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Abson et al.

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[54] **HEATED DIE ASSEMBLY**

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[52] **U.S. Cl.** **72/342**

[51] **Int. Cl.**[2] **B21J 13/02**

[58] **Field of Search** ..... 72/342, 470; 76/107; 100/93 P

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[57] **ABSTRACT**

A heated die assembly designed to bolt onto a conventional hydraulic forge press. The heated die assembly is made of a laminated, load bearing insulating stack to which is attached a plurality of split heater blocks. The blocks contain semi-cylindrical grooves and bolt around cartridge heaters. Bolt-on die face plates are removably mounted on the heater blocks and are readily interchangeable for a variety of forging operations.

14 Claims, 8 Drawing Figures

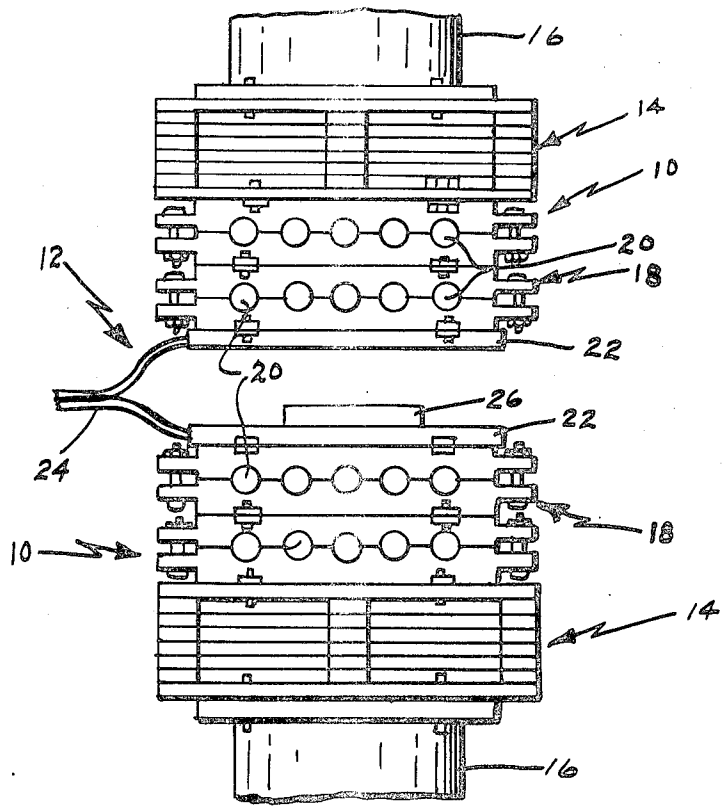
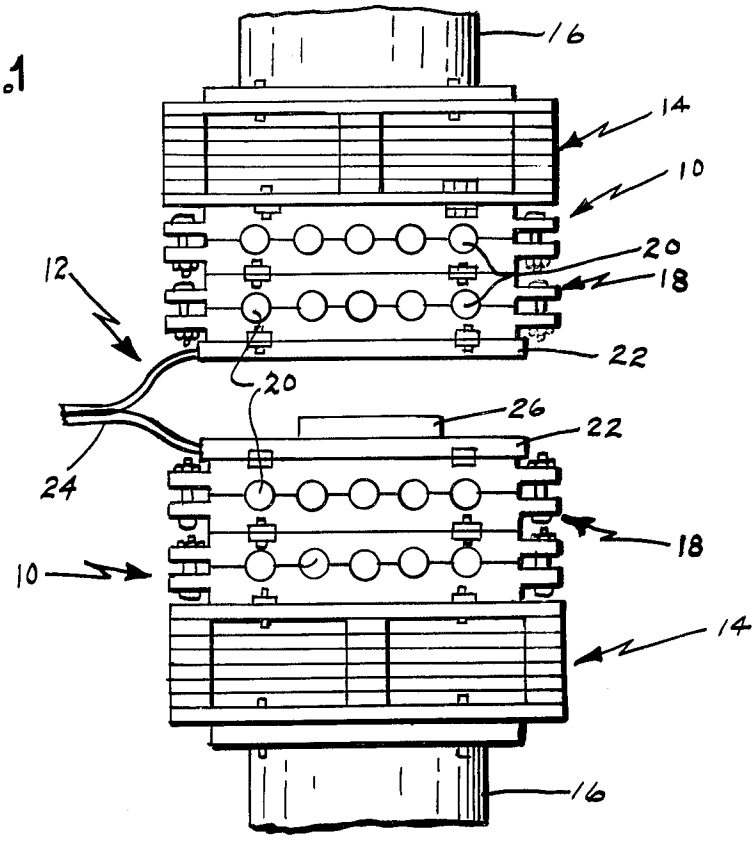


