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2,726,972

METHOD AND APPARATUS FOR FORMING METAL WORKPIECES

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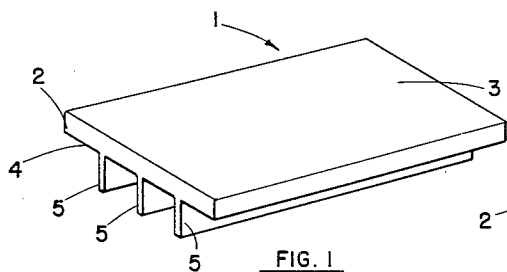


FIG. 1

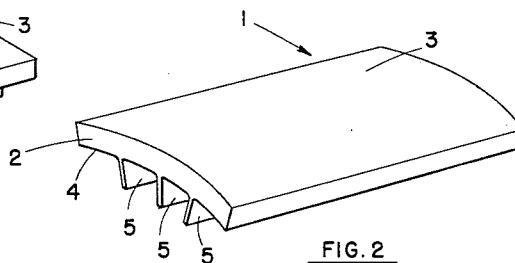


FIG. 2

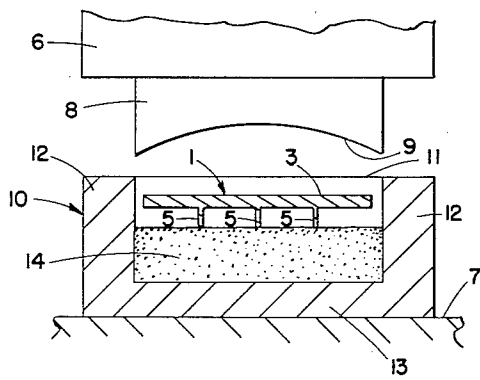


FIG. 3

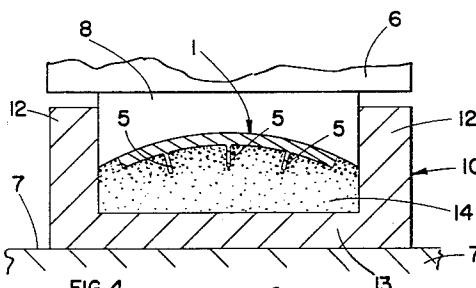


FIG. 4

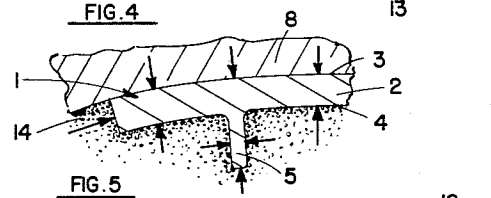


FIG. 5

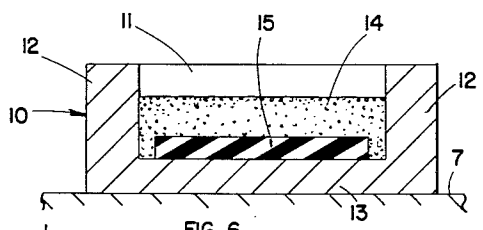


FIG. 6

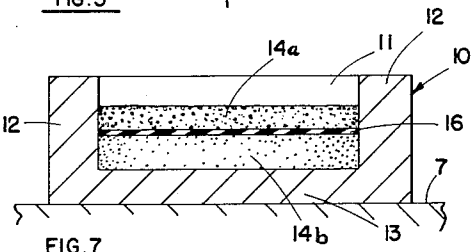


FIG. 7

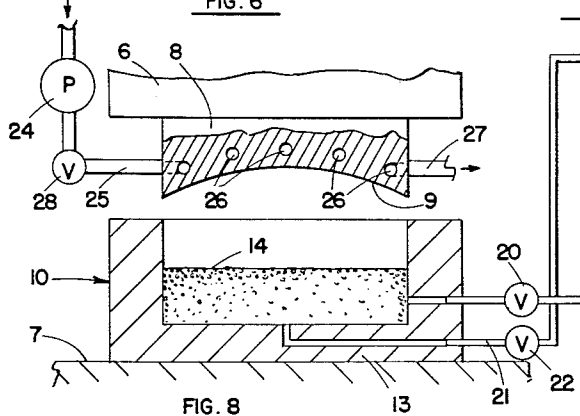
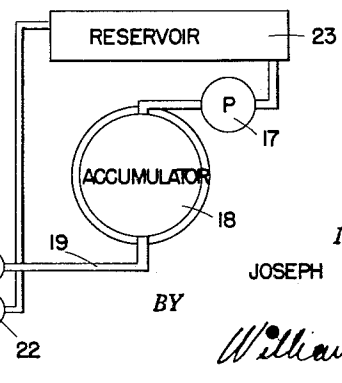


FIG. 8



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METHOD AND APPARATUS FOR FORMING METAL WORKPIECES

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6 Claims. (Cl. 148—11.5)

This invention pertains to metal forming and more particularly to method and means for forming, quenching and stress-relieving metal parts.

This invention provides a method and means for forming, quenching and stress-relieving a workpiece pertaining to that described in my co-pending application, Serial No. 311,981, for Strain Relieving Device, filed September 29, 1952. This basic forming method, wherein metal parts are given a heat treatable temperature prior to forming, and are restrained and quenched as they are formed, is very effective in imparting in a workpiece a desired shape and good strength properties. However, particularly in the case where the workpiece is provided with projecting portions that are relatively thin, certain refinements are necessary. For example, it may be required to produce wing skins for a modern high performance aircraft. These skins may include thin integral stiffeners projecting from one side thereof for giving the finished part maximum strength with a minimum of weight. Prior to the provisions of this invention there has been literally no way of forming such parts that is feasible from a production standpoint. It is impossible to make a matching set of dies that will receive such stiffener elements and at the same time restrain these elements as the workpiece is quenched. A force can be exerted upon the flat portions of such workpiece but on the projecting stiffeners there is no way with matching dies to exert a force against the sides thereof. Of course if the part is not restrained as it is quenched no stress-relieving results and the part will spring back after it is released from its forming dies. Therefore it will not