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METHODS OF FLASHLESS DROP FORGING

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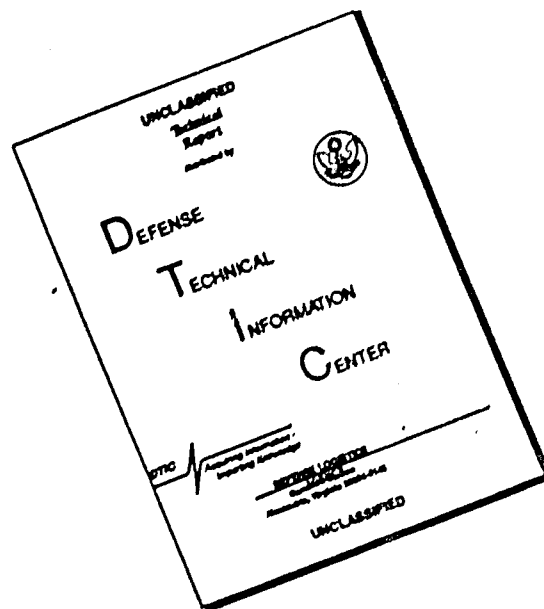
A. D. Bogdan and V. S. Kushnikova



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EDITED TRANSLATION

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English pages: 15

Source: Kuznechno-Shtampovochnoye Proizvodstvo
(Forging and Stamping), No. 7, 1966,
pp. 35-40.

Translated by: W. Pearson/TDBRS-3

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METHODS OF FLASHLESS DROP FORGING

A. D. Bogdan and V. S. Kushnikova

In large-batch and mass production, such as that of the Gorkiy Automobile Factory, hot flashless drop forging is done on swaging hammers, horizontal forging machines and cranking hot-forge presses.

Cylindrical billet sections are used for flashless forging. The billets are heated in chambered and semi-continuous open-flame furnaces or in high-induction heating units. When heating in open-flame furnaces a partial hydraulic cleaning away of scales from the billets occurs before they are forged.

Hammers are usually used for flashless drop forgings of cylindrical form, i.e., the form of gears, flanges, rings and so on. The forging process is accomplished in two basic operations. In the first operation (on the surface area of the forge) the billet is subjected to swaging and in the second (in a special die impression) the final forging takes place. Two to three blows from a hammer are used for the swaging of a billet, and for the final forging 3-4 hammer blows are used.

The stamp for flashless forging (Fig. 1) consists of two halves: the upper half, secured on the head of a hammer, and the lower, which is secured in the anvil cap of an anvil block.

In the lower half of the stamp there is set a retaining flange and the smaller part of a groove slit, in the upper - a holding cavity and the main part of the groove. The lock has the form of a truncated cone, the height of which is 50 mm and more. The height of the lock depends upon the depth of the die D. In practical work this dependence is represented as $C \approx (2-2.5)D$.

The diameter of the lock in the upper part of the truncated cone is equal to the greatest diameter of the die with gap B equal to 0.1-0.4 mm at the side. With an increase of the diameter gap B also increases. This gap is necessary for compensating for the positive tolerance deviations in the flange retainer, which are caused by the intense heat of the flange in the forging process.

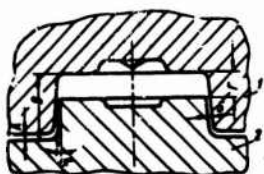


Fig. 1. Diagram of construction of the finishing groove of the stamp for flashless drop forging on hammers:
1 - upper half of the stamp; 2 - lower half of the stamp.

The range of diameters of the forgings done by the method of flashless forging on hammers is limited to 75-200 mm.

The lateral surface of the lock is made with an inclination α of $3-5^\circ$ which serves as a kind of catch of the upper half of the press at the moment of the blow and guards the retaining flange from spalling, which can take place because of the presence of gaps in the hammer guide and mountings.

As a compensator of spatial variations in the billets, the extent of which depends on the precision of the rolling of the metal rods used in forging, the precision of the cut of these points in the billet, and the duration of exposure of the heated metal to forging, there is provided gap A, the size of which is equivalent to the general field of tolerance in the thickness of the forging D.

