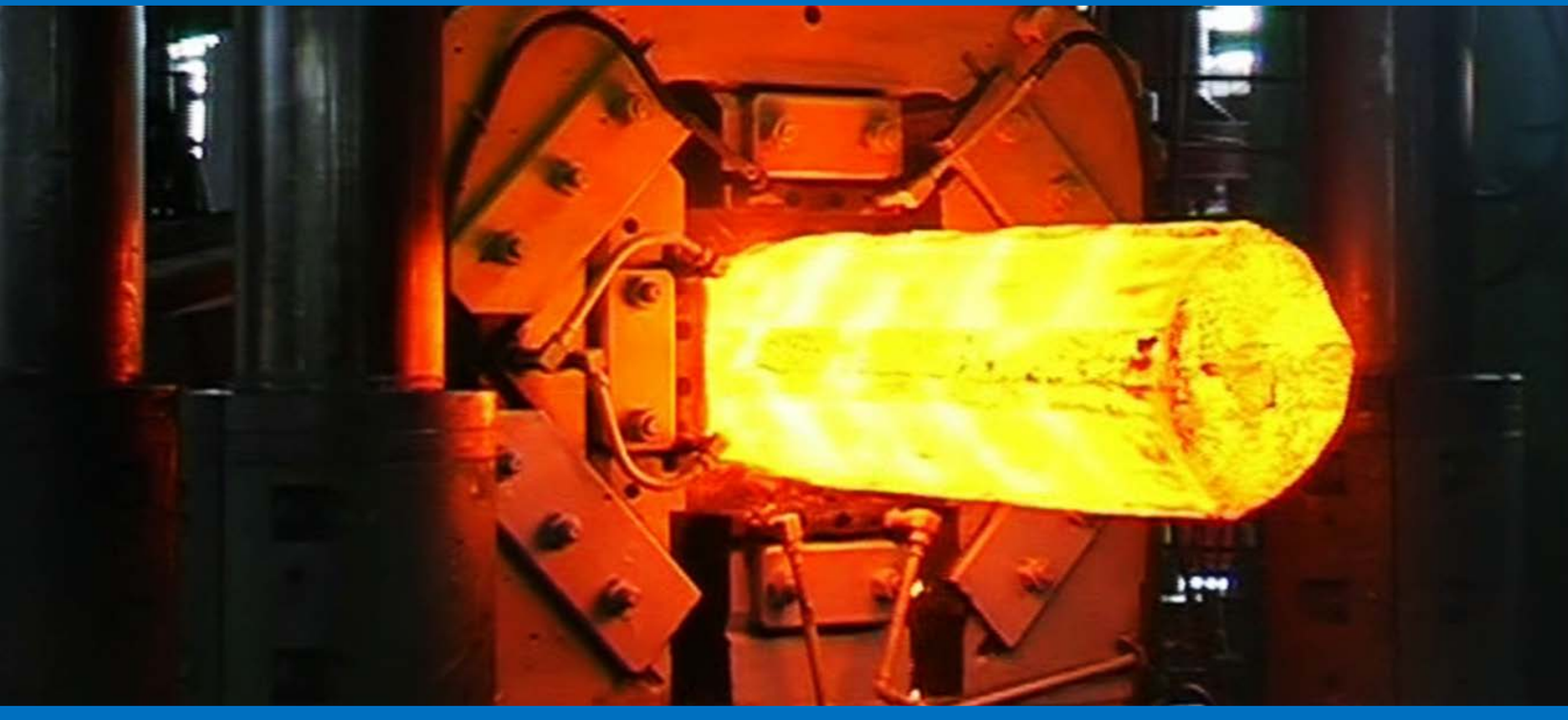
FOUR-DIE FORGING DEVICES (FORGING UNITS)

