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(54) Title: FORGING DIE APPARATUS FOR STEERING RACKS

(57) Abstract: A die apparatus for forging a steering rack from a bar. The die apparatus comprises a first and a second bolster movable towards each other, and at least one gripper adapted to grip the bar as the rack is forged. The gripper comprises first and second gripper halves carried by, and movable relative to, the first and second bolsters respectively. A gripping bias means biases the gripper halves towards each other. As the bolsters move towards each other to forge the rack, the first gripper half abuts against the first bolster, and the second gripper half abuts the second bolster.
FORGING DIE APPARATUS FOR STEERING RACKS

TECHNICAL FIELD

The present invention relates to the manufacture of steering racks for vehicle rack and pinion steering gears, and in particular to a die apparatus for forging steering racks.

BACKGROUND

Typically, vehicle steering racks are manufactured from round solid bar stock with the toothed region broached across the bar near one end. This results in the cross section of the toothed region having a 'D' shape and hence these racks are commonly referred to as "D-racks".

An alternative method of manufacturing a steering rack from round solid bar stock is to forge the toothed region. An advantage of forging is that the teeth may be shaped to have a variable gear ratio. US Patents 4,571,982 (Bishop et al) and 5,862,701 (Bishop et al) disclose die apparatus for flashless warm forging steering racks having a toothed region with a "Y" shaped cross section. These types of racks are known as "Y-racks".

The die apparatus disclosed in US Patent 5,862,701 (Bishop et al) is an improvement over the die apparatus disclosed in US Patent 4,571,982 (Bishop et al). However, the die apparatus disclosed in US Patent 5,862,701 (Bishop et al) still has limitations. This die apparatus has a gripper to grip the bar being forged. The gripper comprises upper and lower halves, each supported by a piston. The lower gripper half bottoms out against the lower bolster during the forging stroke. In contrast, the upper gripper half is only loaded by the hydraulic pressure on its piston, although it may also be supported by other elements of the die. This limits the load that can be applied to the upper gripper half because the size of the piston is limited by the other components in the die apparatus and the overall size limitations of the die apparatus, and because
the hydraulic pressure that can be applied to the piston is limited by the seals and other factors.

To improve the accuracy of the racks being forged, and in particular to improve the control of the offset of the gripped portion of the bar to the forged toothed portion of the rack, it is desirable to apply more load to the gripper than can practically be applied by the die apparatus disclosed in US Patent 5,862,701 (Bishop et al). It is particularly desirable to increase the gripping load at the end of the forging stroke of the die apparatus to prevent the gripper halves from separating at this point, because it is the relative positions of the forging tooling and the gripper at the end of the forging stroke that determine the shape of the forged rack. Preventing the gripper halves from separating also prevents excess material from escaping from the die cavity.

It is an object of the invention to provide an improved die apparatus for forging steering racks.

SUMMARY OF INVENTION

The present invention consist of a die apparatus for forging a steering rack from a bar, the steering rack having a toothed portion, the die apparatus comprising a first bolster and a second bolster movable towards each other to forge the steering rack, a plurality of die elements carried by the bolster, each die element having a forming surface shaped as the obverse of a region of the toothed portion, at least one gripper adapted to grip a portion of the bar as the steering rack is forged, the gripper comprising a first gripper half and a second gripper half, the first and second gripper halves being carried by, and movable relative to, the first and second bolsters respectively, and a gripper bias means adapted to bias the gripper halves towards each other as the steering rack is forged, characterised in that the die apparatus is arranged such that as the bolsters move towards each other to forge the steering rack, the first gripper half moves relative to the first bolster until it abuts against the first bolster, and the second gripper half moves relative to the second bolster until it abuts against the second bolster.
Preferably, the first gripper half is supported by a first piston movable in a first bore in the first bolster, and the second gripper half is supported by a second piston movable in a second bore in the second bolster, the gripper bias means comprising restricting the flow of fluid from the bores as each piston moves in its respective bore.

Preferably, at least one of the first and second gripper halves abuts its respective bolster by means of its respective piston abutting the bolster.

Preferably, at least one of the first and second gripper halves abuts its respective bolster by means of the end face of its respective piston abutting the end of the respective bore that it moves in.

In one preferred embodiment, the end face of the piston is locally relieved to allow fluid to pass the end face of the piston when it is abutting the end of the bore. Preferably, the end face of the piston is locally relieved by means of at least one groove in the end face of the piston. In another preferred embodiment, the end of the bore is locally relieved to allow fluid to pass the end face of the piston when it is abutting the end of the bore.