attain the proper contour nor will it have attained its maximum strength properties. If it is attempted to merely engage the bottom of the workpiece with a bottom die and then introduce fluid into the spaces between the stiffening elements so as to restrain the part, form it and quench it in the general manner described in my co-pending application Serial No. 289,915, for Metal Forming, filed May 24, 1952, further difficulties arise. Where thin stiffening elements are used such elements cannot absorb the large force required between the two dies in holding the workpiece against contraction as it is quenched. If such a high force is exerted against the bottom of a relatively thin member of this type it will collapse. If this large force is not exerted the stiffeners will contract along the surface of the lower die and will not be stress-relieved. An attempt to form a workpiece having stiffeners by means of forcing fluid thereagainst is not practical because the fluid will not restrain the projecting stiffening portions which have only fluid engaging them from both sides. Again therefore there will be no stress-relieving action so that the part will spring back after completion and will not have attained its maximum strength. Furthermore it is impractical to use rubber as a forming medium for locations where there are such thin projecting stiffeners because the rubber will tend to break down the stiffeners and these projections will tend to damage the rubber.

It is therefore an object of this invention to provide

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a method and means for forming, quenching and stress-relieving a workpiece.

Another object of this invention is to provide a method and means for forming, quenching and stress-relieving parts having thin projections extending therefrom.

A further object of this invention is to form and stress-relieve a workpiece by the utilization of but a single die.

A further object of this invention is to form and stress-relieve a workpiece with the use of a relatively low pressure.

Yet another object of this invention is to form and quench a workpiece without the necessity of expensive equipment.

A still further object of this invention is to form and stress-relieve a workpiece so as to give a part its maximum strength properties without any damage to the part.

Yet another object of this invention is to form and stress-relieve a workpiece by means of a granular material as a forming medium.