INNOVATIVE HOT DIE FORGING TECHNOLOGIES

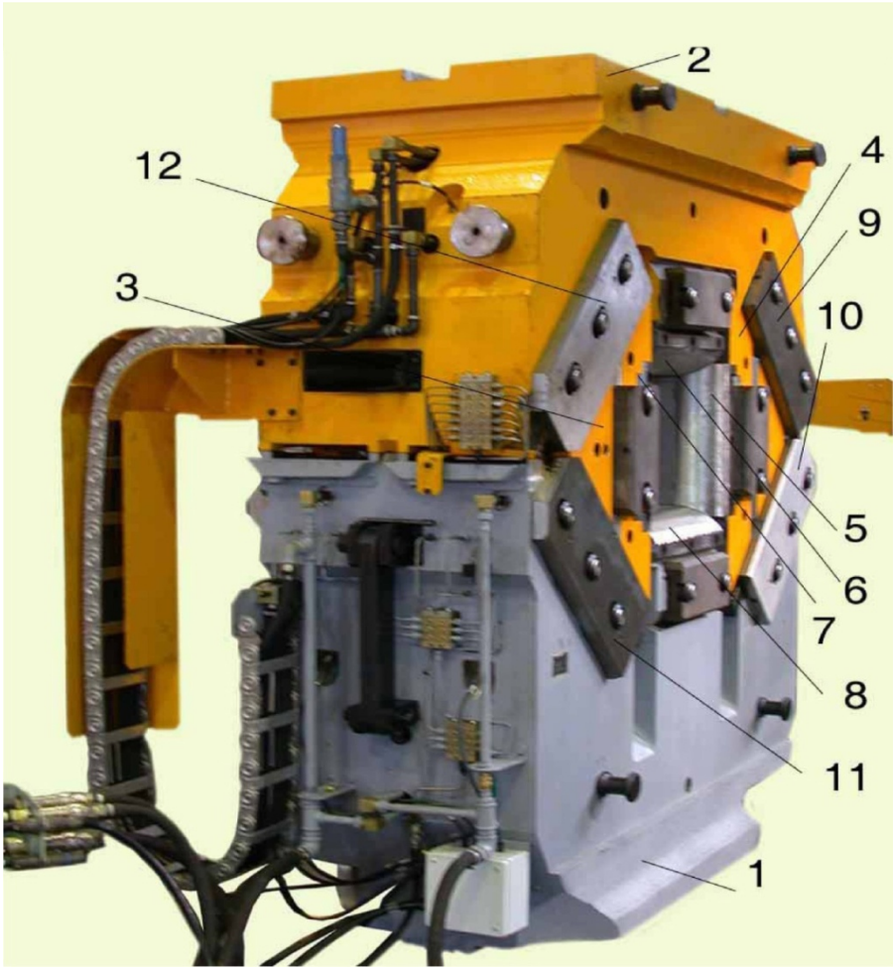


Four-die Forging Devices (forging units)

OAO Tyazhpressmash is the only company in the world where a series production of industrial four-die forging devices (forging units) for hydraulic forging presses has been implemented.
A Four-Die Forging Device is a universal forging tool combining the advantages of radial forging method implemented on radial forging machines (RFM) and conventional two-die forging method implemented on hydraulic forging presses.
A Four-Die Forging Device is designed to be installed on the table of a hydraulic forging press in capacities from 5MN to 150 MN just like conventional forging tools. The four-die forging method provides for complimentary macro-shear effect when forging initial ingots and billets in a press.

The Four-Die Forging Devices are available in two options:

- a Four-Die Device intended to be connected to the press movable cross-beam; .
- a Four-Die Device equipped with a spring designed to lift the device top body, thus no connection to the press movable cross-beam is required.



