

Dec. 31, 1968

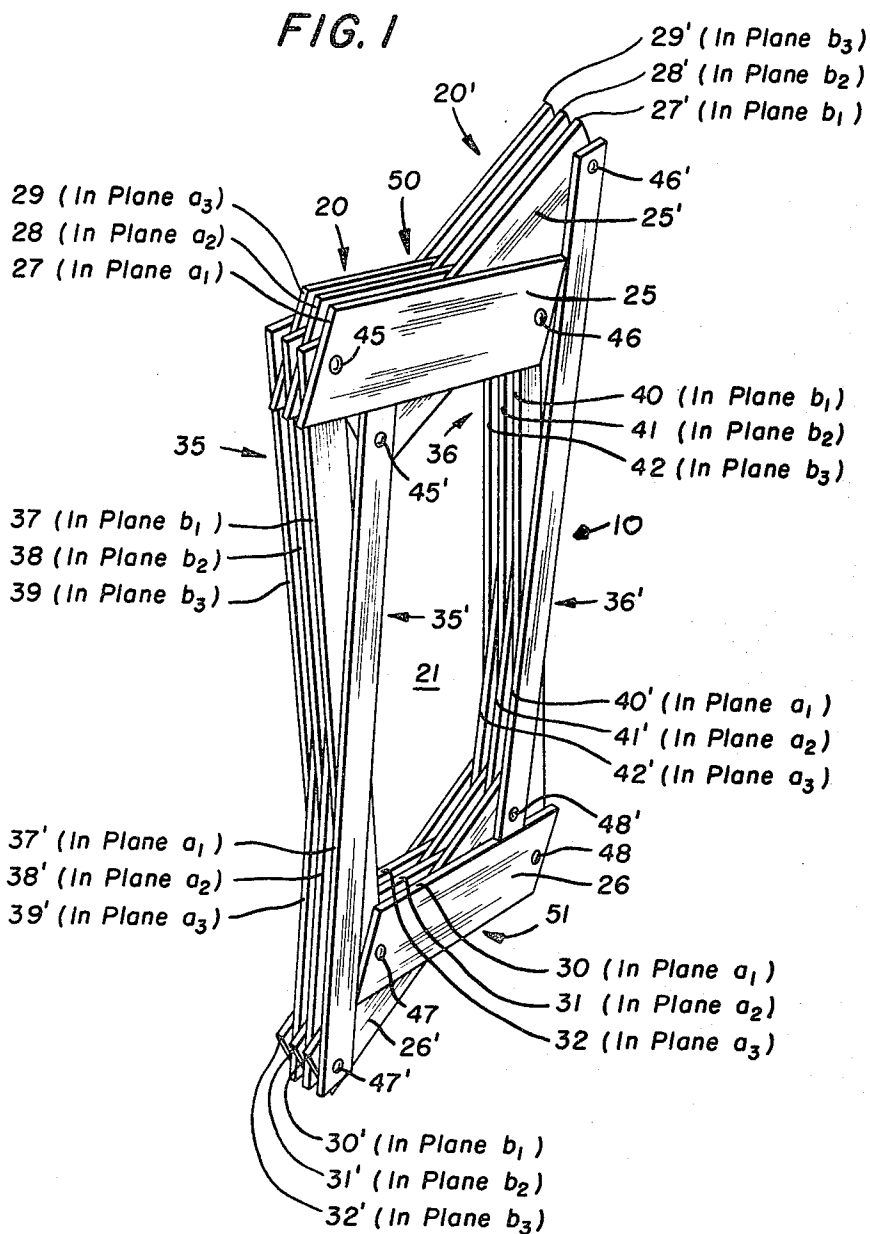
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3,418,922

LOAD-BEARING FRAME STRUCTURE

Filed Jan. 3, 1967

Sheet 1 of 3



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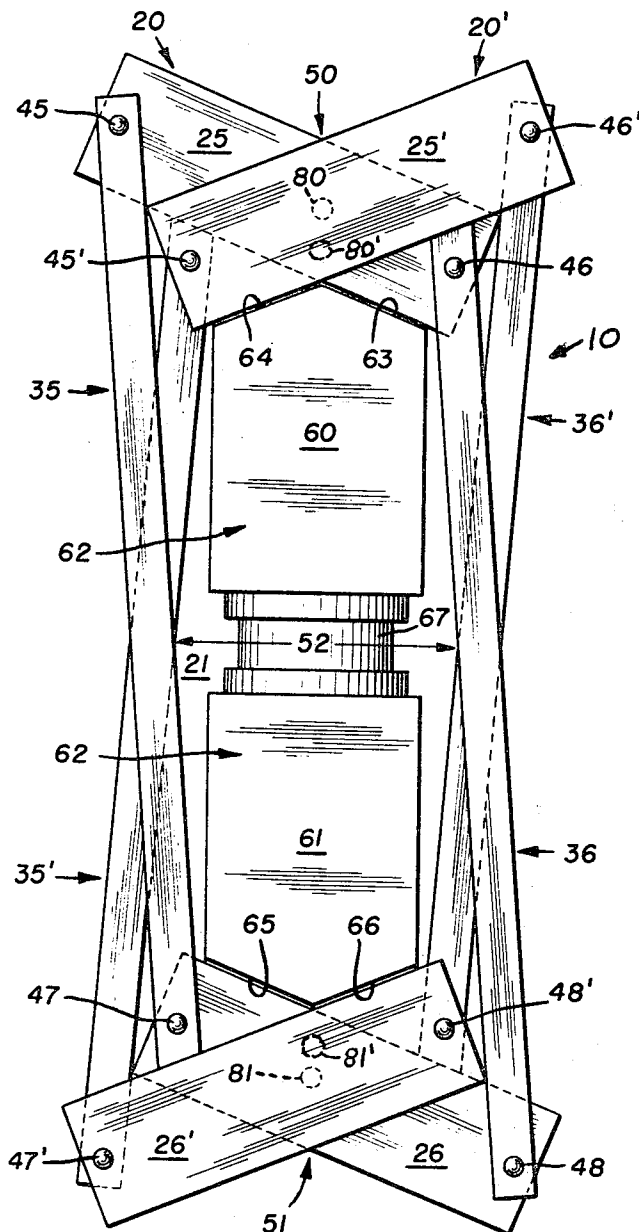