These and other objects will become apparent from the following detailed description taken in connection with the accompanying drawings in which—

Fig. 1 is a perspective view of a workpiece to be formed by the provisions of this invention,

Fig. 2 is a perspective view of the workpiece of Fig. 1 after it has been formed,

Fig. 3 is a sectional view showing a workpiece associated with the granular forming medium prior to a forming operation,

Fig. 4 is a sectional view of the workpiece of Fig. 3 during a forming and quenching operation,

Fig. 5 is an enlarged fragmentary view of the forming and quenching of the workpiece in Fig. 4 illustrating the forces exerted against the workpiece,

Fig. 6 is a sectional view of a modification of the invention employing the use of a rubber pad,

Fig. 7 is a sectional view of a modification of the invention wherein sand is utilized as a granular material, and

Fig. 8 is a sectional schematic view of a modification of the invention wherein fluid is employed.

In Fig. 1 there is illustrated an unformed workpiece 1 which is to be given the contour illustrated in Fig. 2. Such a workpiece has, for example, a relatively thick main sheet metal portion 2 having a flat top surface 3 which is to be given a curved contour as shown in Fig. 2. The bottom surface 4 of the workpiece includes a plurality of relatively thin stiffener elements 5 which project therefrom. The forming forces required for a workpiece such as this vary as to the different parts thereof. Naturally the thin stiffening elements can withstand far less force than the main sheet metal portion 2, which portion must nevertheless be given the curvature illustrated in Fig. 2. However, by the provisions of this invention the forming of such a workpiece is very simple and is easily accomplished.

In carrying out this invention the first essential element is a suitable means of applying pressure to the workpiece. This may be an ordinary press such as that illustrated in Fig. 3 having a movable ram 6 and a stationary bed 7. For the movable ram of the press there is then provided a die member 8 which has a lower surface 9 complementary to the desired upper surface 3 for the finished part illustrated in Fig. 2. This die may be conventional and constructed of any suitable material such as Kirksite, steel, aluminum or copper, the latter two being particularly good heat conductors.

On the stationary bed of the press underneath the movable ram there is disposed a receptacle 10. This receptacle is of any suitable type, preferably of metal, having an open top 11 defined by strong sides 12 projecting from bottom portion 13. A quantity of granular material 14 rests within the receptacle, confined therein

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by sides 12. This may be any finely divided heat resistant material such as, for example, sand or metal shot. The latter is preferred for reasons made more clear hereinafter. The depth of this quantity of finely divided material depends upon the height of the stiffening elements 5 of the workpiece and on the curvature which is to be given to the completed part.

Workpiece 1 is then heated to its normal temperature for heat treating. For example, for 75S aluminum material this temperature is around 920° F. Heating should be carried on for a sufficient time to uniformly heat all portions of the workpiece. This heated workpiece is then quickly transferred to the interior of receptacle 10 where it is disposed on top of granular material 14 with projections 5 extending downwardly as illustrated in Fig. 3. Top surface 3 of the workpiece is thereby disposed below bottom surface 9 of die 8. Before the workpiece has had an opportunity to lose an appreciable amount of heat the ram of the press is then brought downwardly so as to force die 8 against the top of the workpiece. This urges the workpiece down against the material 14 so that projecting elements 5 are received within this material. By being made of fine separate particles material 14 is moved by the force of the die against the workpiece so that it forces the underneath side thereof upwardly, thereby urging the upper side of the workpiece into intimate engagement with surface 9 of the die. This position is illustrated in Fig. 4. Obviously there must be sufficient granular material within the receptacle to receive the entire height of projections 5 and to accommodate all the curvature given to the part. Despite the fact that the ram of the press may be exerting far more force than stiffeners 5 could withstand in direct compression, these projections will be received by the finely divided material 14 and undamaged because surface 2 of the workpiece will be utilized in absorbing the force of the ram. The finely divided material 14 in the receptacle thereby cooperates with die 8 to conform the workpiece exactly to the contour of surface 9 of the die although there was no previous form given to the finely divided material. Preferably die 8 and receptacle 10 are so constructed that the die closely fits within the receptacle, confining the granular material therein and precluding any tendency thereof to be displaced upwardly out of the container.