A Four-Die Device with a top body intended to be connected to the press movable cross-beam

A Four-Die Device consists of a bottom body 1, a top body 2, slides 3,4, dies 5-8 and lateral guideways 9-12. The bottom body is rigidly connected to the press table. Prior to operation the top body of the device shall be connected to the press movable cross-beam. Die is connected to the bottom body; it remains stationary during the forging process. Die 6 is connected to the top body and during forging operation it moves together with the top body. Dies 5, 7 are connected to the slides 3, 4. During the upward stroke of the movable cross-beam the device top body moves, too, and by means of eight lateral guideways 9-12 brings the slides 3, 4 carrying the lateral dies 5, 7 apart, thus opening the device working area. Then an ingot or a billet is fed by means of a manipulator into the device working area and onto the bottom die 8. When the movable cross-beam goes down the top body of the device goes down, too, and by means of inclined surfaces provided on the top and bottom bodies moves the slides 3, 4 carrying the dies 5, 7. It shall be noted here that the 5, 7 dies move not only towards each other, but at the same time they move down in the direction towards the bottom die 8 thus providing for complimentary shear strain in a workpiece being forged. Thus an ingot evtl. a billet forged in the device is simultaneously reduced from four sides.

To facilitate the operation of the device and to provide for an easy interchange between the device and conventional press tools we have developed a device equipped with a spring attachment intended to lift the top body of the device and respectively to bring the dies apart. With this solution no device connection to the press cross-beam and no press top die dismantling are required.

A Four-Die Device equipped with a spring attachment to lift the top body of the device

The devices of this design solution have successfully undergone industrial trials at corporation VSMPO AVISMA plant located in the city of Verkhnaya Salda.
Innovative solution of the lateral guideways provides not only for the alignment of the top body relative to the bottom body and the slides relative to the bodies, but it also allows to bring the slides apart together with the lateral dies fixed to them and thus to open the device working zone without any need to use some additional mechanism. The benefits of this solution are the compact design and high reliability in operation.

Four-die forging devices can be equipped with water cooling system intended to supply coolant to the dies and friction components of the device. Besides, four-die devices are generally equipped with an automatic lubrication system intended to supply lubricant to friction components. The lubrication system control is from the forging press control panel. The cooling system and lubrication system serve to prevent overheating in the friction units and to minimize the dies working surface wearing-out and thus contribute to a longer service life of the device.

Benefits of the four-die forging device:

- 1.5 to 3 times higher forging output as compared to conventional two-die forging method on a press;
- 8 per cent to 15 per cent higher good metal yield;
- 2 to 2.5 times closer dimension tolerances of the forged parts and 1.5 times reduced allowances for finish surface machining which means a 40 to 50 kg metal saving per 1 ton of forged parts;
- 30 per cent to 40 per cent reduced electric energy consumption at drawing operations;
- 25 per cent to 30 per cent reduced gas consumption for metal heating due to reduced re-heating requirements;
- Improved structure isotropy of metal and its physical/mechanical properties;
- A wider range of steel grades which can be processed and a wider range of finish products shapes;
- Possibility to process low-ductile steels and alloys which can not be forged with the help of conventional forging technologies.

Forging operation with two manipulators

Main Forging Process Features:

Forgeable materials:

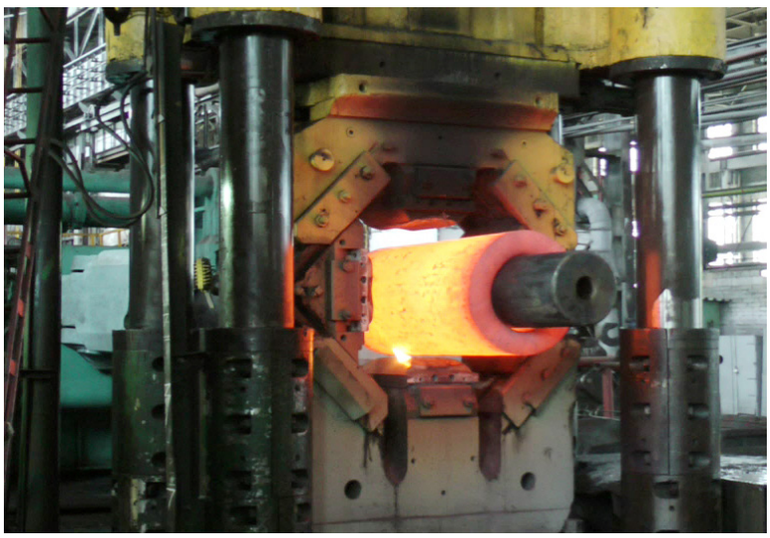
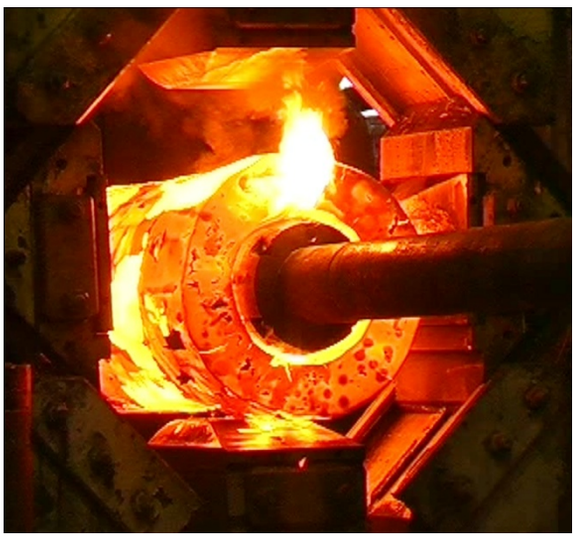
- All steel grades from carbon steels to high-alloyed steels including hardly deformable materials;
- Special alloys – heat-resistant, high-temperature, жаропрочные, precision, etc.
- All ductile materials and alloys (both ferrous and non-ferrous, eg.,titanium, zirconium, aluminium).

Initial parts shapes

- All the types of ingots
- Solid and hollow initial stock
- Rolled stock

Shapes of forged parts

- Circle, square
- Polygonal bars
- Stepped bars
- Hollow forged parts including stepped hollows.

Shapes of initial parts and finish products

Forging machinery which can be equipped with four-die forging devices
- All the types of hydraulic forging presses in capacities from 2 MN до 150 MN;
- All the types of automatic forging plants.

Four-die devices employed on hydraulic forging presses in PRC

Output
During two-die forging operation (conventional technology) each single reduction results in significant lateral spreading of metal. The spreading effect is a considerable limitation for a workpiece extension efficiency along its longitudinal center line. It means that considerable additional reduction strokes and workipece rotation cycles are necessary to obtain a product of required cross-section and length.

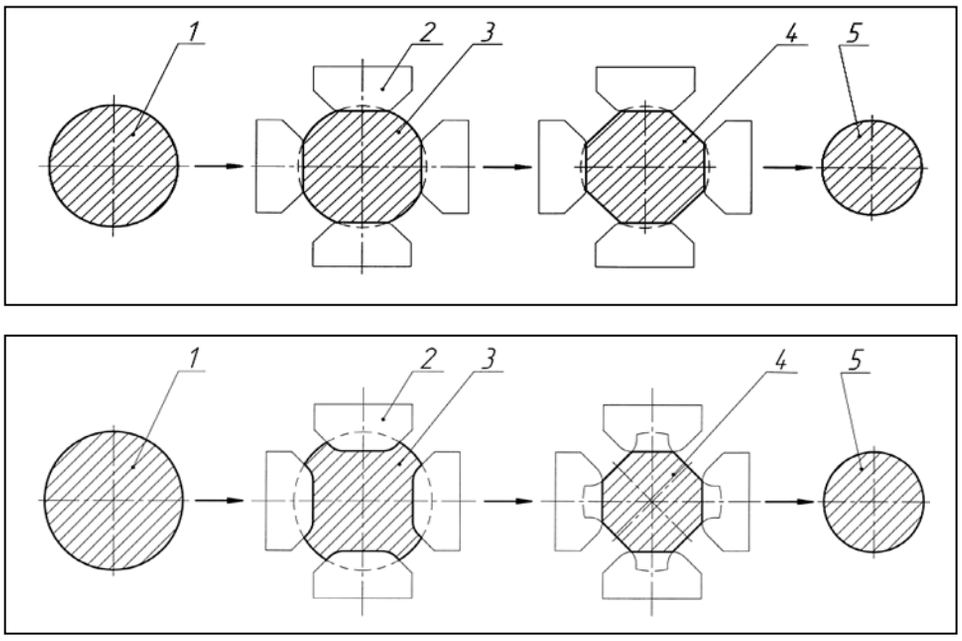
Due to four-side reduction of a workpiece in a four-die device the metal lateral spreading is minimized or even completely eliminated. It means that to obtain a workpiece of the same cross-section and length a reduced number of reductions and rotations are required in the four-die device. The result in a significant increase of the forging process 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.