FIG. 2

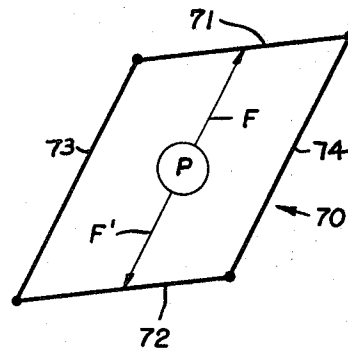


FIG. 3

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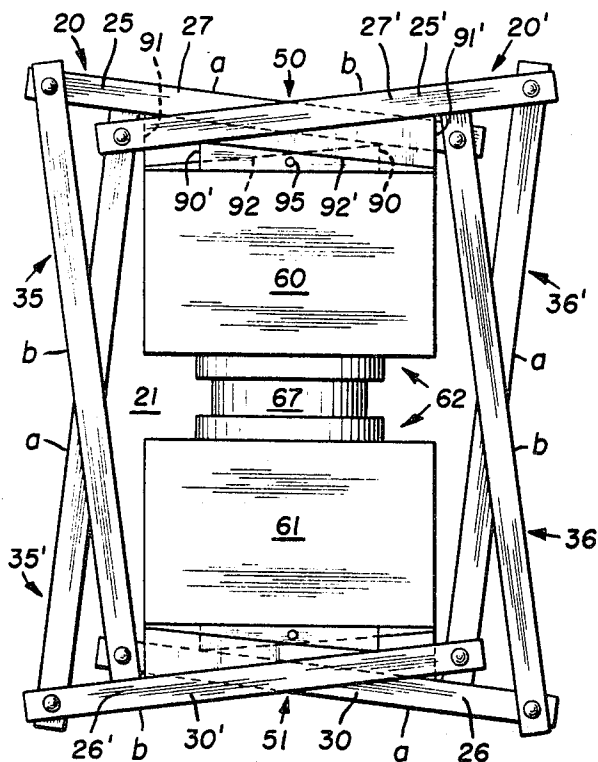


FIG. 4

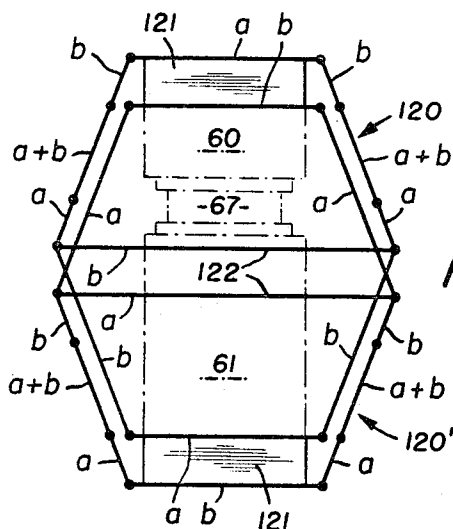


FIG. 7

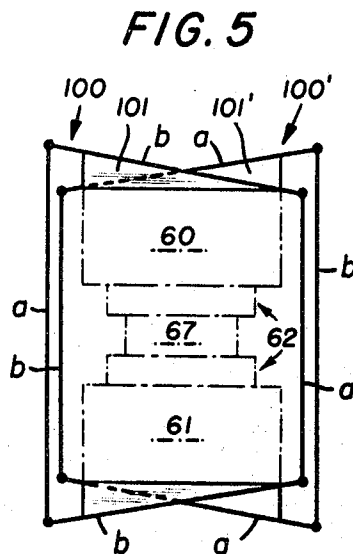


FIG. 5

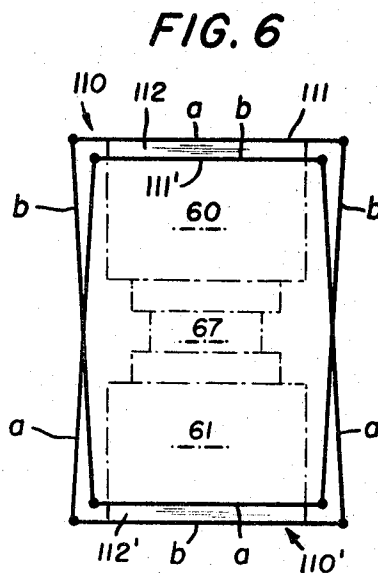


FIG. 6

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LOAD-BEARING FRAME STRUCTURE

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18 Claims. (Cl. 100—214)

ABSTRACT OF THE DISCLOSURE

Frame structures each comprised of two similar closed polygonal load-bearing frames each disposed around a central space within the structure, the frames being each comprised of sets of parallel transversely spaced beams which are connected together by hinge joints and which are all in parallel planes, the frames having respective sets of beams which are interleaved to produce interpenetration of the frames and an overlapping of their respective transverse extents, and the frames being coupled in parallel to a press inside the central space to receive oppositely directed loading forces from the press and to share such loading forces.

