FOUR-DIE FORGING DEVICES
Four die forging devices

Four-die forging devices are designed to forge material from four sides simultaneously on hydraulic forging presses.

Four-die forging unit is a unique forging tool which combines advantages both of radial forging method implemented on radial forging machine and conventional forging method using with two dies implemented on forging presses.

Four-die forging device is intended to be installed and fixed on the table of a hydraulic forging presses in capacities from 2 to 150 MN just in place of conventional dies. It is designed to forge a workpiece with four dies simultaneously which generates supplementary shear strain of the material.

A number of various design options of the four-die device are possible according to various methods of device connection to the press:

- top body of the device connected to the press movable cross-beam or to the top die (a number of options);
- top body of the device is driven by means of a spring (no connection to the movable cross-beam)
The four-die forging device consists of a bottom body 1 and top body 2, slides 3 and 4, dies 5-8 and lateral guideways 9-12. The bottom body is rigidly fixed to the press table. Prior to operation the top body of the device shall be fixed to the press movable cross-beam. The die 8 is fixed to the bottom body and it does not move during the forging operation. The die 6 is fixed to the top body and during the forging operation it moves together with the top body. The dies 5 and 7 are fixed to the lateral slides 3 and 4 respectively. As the press movable cross-beam moves upwards, the top body of the device moves upwards, too, and by means of eight lateral guideways 9-12 it brings apart the slides 3 and 4 with the lateral dies 5 and 7 fixed thereto, thus opening the forging device working area. An ingot or a billet is fed by means of a manipulator into the opened working zone of the device and onto the bottom die 8. As the movable cross-beam moves downwards, the top body moves downwards, too, and via the tapered surfaces provided on the top and bottom bodies imparts motion to the slides 3 and 4 carrying the dies 5 and 7. The dies 5 and 7 move not only towards each other; they also move at the same time downwards and towards the die 8 thus inducing supplementary shear strains in a workpiece being forged. A workpiece forged in such a device is reduced from four sides simultaneously.

To facilitate press operation using alternatively four-die device and conventional press tools and to eliminate the need to dismantle the top press die in order to connect the device to the movable cross-beam, we have developed a device where a spring is used to lift the top body and to respectively bring the dies apart.
The spring-type design is successfully used at a number of production plants. A special design of the lateral guideways serves not only to center align the top body relative to the bottom body and the slides; it also serves to bring apart the slides carrying the lateral dies fixed thereto without using any additional mechanisms. The advantages of this solution are: compact structure of the device and high operational reliability.

**The benefits of the four-die forging device:**

- 1.5 – 3 times higher output as compared to conventional two-die forging method commonly employed on presses.
- 8-15 per cent increased good metal yield
- 2 – 2.5 times reduced dimensional tolerances of the forged products and 1.5 times reduced allowances for finish surface machining which means 40 – 50 kg of metal saved per 1 ton of forged parts.
- 30 – 40 per cent reduced energy consumption at drawing operation.
- 25 - 30 per cent reduced gas consumption for metal heating due to elimination of reheating requirements.
- a better isotropy and improved physical/mechanical properties of forged metal.
- a wider range of steel grades which can be forged in the device and a wider range of finish product shapes.
- a possibility to forge low-ductile steel grades which can not be processed by means of conventional forging technologies.

Four-die forging device for a 30 MN press (China)
A special design of a four-die forging device was developed for finishing operation. It includes a spring member intended to bring the top body of the device to its top position. It also includes a quick-change attachment to change the sets of channel dies.