As a rule, the press grooves are made according to the rated dimensions of the forgings with a calculated 1.5% shrinkage. Margins of variance and tolerances in the forging are calculated according to the second class of GOST 7505-55. An exception to this rule is the gauging of forging D used for the stamp grooves of the forging equal to the minimum size; gap B and angle α must coordinate with gap A. Deviation from this condition can lead to the tight jamming of the stamp at the moment of its free closing, i.e., when closing the stamp when there is no billet in the press groove, after which the stamp becomes unsuitable for further work because of the impossibility of its uncoupling.

While there are several advantages in flashless forging on hammers (such as decreasing metal expenditure, lowering labor consumption and cutting back means and time expended for the preparation of production), this process also contains a number of deficiencies, which essentially amount to the following:

1. The inevitable appearance of a burr on that part of the forging adjacent to the upper plane of the truncated cone of the press lock. The burr can protrude up to 15 mm and be 0.2-3.5 mm thick, depending on the stage of wear of the stamp lock.
2. The possibility of a forging jamming in the upper cavity of the stamp groove. Removing it is accomplished either with a blow of the upper half of the stamp on the following clinched billet or with a blow of the upper stamp on a special ring (Fig. 2), which is superimposed onto the protruding part of the lock in the lower half of the stamp. Such a ring is made of soft carbon steel. The interior diameter D of the ring is 15-20 mm greater than the diameter of the lower base of the truncated cone of the lock; the thickness of the ring is equal to approximately half the height of the lock, and the width of the shell A = 40-50 mm.
3. The necessity of classifying 100% of the forgings according to the size of the face of the burr and also the necessity of deburring the forging in rough-grinding machines, if the burr exceeds the allowable magnitude.
4. The possibility of a breakdown of the forging metal density in the area where the burr is located (Fig. 3), which can arise

with the clogging or the stamping out of the forging in a cold state on hammers or presses.

The presence of the enumerated deficiencies strictly limits the sphere of application of this method of forging, although it is also more effective in comparison with the common open-die forging on hammers (Table 1).

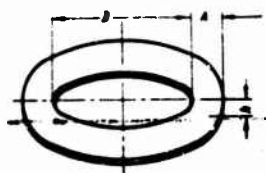


Fig. 2.

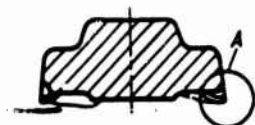


Fig. 3.

Fig. 2. Ring for removal of forgings stuck in a press groove.

Fig. 3. Configuration of a forging made by the method of flashless forging on a hammer:
A - the zone of metal failure when eliminating burrs in a cold state.

Table 1. Comparative effectiveness of flashless and open-die drop forging on hammers.

Nomenclature of forgings	Norms of expenditure of metal for one component, in kg, in forging		Output, in pieces/hr, in forging		Stability of the press, in pieces of forgings, in forging	
	Open die	Flashless	Open die	Flashless	Open die	Flashless
Hub of a coupling disk	1,610	1,390	131	114	5000	2400
Transmission reduction gears of a distributing housing	5,283	4,589	115	100	4000	2500
Block of pinions	7,150	6,299	140	140	7500	5200

Nevertheless, the development of the method of drop forging in stamps with a wedge groove for deburring (Fig. 4), which in recent years has been used more and more, presents a serious competitor to the flashless method.

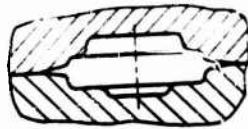


Fig. 4. Diagram of the finishing groove for deburring on the presses for half-closed drop forging on hammers.

Comparative tests of both methods of large-batch production of forgings, which are produced for forgings for truck transmission gear assemblies (Fig. 5), showed obvious advantages of forging in stamps with a wedge groove for deburring. These stamps undoubtedly have established for themselves a place in the progressive technology of the manufacture of stamped forgings on hammers. The coefficient of resistance to wear of the forging stamp with the flashless method is 5200 forgings, and when forging in the presses with a wedge groove for conditioning the burr it is 7500 forgings.