This invention relates to frame structures particularly adapted for industrial uses such as bearing and absorbing the reactive loads exerted by forging presses or other means for doing work on material. More particularly, this invention relates to frame structures of such sort which are comprised of at least two separately identifiable load-bearing frames.

"Laminated-type" frames are well known and generally comprise a closed rectangular frame having two crossheads each formed of a set or "grating" of parallel cross beams transversely spaced from each other to be separated by voids. The two crossheads are coupled together by two sets of parallel tie beams transversely spaced from each other to be separated by voids, the tie beams being interleaved at their ends with the ends of beams of the crossheads, and a hinge pin being passed through each such interleaving to join the interleaved beams together. Because of the voids between the beams in each crosshead and between the tie beams in each set thereof, the structure requires an undesirably large housing space in comparison to its load bearing capacity.

To the end of improving the ratio of load bearing capacity to required housing space, it has been proposed to provide a frame means wherein duplicate single frames of the type described are interlinked like two rings. Both frames are vertical and are disposed so that (1) the vertical planes of the two frames intersect at less than a right angle to form an X, (2) the lower crossheads of the two frames are in abutting relation at the center of the X to form a lower compound crosshead and, likewise the upper crossheads of the two frames are in abutting relation at the center of the X to form an upper compound crosshead. Because of their interlinked relation, each of the two frames provides for the compound crossheads one component crosshead which is inside the other frame and one component crosshead which is outside the other frame.

While this frame structure represents a substantial advance over the prior art and is satisfactory for many applications, it has certain disadvantages as follows.

First, because the two frames of the structure are in non-parallel planes, the structure takes up more room than is desirable in the transverse dimension i.e., the dimension between the ends closest together of the arms of the X. Also, the X configuration of the structure reduces the dimension of the access way for work (i.e., the dimension between the ends farthest apart of the arms of

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the X) to a size less than the horizontal span of the crossheads of the frame.

Second, the inner and outer component crossheads of each compound crosshead are in series with each other for the purpose of receiving and absorbing the load imposed on the compound crosshead. Because of this serial coupling of the two component crossheads of each compound crosshead, the two frames are locked together under load so as to be unable to each respond to the load in a manner which is unconstrained by contact with the other frame. Further, because the load is transmitted to each outer component crosshead through the inner component crosshead, the deformation patterns of the two component crossheads are not necessarily the same, and the inner crosshead is subjected to an outward loading stress which is about twice that on the outer crosshead.

Third, the compound crossheads of the frame structure each provide a fill factor of only 50% for a load applied to the crosshead. That 50% figure is arrived at as follows. First, a determination is made for the beams of the compound crosshead of the effective areas of the inner face portions of those beams to which portions of the outwardly directed load stress are transmitted by wholly parallel couplings of the load to the tie-connected beams of the compound crosshead. By "effective area" is meant the component of the full area of any such face portion which is normal to the direction of application of the load. The total of such effective areas is then divided by the area of the whole circumscribed region occupied by those effective areas to yield the fill factor. As a homely example of fill factor, a checkerboard has a black square fill factor of 50% because the black squares of the checkerboard have a total area which is 50% of the area of the entire checkerboard.

The fill factor so far described may be termed the regional fill factor because it concerns only the region of the compound crosshead which is actually subjected to distributed loading. Also of importance, however, is the span fill factor, i.e., the ratio of the mentioned effective areas to the effective area of the whole transverse and lateral extent of that portion of the compound crosshead which spans the central working space. For best use of a compound crosshead, it is evidently desirable that the span fill factor have a value of at least 50% and preferably be of greater value.

A regional fill factor of only 50% is obtained for the compound crossheads of the described frame structure because, in each of those compound crossheads it is only the beams of the inner component crossheads which provide inwardly facing beam portions to which portions of the outwardly directed load stress are transmitted by wholly parallel couplings of the load to the tie-connected beams of the compound crosshead.

Further, the compound crossheads cannot, practically speaking, be distributively loaded from one side to the other of the central working space enclosed by the frame structure of that patent. That is so because the load on each such compound crosshead should be distributed only over the region thereof within which there is an overlapping of the component crossheads of the compound crosshead, and the size of that region varies directly with the respective extents in their transverse directions of the two component crossheads. If, however, those transverse extents are increased to increase the size of that region, then the access way for work pieces is commensurately reduced in size. It follows that, if the transverse extents of the component crossheads are increased enough to create such a region extending fully from side to side of the central space for the frame structure, there would be no access way at all for work pieces.

It is accordingly an object of this invention to provide

frame structures which are free of one or more of the disadvantages noted above.

Another object of this invention is to provide frame structures which maximize the ratio of the load capacity thereof to the housing space required therefor and to the size of the access way provided by the structure.

