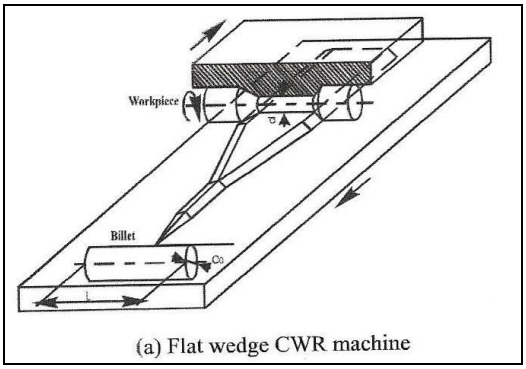
Flat type cross-wedge rolling technology from Russian Federation

Introduction –

Flat type cross-wedge rolling is a new type of rolling developed in the Russian Federation & used extensively in Europe & USA. The equipment manufacturers have supplied more than 100 Flat type cross-wedge rolling machines worldwide, including to Germany, France, Spain, Turkey, UK, USA, Russia, Ukraine, Belarus, Poland & India. It can directly roll the square billets or round bars into different shapes such as axles, rotors, shafts, gear wheels, screws & bolts, ball pins, levers, lances, cutter bodies, connecting rods, pinions and grinding media balls.

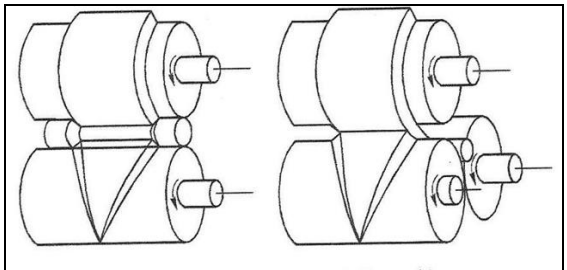
The products made by Flat type cross-wedge rolling have superior characteristics as compared to normal forging. On the other hand, the investment is only one-third of normal forging & the cost of production is also one-third.

This rolling technology is based on Flat type CWR (Cross-wedge rolling) machine as under –



(a) Flat wedge CWR machine

It is the most advanced technology with higher accuracy & higher dimensional stability of the finished products. It has faster production rates and lower cost of production, as compared to the 2 roll / 3 roll CWR machines as under –


(b) Two-roll and three-roll CWR machine

Advantages of flat type cross-wedge rolling, as compared to roller type cross-wedge rolling –

1. The dies are more expensive in roller type cross-wedge rolling.

2. The machinery maintenance is also expensive in roller type. Its drive shafts need to be changed once in a month; it is also complicated to change the drive shafts.

3. Roller type is suitable for making small parts. If the diameter of the feedstock is higher than 60 mm, the rolling will be problematic. In this case, the drive shafts should be very strong, which is difficult to design & maintain. Hence, roller type cross-wedge machines are suitable for making small products only.

4. The capital costs of roller type cross-wedge machines are higher than similar models of flat type cross-wedge rolling machines.

Advantages of flat type cross-wedge rolling, as compared to traditional forging –

1. Higher production capacity of 180 – 240 pieces per hour. The machine capacity does not depend on the skills of the workers.

2. Rolled product weights are lower, as they are more symmetrical and hence need less time for machining. In items like pinion family, diameter steps can be achieved in stem arrangement, which reduces the cost and time of machining.

3. Lower investments, even for larger plant capacities.

4. Automatic process; less manpower needed.

5. Die life is higher, i.e. up to 3,00,000 pieces, as against 10,000 pieces in traditional forging.

6. There is a saving of 5 – 20% in the raw material, as compared to forging (depending on the design of the product to be rolled).

7. Better finish and better roundness, as compared to forging.

8. No flash cut areas.

9. Single process of rolling and cutting, as against 3 – 4 steps in forging.

10. The macro structure of the finished product is superior, with higher strength and higher fatigue resistance.

11. Due to higher accuracy & higher dimensional stability of the finished products and also due to higher uniformity in shape, the machining allowances are lower.

12. Due to reduced cost of making the products, the pay-back period is normally 1 year.

The traditional forging has the following disadvantages –

- Low productivity;
- Low profile accuracy;
- High capital cost; &
- Low finishing.

On the other hand, Flat type cross-wedge rolling has the following advantages –

- Higher fatigue resistance;
- 3 times higher efficiency;
- Higher durability; &
- Reduced cost of equipments.

The die life in Flat type cross-wedge rolling can be up to 300,000 pieces. In the normal operation, it takes 1 hour to change the dies. The tolerance allowance for the product can be up to 0.1 mm. (The tolerance allowance in a 20 mm dia product can be $\pm$0.05 mm).

In Flat type cross-wedge rolling machine, the power consumption for induction heating is 350 - 400 KWh per ton of metal. This power consumption mainly depends on the degree of deformation.

The Flat type cross-wedge rolling machine can be used for 22 hours in a day. The material utilization ratio can be more than 90%, and the end cuttings can be just 8-10%.

There are no limitations on the reduction ratio; but the process speed depends on the extent of deformation. Even square billets of 110 X 110 mm or 150 X 150 mm can be used as raw materials.