FIG. 1



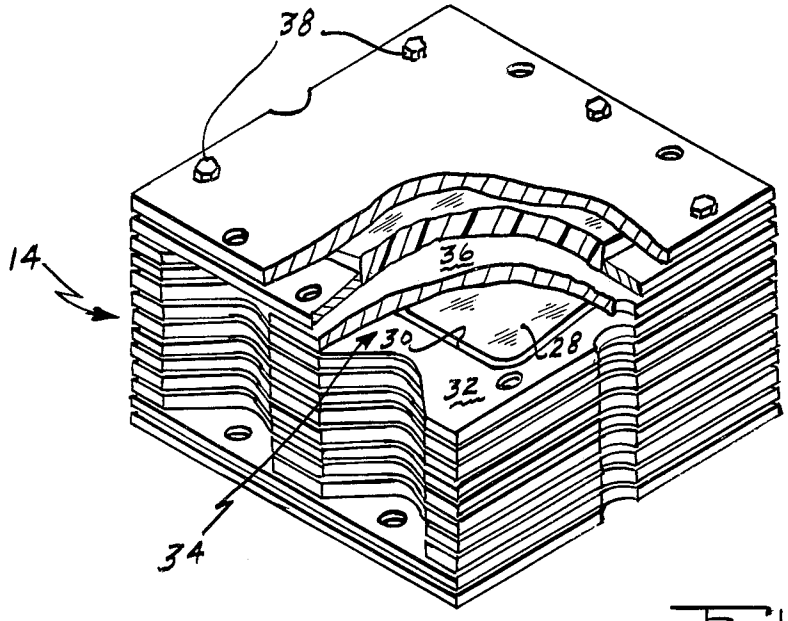


FIG. 2

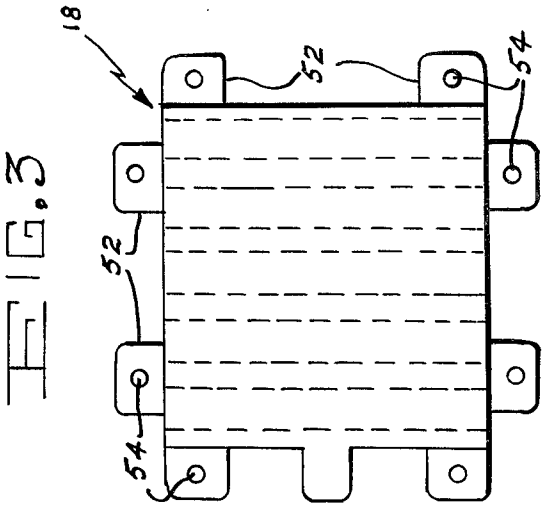


FIG. 3

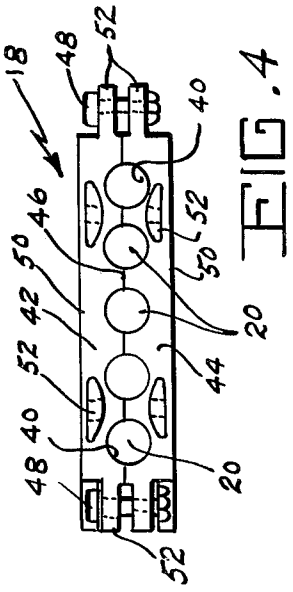


FIG. 4

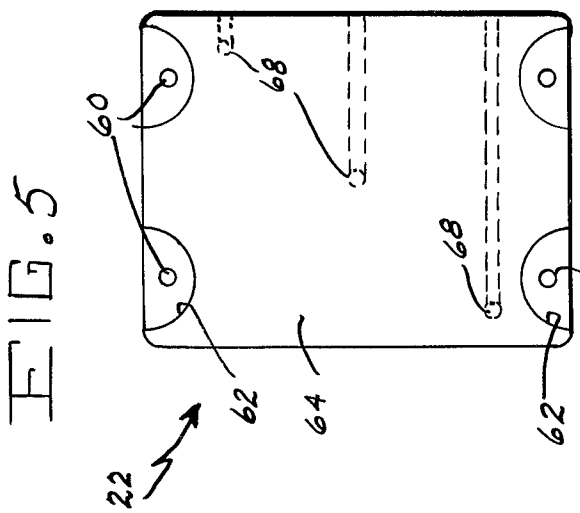


FIG. 5

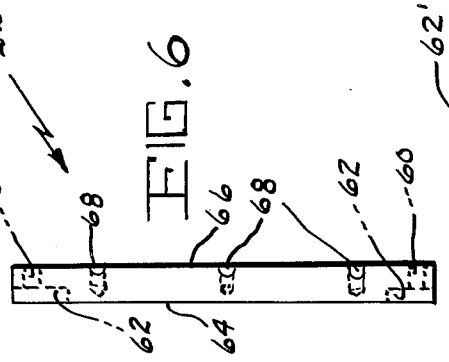


FIG. 6

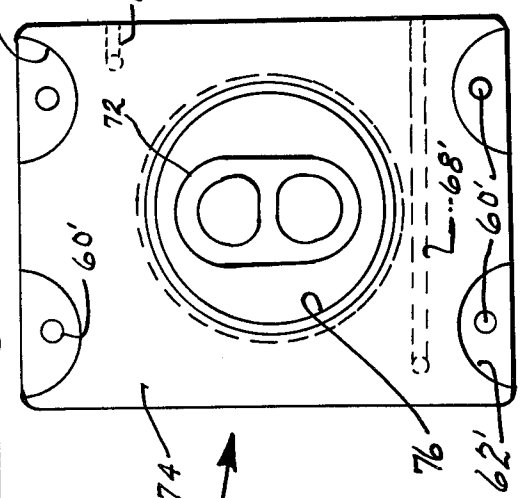


FIG. 8

FIG. 7

HEATED DIE ASSEMBLY

BACKGROUND OF THE INVENTION

This invention relates generally to "Isothermal Forging", and, more particularly, to a heated die assembly designed to bolt onto a hydraulic forge press.

The desire to fabricate new materials which are inherently difficult to forge has lead to the emergence of new techniques called "Isothermal Forging". In contrast to conventional forging this process uses heated tooling and the forging is carried out at slow speeds. The tooling in such a process calls for material which has high strength at temperatures in the order of 1800°F and have a means of generating heat within the dies.

The use of heated dies for the forging of metal offers several important advantages over the use of cold dies. The principal benefits are that workability is improved and surface cracking is reduced, and in some cases forging may be accomplished in one operation so that earlier "blocker" forging operations are not required. In addition, close tolerances can be achieved thereby substantially reducing the extent of subsequent machining operations. There are additional advantages in that when work-piece chilling does not occur slower deformation is practical and lower forging loads are required. This is a consequence of the lower material flow stress resulting both from the uniform elevated temperature, and in view of the high strain rate sensitivity of the workpiece, from the slow speed deformation. The lower processing loads may permit utilization of smaller, and thus less costly equipment.

In the technique of heated die techniques as set forth hereinabove the need arises for a load-bearing buffer between the heated process equipment and the forging press. Such a buffer reduces heat losses from the heated tooling and minimizes heat build-up in parts of the equipment which are not intentionally heated.

Another problem has arisen in the area of generating heat within the dies. A solution to this problem is to generate heat by means of a conventional cartridge heater embedded within a die block. The draw back of this solution is that the cylindrical holes which contain the heater must be perfectly aligned and the gap between hole and heater must be no more than a few thousandths of an inch in order to insure good heat transfer. Conventional drilling of the holes prove costly, while coring of undersized holes during casting gives way to machining problems unless an electrode discharging process is used and this process is also extremely costly.