These and other objects of the invention are realized in a manner as follows. In accordance with one aspect of the invention, a frame structure is provided which is comprised of at least two closed polygonal load bearing frames each disposed around a central space within the structure and each comprised of (a) laterally extending crossheads on longitudinally opposite sides of such space and (b) longitudinally-extending tie means disposed on laterally opposite sides of such space to couple together the crossheads of that frame. The two frames are disposed in relation to each other to have respective lateral-longitudinal midplanes normal to a common line in the transverse direction and to be characterized on each of the laterally opposite sides of such space by an overlapping in the transverse direction of the respective transverse extents of the two frames. Accordingly, the frame structure requires a minimum of housing space in the transverse direction.

As another aspect of the invention, each of the frames is comprised of beams of which at least portions occupy or pass through voids between at least portions of beams of the other frame.

As still further aspects of the invention, the frames may be duplicates in size and shape, may be loaded in parallel, may be in relative floating relation, and may provide for the frame structure both a regional and a span fill factor in excess of 50%.

For a better understanding of how the aforementioned and other objects of the invention are realized and for a better understanding of other aspects and advantages of the invention, reference is made to the following description of exemplary embodiments thereof and to the accompanying drawings wherein:

FIG. 1 is a perspective view of a double parallelogram frame structure according to the invention;

FIG. 2 is a front elevation view of the frame structure of FIG. 1 as employed with a press;

FIG. 3 is a force diagram pertaining to FIG. 2;

FIG. 4 is a front elevation of a modification of the embodiment of FIG. 2; and

FIGS. 5-7 are schematic views of other embodiments of the invention.

In the discussion which follows, any two elements which are counterparts will be designated by the same reference numeral but will be differentiated from each other by using a prime (') suffix for the reference numeral designating one of those elements. It is to be understood that, unless the context otherwise requires, a description herein of any element is to be taken as being equally applicable to its counterpart.

Referring now to FIG. 1, a frame structure 10 is comprised of a pair of frames 20 and 20' of which each is in the form of a skewed parallelogram, and of which each is disposed around a central space 21 within the structure 10. The two parallelogram frames are duplicates in size and shape but have a different orientation, i.e., have a mirror relation to each other in the sense that the shape of frame 20' is the shape of frame 20 as rotated 180° about a vertical axis. Because of the similarity between the two frames, only frame 20 will be described in detail.

The frame 20 is comprised of upper and lower longitudinally spaced crossheads 25 and 26. Upper crosshead 25 is comprised of a set of parallel steel beams 27-29 transversely and equidistantly spaced from each other so as to have voids therebetween of the same thickness as the beams. The crosshead beams 27-29 are disposed in parallel transversely and equidistantly spaced planes which are generally designated herein as the *a* planes, and which

are the planes *a*₁, *a*₂ and *a*₃ for the beams 27, 28 and 29, respectively.

Lowercrosshead 26 is likewise comprised of a set of parallel steel beams 30-32 which are transversely and equidistantly spaced from each other to lie in, respectively, the planes *a*₁, *a*₂, *a*₃, and which have voids therebetween of the same thickness as the beams.

The crossheads 25 and 26 are coupled to each other at their laterally opposite ends by left-hand and right-hand tie means 35 and 36. Tie means 35 is comprised of a set of parallel steel tie beams 37-39 which are of the same thickness as the crosshead beams, and which are transversely and equidistantly spaced from each other to have voids therebetween of the same thickness as those crosshead beams. The tie beams 37-39 lie in a set of transversely and equidistantly spaced planes which are generally designated herein as the *b* planes, and which are parallel to each other and to the *a* planes and are in interleaved relation with the *a* planes to be transversely displaced from the *a* planes by half the distance between adjacent *a* planes. The *b* planes of the three tie beams 37-39 are *b*₁, *b*₂ and *b*₃ respectively.

Tie means 36 is comprised of a similar set of parallel transversely and equidistantly spaced steel tie beams 40, 41 and 42 disposed in, respectively, the planes *b*₁, *b*₂ and *b*₃.

As shown, the longitudinally opposite end portions of the left-hand and right-hand tie beams of frame 20 are interleaved with the laterally opposite end portions of the beams of both crossheads of that frame, and hinge pins 45-48 are passed through the four resulting interleavings to provide load-transmissive couplings in the form of hinge joints by which the crossheads and sets of tie beams are coupled together to form the closed load-bearing polygonal frame 20. The advantages provided by such hinge joints in a load-bearing frame are set out in U.S. Patent 2,968,837 to Zeitlin et al.

The frame 20' differs in structure from frame 20 only in that in frame 20' the beams of its crossheads 25' and 26' are in the *b* planes and the tie beams of its two tie means 35' and 36' are in the *a* planes.

There is no coupling between frames 20 and 20' which would have the effect in the longitudinal and lateral directions of causing a deformation of one of the frames or an adjustment of one of the frames in its shape or in its position (angular or translational) to be wholly or partly constrained by the other frame. Hence, in the longitudinal and lateral directions, the two frames are floating in relation to each other.

Because of the difference in the planes occupied by the crosshead beams of the frames 20 and 20', the respective beams of the separate crossheads 25 and 25' of those frames are enabled to pass by each other. As shown, those beams do pass by each other in interleaved relation to provide an upper compound crosshead 50 having 25 and 25' as component crossheads thereof. Similarly, the respective beams of the separate lower crossheads 26 and 26' of the frames 20 and 20' are beams which pass by each other in interleaved relation to form a lower compound crosshead 51 having 26 and 26' as component crossheads thereof.