Preferably, the at least one gripper comprises two grippers disposed either side of the die elements.

Preferably, the steering rack is a Y-rack and the toothed portion comprises an array of gear teeth, two opposed guide faces angled to each other, and an end face opposite the teeth.

Preferably, the die elements comprise a tooth die having a forming surface shaped as the obverse of the array of gear teeth, a centre punch having a forming surface shaped as the obverse of the end face of the toothed portion, and first and second side punches each having a forming surface shaped as the obverse of a guide face of the toothed portion, the tooth die being supported by the second bolster, the side
punches being supported by the first bolster, and the centre punch being supported by a centre punch piston movable in a bore in the first bolster.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a side view of a typical forged Y-rack.

Fig. 2 is a sectional view along II-II of the Y-rack shown in Fig. 1.

Fig. 3 is a longitudinal sectional view of a die apparatus in accordance with the present invention, shown in its open position.

Fig. 4 is a partial cross section along IV-IV of the die apparatus shown in Fig. 3.

Fig. 5 is a cross section along V-V of the die apparatus shown in Fig. 3.

Fig. 6 is a partial cross section along VI-VI of the die apparatus shown in Fig. 3.

Fig. 7 is a longitudinal section view of the die apparatus of Fig. 3, shown in a partially closed position.

Fig. 8 is a partial cross section along VIII-VIII of the die apparatus shown in Fig. 7.

Fig. 9 is a longitudinal section view of the die apparatus of Fig. 3, shown in a fully closed position.

Fig. 10 is a partial cross section along X-X of the die apparatus shown in Fig. 9.

Fig. 11 is a cross section along XI-XI of the die apparatus shown in Fig. 9.
BEST MODE OF CARRYING OUT THE INVENTION

Figs. 1 and 2 show a typical forged Y-rack 1 having a toothed portion 2 with an array of forged teeth 3. A long cylindrical shank 4 extends from one end of the toothed portion 2, and a short cylindrical portion 5 extends from the other end of the toothed portion 2. Fig. 2 shows the Y-shaped cross-section of the toothed portion 2. The toothed portion 2 has two opposed guide faces 7 angled to each other, and an end face 8 opposite the teeth 3. The Y-rack 1 shown in Figs. 1 and 2 is in the as forged condition, and further machining operations are required to produce a finished steering rack. However, the toothed portion 2 typically does not require any finish machining as the teeth 3 are typically forged to net shape.

Figs. 3 to 11 show a die apparatus 10 for forging the Y-rack 1 from a cylindrical solid bar 6. The die apparatus 10 is an improvement over the die apparatus disclosed in US Patent 5,862,701 (Bishop et al) and some of the details of the operation and construction of die apparatus 10 that are the same as the die disclosed in US Patent 5,862,701 (Bishop et al) are not repeated in the present specification. Furthermore, the details of the operation and construction of the die apparatus that are not fully described in the present specification or disclosed in US Patent 5,862,701 (Bishop et al) are details that those skilled in the art of forging die design would understand as necessary to implement the invention.

Figs. 3 to 6 show the die apparatus 10 in its fully open position with a solid cylindrical steel bar 6 loaded into it. The portion of the bar 6 that will be forged is heated prior to loading it into the die apparatus 10.

The die apparatus 10 comprises an upper bolster 11 and a lower bolster 12. The bolster 11 and 12 are attached to the platens 13 and 14 respectively of a press (not shown) such that the bolsters 11 and 12 are movable towards each other by means of the press to forge a Y-rack 1 from the bar 6. Preferably the press is a screw type press.
Referring to Fig. 5, a centre punch 17, two side punches 18, a tooth die 20, and two side plates 19 are the die elements that forge the toothed portion 2 of Y-rack 1. The centre punch 17 and the side punches 18 are carried by the upper bolster 11, and the tooth die 20 and the side plates 19 are carried by the lower bolster 12. Each of the die elements 17, 18, 19 and 20 has a forming surface that is the obverse of a region of the toothed portion 2.

The tooth die 20 has forming surface shaped as the obverse of the array of rack teeth 3. The centre punch 17 has a forming surface shaped as the obverse of the end face 8 of the toothed portion 2, and the centre punch 17 is supported by a large centre punch piston 22 through a carrier 24. The piston 22 slides in a bore 23 in the upper bolster 11. A chamber 29 in the bore 23 above the piston 22 is connected to a source of hydraulic fluid through a hole 30. The load on the piston 22 is controlled by controlling the flow of hydraulic fluid from the chamber 29 as the die apparatus 10 closes.