The equipment manufacturing companies can produce Flat type cross-wedge rolling machines, induction heaters, control systems, hydraulics & pneumatics, and offer a complete package. Such a manufacturing company has –

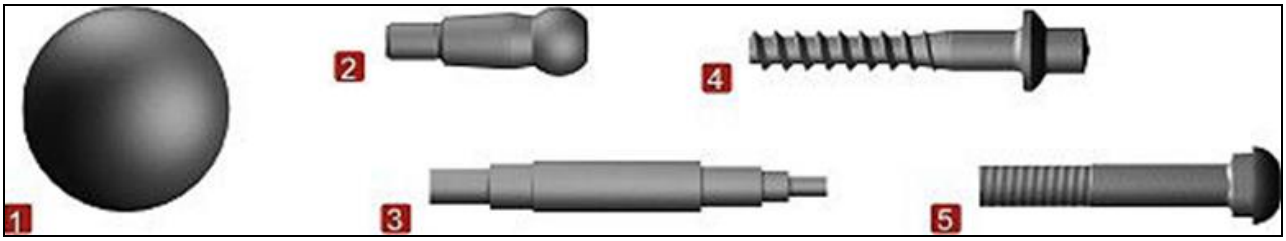
- more than 80 Inventions,
- more than 200 Publications,
- participated in 27 International exhibitions &
- participated in 15 Conferences.

Technology of Flat type cross-wedge Rolling –

Method of Flat type cross-wedge rolling allows products from blanks, having a circular, hexagonal or square cross-section and of the tube. As a result of rolling, the initial profile is converted into a round.

Flat type cross-wedge rolling can obtain products that include elements of circular cross section in the form of cylinders, cones, spheres, rectangular in form of flats, as well as the threaded portions. They can be kept separate elements of the initial blank section in the form of a square or hexagon.

The most common examples of such products include ball 1, ball pin 2, shaft 3, ground screw 4, 5 bolt butt.

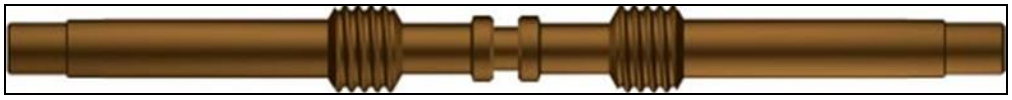


MATERIAL –

Method of Flat type cross-wedge rolling can produce products of structural steels, some grades of tool and high steel, aluminum, brass, copper, titanium. The utilization factor of the material when applying the flat type cross-wedge rolling is 75 - 97%, which is generally higher than during stamping, cutting or molding.

ACCURACY –

One of the advantages of the process of Flat type cross-wedge rolling is highly accurate products towards other hot forming processes. The present level of equipment and technology gives you exactly the diametrical sizes of products at H8, including elements of the thread. An example of such a product is a piece spindle.



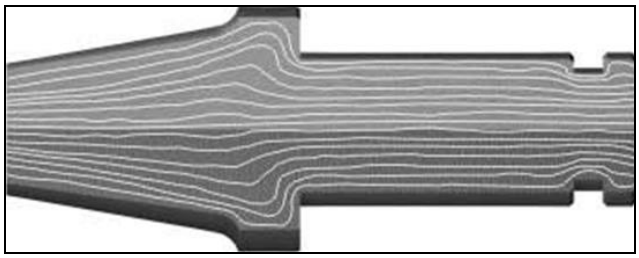
ROUGHNESS –

The surface roughness on the product which is formed by Flat type cross-wedge rolling mainly depends on the surface roughness of the tool, the shape and dimensions of the corrugations by deforming tool faces, plasticity of the product and deformation temperature.

For articles of plastics material, such as brass, is achieved roughness at Ra = 0,35 - 0,65. For steel during hot rolling is achieved at the level of roughness of Ra = 1,5 - 2,5.

STRUCTURE –

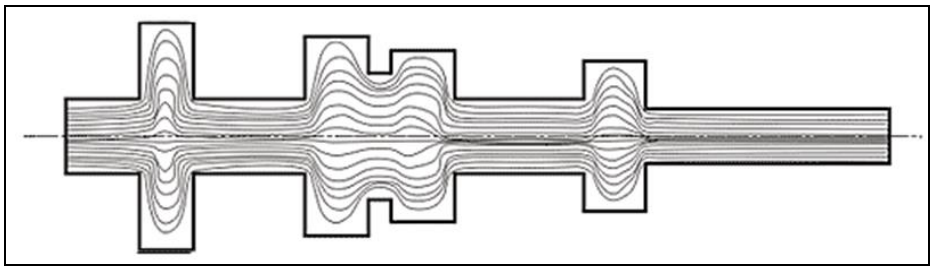
As a result of Flat type cross-wedge rolling, a new article macrostructure material is formed, in which the fibers are continuous and are arranged symmetrically around the axis and sealed at the surface. Such macrostructure enhances the performance of products, in particular the fatigue strength-



Macrostructures tend to change in the shape of the fibers. When Flat type cross-wedge rolling, a new macrostructure:

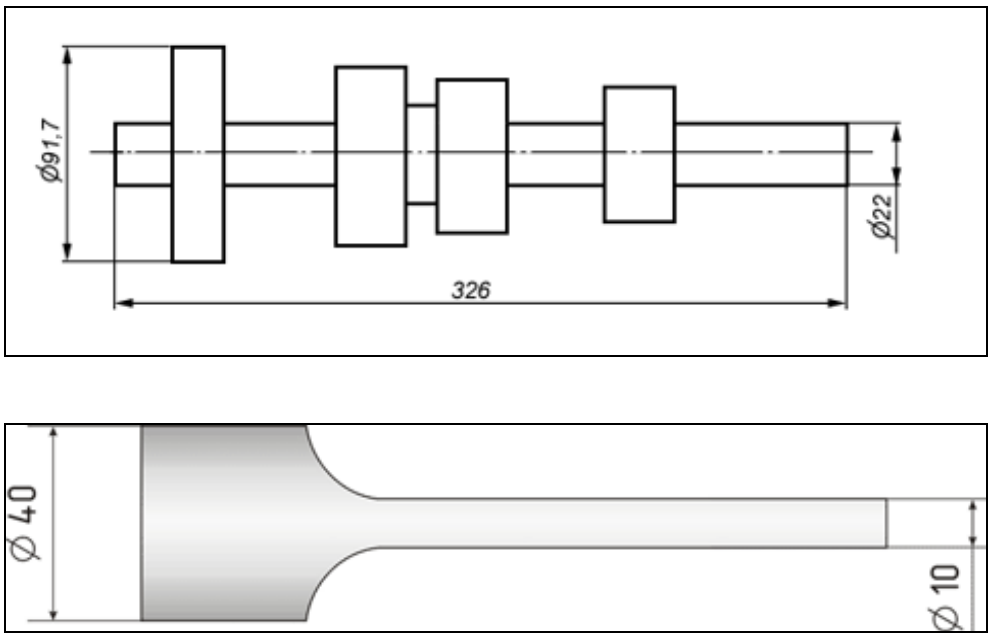
- fibers are continuous throughout the pre-form;
- fiber smoothly around ridges and valleys;
- Sealed the fibers to the surface.

Macrostructure, resulting Flat type cross-wedge rolling, allows improving the performance of products.



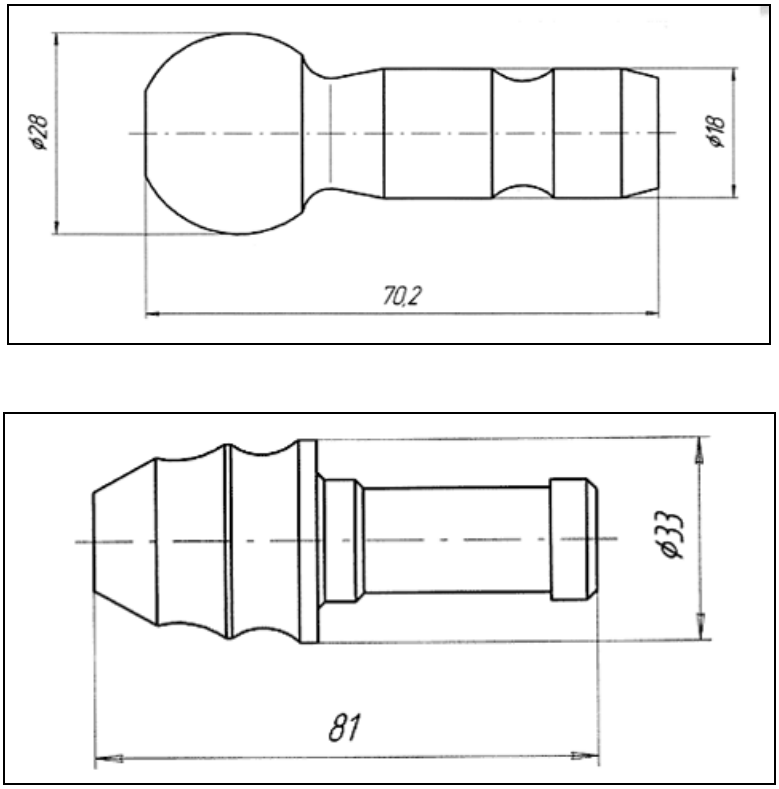
Rolling of parts with high degree of sprain –

Accumulated experience and knowledge make it possible to roll parts with high degree of reduction (diameter decrease up to 5 times).



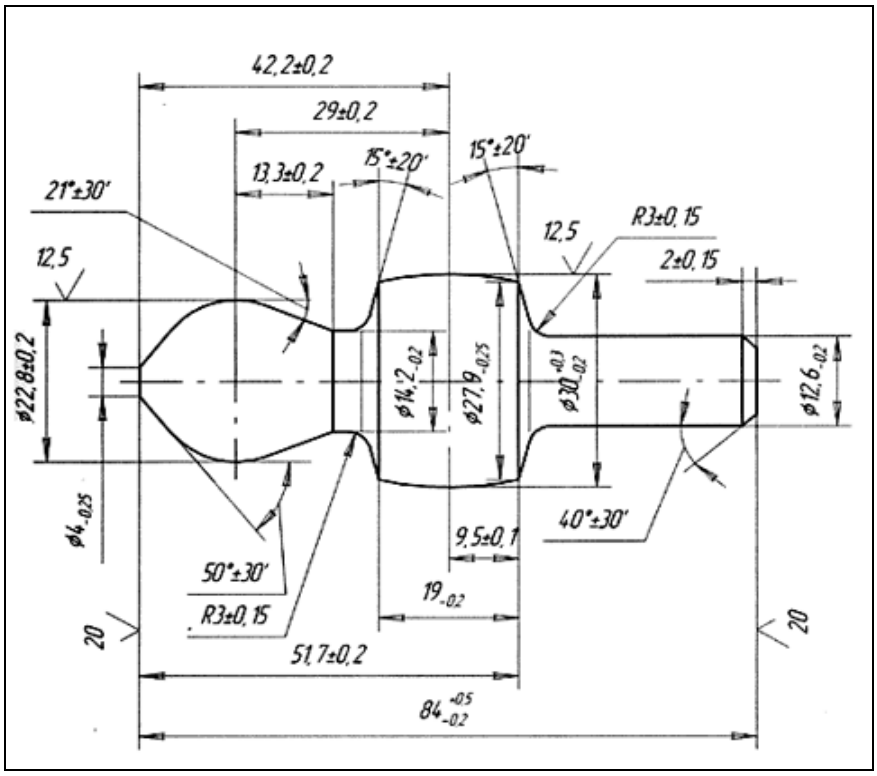
Rolled billet shape –

Long-edge profile of the part practically has no limitations in shape. It can include almost every composition of cylindrical, conical and spherical surfaces. There are examples of such combinations for specific parts:

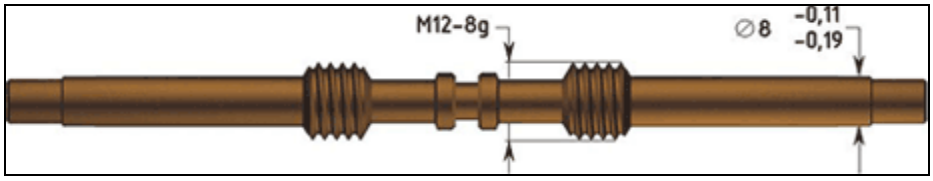


Rolled billet accuracy –

Accuracy level achieved at usual conditions is illustrated on the picture below:



Using the special-purpose tool and equipment, it is possible to achieve considerably higher level of accuracy, as illustrated on the drawing below. Achieved level of accuracy allows manufacturing thread-



Wedge rolling effect to high-cycle fatigue –

The axle rolled parts of St35 (chemical composition C=0.32-0.4; Si=0.17-0.37; Mn=0.50-0.80; Si=0.04; P=0.035; Cr=0.25; Ni=0.30; as=0.08; N=0.008; Cu=0.30) steel were used for tests. The following samples of dimension 50*10*2,1mm were tested:

- 5 samples (N1) were cutting-out of the place that was undergone strain while rolling.

- 5 samples (N2) were cutting-out of the place that was leaving free of distortion while rolling.

Tests were run according to symmetrical cross flexure method with cantilever fitted plate-like sample. Strain amplitude was corresponded to test voltage level 500 MPaG.

As a result of tests the following data was stated:

1. St35 steel sample fatigue life with test stress amplitude of sa=490-545 MPaG has loading cycle of 1,6-3,0 * 104 before disturbance and after grow up with magnify of steel hardness level.

2. In the range of low-cycle fatigue, the number of cycles level before St35 steel sample disturbance after wedge rolling increases by >=3% as against initial state.

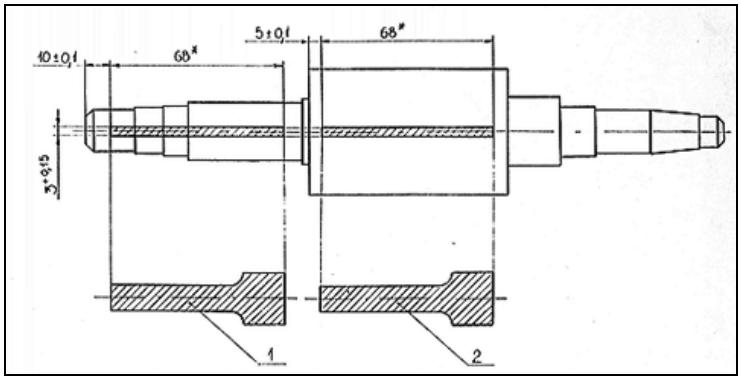


Fig. 1 - Cutting-out samples for fatigue life tests scheme.
(1.strained sample, 2. unstrained sample)

Flat type cross-wedge rolling for railway axles –

A Russian manufacturer has newly developed the Flat type cross-wedge rolling technology to make railway axles for wagons, rail cars & metros. The rolling mill capacity is up to one axle of around 800 kgs per minute or 250,000 – 300,000 tons per year. The quality & endurance of railway axles are much better than those made by the traditional forging method, as the grain size is even. By changing the dies, it is possible to make different types of axles for heavy duty trucks & buses, in the same plant.

The standard railway axles have 2,280 mm length and 220 mm dia. The plant consists of 16 induction heaters of 800 KW each and a 2 stage rolling machine.

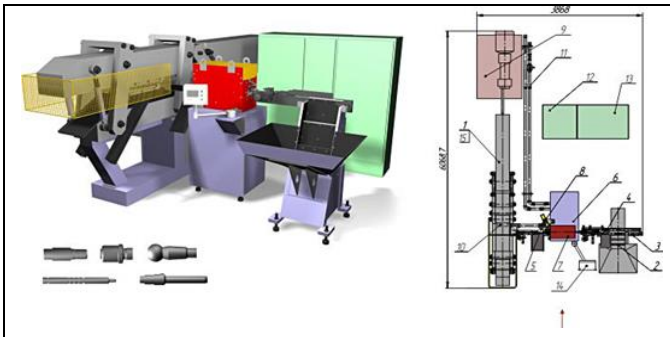
This is a good opportunity for quality steel producers, as the incremental investment on Flat type cross-wedge rolling mill is less than Rs. 100 crores (excluding the subsequent CNC machining process) & the payback period is around 1 year. Assuming that the axles can be sold for Rs.75-80 per kg, the sales turnover can be Rs. 2,000-2,500 crores per year.

