UDC 621.983.044:003.13

M.A. Golovanova[1], B. Gonzalez[2], M.K. Knyazyev[1]

[1] *Zhukovsky National Aerospace University "Kharkiv Aviation Institute", Ukraine*
[2] *LABEIN Technological Research Center, Spain*

EFFICIENCY IMPROVEMENTS OF BATCH PRODUCTION OF SHEET PARTS WITH METHOD OF ELECTROHYDROIMPULSE FORMING

Analysis of influences of main factors that determine efficiency of sheet-forming production: manufacturing, organizational, designing factors, is performed. Analysis of constituents of piece and piece-calculation times for conditions of batch production allowed to reveal the most "time-consumptive" factors that influence on performance of separate elements of a manufacturing process and propose engineering solutions for improvements of equipment and organization of electrohydroimpulse forming process.

sheet-forming production, production volume, economic efficiency, operation time, discharge chamber, repairability

Under conditions of transforming economics the tasks of organization of rapid manufacture of sheet-formed products and submitting them at the markets frequently appear. Such products could be separate articles (for example, things of kitchen utensils) or be components of more complicated and expensive machines and instruments (sheet parts of aircraft engines, car body components, lighting fixture, etc.). Manufacture and selling of relatively small batch of sheet articles could show the need of large-scale or mass production. Rapid output of high-quality products at low prices would allow to manufacturing company to conquer a market.

Impulse sheet-forming methods are most suitable for conditions of small-batch production and shortest pre-production periods for manufacturing of sheet-formed items. One of impulse methods is electrohydroimpulse forming (EHF) that proved its high efficiency under market conditions of economy development and limitations applied to the use of explosives in industry connected with their storage, transportation and utilization. EHF is based on the use of "safety" type of energy – electric energy and allows significantly reduce application of manual labour in manufacture of complicated sheet parts with providing the specified accuracy at the expense of one hard shape-determining surface (die or punch) and positive effects of metal deformation under the impulse loading.

Now EHF manufacturing processes find the increasing application in various branches of industry for production of components from sheet blanks, especially taking into account rise of volume of small-batch production of sheet parts that, in its turn, determines increased interest of specialists to seeking new ways and the most economical means for manufacture of parts with methods of sheet-metal stamping.

Efficiency increase of sheet-stamping production, including EHF method, is mainly determined by rational utilization of various kinds of resources (material, energy, labour, financial) and requires complex approach to consideration and use of these or those technologies for manufacture of articles. Increase of EHF efficiency is stipulated by, on the one hand, the influence of two groups of factors that are connected with reduction of value of capital investments to metalworking equipment, tooling, and current costs (manufacturing cost of sheet-formed parts). On the other hand, these factors could be divided into design-manufacturing and organizational ones. Interconnection between these groups of factors is shown in Fig. 1. Let us consider in more detail influence of separate factors on efficiency of sheet-stamping production.

Main factor of efficiency rise of sheet-stamping production is reduction of manufacturing cost that is determined by a number of indexes, among which reduction of labor expenditures for articles' processing, reduction of materials consumption per a piece, reduction of capital expenditures for purchased equipment, and application of cheaper tooling, that permit to reduce capital allowances for compensation of wear of equipment being in operation (depreciation charges) and decrease costs for manufacturing re-equipment. In its turn, reduction of materials consumption depends on configuration and sizes of a part, material, from which it is made, which, in their turn, influence variant of laying-out of sheet, band or strip that being reflected in the coefficient of material utilization.