Because of the mode of interleaving of the component crossheads of the compound crossheads, each of the latter has two joints which are on laterally opposite sides of the space 21 and which are inside two other joints associated with that compound crosshead. Thus the joints provided by pins 45', 46' of crosshead 50 are inside the joints provided by pins 45, 46', and the joints provided by pins 47, 48' of crosshead 51 are inside the joints provided by pins 47' and 48. As shown, the component crossheads of each compound crosshead are laterally overlapping over the distance between the laterally opposite sides of space 21 (i.e., between the inner sides of the two inside joints of the compound crosshead), and the access way 52 (FIG. 2) for introduction of a piece of work into space 21 is at

least as large as (and, in fact, is larger than) that distance.

The respective tie means of the frames 20 and 25 are also interleaved. That is, the left-hand tie beams 37-39 of frame 20 and the left-hand tie beams 37'-39' of frame 20' pass by each other as shown to be in interleaved relation. Similarly, the right-hand tie beams 40 and 42 of frame 20 and the right-hand tie beams 40'-42' of frame 20' pass by each other to be in interleaved relation.

From the previous description, it will be appreciated that any two adjacent sets of parallel transversely spaced beams are adapted to pass by each other in interleaved relation when the beams of one set occupy the *a* planes and the beams of the other set occupy the *b* planes.

The massive load-bearing frames of FIG. 1 are maintained in their illustrated position by one or more light support frameworks (not shown) which are not part of the present invention. Such one or more frameworks are designed so as to not bear any substantial part of the loads imposed on frames 20 and 20', and so as to not interfere substantially with the responses of those frames to loading and with the floating relation between those frames.

FIG. 2 shows the frame structure of FIG. 1 as employed to receive outward reactive loads on its compound crossheads 50 and 51 from the opposed rams 60 and 61 of a forging press 62 doing work on a piece of work 67 such as a billet. The upper ram 60 has a wedged shaped top providing oppositely-slanting load-transmitting faces 63 and 64 which bear flatly and directly against, respectively, the crosshead 25 and the crosshead 25' of the component crosshead 50. In like manner, the lower ram 61 has a wedge shaped bottom providing oppositely-slanting load-transmitting faces 65 and 66 which bear flatly and directly against, respectively, the crosshead 26 and the crosshead 26' of the lower component crosshead 51. Hence, the oppositely directed loads from the rams 60 and 61 are transmitted in parallel to the frames 20 and 20' and are divided half and half between those two frames.

The frame structure of FIGS. 1 and 2 is a "double strength" composite frame structure like that of U.S. Patent 3,278,993 and shares many of the advantages which are described in that patent for the frame structure disclosed therein. Among other additional advantages of the frame structure of FIGS. 1 and 2, the component frames of that structure have respective longitudinal-lateral midplanes which each are normal to a common line extending in the transverse direction of the structure. Moreover, on each of the laterally opposite sides of space 21 the two frames overlap in their respective transverse extents (i.e., the transverse extent of tie means 35 overlaps with that of tie means 35', and the same is true for tie means 36 and 36'). Hence, structure 10 is a composite frame structure which (1) minimizes the housing space required for the structure in the transverse direction, (2) maximizes in the lateral direction the dimension of the access way for work i.e., the lateral dimension over which work (such as billet 67) can be introduced transversely from outside the frame structure to the central space within that structure so as to be positioned between the rams 60 and 61.

Further, because the two frames are loaded in parallel and are floating in relation to each other, they are each adapted to respond to the loading from press 62 in a manner which is not substantially constrained by a coupling with the other frame by means other than the indirect coupling of the two frames provided by press 62. Moreover, because the two frames are not only floating but are also substantial duplicates in size and shape and in the couplings thereof to press 62, the two frames under loading undergo similar deformations and are subject to similar stresses and, accordingly, tend to automatically equalize between themselves the loads which are borne by each.

As another advantage, because the component cross-

heads of each compound crosshead are laterally overlapping from one lateral side to the other of the space 21 within the frame structure 10, each compound crosshead provides a full strength backing for load over that entire distance, and, accordingly, the compound crosshead can be distributively loaded over most or all of such distance. Also, such increased span over which the compound crossheads can be distributively loaded does not entail any sacrifice in the size of the access way 52 for the billet 67 or other piece of work.

Still further, the frame structure of FIGS. 1 and 2 is relatively inexpensive to construct because it is entirely fabricated from simple beam members and hinge pins of which both are commercially available from steel mills, and which require no alteration from their commercially available shape except (in the case of the beam members) for the boring of holes to accommodate the hinge pins.

The frame structure of FIGS. 1 and 2 does, however, have a shortcoming best understood from FIG. 3. That figure shows a skewed parallelogram 70 representative in shape of the frames 20 and 20'. The short arms 71 and 72 of parallelogram 70 are subjected to equal loading forces *F* and *F'* from a source *P* corresponding to the press 62 of FIG. 2. In the FIG. 3 diagram, the center lines of action of the forces *F* and *F'* are (a) equal and oppositely directed, (b) colinear, (c) parallel to the long arms 73 and 74 of the parallelogram 70. The center lines of action also (d) pass through the centers of the short arms 71 and 72. Because the loading forces *F* and *F'* meet the conditions (a) to (d) just stated, the parallelogram 70 is not subjected to any moment by those forces, the short arms 71 and 72 will be symmetrically loaded about their lateral centers by the forces *F* and *F'*; the long arms 73 and 74 will be subjected to equal tensions, and the parallelogram will be theoretically stable in its shown skewed shape, i.e., will not tend either to collapse or to assume a rectangular form.