The cranking hot-forging presses, which have begun to be widely used in forging production, allow us to set up the most progressive and economic technological manufacturing processes of drop forgings.

At the present time open-die forging in cranking hot-forging presses includes a sufficiently large nomenclature of components of the type of bodies of revolution - symmetrical and nonsymmetrical in form, and components with elongated axis.

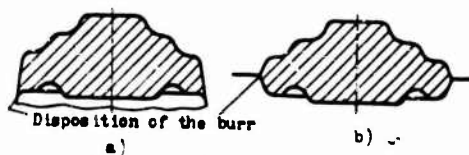


Fig. 5. Configuration of a forging of a block for gears, manufactured: a - by the flashless forging method; b - in stamps with deburring.

Flashless forging is still under investigation and in this area there lies ahead prolonged and tedious work. At the Gorkiy Automobile Plant more than 20 kinds of forgings are manufactured by this method, and a number of experimental works on further uses of this process are also being carried out.

Depending on their configuration, all forgings stamped by the flashless method are subdivided into two groups, characterized by the instrument used for their manufacture. The first group consists of forgings having the form of rotating bodies with and without a core, and the second group - forgings with symmetrical and nonsymmetrical configurations (Fig. 6).

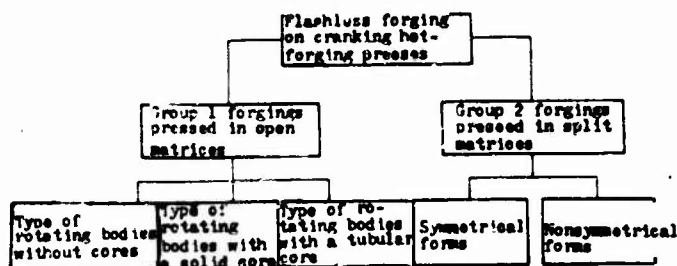


Fig. 6. Diagram of the distribution of forgings by group, manufactured in cranking hot-forging presses.

Drop forging of the type of bodies of rotation without a core (gears, flanges, rings and the like) as a rule is carried out in two operations (Fig. 7). In the first operation the swaging of the billet is executed, in the second - the final forging. Every operation is accomplished with one stroke of a slide press. In the operation of the final pressing there is provided a compensator ring K, the back side of which rests on plate springs, creating counterpressures at the moment of stamping. The gaps between the surfaces of the compensator ring and the surfaces of different components of the stamp adjacent to it in the working zone are equal to 0.15 mm on a side. The gap between the container and the casting die ($\varnothing 174$ mm) is 0.3 mm on a side.

The advantages of the examined stamping method over the methods of manufacture of similar forgings on hammers or on horizontal forging machines are characterized by properties presented in Table 2.

Forgings of the rotating-body type with a solid core are usually stamped in two operations (Fig. 8). In the first operation there occurs the partial pressing of the gear, where the symmetry

necessary for subsequent stamping is imparted to the remaining elements of the billet; in the second the final pressing of gears and flange casting take place. Sometimes, in selecting billet diameter and length, preliminary swaging of the billet is carried out to produce a diameter approaching that of the container of the first operation matrix. Swaging is accomplished in flat matrices of the stamp. The gauge of the swaging is controlled by the fixed measurements of the stamp without any limitation by matrices. The compensator, when stamping similar forgings, is situated at the end of the pressed gear. The height of compensator K is determined by the difference between the minimum and maximum volumes of a billet.

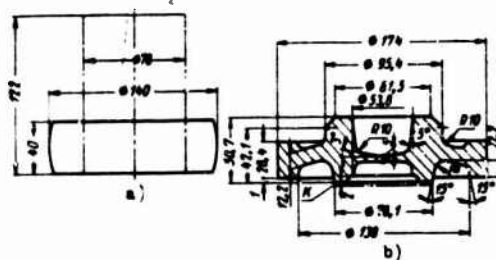


Fig. 7. Operations of flashless forging of gears on a cranking hot-forging press force of 2500 tons: a - first operation - swaging of the billet; b - second operation - final forging.