The side punches 18 each have a forming surface shaped as the obverse of a guide face 7 of the toothed portion 2, and are supported by roll blocks 21, attached to the upper bolster 11, that allow the side punches 18 to roll and maintain contact with the centre punch 17. As the die apparatus 10 closes, the die elements converge on the bar 6 to form the Y-shaped cross section of the toothed portion 2, as shown in Fig. 11. The final position of the die elements relative to the bolsters 11 and 12 is adjusted by various spacer plates in the die apparatus 10.

Referring to Fig. 3, the die apparatus 10 has two grippers 25a and 25b. Each gripper 25a, 25b has an upper half 26a, 26b and a lower half 27a, 27b. The upper gripper halves 26a and 26b are carried by and movable relative to the upper bolster 11. The lower gripper halves 27a and 27b are carried by and movable relative to the lower bolster 12. Each gripper half 26a, 26b, 27a, 27b has a semi-circular gripping surface 28 matched to the diameter of the bar 6. The grippers 25a, 25b are positioned to grip the bar 6 adjacent both ends of the die elements 17, 18, 19 and 20.
A cylindrical end stop 31 is located between the halves 26b, 27b of gripper 25b to prevent material being squeezed axially out of the gripper 25b during forging. The end stop 31 is supported by a wedge member 32 that slides on the top of the lower gripper half 27b. The wedge member 32 contacts a corresponding wedge block 33, attached to the lower bolster 12 as the die apparatus 10 closes to bias the end stop 31 against the end of the bar 6.

Referring to Fig. 4 showing a detail section through gripper 25a, the upper gripper half 26a is supported by a piston 36 through a support block 37 and spacers 38 and 39. The support block 37 moves with the upper gripper half 26a and slides against the upper bolster 11 to prevent the upper gripper half 26a from rotating. The piston 36 is movable in a bore 40 in the upper bolster 11. The piston 36 has a seal 42 and an end cap 41. An optional spacer 44 is attached to the end 43 of the bore 40. A chamber 46 in the bore 40 above the piston 36 is connected to a source of hydraulic fluid through a hole 45 in the upper bolster 11. The shaft of the piston 36 slides in a support block 47, attached to the upper bolster 11, that limits the downward travel of the upper gripper half 26a when the die apparatus 10 is open.

When the die apparatus 10 is open as shown in Fig. 3 to 5, there is a gap 48 between the piston end cap 41 and the spacer 44. The upward travel of the upper gripper half 26a relative to the bolster 11 is limited by the piston 36 abutting the end 43 of the bore 40 through the piston end cap 41 and the spacer 44. Fig. 6 shows a plan view of the piston end cap 41. The piston end cap 41 has a raised region 63 that contacts the spacer 44 when the piston 36 abuts against the end 43 of the bore 40. Radially inside the raised region 63 is a centre recessed region 61 that communicates directly with the hole 45. The piston end cap 41 also has an outer recessed region 62 radially outside the raised region 63.

The raised region 63 is locally relieved by four shallow radial grooves 64 connecting the centre 61 and outer 62 recessed regions. The grooves 64 allow hydraulic fluid to pass the piston end cap 41 when the end cap 41 is in contact with the spacer 44. This allows hydraulic fluid to freely pass radially inwards across the piston end cap 41 to the hole 45 as the end cap 41 approaches the spacer 44. Otherwise excessive
pressure may occur in the chamber 46 as fluid is forced through the narrowing gap between the end cap 41 and the spacer 44.

The grooves 64 also make it easier for the end cap 41 to be pushed out of contact with the spacer 44 by pressurized hydraulic fluid supplied through the hole 45. In this case, the grooves 64 increase the area of the end cap 41 exposed to the supply pressure and relieve the hydraulic stiction due to the thin film of fluid trapped between the contacting flat faces of the end cap 41 and the spacer 44. In other not shown embodiments of the invention, the end cap 41 may be locally relieved by features having a shape other than the radial grooves 64.