In the FIG. 2 structure, on the other hand, although the loading forces on frame 20 are equal and oppositely directed, the center lines of action of those loading forces 20 are not wholly colinear and are not wholly parallel to the long arms of the frame, and such center lines of action do not pass through the lateral centers of the short arms of the frame. The same is true for the center lines of action of the loading forces on the frame 20'. Hence, the loading forces on the two frames exert on them a moment tending to rotate the frame in opposite directions around the press 62. Also, such forces tend to urge the skewed parallelogram frames to assume a rectangular form, and, although the forces similarly load both frames, the forces do not load the individual crossheads of each of frames 20 and 20' symmetrically about their lateral centers so as to produce equal tensions in the tie beams of each of the frames.

Such frame stability problems as are created by the mentioned asymmetries in the individual loadings on frames 20 and 20' may be overcome by constructing the skewed parallelogram frames to each approach as close as possible to the rectangular form (see FIG. 4) consonant with the consideration that the beams of the two frames pass by each other (as shown) to position ones of the joints of each frame inside the other frame. To put it another way, such problems may be overcome by bringing those frame joints which are on the inside of the frame structure within the closest distance practical (see FIG. 4) to the adjacent frame joints on the outside of the frame structure (see FIG. 4). By so constructing the frame structure, the contacts between the frames 20, 20' and press 62 and the friction between those frames and the press will prevent the frames from rotating or changing in shape despite the asymmetry in the loading on each of the frames.

As an alternative to the mode of construction just described or as an addition thereto, any tendencies of the frames to rotate under a moment or to change in shape

may be overcome by the optional use of hinge pins **80**, **80'** and **81**, **81'** passing transversely through the centers of, respectively, compound crosshead **50** and compound crosshead **51**. Each such hinge pin fastens together the two component crossheads of the compound crosshead through which that pin passes so as to cause the horizontal components of the respective loading forces on the two component crossheads to balance each other out. Hence, considering the frame structure **10** as a whole, the pins **80**, **80'** and **81**, **81'** cause the resultant loading forces on that structure to be vertical, colinear, equal and opposite forces and to otherwise meet for that structure the conditions discussed (in connection with FIG. 3) which assure the stability of that whole structure. When, however, such hinge pins are used, they eliminate the ability of the component frames **20** and **20'** to each respond to the load in a manner unconstrained by the other frame.

FIG. 4 shows the FIG. 2 structure as modified to provide the symmetrical loading conditions discussed in connection with FIG. 3. In the FIG. 4 modification, the outer ends of the rams **60** and **61** are flat. Considering the upper ram, interposed between its flat top and the underside of beam **27'** (here shown in front of beam **27**) are lower and upper superposed steel triangular transition pieces **90'** and **91'** for the crosshead **25'** of frame **20'**. Those pieces are of the same transverse thickness as the beam, and they register transversely with the beam so as to transmit loading force to the beam over its full transverse width.

The pieces **90'** and **91'** have therebetween an interface **92'** normal to the lies of the tie beams **35'**, **36'** of frame **20'** of which beam **27'** is a part. If desired a layer of "Teflon" (not shown) may be interposed at interface **92'** between the pieces **90** and **91'** to minimize the frictional resistance to relative sliding of those pieces in the direction of lie of the interface. Piece **91'** is coupled to beam **27'** by conventional fastening means (not shown) which prevents lateral sliding between that piece and the beam. The two pieces **90'** and **91'** are disposed in the lateral dimension of beam **27'** so that the center line of action of the load force transmitted through interface **92'** is directed to pass through the lateral center of beam **27'**. That transmitted load force is normal to interface **92'** and, hence, parallel to the tie beams **35'** and **36'** of frame **20'**.

Two similar upper and lower transition pieces **90** and **91** are disposed behind transition pieces **90'**, **91'** to be interposed between the top of ram **60** and the beam **27** of crosshead **25** of frame **20**. The pieces **90** and **91** are arranged (with **91** being fastened to beam **27** to prevent lateral sliding therebetween) so that loading force transmitted through their interface **92** (or through a "Teflon" layer between the two pieces) is directed to pass through the lateral center of beam **27** and to be normal to interface **92** and, hence, parallel to the tie beams **35** and **36** of frame **20**.

The pair of transition pieces under beam **27'** is duplicated by a like pair of transition pieces under each of the other beams in crosshead **25'**. Moreover, the pair of transition pieces under beam **27** is duplicated by a like pair of transition pieces under each of the other beams in crosshead **25**. All of the lower left-hand transition pieces (e.g., piece **90**) are fastened to all of the lower right-hand transition pieces (e.g., piece **90'**) by a pin **95** passing transversely through the interleaving of the lower left-hand pieces and lower righthand pieces. The whole array of transition pieces under compound crosshead **50** is duplicated by a like array of transition pieces interposed between the flat bottom of ram **61** and the lower compound crosshead **51**.

Upon loading of the frame structure of FIG. 4 by the press **62**, the described transition pieces cause the center lines of action of the loading forces on the crossheads of each of the frames **20** and **20'** to pass through the lateral centers of those crossheads in a direction parallel

to the lie of the tie beams coupled to those crossheads. Hence, for the reasons discussed in connection with FIG. 3, each of the component frames of the FIG. 4 frame structure will be stably loaded so as to have no moment thereon and no tendency of change shape. Moreover, the crossheads of each of the component frames will be symmetrically loaded about the lateral centers of such crossheads, and, in both frames, the two sets of tie beams in the frame will be under equal tension.