Metal quality and forged parts accuracy
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 even low-ductile and hardly deformable steels and alloys in a four-die forging device. In this aspect the forging process in a four-die device is rather similar to the radial forging process implemented on the radial forging machines (RFM). In other aspects the four-die forging technology offers significant benefits over the forging process implemented on the radial forging machines. Forging operation on a radial forging machine does not yield uniform quality deformation of metal structure over the total cross-sectional area.

While the dies in a radial forging machine move in radial direction only, the dies in a four-die forging device move in radial and tangential directions simultaneously. This movement schedule serves to induce complimentary shear deformations in the total cross-sectional area of a workpiece being forged. Together with increased single reductions amount (as compared to the reductions in a radial forging machine) it contributes to a deep deformation treatment of cast metal structure.
When forged in a four-die forging device, the forged products in a variety of structural, alloyed, tool and stainless steel grades, as well as precision, high-temperature and heat-resistant steels are free from porosity defects, and the metal quality is much higher than then obtained on a radial forging machine.

Four-die forging technology provides for tolerances in the range of ± 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 after initial rough forging.



Reduction schedules

Finish forged parts

Metal saving

Four-die fording schedule implemented in a four-die forging device of a special design generates compressive stress 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 contributes, too, to a higher good metal yield and thus to considerable metal saving.

Energy consumption

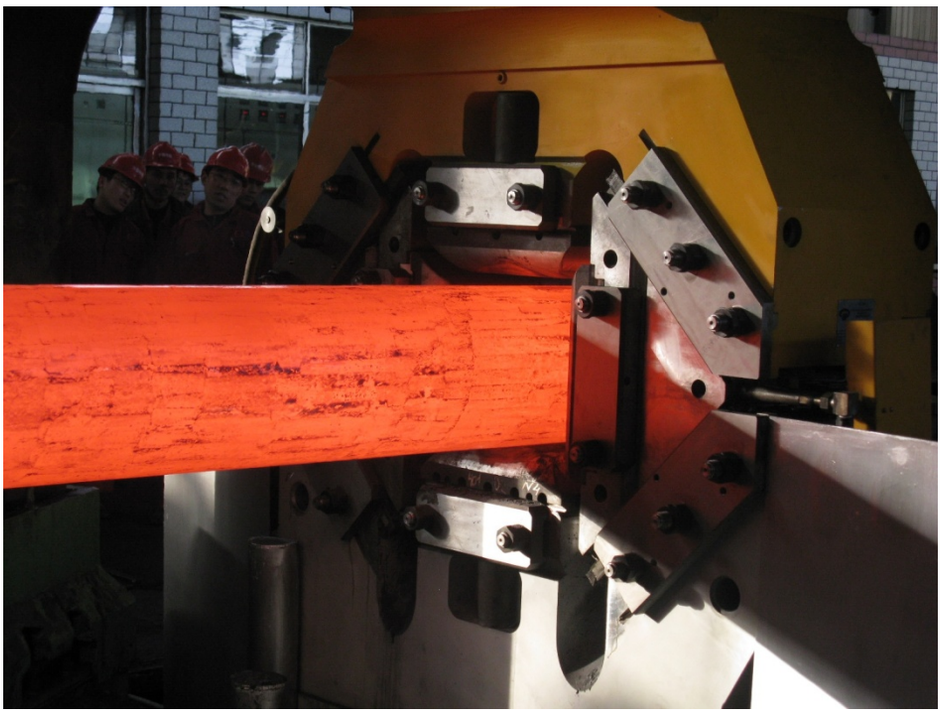
Energy consumption for forging operation performed in a four-die forging device is much lower as compared to conventional two-die forging process on a press. The energy saving results due to a higher efficiency of the forging process resulting from practically eliminated lateral spreading of material. 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 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 4Х5МФС steel grade on a 20 MN press was made on the basis of actual process parameters. The efficiency calculation results are as follows:

- 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 peeling treatment on parts in diameters of 300-400mm, which means 40 kg metal saving for 1 ton of forged parts.