In Flat type cross-wedge rolling, the billets are heated up to 1,200^{0}C. The finished product after rolling comes out at 1,050^{0}C – 1,150^{0}C, and it can be hardened directly. The output sizes can be 20 mm to 220 mm in dia and the lengths can be up to 1,200 mm. The Flat type cross-wedge machine also comes with a water circulation pump, an air compressor and a hydraulic drive.

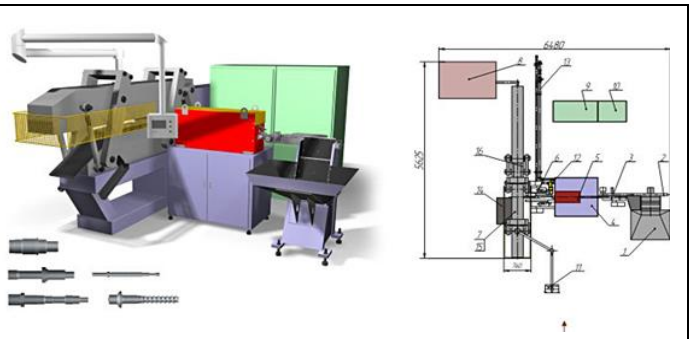
Technical specifications of some models of Flat type cross-wedge rolling machines –

Parameters	**Models**						
	Model 1250	**Model 1600**	**Model 2000**	**Model 2500**	**Model 3400**	**Model 4200**	**Model 5000**
Productivity, strokes/hour	600	720	400	514	360	260	180
Dimensions of the rolled product, mm -diameter -length	12...35 up to 300	25...50 up to 400	32...60 up to 450	32...60 up to 450	40...90 up to 650	50...120 up to 750	65...150 up to 800
Main drive power, kW	25	40	60	115	200	250	360
Induction heater power, kW	120	250	500	500	600	800	800
Maximum life time of the wedge die (including periodical repairs)	300,000 pcs	300,000 pcs	300,000 pcs	300,000 pcs	300,000 pcs	300,000 pcs	300,000 pcs
Heater temperature of blanks, ^{0}C	900... 1,200	900... 1,200	900... 1,200	900... 1,200	900... 1,200	900... 1,200	900... 1,200
Operating staff, persons	1	1	1	1	1	1	1
Floor space needed	23 m^2	36 m^2	39 m^2	31 m^2	58.5 m^2	81 m^2	122 m^2
Weight, kgs	7,000	10,000	13,500	12,000	40,000	80,000	98,000

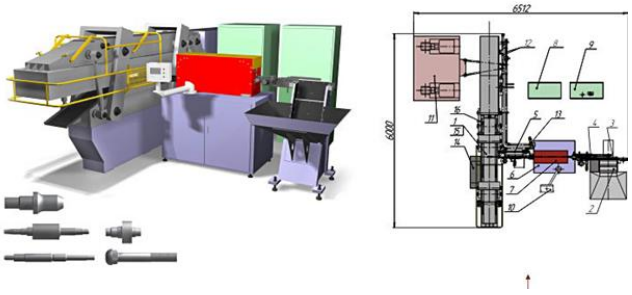
Models of Flat type cross-wedge rolling machines