Important factor of efficiency rise of sheet-stamping production is an annual program of manufacture and volumes of batches. It is known that depend on

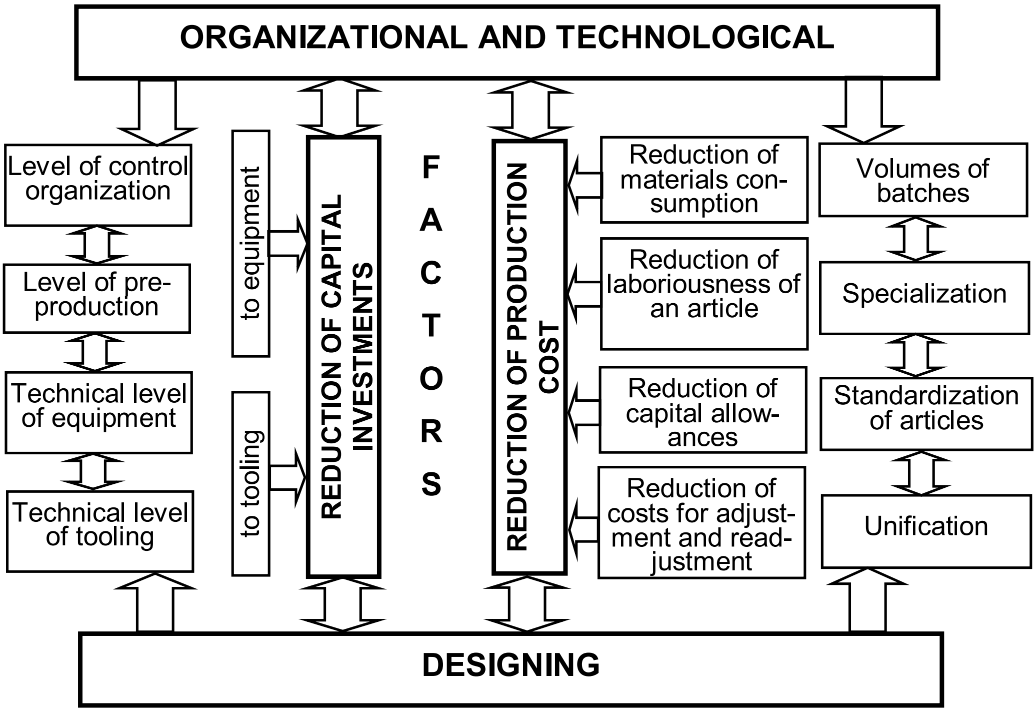

Fig. 1. Factors of efficiency increase of sheet-stamping production

sizes of parts the value of annual output program could change in 5…250 times.

Increase of production volumes of parts of the same name allows to reduce conditional-permanent segment of manufacturing cost of output products connected with amortization of special metalworking equipment, discarding the tooling, with adjustment and tuning of presses, etc.

Depend on production conditions each press could be engaged for manufacturing from several tens at conditions of batch or small-batch production to one-two item name at conditions of mass production. When batch volume increases, this feature allows significantly raising productivity of metalworking equipment and reducing labouriousness of works.

Previous investigations [1, 2] showed high technical and economical effectiveness of the EHF method under conditions of individual and small-batch production. But EHF equipment is characterized by lower productivity as compared with traditional metalworking equipment for sheet forming that practically exclude its application for middle-batch and large-batch production. This is connected, first of all, with peculiarities of organization of EHF process, which includes large number of auxiliary functions that are to be provided and performed by EHF equipment before the beginning of impulse forming of a part and after its completing.

Change of productivity of metalworking equipment at various production volumes (volumes of batches) significantly influences the time of auxiliary motions that occupies the largest specific weight in the time per piece. Thus, analysis of structure of time allowance per piece for sheet-stamping works shows that auxiliary time occupies 50-60 % and more of total time allowance. Preparation-completing time substantially changes at various volumes of batches. At conditions of batch production the preparation-completing time reaches 30 % of actual time fund in press shops, while at mass and large-scale production it does not exceed 5-12 % [3]. Rise of specific weight of preparation-completing time at small-batch production in comparison with large-scale and mass production occurs at the expense of increase of quantity of batches putting into production and, hence, quantity of readjustments of equipment.

Thus, with rise of batches volumes the specific weights of preparation-completing and auxiliary times reduce, and, hence, hour and annual productivities increase.