Table 2. Fundamental advantages of flashless drop forging of first and reverse gears on a cranking hot-forging pass (CHFP) in comparison with forging on a horizontal forging machine (HFM) and on hammers.

Indexes	Methods of manufacture of forgings		
	Flashless die on CHFP	Flashless die on HFM	Open-die on hammers
Class of manufacturing precision of forgings according to GOST 7505-55	1	2	2
Weight of forgings in kg	4,070	5,400	5,325
Norm of expenditure of metal in the manufacture of 1 forging, in kg	4,445	5,740	6,500
Productivity of drop forging in pieces/hour	185	143	160

The excess of metal (compensator) is cut away in a special stamp. The gap at the side between the matrix container and the die in both operations is equal to 0.2% of the diameter of the container. The gap between the withdrawing device and the aperture underneath the core in the matrices is 0.4-0.5 mm. The opening for the pressed gear in the matrix of the second operation can be up to 1% greater than the opening in the matrix of the first operation.

Until a factory's acquisition of cranking drop forging presses the forged piece under consideration is manufactured in a horizontal forging machine (Fig. 9).

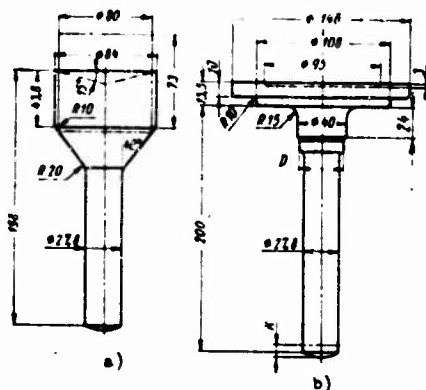


Fig. 8. Operations of stamping of a planetary transmission driveshaft on a 2500-ton CHFP: a - first operation - extrusion of the rod; b - second operation - stamping of the flange.

Then the initial billet, which has a diameter of 60 mm and a length of 308 mm is preliminarily turned on a lathe until it has acquired the final dimensions of the forging according to the length of the gear (177 mm) and length of the collar (24 mm). The application of such technology depends on the fact that for flange heading from a billet with a diameter of 27 mm there were required a great number of processes which were not placed on first priority on the HFM.

The advantage of the flashless method of pressing on the CHFP for the manufacture of forgings of the planetary transmission driveshaft (Fig. 8) in comparison with the heading of such a component on the HFM is obvious from the data given in Table 3.

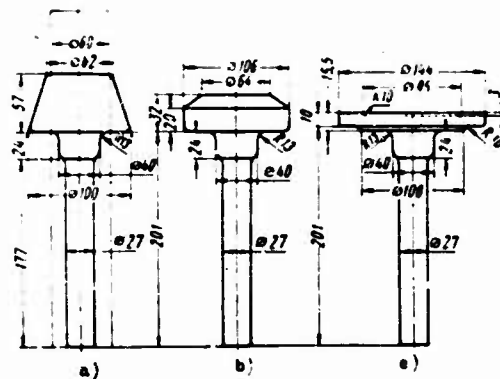


Fig. 9. Operations of the heading of a planetary transmission driveshaft on an HFM:

a - first operation - swaging of the billet to a cone;
b - second operation - swaging of the billet to a cylinder;
c - third operation - forming of the flange.

Table 3. Comparative indexes of drop forgings of planetary transmission driveshafts on a CHFP and an HFM.

Indexes	Method of production	
	Pressing on CHFP	Heading on HFM
Class of accuracy of forgings production according to GOST 7505-55	1	2
Norm of metal expenditure in manufacturing 100 forgings per kg	2.97	7.08
Stamp output in pieces/hour	106	86

More complicated, but also more interesting, are the processes of flashless pressing of forgings of the type of rotating bodies with a tubular core. Figure 10 depicts the stamping operations of a journal of the rotating cam of a truck by the press method on a CHFP. To carry out every operation one strike of the press slide is made. In the first operation the swaging of the billet in flat matrices is done; in the second - the making of a rough draft and giving to the billet the symmetry of a rotating body, necessary for the correct embossing of the subsequent operations; in the third - the punching out of an opening and pressing a tubular core; in the fourth - the final forming of all elements of the forgings.