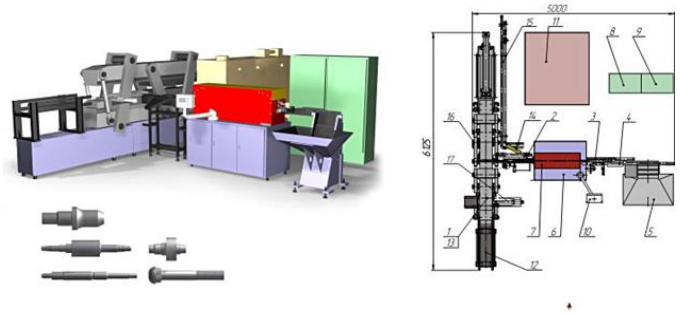
Model 1250



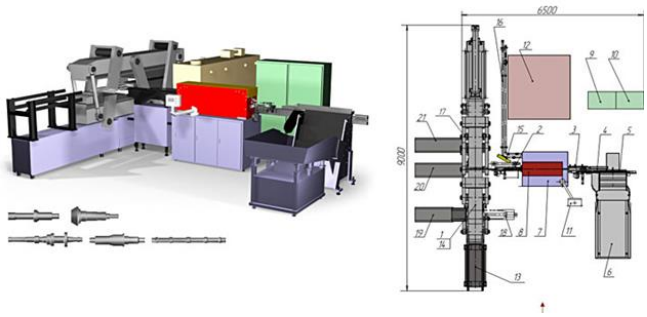
Model 1600



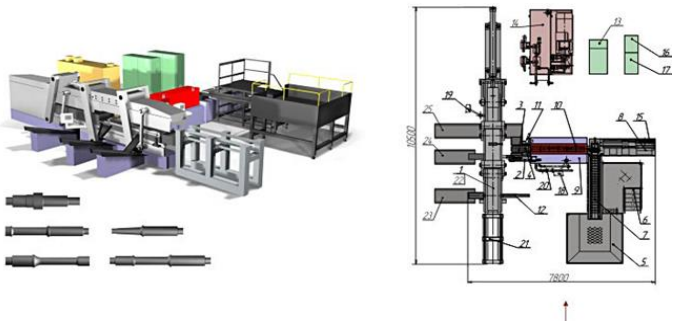
Model 2000



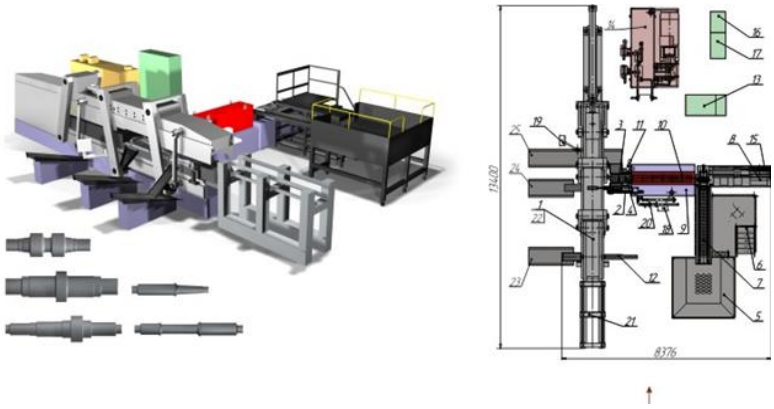
Model 2500



Model 3400



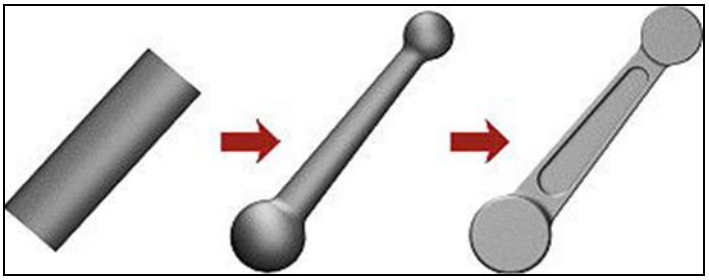
Model 4200



Model 5000

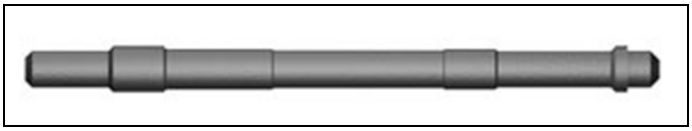
Applications of Flat type cross-wedge Rolling –

Production of billets for subsequent forging can improve the material utilization and performance. Most common example of the use of Flat type cross-wedge rolling for subsequent stamping parts production is "crank."



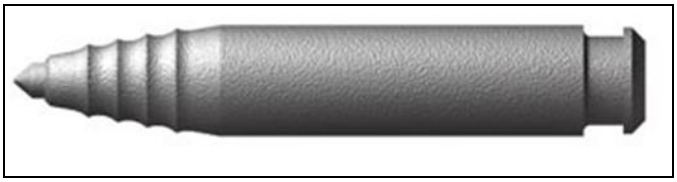
The achieved level of accuracy in the process of Flat type cross-wedge rolling allows stock for subsequent stamping with minimal burr or without them.

Production of billets for further processing finish turning can improve material utilization and reduce the complexity of the production of the final product.



Production of billets for subsequent processing by grinding, to reduce the complexity of the production of final product.

Manufacture of finished articles or pieces that do not require further surface treatment. Example of such a product is the cutter body, where wedge rolling gives the required level of accuracy and roughness.

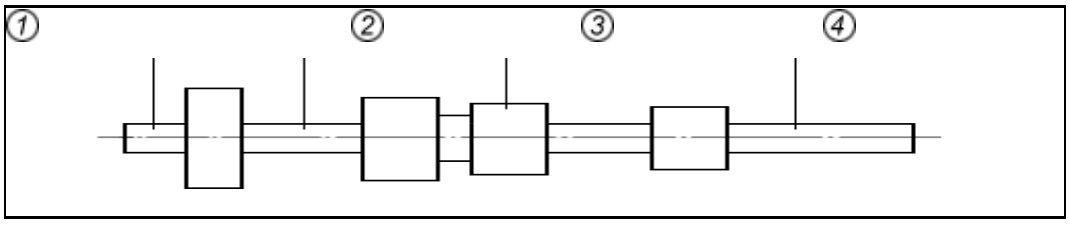


Materials suitable for Flat type cross-wedge Rolling –

The experience allows rolling of products from the following materials:

- Structural steel and steel with a content of the alloying elements of up to 5%;
- Some grades of steel with a content of alloying elements of more than 5%;
- Aluminum;
- Copper;
- Zirconium;
- Titanium;
- Brass.

The influence of rolling in a wedge structure expressed in a seal material at the surface relative to its state prior to rolling; below is a laminated pre-form, which is the region 1, 2, 3, 4, research microstructure.



Ball-Rolling machines –

Ball rolling machines are designed for manufacturing of balls with diameter 20…160 mm by heating and further helical rolling. Ball rolling machines are designed as automatic lines with induction heaters; they help to make automatic production of balls.

Helical rolling technology of receiving steel balls is put in operation as against the existing working procedure of ball rolling equipment. The technology makes it possible to manufacture balls on the equipment having flat moving tools. Low cost of equipment and flat tool are the main advantages of the machines. Helical rolling technology is less time-taking and does not need special equipment application, as it is with irregular shape precision tool.