An alternative method of heating the dies would be to use embedded quartz heaters. This method, however, does not eliminate the problems set forth hereinabove and in addition provides a low heat output. Another alternative heat source is induction heating. This method, however, is best suited to the forging of parts with cylindrical symmetry using tooling which is also cylindrical, since heat is generated within the workpiece and tooling. In addition, this heating method is not very flexible and requires expensive immobile RF equipment. Still another alternative heating source is flame heating. However, flame heating not only provides an inherent danger from flames but also has problems with insulation, atmosphere control and removal of fumes.

In the severe service conditions imposed on forging dies operated at elevated temperatures, swift deterioration of the dies occur because of wear. In addition, problems such as interaction with lubricants and the build-up of adhered lubricants makes simple removal of the dies a desirable feature in order to minimize "down-time" on heated die forging equipment. In the heated die equipment of the past, however, the fabrication of the shaped dies either contained embedded heaters or alternatively consisted of massive blocks in which heat is generated by induction. In conventional forging since impact loading of dies occurs such massive dies were acceptable. However, their adaptation to heated die forging equipment has given rise to heated dies which are unnecessarily bulky.

SUMMARY OF THE INVENTION

The instant invention overcomes the problems set forth hereinabove by providing a heated die assembly which is designed for easy mounting onto a conventional hydraulic forge press. The die assembly is made up of (a) split heater blocks which contain semi-cylindrical grooves and which bolt in pairs around cartridge heaters, thereby facilitating both fabrication of the blocks and replacement of defective heaters; (b) bolt-on die face plates which are readily interchangeable and which may have either flat or a shaped work-face; and (c) laminated, load bearing insulating stacks made of alternate layers of oxidation resistant material having high toughness and a high compressive strength material having low thermal conductivity.

In the present invention, the laminated back-up tooling consists of alternate layers of (a) a sheet of nickel-base superalloy or other suitable metal and (b) a ceramic slab contained within a further sheet of metal. The presence of the ceramic, and of the many interfaces, give a substantially lower thermal conductivity than that of the metal alone. In addition the metal sheets can be machined easily so that provision can be made for fastening all the plates together, and for interfacing with adjacent tooling. By reducing heat losses, the laminated back-up tooling of this invention is likely to reduce operating costs along with a substantial reduction in tooling fabrication cost.

Hot forging operations carried out at slow speeds also require the use of heated tooling. The instant invention utilizes die bolsters within which heat is generated by means of embedded cartridge heaters. The die bolsters are made into matching halves, each containing semi-cylindrical grooves on one face. These bolsters are bolted together around the set of cartridge heaters. Such a design simplifies fabrication of the bolster plates and also facilitates removal and replacement of defective heaters. It is possible to have two identical halves of the heater block, each with one flat face. An extension of the bolt-together concept would then permit each pair of die bolsters to be attached either to another set of bolsters, to a replaceable die face plate, or to other parts of the tooling.

With the new technology of heated-die forging several problems arise such as the high cost of fabrication of massive, precision cast dies and the handling of these dies when removal from the forging press becomes necessary for replacement due to wear or for cleaning. The present invention involves:(a) dissociation of the dies from the back-up tooling, in which heat is generated by embedded heaters or by induction, (b) reduction of the depth of the die, to the minimum practical

thickness, and (c) making provision for easy die replacement using bolts or other suitable fasteners.

It is therefore an object of this invention to provide a heated die assembly which is designed for easy mounting onto conventional hydraulic forge presses.

It is a further object of this invention to provide a split heater block whereby fabrication of the heater assembly and replacement of defective heaters are simplified.

Another object of this invention is to provide a load bearing insulating stack (back-up tooling) which permits (a) a reduction in the heat input required to maintain a given temperature, (b) an increase in the temperature which can be maintained for a fixed heat input, and (c) an increase in the maximum permissible work piece height for a fixed heat loss through the tooling.

Still another object of this invention is to provide die face plates which are of the minimum thickness consistent with having sufficient strength and are easily mounted to back up tooling.