Analysis of constituents of piece and piece-calculation times for production of one article allows to reveal the most “time-consumptive” links, to reveal those factors that influence on performance of separate elements of a manufacturing process and propose engineering solutions for improvements of equipment and organization of a forming process.

Modern condition of sheet-stamping production for specific types of nomenclature of sheet-formed parts is characterized by large volume of hand works. This could be explained by that at conditions of mechanized small-batch and batch production the complicated and expensive tooling could be economically not sound, therefore the simplified manufacturing processes, which apply simple tooling and hand labour for finishing works, are used. On the other hand, finishing works for formed parts occupy substantial specific weight in total labouriousness of works. Finishing works are consequence of low pressures generated at forming in certain types of equipment. The most of press equipment do not allow to obtain parts from hardly-deformed metals and alloys that causes necessity of production of part’s segments with sequent welding and straighten-

Fig. 2. Conical discharge chamber and tooling placed in technological unit of the installation UEHSh-2

ing that still more increases labouriousness of hand works.

Main forming time, as a constituent of total machine and operation times, at EHF is connected with performance of specified quantity of cycles of charge-discharge of capacitors' bank. Here the reduction of charge time is reached at the expense of mightier source of direct current.

Another reserve for reduction of main time is such an organization of forming process that provides decrease of discharges' quantity and, respectively, consumptions of time and energy.

Thus, during adjustment of forming process for the part "model lamp reflector for exterior lighting" from aluminum alloys AD1M and 1080 in experimental installation UEHSh-2 (Fig. 2) two approaches to planning of forming process were tested. When using "classic" (traditional) approach the discharges of lower voltage of 13 kV were applied at the stage of forming of general shape, at the stage of forming of local elements – 14-15 kV, at the stage of calibration – 16 kV with capacitance of 50 microfarad. Total number of discharges was 8, total energy consumption – 42.2 kJ and main forming time – 74 s (8 charge-discharge cycles). When using nontraditional approach with higher voltage of 20-30 kV and less capacitance of 33.2 microfarad the required number of discharges reduced to two. At that total energy consumption was 21.5 kJ, and forming time decreased to 16 s that is comparative with parameters of traditional forming in the die-and-punch tooling on hydraulic presses.

Further reduction of main forming time is possible with increase of power of supply source of charge circuit.

In respect of reduction of forming time for middle- and large-size parts it could be very useful application of multi-electrode discharge blocks of directed

Fig. 3. General view of die and article "fairing" of 488 mm outside diameter from steel St3kp of 1,5 mm thickness

action (MDB) that allow to generate the optimized loading fields, which correspond to geometric parameters of a part. For example, during forming the part "fairing" (Fig. 3) that represents a half-torus, the load was applied only to the weighed-down segment of blank by connecting of corresponding electrodes of the installation UEHSh-2, excluding central zone where blank has round hole according to the part's shape [4]. Use of dome-shaped discharge chamber with single electrode pair in this case would require much more quantity of mighty discharges to create specified pressure at the periphery of the chamber where torus profile is to be formed. At that the highest intensity of loading would be created in the central zone of die and the most of energy would be utilized extremely unproductive.

In order to provide high productivity it is necessary that each MDB electrode pair have its "own" discharge circuit. Though MDB is quite operable with less quantity of discharge circuits and even with one circuit. In the described case (ref. Fig. 3) forming of fairing was performed with six discharge circuits, though it is necessary to connect 12 electrode pairs for loading along all weighed-down segment of blank. Forming time with 6 electrode pairs (with use of 6 discharge circuits) was 14.5 min. taking into account rotation of the part in the die in 30^{o} after the first pass. According to our estimation it would be necessary only 2.5-3 min., if forming would be realized with 12 electrode pairs at present power of charging source.

Next group of technical means provides shortening of auxiliary time. Significant feature of EHF equipment is large number of auxiliary motions necessary for providing the main function – impulse loading of blank. These auxiliary passes could be combined in time and, thereby, to reduce total machine time (тable).