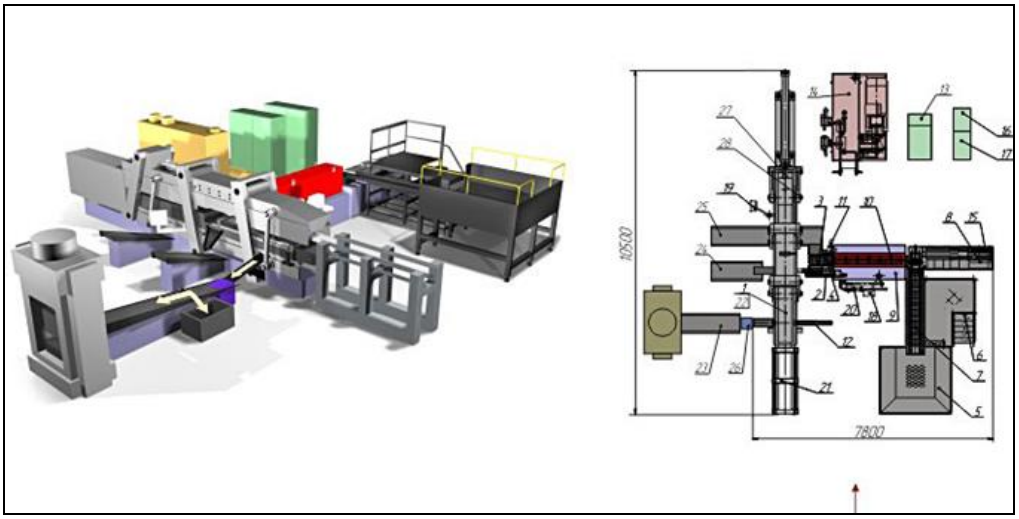
Balls received by helical rolling by means of Ball rolling machines are applied as grinding work pieces for ball crushers in ore mining, coal, cement and other branches of industry. Balls received by

ball rolling machines are also used in engineering industry, particularly for anti-friction bearing manufacture.

The advantages of rolling of balls in comparison with forging and stamping are the following –

- Balls received by Ball rolling machines have more regular shape and precision measurements;
- Productivity rate in rolling is 3-8 times more than forging and stamping;
- Tool durability of Ball rolling machines is several times greater than press-tool durability.

New Line of Flat type cross-wedge rolling machines –



The machines of the new line are developed to produce pre-forms for further forging. The pre-forms produced on new wedge rolling machines acquire properties that are important for forging:

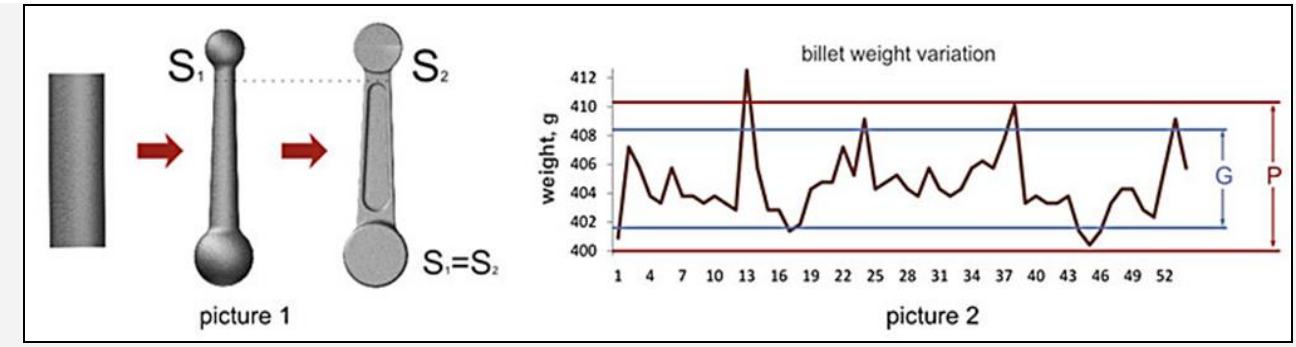
1. Optimum shape
2. Required weight

Optimum shape of the preform received by Flat type cross-wedge rolling for further forging means, the preform of round section that have longitudinal profile, in which distribution of the material along the axis of the round preform is in direct proportion to distribution of the material along the axis of the part after forging.

During forging process of such preform, the filling of the forging mold is realized evenly along the perimeter, the material is drifting along the shortest path. When using the preforms of the optimum shape for forging, this process is accomplished with minimal fin or without it. Meanwhile, the minimum energy is spent and the lifetime of the forging die increases.

On picture 1 there is an example of the optimum shape preform for forging of the part “connecting rod”. The longitudinal profile of the preform of round section is calculated in such way that on each length segment the sectional area of the round preform is equal to the sectional area of the forged item.

Required weight- Forging of preforms in the required weight interval allows reducing the quantity of the material in fin to minimum, and makes it possible to forge preforms without fin.



picture 1 picture 2

Flat type cross-wedge rolling machines of the new line work in the following way –

The cylindrical billets are loaded in bulk into the feed hopper 5. From the feed hopper 5 billets are automatically loaded at the required speed into the inductor 10, where they are being heated. The temperature is controlled by the pyrometer 11. From the inductor 10 the billets are loaded into the Flat type cross-wedge rolling machine 1 for rolling. The billets rejected by the temperature are directed into separate container. After rolling the manipulator carries the billet onto the scales 26. The information about the weight of the billet is transferred into controller, which is mounted in the electric equipment cabinet 16. The controller takes one of the following decisions depending on the weight of the billet:

1. To direct the billet to the press for forging.

2. To direct the billet to the press for forging and to regulate the diametric dimensions of the billet. The regulation is carried out by the reducer 27. The regulation degree is controlled by the transmitter of the rotation angle 28.

3. To direct the billet into container for the billets rejected by weight and to regulate the diametric dimensions of the billet.