Forged part with minimum allowance for finish surface machining

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. Energy saving at peeling operation. Considering the above-mentioned benefits we can say that actual savings at four-die device employment are even higher.

A long-term operation of four-die forging devices installed on 25 MN forging presses in prime-metal production proved high reliability of the device design.

By 2014 OAO Tyazhpressmash has designed and built 15 four-die forging devices.
The first Russian customer was OAO Corporation VSMPO-AVISMA (located in the city of Nizhny Tagil). Now three four-die devices are used in production there. Two of them are installed on 20MN presses and one device is installed on a 25 MN press.

Nine devices were supplied to customers abroad. Eight devices were supplied to PRC and one to Germany.

Effective operation (since more than 3 years) of a four-die forging device in PRC

Technical specifications and model range of the four-die forging devices

MODELS	**РУК39**	**РУК40**	**РУК41**	**РУК42**	**РУК43**	**РУК45**	**РУК46**	**РУК48**	**РУК49**	**РУК50**	**РУК51**	**РУК52**
Rated force on the top body of the device (rated press force, MN)	8	10	12,5	16	20	31,5	40	50	60	80	100	125
*Max. cross-sectional size of initial ingot (billet), mm	450	520	600	800	950	1300	1450	1550	1650	1800	2000	2300
*Minimum cross-secional size of forged product, mm	80	100	120	150	180	250	300	320	340	360	380	400

*Initial ingots size and forged product size 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.

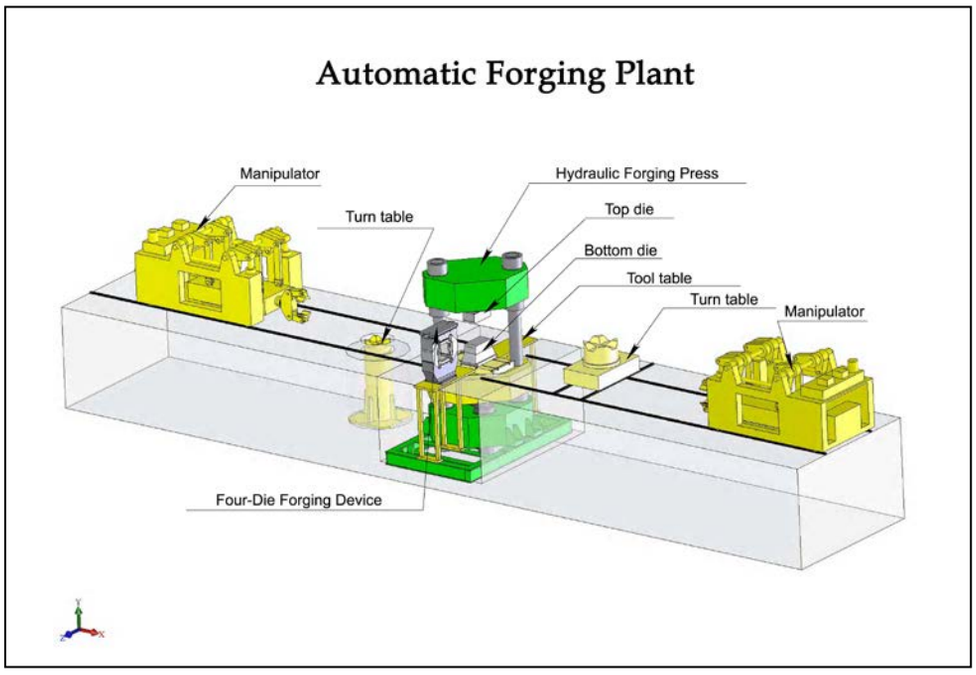
Four-die forging device employed to forge titanium at OAO VSMPO-AVISMA plant (Nizhny Tagil)

Prospects of Four-Die Forging Devices application in Automatic Forging Systems.