Referring again to Fig. 4, the lower gripper half 27a is supported by a piston 50 through a spacer 51. The lower gripper piston 50 is smaller in diameter than the upper gripper piston 36, such that if the same pressure is applied to both pistons 36 and 50 the gripper 25a as a whole is biased to move downwards. The lower gripper half 27a slides through a support plate 56 attached to the lower bolster 12. The support plate 56 also limits the upward travel of the lower gripper half 27a when the die apparatus 10 is open. A spacer 57 located in the lower bolster 12 limits the downwards travel of the lower gripper half 27a. The piston 50 is movable in a bore 52 in the lower bolster 12. The piston 50 has a seal 54 and an end cap 53. The bore 52 has an end cap 55. A chamber 59 in the bore below the piston 50 is connected to a source of hydraulic fluid through a hole 58 in the lower bolster 12.

When the die apparatus 10 is fully open, as shown in Figs. 3 to 5, the chambers 46 and 59 are pressurised to fully extend the grippers halves 26a and 27a away from the bolster 11 and 12 respectively. As the die apparatus 10 closes to forge the Y-rack 1 and the gripper halves 26a and 27a contact each other to surround and grip the bar 6, the gripper halves 26a and 27a are pushed back towards their respective bolsters 11 and 12. Pressure in the chambers 46 and 59 is generated by restricting the flow of hydraulic fluid from them thereby biasing the gripper halves 26a and 27a towards each other. As an example, the flow of hydraulic fluid may be controlled by means of a relief valve or spool valve, and such methods are described in more detail in US Patent 5,862,701 (Bishop et al).
The gripper halves 26b and 27b of gripper 25b are supported in the same manner as the gripper halves 26a and 27a of gripper 25a.

The operation of the die apparatus 10 to forge the Y-rack 1 will now be described. With the die apparatus 10 in its open position shown in Figs. 3 to 5, the heated bar 6 is loaded into the lower gripper halves 27a and 27b. The bolster 11 and 12 then commence moving towards each other by means of the press.

Figs. 7 and 8 show the die apparatus 10 in a partially closed position. In this position, the grippers 25a and 25b are gripping the bar 6 by means of the upper gripper halves 26a, 26b being biased towards the lower gripper halves 27a, 27b, as described above, to surround the bar 6. In this partially closed position, the lower gripper halves 27a and 27b have moved relative to the lower bolster 12 until they abut against the lower bolster 12 through the spacers 51 and 57. The lower gripper halves 27a and 27b remain abutted against the lower bolster 12 as the die apparatus 10 continues to close. In this partially closed position, there is still a gap 48 between the end caps 41 of the upper gripper pistons 36 and the spacers 44, such that the pistons 36 are only loaded by hydraulic pressure.

In this embodiment, the large piston 22 that controls the centre punch 17 also provides some support to the upper gripper halves 26a and 26b at some stage of the die apparatus 10 closing by means of the end edges of the carrier 24 contacting the upper gripper halves 26a and 26b through the spacers 39.

Figs. 9, 10 and 11 show the die apparatus 10 in its fully closed position, having completely forged the bar 6 into a Y-rack 1. In this fully closed position the bolster 11 and 12 abut each other through blocks 34 on both bolsters 11 and 12. Also in this fully closed position, the upper gripper halves 26a and 26b have moved relative to the upper bolster 11 until they abut against the upper bolster 11 by means of the pistons 36 abutting the ends 43 of the bores 40 through the piston end caps 41 contacting the spacers 44. The upper gripper halves 26a and 26b may abut the upper bolster 11 slightly before the die apparatus 10 fully closes. This is possible because the steel
bolster 11 acts as a highly stiff spring that deflects elastically slightly after the piston end caps 41 contact the spacers 44. In the fully closed position of the die apparatus 10, the lower gripper halves 27a, 27b continue to abut against the lower bolster 12.

By abutting the both the upper gripper halves 26a and 26b against the upper bolster 11 and the lower gripper halves 27a and 27b against the lower bolster 12, much greater gripping force on the bar 6 can be generated than relying on hydraulic pressure only on the pistons 36. This enables the upper 26a, 26b and lower 27a, 27b gripper halves to resist separating as the forging loads increase steeply as the die apparatus 10 approaches its fully closed position, thereby improving the accuracy of the forged Y-rack 1.

In other not shown embodiments of the invention, the spacers 44 attached to ends 43 of the upper gripper piston bores 40 may be omitted. In this case, the piston end caps 41 abut directly against the ends 43 of the bores 40. Also, the radial grooves 64 in the piston end caps 41 may be replaced with grooves, or other local relief features, in the ends 43 of the bores 40, or in the spacers 44.