If it is desired to stress-relieve the workpiece so that it will retain the exact contour of surface 9 of the die, and to impart maximum strength properties thereto, it is necessary to quench the workpiece while so engaged by the die and material 14. The quenching range for 75S aluminum material extends down to approximately 500° F. so that the part must be cooled to at least this temperature. At the same time this quenching takes place the workpiece must be firmly engaged and held so that it is precluded from contracting as its temperature lowers. This uniformly works the part as it is quenched, thereby relieving all residual internal stresses. If this is accomplished the workpiece will retain the contour of the die and will attain its maximum strength properties. By the provisions of this invention wherein finely divided material is employed as a forming medium it is possible to obtain such an effect despite the fact that thin stiffening elements project from the main sheet metal portion of the workpiece. As indicated by the arrows in the fragmentary view of Fig. 5 a force will be exerted by this granular material on all surfaces of the workpiece. Thus even the edges of the workpiece, the sides of stiffeners 5 and the ends of these stiffeners, as well as the underneath surface of portion 2 of the workpiece, will be firmly engaged by material 14. Note that material 14 grips and retains the projecting portions 5 from both sides which could not be accomplished by a complementary die or by a fluid forming medium. At the same time die surface 9 engages top surface 3 of the workpiece and exerts a force thereon. If the die member is maintained in

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such engagement with the workpiece the workpiece will be quenched by flow of heat from the workpiece to die member 8 and to granular material 14. While this goes on the forces exerted by the die and by the granular material will retain the workpiece in such position so that it will be precluded from contracting as it cools and will therefore be uniformly worked and stress-relieved. When the workpiece has been removed after such a forming and quenching operation it will therefore have very good strength properties and will have no tendency to spring back from the exact shape which was given to it.

Although being particularly effective for forming operations wherein the workpiece has thin projecting portions extending therefrom—possibly the only feasible way to make such parts—the arrangement of this invention may be used to advantage in forming parts of many different types. It has been found that granular material 14 enables the use of even lower pressures for forming and restraining the workpiece during the quenching than was formerly the case where two sets of matching dies or other types of forming members were used. This is because the material is intimately engaged at every portion thereof by the granular material due to the ability of the granular material to move about when the force is exerted by the ram of the press. The uniform force from the granular material on one side results in better die contact on the other. No matter how accurately matching dies are machined there may still be some surface irregularities therein preventing perfect contact with every bit of the surface of a workpiece. Therefore a marked advantage is realized from the utilization of this granular material as a forming medium because of the intimate contact with the workpiece resulting therefrom. Furthermore, each of the individual granules of the material 14 will have a high frictional force at its point of engagement with the workpiece so as to assist in the restraining action. Aluminum parts have been successfully formed and stress-relieved in this manner with a force of around 1,650 p. s. i. exerted thereon. This intimate contact between the workpiece and the granular material for forming the workpiece is desirable also from the high rate of heat transfer from the workpiece to the forming medium which results. Because the material is engaged at all portions thereof and there are no insulating air gaps where the workpiece fails to engage the forming medium, heat transfer from the workpiece will be facilitated thereby speeding up the quenching operation.

In the preferred embodiment, as mentioned briefly above, metal shot is employed as the forming medium. This has one obvious advantage in its high rate of heat transfer whereby it facilitates removal of heat from the workpiece for the quenching thereof. Furthermore, metal shot is noncohesive in that despite the action of the die in forcing the workpiece into the granular shot material it does not pack together, and the individual particles do not tend to stick to each other. As a result there is little difficulty encountered in loosening up the bed of granular material following a forming, quenching and stress-relieving operation and preparatory for a second forming operation on another workpiece. When sand is used there is a tendency for the sand to pack down to in effect form a permanent die, which requires agitation of the sand to return it to the random state illustrated in Fig. 3.