Maximum benefits of four-die forging devices can be achieved when the devices are used incorporated into automatic forging systems.

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

OAO Tyazhpressmash offers to manufacture and supply specialized automatic forging system equipped with four-die forging devices capable to perform forging of ingots and billets in various steels and alloys under isothermal forging conditions.



Industrial operation experience

Four-die forging devices installed on two 25 MN presses are in operation at OAO Tyazhpressmash since 2005. The devices are used to forge ingots in carbon-, structural-, alloyed- and tool steels in weights from 5 ton to 10 ton.
Experience of the devices operation on 25 MN presses proved the following:
- Forging output increased two times as compared to conventional two-die forging ingot forging process performed on the same presses;
- Good metal yield of the forged parts produced using the four-die technology increased by 10 -12 per cent,
- Finishing operation performed in a four-die device resulted in 2 -2.5 times closer tolerances and 1.5 times closer allowances for further surface machining;
- 1.5 times closer allowance for forged parts peeling resulted in a 40 to 50 kg metal saving per a ton of forged products;
- Gas consumption reduced by 25-30 per cent due to reduced reheating requirements.

Patent rights protection

Structure of the Four Die Forging Device (Forging Unit), as well as the corresponding forging technology are protected by the following patents:

1 Patent No.2240199 (RF) dd. November 20, 2004, IPC B21J13/02 Tools for Radial Forging.
2 Patent No.2242322 (RF) dd. December 20, 2004, IPC B21J13/10 Four-Die Forging Device.
3 Patent No.2243056 (RF) dd. December 27, 2004, IPC B21J13/10 Forging System.
4 Patent No.2242321 (RF) dd. December 20, 2004, IPC B21J13/10 Four-Die Forging Device.
5 Patent No.2283718 (RF) dd. September 20, 2006, IPC 7B21J7/16, B21J13/02 Four-Die Forging Device.
6 Patent No. 2283716 (RF) dd. September 20, 2006, IPC B21J1/04 Method of Forged Bar Finishing in a Four-Die Forging Device.
7 Patent No. 2283715 (RF) dated September 20, 2006, IPC B21J1/04 Method of Square- and Flat Parts Production.
8 Patent No. 2283714 (RF) dd. September 20, 2006, IPC B21J1/04 Method of Parts Forging in Four-Die Forging Device.
9 Patent No. 2288065 (RF) dd. November 27, 2006, IPC B21J1/04, B21J15/02 Method of Forged Parts Production and Forging System for its Implementation.
10 Patent No. 2288803 (RF) dd. December 10, 2006, IPC B21J1/04 Method of Ingots Forging in a Four-Die Forging Device.
11 Patent No. 2284874 (RF) dd. October 10, 2006, IPC B21J1/04 Method of Forged Parts Production.
12 Patent No. 2291755 (RF) dd. January 20, 2007, IPC B21J1/04, B21J13/02 Method of Finished Forged Parts Production and Tools for its Implementation.
13 Patent No. 2299779 (RF) dd. May 27, 2007, IPC B21J13/02 Four-Die Forging Device.
14 Patent No. 2314175 (RF) dd. January 10, 2008, IPC B21J13/02 Four-Die Forging Device.
15 Patent No. 2237784 (RF) dd. November 10, 2008, IPC B21J1/04 Method of Forged Parts Production.
16 Patent No. 2352428 (RF) dd. April 20, 2009, IPC B21J13/02, B21J7/16 Multi-Die Forging Device.
17 Patent No. 2362647 (RF) dd. July 27, 2009, IPCB21J1/04, B21J21/00 Method of Hollow Parts Production.
18 Patent No. 2362648 (RF) dd. July 27, 2009, IPC B21K21/16 Method of Hollow Flat Parts Production.
19 Patent No. 2393045 (RF) dd. June 27, 2010, IPC B21J13/00 Four-Die Forging Device.
20 Patent No. 2398648 (RF) dd. September 10, 2010, IPC 7B21J7/16 Four-Die Forging Device.
21 Patent No. 2394663 (RF) dd. July 20, 2010, IPC B21J1/04 Method of ingots forging in a four-die device.
22 Patent No. 2406588 (RF) dd. December 20, 2010, IPC B21J1/04, B21J5/00 Method of billet forging in a four-die device.
23 Patent No.2431539 (RF) dd. November 20, 2011, IPC B21K21/00, B21J1/04 Method of large-size hollow parts production.
24 Patent No. 2417856 (RF) dd. May 10, 2011, IPC B21J13/02 Method of billets isothermal forging in a four-die device.