It might be noted that the FIG. 3 parallelogram is only theoretically stable since, if the forces **F** and **F'** were to be point forces exerted as shown, any maintained departure of those forces from colinearity would cause the parallelogram to jack and to thereby collapse to a configuration approximating a straight line. In the FIG. 4 frame structure however, the tendency of each component frame to be dynamically unstable like the FIG. 3 parallelogram is overcome by the fact that the loading forces on the frame from the contained press and the contact made between the frame and that press are both distributed over a substantial lateral extent of each of the crossheads of the frame.

In addition to its other advantages, the FIG. 4 structure provides a regional fill factor and a span fill factor which are each greater than 50%. That is so because the inner face portions of the beams of each compound crosshead to which portions of the distributed load are transmitted in parallel are beam portions of which the effective areas have a total area more than 50% of the area of the whole region occupied by those effective areas and more than 50% of the effective area of the lateral and transverse extent of that portion of each compound crosshead which laterally spans the central working space **21**. At the cost of introducing a slight asymmetry in the loading on each of frames **20** and **20'**, the regional fill factor may be increased to 100% by modifying the transition pieces in each array thereof so that the pieces in the *a* planes and the pieces in the *b* planes are laterally coextensive.

FIGS. 5 and 6 and 7 are schematic diagrams of further embodiments of the invention. In each of those diagrams, the heavy black lines represent transversely spaced sets of beams, the letters *a* and *b* denote the planes in which the beams in such sets lie, and the heavy black dots represent hinge joints.

In the FIG. 5 structure, the component frames **100** and **101**, are in the form of interleaved trapezoids which are duplicates in size and shape and which are in mirror relation to each other so that the parallel sides of each trapezoid are vertical to provide the sets of tie beams for the structure. The load is transmitted from the press **62** to the component frames via triangular transition pieces (one per beam) which are in fixed relation with the corresponding beam, and of which the piece **101** and the piece **101'** (partly behind piece **101**) are exemplary. The FIG. 5 structure has all the advantages of the FIG. 4 structure and the further advantage that its sets of tie beams are vertical so as to take up a minimum of room.

In the FIG. 6 structure, the component frames **110** and **110'** are in the form of interleaved duplicate trapezoids disposed so that the parallel sides of each trapezoid are horizontal to provide the component crossheads of the structure. The structure's upper compound crosshead is comprised of an upper component crosshead **111** (provided by frame **110**) and a lower component crosshead **111'** (provided by frame **110'**) of slightly lesser span than crosshead **111**. Because the beams of crossheads **111** and **111'** are in planes *a* and *b* respectively, the beams of the two crossheads, although parallel, may be partly interleaved. That is, the upper beams may occupy those portions of the voids between the lower beams which are above the pins by which the crosshead **111'** is connected to its tie beams.

In loading the upper compound crosshead, the top of ram **60** bears directly against the inner crosshead **111'**, and loading force is transmitted from the ram to the outer

crosshead **111** through rectangular transition bars **112** inserted in the voids between the beams of crosshead **111'** so that the tops of the bars bear against the bottoms of the beams of crosshead **111** and the bottom sides of the bars **112** are flush with the bottom sides of the beams of crosshead **111'**.

The lower compound crosshead of the FIG. 6 structure has a construction similar to that of the upper compound crosshead just described.

The FIG. 6 structure has all the described advantages of the FIG. 4 structure and the further advantage that, in the FIG. 6 structure, a regional fill factor of 100% and a span fill factor in excess of 50% are obtained without the introduction of any accompanying symmetry into the loading of the component frames. Because the outer component crosshead **111** of the upper compound crosshead is of slightly longer span than the inner crosshead **111'** thereof and, also, is subject to compressive stress by the horizontal components of the tensile forces in the tie bars to which crosshead **111** is connected, crosshead **111** might tend to have a larger bowing deformation than crosshead **111'** if the same load were to be applied under the same conditions to each crosshead, and the frames **110**, **110'** were not floating in relation to each other. The tendency of crosshead **111** to bow more than crosshead **111'** is however, largely or entirely overcome by the fact that the load on crosshead **111** is transmitted thereto through the transition bars **112** which, in effect, provide an extra stiffening for the outer component crosshead. The considerations just discussed also apply to the lower compound crosshead. Moreover, irrespective of the relative sizes of the deformations of the inner and outer component crossheads of each compound crosshead, the floating relation between frames **110** and **110'** cause the two frames to automatically share equally between them the total load impressed on the FIG. 6 frame structure and thereby cause the two component crossheads of each compound crosshead to bear the same load.

In the FIG. 7 structure, the component frames **120** and **120'** are interleaved hexagons. In each of the frames, two laterally opposite ones of the "tie" sides of the hexagon are formed by the joining together by a spaced pair of hinge pins of interleaved *a* beams and *b* beams so that the *a* beams project from opposite ends of the structure thus formed and are overlapping over the distance between the two hinge pins. Each compound crosshead of the FIG. 7 structure is formed of an inner crosshead which bears directly against the corresponding ram and of an outer crosshead which receives loading forces from that ram via rectangular transition bars **121** similar to those already described in connection with FIG. 6. In each frame, the hinge joints at the widest part of the hexagon are connected by beams **122** which prevent the hexagon from collapsing under load into rectangular form. Those beams **122** may be connected to the pins of the mentioned joints at positions transversely outside the connections thereto of the tie beams which are joined by those pins, and such beams **122** may provide part of the platform for the work **67**. The FIG. 7 structure provides the same advantages as the FIG. 6 structure and the additional advantage that the two component crossheads of each compound crosshead are of equal span.