It is still a further object to provide a heated die assembly which is economical to produce and which utilizes conventional, currently available components that lend themselves to standard mass producing manufacturing techniques.

For a better understanding of the present invention together with other and further objects thereof, reference is made to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

DESCRIPTION OF THE DRAWING

FIG. **1** is a side elevational view of the heated die assembly of this invention shown in conjunction with a hydraulic forging press;

FIG. **2** is a pictorial view of the load bearing insulating stack of this invention;

FIG. **3** is a plan view of the split heater block of this invention;

FIG. **4** is a side elevational view of the split heater block of this invention;

FIG. **5** is a plan view of the die face plate of this invention;

FIG. **6** is a side elevational view of the die face plate of this invention;

FIG. **7** is a plan view of a modified die face plate of this invention; and

FIG. **8** is a side elevational view of the modified die face plate shown in FIG. **7.**

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is now made to FIG. **1** of the drawing which best shows the completed heated die assembly **10** of this invention mounted on the upper and lower sections of a conventional hydraulic forge press **12.**

Heated die assembly **10** of the present invention is made up of a load bearing insulated stack **14** fixedly secured at one end thereof to a water cooled maraging steel block **16.** Secured to the other end of insulating stack **14** are split heater blocks **18** which contain conventional cartridge heaters **20** therein. Heat is generated by a plurality of cartridge heaters **20** each heater supplying up to 320 watts. The heaters **20** are powered by any suitable power supply such as a conventional SCR power unit (not shown) which give a maximum work-face temperature of approximately 1850°F. Mounted on the work surface of heater blocks **18** is a die face plate **22** which contains therein thermocouples **24** for temperature control and monitoring. Die face plate **22** is removable and may have either a flat or shaped work-face. Compressed between die face plates **22** is the work piece **26.** All elements which make up this invention are described in detail hereinbelow.

Reference is now made to FIG. **2** of the drawing which shows, in pictorial fashion, the laminated insulating stack **14.** Stack **14** is made of alternate layers of ceramic **28** and metal sheets **36.** The ceramic material **28** preferably has a high compressive strength and low thermal conductivity and may be made from any suitable material such as alumina, beryilla, cermet or nonmetallic silicon nitride. Ceramic material **28** is contained within one or more openings **30** in a sheet of metal **32,** and this composite layer **34** is sandwiched between complete metal sheets **36.** The sheets of metal **32** and **36** should be oxidation resistant having high toughness such as super alloys based on iron, nickel or cobalt. Examples of such super alloys are Inconel 601 having the following composition: 23.0%Cr, 14.1%Fe, 1.35%Al, 0.05%C, 0.5%Mn, 0.007%S, 0.25%Si, 0.25%Cu with the remainder a base of Ni; and Haynes alloy 188 having the following composition: 22%Cr, 22%Ni, 14.5%W, 3.0%Fe, 0.15%C; 0.15%La with the remainder a base of Co.

In order to compensate for the difference in thermal expansion coefficient, the room temperature thickness of the ceramic **28** should be slightly greater than that of the metal **32.** Bolts **38** or any other suitable fastener are utilized to hold the plates **34** and **36** together and further to attach the laminated stack **14** to adjacent tooling. THe metal/ceramic interfaces provide planes of easy shear as distortion occurs due to differential thermal expansions or to non-axial loading. Even if the ceramic **28** should fracture, the pieces would be contained by a surrounding sheet of metal and the operation of the stack **14** would not be affected. A typical heat transfer calculation with relative thickness of ceramic to metal of 1.13 to 1.0, for a 13 layer stack will give an effective thermal conductivity approximately 1.1 times that of alumina and approximately 0.4 times that of Inconel 601.

Since the ceramic material **28** is used in the form of flat slabs, expensive fabrication processes on this material are avoided. Further cost reduction may be effected where the heated forging dies are large or have an unusual shape, since the laminated stacks **14** of this invention may be utilized side by side thereby minimizing the variety of back-up tooling required for forging a number of different shapes and sizes.