Another specialized solution of a four-die forging device was developed to produce flat products. Flats can be produced in a wide range of dimensions, for which purpose the device includes a feature of adjustment of the device working area between the dies.
General specifications of the forging operation:

**Materials to be forged**
- All steel grades from carbon steels to high-alloy steels, including hard-to-deform steels
- Special alloys – high-temperature, heat-resistant, precision, etc.
- All ductile metals and alloys (ferrous and non-ferrous, e.g. titanium, zirconium, aluminum)

**Shapes of initial components**
- All types and shapes of ingots
- Solid and hollow billets
- Rolled stock

**Shapes of forged parts**
- Round, square, flat
- Bars of polygonal cross-section
- Stepped parts
- Hollow parts, also stepped ones

Four-die forging device for a 25 MN press
(Russia)
Employment of a four-die forging device on a 45MN- and a 25MN presses (China)

**Output**

During two-die forging operation (conventional method) each single reduction results in considerable lateral spreading of metal which means a limitation of workpiece drawing in lengthwise direction. Thus in order to obtain a forged part of required cross-section and length it becomes necessary to perform more additional workpiece turning and reduction cycles.

Due to the four-side reduction method, lateral metal spreading phenomenon is eliminated or at least minimized. Thus the number of workpiece turning and reduction cycles can be considerably reduced, which means a higher forging output.

Due to intensive deformation-heat generation a workpiece formed in a four-die forging device cools down much slower as compared to conventional two-die forging operation. This phenomenon also contributes to reduction of reheating requirements and thus to a shorter production cycle duration.

Presses which can be equipped with four-die forging devices

- All types of hydraulic forging presses in capacities from 2 to 150 MN
- All types of automatic forging plants
Metal quality and accuracy of forged parts

Four-side reduction schedule implemented in a four-die forging device generates compressive stresses across the workpiece cross-section which makes it possible to successfully forge in a four-die forging device even low-ductile and hardly deformable steels and alloys. In this aspect the forging process in a four-die device looks similar to the radial forging process implemented on the radial forging machines (RFM).

Moreover, forging operation performed in a four-die forging device contributes to a uniform deformation treatment of cast metal structure across the total cross-sectional area of a workpiece.

While the dies in a radial forging machine move in radial direction only, the dies in a four-die forging device make a combined movement in radial and tangential directions. It serves to induce complimentary shear strains in the total cross-sectional area of a workpiece being forged. Due to this benefit and also due to the larger single reductions a considerably deep deformation treatment of cast metal structure is obtained.

When forged in a four-die forging device, the products in a variety of structural-, alloyed-, tool- and stainless steel grades, as well as precision-, high temperature- and heat resistant steels appear to be free from porosity defects, and the metal quality is much higher than that obtained on a radial forging machine.
Technology

Four-die forging technology provides for tolerances in the range of \( \pm 0.8 \) to 2.0 mm depending upon the cross-sectional size of the product. In order to achieve tolerances as close as that, the forged parts after rough forging are either finished in specially shaped dies or finish-forged without reheating in a special finishing four-die device right after initial rough forging.

Stresses induced at four-die forging and two-die forging operations

Strain at four-die forging and two-die forging operations
Finishing operation can be performed using either flat or channel dies. Finishing with four channel dies gives a 40 – 60 per cent higher output as compared to finishing using four flat dies.

Stresses induced at finishing with four dies

Strain at finishing with four dies
**Metal saving**

Four-die forging schedule implemented in a four-die forging device of a special design generates compressive stresses in circular peripheral area of a workpiece which results in defect-free forged parts. The benefits are the follows: a thinner poor surface layer to be removed at finish surface machining and thus a higher good metal yield.

Besides, since reheating requirements are significantly reduced, burned metal loss is significantly reduced, too, and it also contributes to a higher good metal yield and thus to considerable metal saving.

**Energy consumption**

Energy consumption for forging operation performed in a four-die forging device is much lower as compared to conventional two-die forging process on a press. The energy saving is achieved due to a higher efficiency of the forging process which results from practically eliminated lateral spreading of material. With no spreading effect, all the material deformed at each single reduction is forced to stretch along the workpiece longitudinal axis. Energy saving at initial parts heating to reach forging temperature is achieved due to reduced reheating requirements.
Economical efficiency of the process

Calculation of the economic efficiency of the device application in production of forged parts in 4Х5МΦC steel grade on a 20 MN press was made on the basis of actual process parameters, which provided for the following benefits:
- 2 times higher forging output;
- 9 per cent increased good metal yield;
- 1.5 times closer allowances for finish surface machining and 1.5 times closer allowances for finish peeling on parts in diameters of 300-400mm, which means 40 kg metal saving per 1 tonne of forged parts.