.016-inch-diameter steel shot has been found to be satisfactory in withstanding the forces exerted by the ram of the press and in removing heat from the part. Copper and aluminum particles may be used and are desirable because of their particular ability to transmit heat. Stainless steel is sometimes preferred because of its resistance to corrosion.

In the modification illustrated in Fig. 6 a rubber pad 15 is disposed in the bottom of receptacle 10 beneath granular material 14. When the ram of the press is brought down on a workpiece disposed on a bed of granu-

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lar material wherein this pad is employed, the pad will be compressed and give some assistance to the forming operation. Its chief advantage however resides in its resilience whereby after the forming operation the pad will return to its original shape thereby loosening up the forming material 14 so that it again attains its random state having no indentation or other form indicating the shape of the completed workpiece.

In the modification of Fig. 7 a metal shot bed 14a is provided on top of a rubber pad 16 which in turn is disposed over a bed of sand 14b on the bottom of the receptacle. Sand of course is very cheap and a good granular material for shifting around in forming the workpiece but by being disposed below the rubber pad and not in engagement with the workpiece will not tend to receive any permanent indentations from the projecting flanges or any other portion of the workpiece when the forming operation takes place.

Still another modification of the invention is shown in Fig. 8 wherein fluid is employed with granular material 14. This material may be water or oil, although the latter is preferable because of its noncorrosive effect where the metal shot is employed as the granular material. A pump 17 connects with an accumulator 18 which through line 19 connects to the interior of receptacle 10. Valve 20 controls the admission of fluid through line 19 and the accumulator assures that the fluid can be admitted rapidly. Similarly a return line 21 controlled by valve 22 leads to reservoir 23 where the fluid utilized is stored. When this modification is employed, when the die has forced the workpiece into the granular material and the granular material has co-operated with the die to urge the material into intimate contact with the die, the valve 20 is opened to admit pressurized fluid into the interior of the receptacle. This fluid will aid in the forming of the workpiece and will also increase the rate of heat transfer between the workpiece and the forming mediums so that the workpiece may be more rapidly quenched. After the forming operation has been completed and the workpiece has been quenched and restrained by the forming mediums, valve 20 is closed and valve 22 is opened to return the forming fluid to the reservoir. This fluid will also give some advantageous effect by assisting in redistributing the granular material to a random state after the forming operation has been completed.

Another optional feature is shown in Fig. 8, this being a provision for cooling die 8 by external means so as to further assist in quenching the workpiece. Obviously if the die is maintained at a relatively low temperature it will conduct away more heat from the part than if the die becomes heated. Normally such auxiliary die cooling will be required only for large parts of particularly heavy gage because in other cases the mass of the die is sufficient to absorb enough heat to quench the part. The die cooling of Fig. 8 is achieved by means of pump 24 which forces water through line 25 to passageways 26 extending through the die. A suitable drain 27 permits the water to escape from and circulate through the die, while valve 28 controls admission of this fluid. This enables the accomplishment of a controlled die temperature.

It should be understood that no matter what modification of this idea is employed the action is essentially the same in that the granular material is readily displaced so as to force the top of the workpiece against the die and so as to form the workpiece without any damage to projecting portions on the bottom of the workpiece. The granular material then also restrains the workpiece and absorbs heat therefrom so that the workpiece is quenched and precluded from contracting, thereby stress-relieving the workpiece and imparting strength properties thereto. Without this restraining action and quenching no stress-relieving will take place and the part will materially spring back when released following the forming operation. It is of course not necessary that die 8 be a female die as illustrated in the drawing. It may as well be a male

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die and a curvature opposite to that illustrated be given to the part.

It is possible, if desired, to use the teachings of this invention for a forming operation alone without the further feature of stress-relieving the part. In such cases the workpiece is not restrained after it is formed and the die need not be maintained forced against the workpiece.

The foregoing detailed description is to be clearly understood as given by way of illustration and example only, the spirit and scope of this invention being limited only by the appended claims.