In other not shown embodiments of the invention, the bias means for the gripper halves may comprises springs instead of hydraulic pressure applied to the pistons.

The gripper arrangement of the present invention is also suited to other types of die apparatus, such as die apparatus for forging D-racks.

As used herein, when a first object is said to "abut" a second object it means that the first object moves towards the second object until it is blocked from further movement by the second object, either by directly contacting the second object or by contacting a spacer or other relatively rigid member placed between the two objects. Therefore the use of the words "abut" or "abutting" does not necessarily require that the objects directly contact each other.

The term "comprising" as used herein is used in the inclusive sense of "including" or "having" and not in the exclusive sense of "consisting only of."
CLAIMS

1. A die apparatus for forging a steering rack from a bar, the steering rack having a toothed portion, the die apparatus comprising a first bolster and a second bolster movable towards each other to forge the steering rack, a plurality of die elements carried by the bolsters, each die element having a forming surface shaped as the obverse of a region of the toothed portion, at least one gripper adapted to grip a portion of the bar as the steering rack is forged, the gripper comprising a first gripper half and a second gripper half, the first and second gripper halves being carried by, and movable relative to, the first and second bolsters respectively, and a gripper bias means adapted to bias the gripper halves towards each other as the steering rack is forged, characterised in that the die apparatus is arranged such that as the bolsters move towards each other to forge the steering rack, the first gripper half moves relative to the first bolster until it abuts against the first bolster, and the second gripper half moves relative to the second bolster until it abuts against the second bolster.

2. A die apparatus as claimed in claim 1, wherein the first gripper half is supported by a first piston movable in a first bore in the first bolster, and the second gripper half is supported by a second piston movable in a second bore in the second bolster, the gripper bias means comprising restricting the flow of fluid from the bores as each piston moves in its respective bore.

3. A die apparatus as claimed in claim 2, wherein at least one of the first and second gripper halves abuts its respective bolster by means of its respective piston abutting the bolster.

4. A die apparatus as claimed in claim 3, wherein at least one of the first and second gripper halves abuts its respective bolster by means of the end face of its respective piston abutting the end of the respective bore that it moves in.
5. A die apparatus as claimed in claim 4, wherein the end face of the piston is locally relieved to allow fluid to pass the end face of the piston when it is abutting the end of the bore.

6. A die apparatus as claimed in claim 5, wherein the end face of the piston is locally relieved by means of at least one groove in the end face of the piston.

7. A die apparatus as claimed in claim 4, wherein the end of the bore is locally relieved to allow fluid to pass the end face of the piston when it is abutting the end of the bore.

8. A die apparatus as claimed in claim 1, wherein the at least one gripper comprises two grippers disposed either side of the die elements.

9. A die apparatus as claimed in claim 1, wherein the steering rack is a Y-rack.

10. A die apparatus as claimed in claim 1, wherein the steering rack is a Y-rack and the toothed portion comprises an array of gear teeth, two opposed guide faces angled to each other, and an end face opposite the teeth.

11. A die apparatus as claimed in claim 9, wherein the die elements comprise a tooth die having a forming surface shaped as the obverse of the array of gear teeth, a centre punch having a forming surface shaped as the obverse of the end face of the toothed portion, and first and second side punches each having a forming surface shaped as the obverse of a guide face of the toothed portion, the tooth die being supported by the second bolster, the side punches being supported by the first bolster, and the centre punch being supported by a centre punch piston movable in a bore in the first bolster.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl.
522/175 (2006.01) B21J 13/02 (2006.01) B21K 1/76 (2006.01)
B21J 7/14 (2006.01) B21K1/30 (2006.01) B62D 3/12(2006.01)

According to International Patent Classification (IPC) or both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of data base and, where practicable, search terms used)
WPI, EPODOC B21J7/-, B21J13/-, B21K1/30, 1/36 and keywords: platen, bolster, die, mold, gripper, holder, vice, clamp, manipulate, WPI, Electronic Documentation

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>A</td>
<td>US 4571982 A (BISHOP et. al) 25 February 1986 See col 6, lines 11 to 16 and 57 to 66.</td>
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<tr>
<td>A</td>
<td>US 5862701 A (BISHOP et. al) 26 January 1999 See col 5, lines 14 to 19 and 36 to 47; col 6, lines 33 to 35, col 9, lines 40 to 47.</td>
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX