The energy of sheet bending on a crank-type press

Marat Abdulganiev, Miroslava Ray

Volodymyr Dahl East-Ukrainian National University, Lugansk, Ukraine

S u m m a r y. The analytical method of power calculation of crank-type press working stroke is developed instead of graph analytical method. This analytical method allows substantially reducing working hours of calculation and promoting exactness of the results. Bending and coining are offered to execute separately. That will allow to make this processes more economically and to reduce depreciate charge.
K e y w o r d s. A crank-type press, a working stroke, a deformation, a sheet bending.

INTRODUCTION

Sheet bending is one of the most widespread operations of the sheet stamping. The technology of sheet bending is given in literature fully enough. At the same time the problems of energy losses on the sheet stamping process itself are not paid attention. So its hard to make the choice of equipment for automation the process.

ANALYSIS OF PUBLICATIONS

The sheet stamping, as well as sheet bending, belongs to most widespread operations of processing of metals forming. Sheet bending processes are quite fully presented in works [Malov 1969; Malov 1969; Forging and stamping 1987; Evstratov, Pivova, 2007].

The most fully sheet bending operations are given by Zubov M.E. in his work. The descriptions of bending and coining processes which allows to decrease springing of material and to improve quality of good. The example of determination the sheet bending efforts of the steel staple is given [Zubov 1980].

It is shown that the sheet bending effort makes 60,15kN, coining effort at the end of slide-block stroke of the press – 816 kN. Coining effort is in 16,3 times more than sheet bending effort. Sheet bending is the most common conjointly with coining on mechanical crank-type presses. The description of function and the construction of which led in monographs and literature on blacksmith-stamping equipment [Zaleskiy 1964; Zaleskiy 1973, Lanskoy, Banketov 1966; Banketov, Bocharov, Dobrinskiy, Lanskoy 1982; Zhivov, Ovchinnikov 1966; Stoyanov, Shenkman 2010; Zhivov, Ovchinnikov 1981; Zhivov, Ovchinnikov, Skladchikov 2006; Ryabicheva,Tsirkin, Usatyuk 2010; Bocharov 2008; Vlasov, Borzykin, Bukin-Batyrev 1982; Ray, Monyatovskiy 2000; Svistunov 2008].

Technical descriptions of crank-type presses are given in reference books on blacksmith's equipment [Rudman, Zinchuk, Marchenko 1989; Forging-press equipment 1982].

In technical literature methods are expounded in the general view for graph analytical calculation of power parameters of working stroke of crank-type presses, they are based on the graph of technological efforts of deformation. Bases of this method are resulted in works of Lanskoy [Lanskoy 1982]. In works [Lanskoy, Banketov 1966; Zhivov, Ovchinnikov 1981; Zhivov, Ovchinnikov 1966] is expound the same graph analytical method with insignificant clarifications. The indicated method is used without changes in works of other authors [Vlasov, Borzykin, Bukin-Batyrev 1982; Belyaev, Bogdanov, Tynyanov 1989; Bocharov 2008; Svistunov 2008].

The method of numeral integration of power parameters calculation of working stroke crank-type presses is given in work [Ray, Monyatovskiy 2000].

PURPOSE OF THE WORK

A purpose of work is the development of analytical method of calculation the energy expenses on the working stroke of crank-type presses that works making workpiece on sheet bending operations.

OBJECTS AND PROBLEMS

The energy expenses on a working stroke of the press is determined from the dependence

$$A = A_g + A_f + A_{fy}\,, \qquad (1)$$

where: A_g – work of plastic deformation, contains two constituents

$$A_g = A_{g1} + A_{g2}\,, \qquad (2)$$

A_{g1} – work on the bending area workpiece

$$A_{g1} = P_1 h_n\,, \qquad (3)$$

h_n – moving the slider on the site of bending workpiece (fig.);

P_1 – permanent effort, it is accepted equal,

$$P_1 = 0{,}2P_n\,,$$

P_n – nominal effort of the press.

A_{g2} – work of plastic deformation in the coining area

$$A_{g2} = 0{,}5(P_1 + P_n)h_k\,, \qquad (4)$$

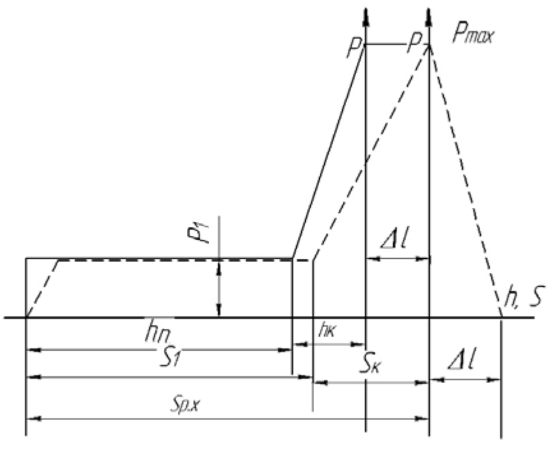

Fig. 1. The effort graph of plastic deformation – 1, the load graph of the press – 2

The start of the working stroke Zhivov L.I. [Zhivov, Ovchinnikov, Skladchikov 2006] offers to determine the rotation angle of the main shaft equal 60 degrees. According to [Yavtushenko 2008; Yavtushenko O.V., Glebenko T.O., 2012] absolute deformation on the coining area is equal to 0,03 Sн (Sн – nominal stroke of the press slide-block) and if one considers the increase of the closed height of the press in consequence of plastic deformation, these it is possible to express from the dependence

$$S_{\left(\alpha=60^o\right)} = h_n + 0{,}03S + P_n / C\,, \qquad (5)$$

where: $S_{\left(\alpha=60^o\right)}$ – moving of slide-block is proper the corner $\alpha = 60^o$ turning of main billow of the slide-block counted off from extreme lower position;

$0{,}03S$ – absolute plastic deformation on the coining area, accepted aaccording to the recommendations [Yavtushenko, Glebenko 2012];

C – technological stiffness of crank press.

The energy losses on a friction are determined from the dependence

$$A_f = \int_{\alpha_н}^{\alpha_к} P_{(\alpha)} m_f d\alpha\,. \qquad (6)$$

At the first bending area for solutions to (6) made:

$$\begin{cases} \alpha_н = 60^o;\ \alpha_p = \sqrt{\dfrac{2(0{,}03S + P_n / C)}{R(1+\lambda)}}, \\ m_f = \mu\left[\lambda(r_a + r_o)\cos\alpha + r_b + r_o\right], \end{cases}$$

where: μ – a coefficient of friction in kinematics pair;

λ – coefficient of multiplicity of bell crank;

α_p – angel of coining;

r_a, r_b, r_o – radiuses of bearings trunnion of articulation of crank-type shaft with connecting rod, crank-type shaft with a slide-block, supporting pin of main shaft.

After a substitution (7) in (6) and integrations we will get following expression for determination of losses on a friction on the bending area

$$A_f = \mu P_1 \begin{bmatrix} \lambda(r_b + r_a)(\sin\alpha_n - \sin\alpha_p) + \\ + (r_a + r_o)(\alpha_n - \alpha_p) \end{bmatrix}. \qquad (7)$$

For determination of energy losses on a friction on the bending area are determined by dependences included in equalization (6).

Effort on a slide-block in the function of corner of the turn of main shaft would be

$$P_\alpha = P_{max} - \frac{P_{max} - P_1}{S_p} S_{(\alpha)}, \quad (8)$$

where: $S_{(\alpha)}$ – moving the slide-block in the function of the rotation angle of crank shaft,

S_p – moving the slide-block on the bending area considering to the plastic deformation of the press

$$S_p = h_k + P_{max} / C ; \quad (10)$$

Resulted shoulder of friction forces, taking into account the small values of corner α_k, in obedience to recommendations of Zhivov L.I. [Zhivov, Ovchinnikov, Skladchikov 2006] is accepted permanent, in formula (6) $cos\,\alpha = 1,0$.

After a substitution (8) and (9) in (6) taking into account of constancy the resulted shoulder of friction forces and limits of integration, we will find dependence for determination of energy losses on a friction on the bending area

$$A_f = m_f \left\{ \begin{array}{l} P_{max}\alpha_p - \frac{P_{max} - P_1}{S_p} R \cdot \\ \cdot \left[\left(1 + \frac{\lambda}{4}\right)\alpha_p - sin\,\alpha_p - \frac{\lambda}{8} sin\,2\alpha_p \right] \end{array} \right\}. \quad (11)$$

If we express $sin\,2\alpha_p = 2 sin\,\alpha_p cos\alpha_p$ and accept $cos\,\alpha_p = 1$, equalization (11) for determination of energy losses on a friction on the bending area it is possible to present like

$$A_{f2} = m_f \left\{ \begin{array}{l} P_{max}\alpha_p - \frac{P_{max} - P_i}{S_\kappa} R \cdot \\ \cdot \left[\left(1 + \frac{\lambda}{4}\right)\left(\alpha_p - sin\,\alpha_p\right) \right] \end{array} \right\}. \quad (12)$$

For determination of losses on a friction at the plastic unloading press in equation (12) $P_{max} = P_n$ $S_k = \Delta\ell$; $\alpha_k = \alpha_y$; $P_i = 0$ is accepted and we will get

$$A_{fy} = m_f P_n \left\{ \alpha_y - \frac{R}{\Delta\ell} \left[\left(1 + \frac{\lambda}{4}\right)\left(\alpha_y - sin\,\alpha_y\right) \right] \right\}, \quad (13)$$

In (13) constituents are determined as following:

the size of plastic deformation of the press on the closed height

$$\Delta\ell = P_n / C, \quad (14)$$

the rotation of an angel of crank shaft is appropriate for plastic deformation of the press

$$\alpha_y = \sqrt{2\Delta\ell / \left(R(1 + \lambda)\right)}. \quad (15)$$

For the evaluation of energy losses on a friction at the plastic press unloading is determined by plastic deformation of the press on dependence

$$A_y = P_n^2 / (2C). \quad (16)$$

Efficiency of the press on the bending area and efficiency of the working stroke determined on the generally accepted method as attitude of ratio of the plastic deformation (useful work) to expended (expressed as the sum of the energy lost to friction and useful work). The basic parameters and results of the calculation of the energy parameters of the working stroke are given (table. 1, table. 2).

Table 1. The basic parameters of the calculation of the energy parameters of the working stroke

№	1	2	3	4	5	6
P_n, MN	1,6	3,15	6,3	10,0	16,0	25,0
S, mm	160	400	320	400	400	600
$C \cdot 10^9$ MN/m	0,6	0,9	1,2	1,5	1,9	2,4
λ	0,085	0,095	0,105	0,115	0,120	0,125
r_a, mm	230	335	375	430	470	475
r_b, mm	90	90	125	160	190	190
r_o, mm	90	125	160	180	190	200
m_f, mm	21	29	36	42	44	46

The analysis of the results shows the high economy of bending process compared with the process of coining. This can be explained by the occurrence of precipitation process at high angles of rotation of the main shaft 60 ° ... 25 °, and 25 ° ... 0 ° bending process as kinematical efficiency slider-crank mechanism with decreasing angle of the main shaft. Since the efficiency of the working stroke in the bending area is 0,84 ... 0,91, in the coining area 0,30 ... 0,44. The efficiency of full working stroke include the bending area and coining is at 0,47 ... 0,62, that is, at the level of efficiency of the crank presses stroke working in punching and cutting operations with sheet metal. Significant energy losses observed in the plastic unloading of the press, the energy expended to overcome friction is 53 ... 116% of the plastic work during coining.

Analysis of the load graph of the press shows that the bending should perform on press in several times lower than the nominal force, which would reduce energy costs and depreciate charge.

Table 2. The results of the calculated parameters of the bending process

№	1	2	3	4	5	6
$\Delta\ell_y$, mm	2,7	3,5	5,3	6,7	8,4	10,4
α_y, deg	10,3	10,3	14,0	14,0	15,7	13,9
α_k, deg	0,42	0,38	0,41	0,43	0,43	0,41
A_y, kJ	2,1	5,5	13,2	33,3	67,4	130,2
A_{fy}, kJ	5,11	11,4	38,7	72,4	135,1	195,7
h_1, mm	35,5	91,5	71,0	91,0	89,1	112,7
S_n, mm	43	107	86	109	09	168
S_k, mm	7,5	15,5	15	19	20,5	29,3
h_k, mm	4,8	12	9,6	12	12	18,9
h_n, mm	3,5	91,5	71,5	90,3	88,6	138,7
A_{f1}, kJ	2,1	5,6	10,9	18,0	32,7	58,4
A_{f2}, kJ	10,5	25,9	70,4	131,8	228,4	355,3
A_{g1}, kJ	11,4	57,6	90,1	182	285	694
A_{g2}, kJ	4,6	22,7	36,7	72,0	115,0	284,0
ΣA_g, kJ	16,0	80,3	126,8	254,0	400,0	978,0
ΣA_f, kJ	17,7	42,9	124	223	396	609
η_1	0,84	0,91	0,89	0,91	0,89	0,91
η_2	0,3	0,53	0,34	0,36	0,34	0,44
$\eta_{1,2}$	0,47	0,65	0,51	0,53	0,50	0,62
A_{fy} / A_g	1,1	0,5	1,1	1,0	1,2	0,7
A_{fy} / A_y	2,4	2,1	2,9	2,2	2,0	1,5

It is desirable to perform coining on presses with less speed slider and more technological rigidity, such as embossing. Making bending or coining on universal crank presses substantial economic savings can be achieved by improving the conditions of friction in the joints of the main actuator, friction coefficient from 0,06 to 0,03 will allow to increase 30% in efficiency of the working stroke press.

CONCLUSIONS

1. The proposed method of analytical calculation of energy on the working stroke of the press instead of the graph analytical on the operations of coining can reduce the complexity of calculation and improve the accuracy of its results.

2. Bending operations should be carried out separately from the coining, which allows in a few times to reduce the power of the press. We suggest coining operations to make on presses with less speed slider and more rigid, such as embossing presses.

3. The use of hydrodynamic lubrication conditions will significantly reduce the energy losses on friction and increase the efficiency of the working stroke of the press on 30%.

REFERENCES

1. **Banketov A.N., Bocharov Y.A., Dobrinskiy N.S., Lanskoy E.N., 1982.:** Blacksmith-stamping equipment. Moscow, Machinbuilding, 576p.
2. **Belyaev S.I., Bogdanov E.F., Tynyanov V.N, 1989.:** Determination of the rational productivity of heavy crank-type presses. Blacksmith-stamping production, P.15–19.
3. **Bocharov Y.A., 2008.:** Blacksmith-stamping equipment. Moscow, Press Center «Academy», 480p.
4. **Evstratov V.A., Pivovar V.S., 2007.:** The state and prospects of development of production of the bent types and special equipment. Proceedings of international scientific technical conference of «Machine and plastic deformation of metals». 20–23 November, Zaporozhia, P. 92–93.
5. **Forging and stamping, 1987.:** A reference book is in 4th volumes. T.4. Sheet stamping. Moscow, Machinbuilding, 544p.
6. **Forging-press equipment, 1982.:** Reference book. Science research institute of information of machinbuilding. Moscow, 88p.
7. **Lanskoy E.N., Banketov A.N., 1966.:** Elements of calculation of details and knots of crank-type presses. Moscow, Machinbuilding, 380p.
8. **Malov A.N., 1969.:** Technology of the cold stamping. Moscow, Machinbuilding, 568p.
9. **Ray R.I., Monyatovskiy S.S., 2000.:** Blacksmith-stamping equipment. The press crank-type. Lugansk, The East-Ukrainian National university named after V.Dahl, 216p.
10. **Rudman L.I., Zinchuk A.M., Marchenko V.L., 1989.:** Reference book for the sheet stamping. Kiev, Technic, 231p.
11. **Ryabicheva L.,Tsirkin A., Ysatyuk D. 2010:** Warm deformation of copper porous powder billets. TEKA Commission of Motorization and Power industry, V.XB, p.134-140.
12. **Stoyanov A., Shenkman G. 2010:** Manufacturing technology of complicated shape parts of sintered metal powders. TEKA. Commission of motorization and power industry in agriculture, V. XB, P. 220-226.
13. **Svistunov V.E., 2008.:** Blacksmith-stamping equipment. Crank-type the press. Moscow, Machinbuilding, 698p.
14. **Vlasov V.I., Borzykin A.Y., Bukin-Batyrev I.K., 1982.:** Crank-type forging-press machines. Moscow, Machinbuilding, 576p.
15. **Yavtushenko O.V., 2008.:** Design and calculation crank presses. Textbook. Zaporozhia, ZNTU, 448p.
16. **Yavtushenko O.V., Glebenko T.O., 2012.:** Design and calculation crank presses. Course design. Textbook. Zaporozhia, ZNTU, 448p.
17. **Zaleskiy V.I., 1964.:** Equipment of forging-press workshops. Moscow, 600p.

18. **Zaleskiy V.I., 1973.:** Equipment of forging-press workshops. Moscow, 630p.
19. **Zhivov L.I., Ovchinnikov A.G., 1966.:** Blacksmith-stamping equipment. Presses. Kharkov, University, 456p.
20. **Zhivov L.I., Ovchinnikov A.G., 1981.:** Blacksmith-stamping equipment. Presses. Kiev, 376 p.
21. **Zhivov L.I., Ovchinnikov A.G., Skladchikov E.N., 2006.:** Blacksmith-stamping equipment : textbook for the machine-building institutes. Moscow, MSTI name of A.D. Baumana, 560p.
22. **Zubtsov M.E., 1980.:** Sheet stamping. Leningrad, 432p.

ЭНЕРГЕТИКА ГИБКИ ЛИСТОВОГО МЕТАЛЛА НА КРИВОШИПНОМ ПРЕССЕ

Абдулганиев Марат, Рей Мирослава

Аннотация. Разработанный аналитический метод энергетического расчета рабочего хода кривошипного пресса вместо графоаналитического позволяет существенно снизить трудоемкость расчета и повысить точность его результатов. Предложено свободную гибку и правку (чеканку) выполнять раздельно, что позволит экономичность процессов и снизить амортизационные отчисления.
Ключевые слова. Кривошипный пресс, рабочий ход, деформация, гибка листового металла.