As in the previous case, there is a compensator for eliminating the volumetric variation of the billets in the end of the tubular core of the forging. The depth of the cavity of the compensator is made by means of decreasing the calculated length of the ring of the lower withdrawing device of the press.

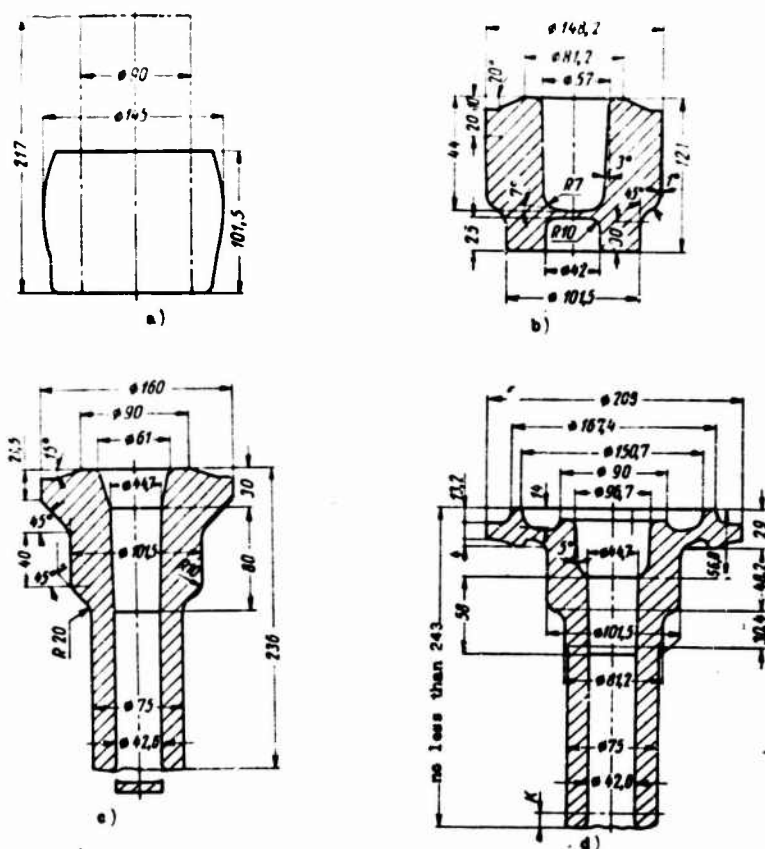


Fig. 10. Forging operations of the journal of a turning cam on the CHFP with a force of 2500 tons: a - first operation - billet swaging; b - second operation - cutting the rough stock; c - third operation - penetrating the opening and pressing the gear; d - fourth operation - final forming of the forging.

Drop forging processes similar to those mentioned above are carried out in stamps which have sliding casting dies.

The difference between the diameter of the casting die and the diameter of the container in matrices of the second, third and fourth operations comprises 0.25% of the diameter of the container of the given operation.

The examined process in comparison with the process of heading a journal at SKM has a number of advantages, shown in

Table 4, characterizing the cost of producing forgings according to the elements of expenditures.

Despite the obvious advantages of the method of flashless pressing in closed matrices, the latter possesses one definite shortcoming - inevitably in the forgings the tip of the burr will always arise in each operation of the forging. The magnitude of the burr is found to be in direct relation to the size of the gap E (Fig. 11a) which, in turn, depends on the following factors: accuracy of manufacture of the instrument and accuracy of maintaining axial alignment of the grooves of the upper and lower halves of the stamp; and warming up stages of the matrices and dies in the work process.