25 Patent No. 2421295 (RF) dd. June 20, 2011, IPC B21K21/00, B21J1/04 Method of hollow parts production.
26 Patent No. 2447967 (RF) dd. April 20, 2012, IPC B21K21/00, B21J1/04 Method of production of hollow parts of ball-cock body type.
27 Patent No. 2438826 (RF) dd. January 10, 2012, IPC B21K21/00, B21J1/04 Method of hollow parts production.
28 Patent No. 2446906 (RF) dd. April 10, 2012, IPC B21J13/02 Four-die forging device (currently under proceedings of international patent office).
29 Patent No. 2454293 (RF) dd. June 27, 2012, IPC B21J13/10 Die-changing attachment for four-die forging devices (currently under proceedings of international patent office).
30 Patent No. 2501625 (RF) dd. December 12, 2013, IPC B21J13/02, B21J13/04, B21K31/00 Four-die forging device.

Validity of patent No. 2314175 (Ru) C2 IPC B21J13/02 Four-die forging device in the territories outside Russia.

The patent has been registered in United Kingdom, France, Spain, Germany on March 24, 2010. EPO No. 2014390.
The patent has been registered in PRC on June 22, 2011, No.ZL200780001312/2
The patent has been registered in Kazakhstan on January 24, 2007, No.24601
The patent has been registered in Ukraine on October 11, 2010, No. 92182
The patent has been registered in South Korea on February 10, 2012, No.1189333.

Additional information concerning Four Die Forging Devices can be found in the following articles:

1. Volodin A.M., Lazorkin V.A., Bogdanovsky A.S. – Radial forging of ingots in four die forging devices// Blank production in machine building. 2005. No.6, June. P. 34 – 37.
2. Lazorkin V.A., Yatsenko R.V., Melnikov Y.V. – Quality of forgings, produced by method of radial forging on hydraulic presses// Forging and forming industry. OMD. 2005. No. 5. P. 8 – 11.
3. Volodin A.M., Lazorkin V.A., Bogdanovsky A.S. – Radial forging of ingots in four die forging devices on hydraulic presses – base for developing new automated forging systems// Forging and forming industry. OMD. 2005. No. 10. P. 36 – 39.
4. Volodin A.M., Lazorkin V.A., Bogdanovsky A.S. – Operating experience of press equipped with four die forging device// Tools and equipment. 2005. No. 8. P. 8 – 9.
5. Volodin A.M., Lazorkin V.A., Sorokin V.A., Petrov N.P. – Innovative technologies and equipment for radial forging of ingots// Forging and forming industry. OMD. 2006. No. 10. P. 22 – 27.
6. Volodin A.M., Lazorkin V.A. – The early industrial four die forging devices for production of steels and alloys on hydraulic forging presses// Ferrous Metals. 2008, February, p. 14 – 19.
7. Victor Lazorkin, Nikolay Petrov/ Proc. 16th JFM 2006, Oct. 15-19, Cutlers Hall, Sheffield, UK, p. 269 – 276.
8. A.M. Volodin, V.A. – Advantages of ingots forging on hydraulic forging presses in four-die forging devices//Forging-Forming Production OMD 2009. No. P.17-23.

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