Referring to FIGS. **3** and **4,** which show a typical configuration of a split heater block, it is shown that the present invention also provides means whereby fabrication of the heater blocks **18** and subsequent replacement of defective cartridge heaters **20** are simplified. In addition, this invention insures accurate fitting of cartridge heaters **20** to the holes **40.** The heater blocks **18** are fabricated in two parts **42** and **44,** split at the diametral plane of each heater. Holes **40** are cast into face **46** of each part **42** and **44,** respectively, as semi-cylindrical grooves. These grooves are brought accurately to size by precision grinding. This method of fabrication replaces an expensive drilling or machining operation by a less expensive grinding process. The two halves or parts **42** and **44** of heater blocks **18** are fastened together around the heater cartridges **20** by bolts **48** or other suitable fasteners.

Although it is not necessary that all the heaters **20** lie in the same plane, such an arrangement simplifies the machining operation. While the back face **50** of one of the block halves **42** or **44** may be ground flat, the back face of the other piece might be expected to contain the die shape. This is not necessarily the case, however, since fabrication of two identical heater block halves, each with one flat face, has several advantages. Although such a configuration requires a separate die face plate, it does permit a greater flexibility of use of the tooling, since heater blocks **18** can be stacked in more than one layer to provide additional heat input or side by side to supply heat to a large die. Moreover, die face plates **22** can be replaced easily as they become unserviceable, or if different shapes are to be forged.

The typical configuration for a heater block **18** appears in FIGS. **3** and **4** and shows a heater half or part **42,** for example, having one flat face **50** and several projecting lugs **52** which contain bolt holes **54** therein. The lugs **52** allow the heater block halves **42** and **44** to be clamped firmly around a single row of cartridge heaters **20** and also to be interfaced with other parts of the tooling. Since the curved surfaces of holes **40** are easily accessable, they can be ground accurately to fit the size and shape of the cartridge heaters **20.** Accurate fitting is important if good heat transfer is to be obtained from heaters **20** to the blocks **18.** Coating the curved surfaces of holes **40** with graphite also improves heat transfer, and can be done most effectively in the present invention. The heater block **18** shown in FIGS. **3** and **4** of the drawing provide for an embedded heater length of approximately 5''. A typical heater block **18** of this invention has two rows of cartridge heaters **20** clamped between four identical die bolster halves. Use of identical parts reduces the initial casting cost and permits the maintenance of a smaller inventory of spare parts. Advantages of the heater block **18** of this invention includes the reduction of "down-time" for removal and replacement of either an unserviceable die face **22** or a defective cartridge heater **20.** Moreover, several heater blocks **18** can be used, stacked on top of one-another, to give a higher heat input per unit area, or stacked side by side to supply heat over a large area. This latter modular arrangement would give the system wide flexibility since a small range of heater blocks **18** could accommodate a wide variety of die shapes and sizes. Moreover, a more precise temperature control can be achieved if different heat input is arranged to different parts of the die faces **22.** In this way, a uniform temperature is achieved in spite of local differences in heat loss; alternatively, a particular temperature profile can be imposed for such purposes as microstructure control.

Reference is now made to FIGS. **5** and **6** which best show the bolt-on die face plate **22** of this invention. Die face plate **22** is cast in a substantially rectangular configuration of, for example, 6½ inches by 5½ inches by ½ inch, out of a high strength super alloy such as IN 100 having the following composition: 15%Co, 10.0%Cr, 5.5%Al, 4.7%Ti, 3.0%Mo, 1.0%V, 0.18%C, 0.014%B, 0.06%Zr with the remainder a base of Ni. The plate **22** contains a plurality of bolt holes **60** located within recesses **62** for bolt heads. The front and back faces **64** and **66,** respectively, are ground flat and provisions are made for locating thermocouples **24** therein by drilling holes **68** therein.