For lessening the influence of the first factor on the size of gap E elastic binding of the casting dies is used (Fig. 12) or a corresponding gap between the die and the die-holder is selected when applying stamps with piercing dies.

Table 4. Comparative cost of forging production of a journal for a turning cam (100 units).

Elements of expense	Methods of forging production	
	Pressing on CHPP	Heading on HPM
Norm of metal expenditure in kg	1128,70	1374,00
Weight of forgings in kg	1046,00	1289,00
Cost of metal in rubles	101,58	123,66
Wages with extra costs in rubles	3,83	3,59
Cost of working medium in rubles	2,52	5,77
Cost of the instrument in rubles	9,32	6,60
Amortized deductions in rubles	7,69	4,58
Total in rubles	124,94	144,20

For reducing the influence of the second factor intensive cooling of containers and forming dies is applied, using water and compressed air, where the water either moves directly to the surfaces of the container mounting (Fig. 11b) or withdraws heat through the clamps of the mounting bindings (Fig. 11a). Compressed air passes directly to the working surfaces of the containers and dies.

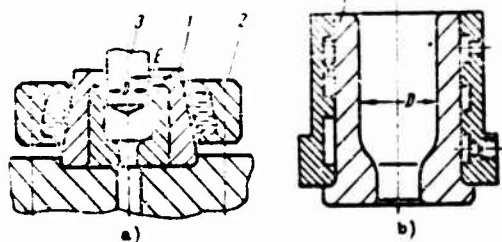


Fig. 11. Methods of feeding cooling water to the mountings of the containers:
a - withdrawal of heat by water through the clamp of the container mounting; b - feeding water directly to the wall of the container; 1 - container mounting; 2 - container mounting clamp; 3 - punching die.

However, despite the cooling methods used, the possibility of completely eliminating gap E between the container and the casting die (see Fig. 11a) does not present itself. In practical work the gap is formed on the basis of the working diameter of container D and is equivalent to 0.25% of the container.

The presence of the facing burr, especially in a multi-phase pressing process when in each subsequent operation a burr forms on the body of the forging, points out the necessity of using increased machining allowances from the side of the forging surface adjoining the working plane of the casting die.

In recent years much work has been conducted on the realization of the processes of hot pressing of forgings in split matrices. The successful adoption of this method of forging by industry depends on the positive resolution of a number of factors.

The principal factors: the absence of reliable and efficient equipment for rigid fastening of the matrix halves during the embossing of a forging; the presence of a facing burr; the difficulty of obtaining the required accuracy of the joining matrix planes in stamps for pressing nonsymmetrical forgings; the intensity with which the working parts of pressing dies heat up during the work process; the considerable extent of variations in billets, which is dependent upon the precision of dimensions of the initial section of metal, the accuracy of its cut in the billet and the stability of the heading regime of the metal for stamping.

Operations on mastering the process of pressing billets for crosspieces of truck differentials for their subsequent stamping in ordinary open-die matrices, conducted by us jointly with the Experimental Scientific Research Institute of Forging-and-Pressing Machinery (ENIKMASH) confirmed the stated conclusions.

Figure 13 shows a diagram of flashless pressing of the billet of a differential crosspiece. In the original version gap A was made equal to 0.015-0.020 mm on a side. In the beginning of a test of such a stamp, when pressing the second forging, the working part of the die heated up intensely and the die, due to insufficient strength of the springs which provided the opening of the half-matrix, wedged in the container. With the aim of eliminating this shortcoming, gap A was increased to 0.15 mm, and testing of the stamp continued. After the manufacture of 10-15 forgings there began to appear in gap A a burr, whose size after manufacturing 2000 forgings reached 7-10 mm. Besides that, the burr appeared also on the joining planes of the upper and lower matrices, and during the testing it was observed that when forging billets at a lower temperature the magnitude of the burrs was less than when forging billets at a high temperature.

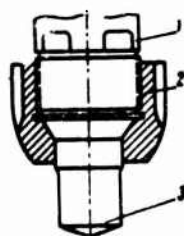


Fig. 12. Elastic fastening of extrusion punches:

- 1 - punch holder;
- 2 - clamp nut;
- 3 - extrusion punch.