The above-described embodiments being exemplary only, it is to be understood that additions thereto, modifications thereof and omissions therefrom can be made without departing from the spirit of the invention, and that the invention comprehends embodiments differing in form and/or detail from those specifically described. For example, while the description herein has been limited to frame structures formed of only two component frames, it will be appreciated that each such component frame may be divided in the transverse direction into a plurality of separate frames.

Accordingly, the invention is not to be considered as

limited save as is consonant with the recitals of the following claims.

1. In apparatus comprised of a load bearing frame structure comprised of at least two closed polygonal load-bearing frames each disposed around a central space within said structure, each frame being comprised of laterally extending crossheads on longitudinally opposite sides of said space and of separate longitudinally extending tie means disposed on laterally opposite sides of said space and coupled with such crossheads by load-transmissive couplings productive of an opposed relation in said tie means between respective outward loads on said crossheads, said frame structure being characterized by compound crossheads disposed on longitudinally opposite sides of said space and each comprised of component crossheads of which each is a crosshead of a respective one of said frames, the improvement in which said frames have respective longitudinal-lateral midplanes which are each substantially normal to a common line extending in the transverse direction of said structure, and in which said frames are relatively disposed in said direction to be characterized on each of said laterally opposite sides of said space by an overlapping in said direction of the respective transverse extents on that side of said two frames.

2. The improvement as in claim 1 further comprising, means in said space to subject each of said compound crossheads to an outwardly directed load, and means by which such load on each compound crosshead is received in parallel by the component crossheads thereof.

3. The improvement as in claim 1 in each of said two frames has a response to load which is unconstrained by contact with the other frame.

4. The improvement as in claim 1 in which each of the component crossheads of each compound crosshead is comprised of transversely spaced beams separated by voids and disposed in respective planes which are parallel to and in transversely displaced relation with the respective planes of such beams of the other component crosshead of that compound crosshead.

5. The improvement as in claim 4 in which the component crossheads of each compound crosshead have respective beams of which at least portions are disposed in the voids between beams of the other component crosshead so as to be interleaved with at least portions of the last named beams.

6. The improvement as in claim 1 in which each component crosshead of each compound crosshead is comprised of transversely spaced beams separated by voids to thereby render such compound crosshead comprised of beams, said apparatus further comprising, means in said central space to apply to each of said compound crossheads an outwardly directed distributed load, and means by which such outward load on each compound crosshead is received in parallel by beams thereof on inner face portions of such beams, the effective areas normal to the direction of load application of said portions being disposed within a circumscribed region and having a total area of at least 50% greater than that of said whole region to thereby provide a regional fill factor of more than 50% for such compound crosshead.

7. The improvement as in claim 6 in which each such compound crosshead has a span fill factor in excess of 50%.

8. The improvement as in claim 1 in which each of said frames is comprised of transversely spaced beams separated by voids, and in which each of said frames has beams passing through the voids between and in interleaved relation with beams of the other frame so as to render each frame partly inside and partly outside the other frame.

9. The improvement as in claim 8 in which said frames are substantial duplicates in size and shape.

10. The improvement as in claim 9 further comprising means in said central space to subject each of said com-

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pound crossheads to an outwardly directed load, and means by which such load of each compound crosshead is divided between said frames to produce substantially similar loading stresses on each frame.

11. The improvement as in claim 9 in which said load bearing frame structure is substantially symmetrical in a longitudinal-lateral plane about a longitudinal axis in such plane, said last named plane passing through both of said frames of said structure.

12. The improvement as in claim 9 in which said load bearing frame structure is substantially symmetrical in a longitudinal-lateral plane about a lateral axis in such plane, said last named plane passing through both of said frames of said structure.

13. The improvement as in claim 1 in which at least one of said frames is of skewed parallelogram shape.

14. The improvement as in claim 1 in which at least one of said frames is of trapezoidal shape.

15. The improvement as in claim 1 in which at least one of said frames is of hexagonal shape.

16. The improvement as in claim 1 in which the component crossheads of each compound crosshead are relatively disposed to position two of said couplings of such component crosshead inside two other of such couplings, and in which said component crossheads of each compound crosshead are laterally overlapping over the span of such compound crosshead between said two inside couplings.

17. The improvement as in claim 16 in which said frame structure provides an access way at least as large in lateral dimension as said span for introduction of a piece of work transversely into said central space from outside said frame structure.

18. In a frame structure comprising at least two crosshead means disposed at longitudinally opposite ends of a central space within said structure and each having oppo-

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site ends on opposite sides of said space and being comprised of beams extending in the direction between such opposite ends, and a plurality of tie means disposed on opposite ones of said sides to couple said two crosshead means together, the improvement in which each crosshead means has only two ends which are laterally opposite each other, said beams of each crosshead means are laterally overlapping in the laterally central portion of that crosshead means and provide at each such end of that crosshead means and in the transverse direction normal to the longitudinal and lateral directions an alternation between beams having laterally salient end portions and beams having laterally indented end portions, and in which said tie means couple said two crosshead means together by being coupled to both said laterally salient portions and said laterally indented portions of said beams of said two crosshead means.

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