I claim:

1. The method of forming a metal workpiece comprising the steps of providing a die surface with a contour corresponding to that desired for said workpiece; providing a quantity of granular material in an open receptacle; heating said workpiece to a heat treatable temperature; disposing said heated workpiece on said granular material; forcing said surface of said die against said workpiece whereby said die and said granular material cooperate to conform said workpiece to the contour of said surface; and maintaining said die so forced against said workpiece thereby to cool said workpiece by heat transfer to said die and said granular material, and with sufficient force to substantially preclude any movement of said workpiece during said cooling for thereby relieving internal stresses from said material and permanently imparting the contour of said die thereto.

2. The method of forming and quenching an aluminum workpiece having projecting portions extending from one side thereof comprising the steps of providing a quantity of granular material in an open receptacle; heating said workpiece to a heat treatable temperature; disposing said workpiece so heated on said granular material with said projections disposed adjacent thereto; urging against the side of said workpiece remote from said projections a forming member defining a contour complementary to that desired for a finished part, whereby said projections are received by said granular material, and said workpiece is urged into intimate contact with said forming member; and maintaining said workpiece so engaged until cool and with sufficient force whereby said forming member and said granular material cooperate to restrain said workpiece from contraction and quench all portions of said workpiece and said workpiece is strengthened and relieved of internal stresses.

3. The method of forming and quenching an aluminum workpiece comprising the steps of providing a stationary open receptacle; disposing a flexible member in said receptacle; disposing a quantity of finely divided material in said receptacle above said flexible member; heating said workpiece to a heat treatable temperature, disposing said workpiece so heated on said finely divided material; urging a die member against the side of said workpiece remote from said finely divided material whereby said finely divided material forces said workpiece into intimate contact with all portions of said die member so that said workpiece assumes the contour thereof; maintaining said workpiece so engaged whereby said die member and said finely divided material absorb heat therefrom to cool said workpiece, said engaging force being of sufficient magnitude to substantially preclude contraction of said workpiece during said cooling whereby said workpiece is relieved of internal stresses; and subsequently releasing said die member from said workpiece whereby said flexible member moves said finely divided material within said receptacle to a random position.

4. The method of forming, quenching and stress-relieving a sheet metal workpiece having integral stiffening elements extending from one side thereof comprising the steps of introducing a quantity of granular material into an open receptacle; heating said workpiece throughout to its heat treatable temperature; placing said work-

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piece in said receptacle on said granular material with the side thereof provided with said stiffening elements adjacent thereto; urging a die of predetermined contour against the opposite side of said workpiece whereby said granular material is brought into intimate contact with all portions of said firstly mentioned side of said workpiece and said opposite side thereof is brought into intimate contact with said die; and maintaining said die so urged against said workpiece whereby said die and said granular material absorb heat from said workpiece to quench the same, said workpiece being so engaged with a force whereby said die and said granular material exert forces normal to all surfaces of said workpiece sufficient to substantially preclude contraction thereof during said quenching so that said workpiece is strengthened and relieved of internal stresses.

5. The method of forming, quenching and stress-relieving a metal workpiece comprising the steps of providing in an open receptacle a quantity of granular material; heating said workpiece to a heat treatable temperature; disposing said workpiece when so heated on said granular material; urging against portions of said workpiece remote from said granular material a die having a predetermined contour; circulating fluid through said granular material in said receptacle; and maintaining said workpiece engaged by said die and granular material in such manner whereby said die, granular material and fluid cooperate to quench said workpiece, and with suffi-

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cient force so that said die and granular material simultaneously restrain said workpiece thereby effecting uniform working and stress-relieving thereof.

6. A device for forming, quenching and stress-relieving a heated workpiece comprising a fixed receptacle; a quantity of granular material in said receptacle adapted to receive and support said workpiece; means for moving said die towards said receptacle whereby said die is brought into engagement with portions of said workpiece remote from said granular material to force said workpiece into intimate engagement with said die; and means for circulating fluid through said granular material in said receptacle whereby said workpiece is quenched by said die granular material and fluid, and whereby simultaneously said workpiece is restrained by said granular material and said die for uniformly working and stress-relieving said workpiece.

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