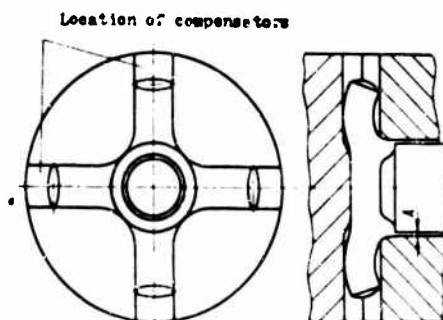


Fig. 13. Diagram of flashless die forging of blanks for a differential U-joint on a 1600-ton CHFP.

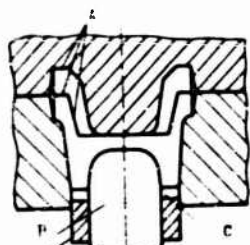


Fig. 14. Diagram of flashless forging of a cardan fork.

Figure 14 shows the fork of a cardan shaft of a truck, the manufacture of which is accomplished by the method of flashless pressing in split matrices. Preliminary tests of the stamp intended for the realization of such a process showed some results better than those obtained from stamping by the ENIKMASH. Improved results were attained by means of making sturdier fastening equipment for the upper and lower matrices, and also by means of setting the pressing die B and the circular compensator C in those cavities of the stamp groove which are most difficult to fill with metal. However, although the half-matrices were rigidly fastened during the forging process, the appearance of a burr on the line of the joint A was not completely eliminated due to the inaccuracy of the joining planes of the retainers of the upper and lower matrices, and also because of the uneven warming up of the matrices during the work process.

In an analogous scheme the forging of turning cams of trucks and a number of different forgings is adapted.

The operations carried out in the mastering of processes of hot flashless drop forging allow us to arrive at the following conclusions:

1. Flashless drop forging on hammers for large-batch and mass production cannot be a progressive process. The presence of a facing burr, occurring in the working zone of the joining of the stamps, hampers the machining of forgings, and their removal in a forge shop requires additional expenses which, in the majority of cases, are higher than the savings achieved by introducing this method of forging.

Such a process of forging manufacture can be justified only in cases of the manufacture of small series of forgings with their subsequent machining in multi-purpose machines, without applying complex special devices.

In large-batch and mass production with its great work tempo it is more expedient to employ semi-flashing forging using stamps with a wedged sample for deburring which allows us to obtain that effectiveness achieved with flashless forging.

2. The processes of hot flashless pressing of forgings on the CHFP in closed and split matrices are obviously the next stages of the further development of forge-stamping production.

DATA HANDLING PAGE				
04-ACCESSION NO. TP0000012		98-DOCUMENT LOC		
09-TITLE METHODS OF FLASHLESS DROP FORGING -U-		39-TOPIC TAGS drop forging, forge press, metallurgic process		
47-SUBJECT AREA 11, 13				
42-AUTHOR CO-AUTHORS BOGDAN, A. D. ; 16-KUSHNIKOVA, V. S.				10-DATE OF INFO -----66
43-SOURCE KUZNECHNO SHTAMPOVOCHNOYE PROIZVODSTVO (RUSSIAN)				68-DOCUMENT NO. HT-23-206-69
				69-PROJECT NO. 60108
63-SECURITY AND DOWNGRADING INFORMATION UNCL. O			64-CONTROL MARKINGS NONE	97-HEADER CLASH UNCL
76-REEL/FRAME NO. 1091 0122	77-SUPERSEDES	78-CHANGES	80-GEOGRAPHICAL AREA UR	NO. OF PAGES 15
CONTRACT NO. F33657-68-D- 0865-P002	X REF ACC. NO.	PUBLISHING DATE	TYPE PRODUCT TRANSLATION	REVISION FREQ NONE
STEP NO. 02-UR/0182/66/000/C07/0035/0040				
ABSTRACT (U) This article examines the problems and methods of flashless drop forging for mass production. It compares these methods with those of open-die forging.				