As one can see from the cyclogram the combinations of such motions as vacuuming switching-on, filling a discharged chamber with water and charge of capacitor's bank at incomplete pouring water out discharged chamber (combination during the time τ5); pouring out water and unclamping of tooling (τ7); travel of table to auxiliary position, supply of compressed air into die and removal of formed part (τ8) significantly reduce the total cycle time.

Table

Modified operation cyclogram of electrohydraulic press

No.	Name of motion	τ1	τ2	τ3	τ4	τ5	τ6	τ7	τ8
1.	Cleaning and oiling of die	■							
2.	Blank mounting		■						
3.	Travel of table to working zone			■					
4.	Clamping of tooling				■				
5.	Vacuuming of die cavity					■	■		
6.	Filling disch. chamber with water					■			
7.	Charge-discharge cycles					■	■		
8.	Pouring water out disch. chamber							■	
9.	Unclamping of tooling							■	
10.	Travel of table to auxiliary position								■
11.	Supply of compressed air into die								■
12.	Removal of formed part								■

Further shortening of operation time the authors see in application of mightier sources of hydraulic energy or hydraulic accumulators for accelerated motions of table and clamping-unclamping of tooling, increase of open flow areas of pipes for reduction of time for filling-pouring-out water, use of mode of incomplete pouring water out discharge chamber, increase of capacity of vacuum pump and/or application of vacuum receiver. As a special mean, robots-manipulators could serve for mounting and removal of blank, cleaning and oiling of die, and excluding the table's travels, as well as for transfer of formed article to the next press for sequent processing.

The very important characteristic of EHF equipment is its suitability for repair and maintenance. It is known that "weak" link of discharge units is high-voltage insulator of electrodes that operates under heavy conditions of impulse loading (tens thousands bars) and high electric field strength, which determine its short service life. Unfortunately, today there are no materials able to withstand such loads for a long time (comparative with service life of metallic components of a discharge chamber). Therefore design of discharge chamber should provide fast replacement of worn electrode or work part of insulator. This characteristic acquires especial value for multi-electrode discharge blocks under conditions of batch production.

Scientific workers of the KhAI EHF laboratory developed multi-electrode discharge block that provides fast replacement of caps of electrode insulators with use of quick-changeable units for clamping of discharge plate and hold-down plate with rubber diaphragm. Besides that the fast replacement of discharge units in technological block aiming to shortening of repair time with sequent replacement of electrodes or their caps on the auxiliary position of EHF production area is provided.

Application of coaxial discharge surfaces with fixed spark gaps in the MDB design excludes the adjustment time (reduces preparation-completing time) spent for tuning of optimal spark gap value.

Conclusions

Performed technical and economic analysis allowed to reveal process parameters limiting the reduction of processing cycle of EHF method under conditions of batch production.

Investigations results were used to develop technical and organizational means for providing batch production of sheet-formed articles, directions for further investigations were determined.

References

1. Chachin V.N. Electrohydraulic processing of engineering materials // Minsk: Science and engineering. – 1978. – 184 p. (in Russian).

2. Knyazyev M.K. Economical technology for production of small batches of sheet parts // Business-most, 2004, No. 4(23). – P. 17-19 (in Russian).

3. Byalkovskaya V.S. Estimation of economic efficiency of new equipment in press-forging production. Moscow: Mechanical engineering, 1972. – 111 p. (in Russian).

4. Knyazyev M.K., Chebanov Yu.I. Multi-Electrode Discharge Blocks for Electrohydraulic Forming and their Capabilities // Eastern-European Journal of Enterprise Technologies. – 2004. – No. 3 (9). – P. 13-20 (in English).

Поступила в редакцию 7.04.2007

Рецензент: д-р техн. наук, проф. Ю.С. Воробьев, Институт проблем машиностроения им. А.Н. Подгорного НАН Украины, Харьков.