss being of tapering configuration.

14. An improvement as set forth in claim **13** in which said boss terminates short of the plane of the outer surface of said second member to avoid forming a void in the head portion of the final rivet.

15. An improvement as set forth in claim **14** in which said boss is of generally conical configuration to form a void of corresponding configuration in the root end of the shank of the final rivet.

16. In the process of forming a hollow rivet of a given overall configuration in a first member of sheet material of a given stock thickness with the shank of the rivet extending through an aperture of a second member and with the head of the rivet engaging the outer surface of the second member for anchoring the second member to the first member,

which includes the step of squeezing the sheet material of the first member across its thickness to a residual thickness in a zone of generally annular configuration to extrude the sheet material radially inwardly of the annular zone into a central axially extending space to form a hollow preliminary rivet of substantially the diameter of the shank of the final rivet configuration,

and which includes the later steps of positioning the preliminary rivet in the aperture of the second member and then deforming the preliminary rivet to form the final rivet in engagement with the second member,

the improvement comprising:

employing a pair of dies for movement towards each other to a given minimum spacing of the two dies to carry out the squeezing operation,

one of said dies having a central cavity of substantially the cross section of the final profile configuration of the rivet,

said one die having an advanced working face around the die cavity to form said annular zone of the first member, the area of said advanced working face being at least eight times the cross-sectional area of the die cavity,

said minimum spacing of the two dies in the area of said working face being sufficiently less than said stock thickness to extrude into the die cavity a volume of material equivalent to a solid cylinder of the diameter of the cavity and of an axial dimension equal to at least twice said given stock thickness, reforming the hollow preliminary rivet to said final rivet by applying axial force to the outer end of the preliminary rivet while the preliminary rivet extends through said aperture without internally supporting the hollow preliminary rivet against axial compression thereby reducing the void in the hollow preliminary rivet and displacing material into the shank region of the final rivet to add strength to the shank of the final rivet and to form a substantially solid rivet head in engagement with the second member.

17. An improvement as set forth in claim **16** in which the ratio of the outside diameter to the inside diameter of said advanced working face is in the range of 2:1 to 6:1.

18. An improvement as set forth in claim **16** in which the minimum spacing of the two dies in the area of said working face is sufficiently less than the given stock thickness to extrude into said cavity a volume of material equal to a body of the same cross section as the cavity and of a thickness in the range of 2 to 3 times said stock thickness.

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