In addition to the die face plate **22** shown in FIGS. **5** and **6,** a die face plate **70** may be made of two or more materials as shown in FIGS. **7** and **8.** In such a case the die shape might be formed in a material **72** which has good abrasion and wear resistance, surrounded by a material **74** which has high toughness such as a super alloy or coated refractory metal. The shape may be formed within a truncated cone or pyramid of ceramic or metal powder which is then sintered. Such a shape would have a flat base and could be held in place by the inclined face of the hole **76** in the plate **74.** An alternative method of obtaining the die shape would be by electrodischarge machining if the die material is an electrical conductor. As in die face plate **22** shown in FIGS. **5** and **6,** bolt holes **60'**, recesses **62'** and thermocouple holes **68'** are provided in die plate **70.**

The advantage of the bolt on die face plates **22** and **70** of this invention are lower die fabrication cost, easier handling and storage of thinner dies and shorter "down-time" when changing of the dies becomes necessary. A further benefit is that thermocouples **24** can be located directly behind the die faces. In addition due to the bolt-on concept, dies can be made of a different material from that of the back up tooling.

The present invention sets forth a heated die assembly **10** which can be substituted as a whole for the die blocks used in the past. In addition the individual elements (insulating stack **14,** split heater blocks **18** and die face plate **20**) which make up this invention constitute a novel approach to the "Isothermal Forging" art.

Although this invention has been described with reference to particular embodiments it will be understood to those skilled in the art that this invention is also capable of a variety of alternative embodiments within the spirit and scope of the appended claims.

We claim:

1. A heated die assembly adapted to be used in conjunction with a forge press comprising a load bearing insulated stack, at least one heater block secured at one end thereof to said load bearing insulated stack and a die face plate secured to the other end of said heater block, said load bearing stack being made of alternate layers of at least two plates, one of said plates being made of a material having a high toughness, the other of said plates being made of a composite construction of two materials, one of said materials of said composite construction having high toughness and the other of said materials of said composite construction having a high compressive strength and low thermal conductivity and said heater block being made of two heater elements which contain a means for generating heat therein.

2. A heated die assembly as defined in claim **1** wherein said die face plate is removably secured to said heater block.

3. A heated die assembly as defined in claim **1** wherein the other of said plates has a cut-out portion therein, said high compressive strength, low thermal conductive material being located in said cut-out and the thickness of said high compressive strength low thermal conductive material being greater than the thickness of the plate which surrounds it.

4. A heated die assembly as defined in claim **3** wherein each of said elements of said heater block contain at least one groove therein thereby forming a hole in said heater block by the mating of adjacent grooves.

5. A heated die assembly as defined in claim **4** wherein said die face plate is removably secured to said heater block.

6. A load bearing insulated stack adapted to be used in a forge press comprising at least two plates, one of said plates being made of a material having a high toughness, the other of said plates being made of a composite construction of two materials, one of said materials of said composite construction having high toughness and the other of said materials of said composite construction having a high compressive strength and low thermal conductivity.

7. A load bearing insulating stack as defined in claim 6 wherein said other of said plates has a cut-out portion therein, said high compressive strength, low thermal conductive material being located within said cut-out portion and the thickness of said high compressive strength, low thermal conductive material being greater than the thickness of the plate which surrounds it.

8. A load bearing insulating stack as defined in claim 7 further comprising a plurality of alternate layers of said plates and said plates being removably secured to one another.

9. A load bearing insulating stack as defined in claim 8 wherein said high compressive strength, low thermal conductive material is ceramic.

10. A load bearing insulating stack as defined in claim 9 wherein said high toughness material is a super alloy.

11. A heater block adapted to be used in a forge press comprising a pair of heater elements, each of said heater elements having a plurality of grooves therein, said heater elements being secured together in such a manner that adjacent grooves form a plurality of holes within said heater block and a means for generating heat being located within said holes.

12. A heater block as defined in claim 11 wherein said interior portion of said holes are coated with a means for improving the thermal conductivity thereof.

13. A heater block as defined in claim 12 wherein said heater elements are identical in construction and are removably secured to one another.

14. A heated die assembly adapted to be used in conjunction with a forge press comprising a load bearing insulated stack, at least one heater block secured at one end thereof to said load bearing insulated stack, said load bearing stack being made of alternate layers of two types of material one of said materials having a high compressive strength and low thermal conductivity and the other of said materials having high toughness and said heater block comprising a pair of heater elements, each of said heater elements having a plurality of grooves therein, said heater elements being secured together in such a manner that adjacent grooves form a plurality of holes within said heater block and a means for generating heat being located within said holes.

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