Economic efficiency amounted to more than 300$ per 1 tonne of forged parts.

Production of forged parts with minimized allowances for finish surface machining on a 30 MN press (China)

For a more detailed calculation of economical efficiency of four-die forging devices the following issues shall be taken into consideration:

- Reduced energy consumption for metal heating (gas or electricity);
- Reduced energy consumption at forging operation (electricity);
- Reduced labour input at forged parts peeling operation due to a thinner metal layer to be peeled-off. Considering the above-mentioned benefits we can say that actual savings at four-die device employment are even higher.
Long-term operation of four-die forging devices installed on various presses in industry proved high reliability of the device design

By 2014, 21 four-die forging devices are installed and working in industry.

Three four-die forging devices are employed now at OAO Corporation VSMPO-AVISMA (located in the city of Verkhnyaya Salda, Russia) Two of them are installed on 20 MN presses and one device is used on a 25 MN press.

Four-die forging devices installed on presses in capacities from 5MN to 45 MN are employed in production in Ukraine, Russia, China, Germany, Spain, Italy and Brazil.

Efficient operation (since more than 3 years) of a four-die forging device on a 45 MN press (China)
### Four-Die Forging Devices: Reference Technical Specifications and Model Range

<table>
<thead>
<tr>
<th>MODEL</th>
<th>FDF 5</th>
<th>FDF 8</th>
<th>FDF 10</th>
<th>FDF 12.5</th>
<th>FDF 16</th>
<th>FDF 20</th>
<th>FDF 30</th>
<th>FDF 40</th>
<th>FDF 50</th>
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<th>FDF 80</th>
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<tr>
<td>Rated press force, MN</td>
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<td>16</td>
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<td>60</td>
<td>80</td>
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<td>*Max. cross-sectional size of an ingot (a billet), mm</td>
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<td>500</td>
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<tr>
<td>*Min. cross sectional size of forged product, Mm</td>
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<td>320</td>
<td>340</td>
<td>360</td>
<td>380</td>
<td>400</td>
</tr>
</tbody>
</table>

* Initial ingot sizes and sizes of forged product produced in a four-die forging device are valid for medium-alloyed steel grades.

Four-die forging devices are developed and built to suit individual features of a customer’s press depending on its design, specifications, operating conditions as well as sizes and material grades of initial ingots (billets) and finish products.
Maximum benefits of four-die forging devices can be achieved when the devices are used incorporated into automatic forging plants.

Automatic forging plants equipped with four-die forging devices allow to perform the forging process under isothermal conditions which results in considerably higher metal quality.

On a basis of a license agreement we can develop a four-die device solution customized to any existing forging press, supply a complete set of engineering documentation for the device, render our assistance at the device manufacturing stage and at launching the device in production at a customer’s site.

Moreover, we can develop optimized forging schedules for the total range of initial ingots used at our customer’s sites, and also offer our assistance at implementation of such technologies.

Four-die forging device employed on a 25MN press to forge titanium billets at VSMPO-AVISMA plant (Verkhnyaya Salda, Russia)
Patent protection

Design of the four-die device (forging unit) and also four-die forging technology are protected by the following patents:

6. Patent No. 101909 (Ukraine) dd. 05.03.2012, IPC B21J 7/16, B21J 13/08 Method of dies changing in a forging device incorporating more than two dies.

Heat-resistant alloy forged on a 25 MN press in a four-die forging device (Russia)
More information about the four-die forging devices is available in the following publications:


Stainless steel Ingot forged on a 30 MN press (Brazil)
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High-alloy stainless steel ingot forged on a 30 MN press (Italy)
INNOVATIVE TECHNOLOGIES FOR OPEN-DIE FORGING ON PRESSES