Operation 1 is performed when the weight of the billet is within the regulation inhibit range G (picture 2).

Operation 2 is performed when the weight of the billet is within the permissible weight range P, but out of the regulation inhibits range G (picture 2).

Operation 3 is performed when the weight of the billet is out of the permissible weight range P (picture 2).

The permissible weight range P and the regulation inhibit range G can be promptly specified during the operating cycle of the Flat type cross-wedge rolling machine.

Technological operating cycle of the Flat type cross-wedge rolling machines of the new line can be represented in the following way –

ROLLING – SCALING – DIAMETER REGULATING – ROLLING

Flat type cross-wedge rolling machines of the new line are constructed in such way that it becomes possible to regulate the diametric dimensions of billets with the resolution 0,02…0,05 mm. The regulation can be carried out within the time period, when the wedge dies are moving into home position that is why it is not necessary to stop the machine to make the regulations. The accuracy of regulation allows reaching the weight accuracy of billets for forging in the range of 1.5%.

Products manufactured by Flat type cross-wedge Rolling –

More than **300 technological products** have been developed, based on Flat type cross-wedge rolling. This section contains some **article examples**, which can be divided into **three groups**:

1. Pre-forms for further turning.
2. Pre-forms for further smooth finishing.
3. Finished articles by external shape.

SHAFT

- Preform for further turning
- Maximum diameter – 150 mm
- Length – 569 mm
- Material – steel 38XFR
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of forging

ROAD ROLLER SHAFT

- Preform for further turning
- Maximum diameter – 120 mm
- Length – 497 mm
- Material – steel 38XFR
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of forging

DRIVING SHAFT OF INTERMEDIATE AXLE

- Preform for further turning
- Maximum diameter – 70 mm
- Length – 546 mm
- Material – steel 35XGCA
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of forging

MAIN SHAFT OF GEARBOX

- Preform for further turning
- Maximum diameter – 130 mm
- Length – 588 mm
- Material – steel 20XGHMTA
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of forging

GEAR SHAFT

- Preform for further turning
- Maximum diameter – 75 mm
- Length – 385 mm
- Material – steel 40X
- Dimensional accuracy according to h14 and IT12/2
- Earlier was manufactured by means of forging

MAIN SHAFT OF GEARBOX

- Preform for further turning
- Maximum diameter – 130 mm
- Length – 563 mm
- Material – steel 20XGHMTA
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of forging

SHAFT

- Preform for further forging
- Maximum diameter – 23 mm
- Length – 250 mm
- Material – steel 18XGT
- Dimensional accuracy according to h12 and IT12/2

SHAFT

- Preform for further turning
- Maximum diameter – 38 mm
- Length – 452 mm
- Material – steel 40X
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of turning on automatic lathe

VALVE

- Preform for further smooth finishing
- Maximum diameter – 26 mm
- Length – 237 mm
- Material – steel 40X
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of turning on automatic lathe

AXLE

- Preform for further turning
- Maximum diameter – 52 mm
- Length – 115 mm
- Material – steel 45
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of turning on automatic lathe

PREFORM FOR FURTHER FORGING

- Maximum diameter – 45 mm
- Length – 188 mm
- Material – steel 18XGT
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of forging

CLAPPER

- Preform for further turning
- Peak cross-section, hexahedron – 32 mm
- Length – 227 mm
- Material – steel 35
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of turning on automatic lathe

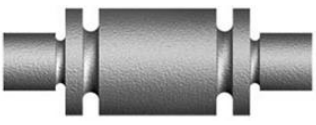
PINION SHAFT

- Preform for further turning
- Maximum diameter – 45 mm
- Length – 236 mm
- Material – steel 18XGT
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of forging

AXLE

- Preform for further smooth finishing
- Maximum diameter – 10 mm
- Length – 127 mm
- Material – steel 40X
- Dimensional accuracy according to h9 and IT12/2
- Earlier was manufactured by means of turning on automatic lathe

AXLE



- Preform for further turning
- Maximum diameter – 35 mm
- Length – 97 mm
- Material – steel 40X
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of turning on automatic lathe

AXLE

- Preform for further smooth finishing
- Maximum diameter – 16 mm
- Length – 74,6 mm
- Material – steel 35
- Dimensional accuracy according to h12
- Earlier was manufactured by means of turning on automatic lathe

CLAPPER

- Preform for further smooth finishing
- Maximum diameter – 10 mm
- Length – 121 mm
- Material – steel 40X
- Dimensional accuracy according to h12
- Earlier was manufactured by means of turning on automatic lathe

WORKHOLDER'S BODY

- Preform for further turning
- Maximum diameter – 34 mm
- Length – 51 mm
- Material – steel 35
- The method of coupling of two items with their posterior separation is applied during wedge rolling

SCREW

- Preform for further smooth finishing
- Maximum diameter – 15 mm
- Length – 192 mm
- Material – steel AC35G2
- Dimensional accuracy according to h12
- Earlier was manufactured by means of turning on automatic lathe

SHAFT

- Further surface treatment is not required
- Maximum diameter – 33 mm
- Length – 61 mm
- Material – steel 45
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of turning on automatic lathe

AXLE

- Preform for further turning
- Maximum diameter – 22 mm
- Length – 157 mm
- Material – steel 40X
- Dimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of turning on automatic lathe

AXLE

- Maximum diameter – 50 mm
- Length – 140 mm
- Material – steel 40XDimensional accuracy according to h12 and IT12/2
- Earlier was manufactured by means of turning on automatic lathe

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