Designing of a Crank press on the Basis of High Class Planar Linkages

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Abstract

Currently, crank presses based on planar linkages received prevalence for presswork. One of the major problems of these presses is skewness of slide caused by eccentric application of deforming force and total linear elastic deformation of the press links and stamps under load. The skewness of the slide of the crank press reduces the accuracy of punching and causes its jamming and lead to its breakage. To eliminate these problems, it is proposed to use high-class planar linkages to design crank presses in the work. Schemes of planar linkages of class IV for designing of new crank presses were obtained. A new crank press was synthesized on the basis of planar linkages of class IV and its prototype was made. The tests of the prototype of the new crank press were carried out

Keywords

Crank Press Linkage Assur Group High Class Stamp

Designing of a Crank press on the Basis of High Class Planar Linkages

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Abstract. Currently, crank presses based on planar linkages received prevalence for presswork. One of the major problems of these presses is skewness of slide caused by eccentric application of deforming force and total linear elastic deformation of the press links and stamps under load. The skewness of the slide of the crank press reduces the accuracy of punching and causes its jamming and lead to its breakage. To eliminate these problems, it is proposed to use high-class planar linkages to design crank presses in the work. Schemes of planar linkages of class IV for designing of new crank presses were obtained. A new crank press was synthesized on the basis of planar linkages of class IV and its prototype was made. The tests of the prototype of the new crank press were carried out.

Keywords: Crank Press, Linkage, Assur Group, High Class, Stamp

1 Introduction

The crank press is a machine with a crank-slide mechanism designed for stamping various parts [1]. During the operation of the crank press, significant dynamic loads occur in the nodes and mechanisms. These dynamic loads are associated with operational aspects of the crank press, which is in impact cyclic loads. The study of the dynamics of the crank presses is of the utmost interest. Fig. 1 shows structural flow chart of the press [1]

Operating principle of the crank press (see Fig. 1): crank 1 rotates around axis 2 and drives through coupler 3 the slide 4 with stamping tool 5. Detail 6 is processed by mobile 6 and fixed 7 parts of the stamping tool. The press drive consists of electric motor 8, V-belt transmission 9 and flywheel 10. Press clutch 11 is located between the flywheel 10 and the crank 13. Brake 12 serves to stop the press.

The crank press contains movable parts and links, of which mass is from one hundred kilogram to several tons. These parts and links cyclically move at high speeds and they are subject to large dynamic loads. One of the important parameters of the crank press [1] is the stamping accuracy.

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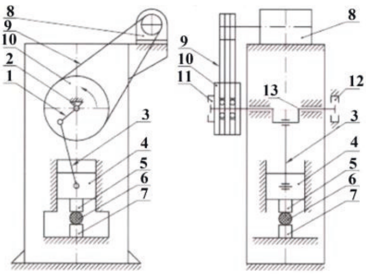


Fig. 1. Structural flow chart of the crank press.

The accuracy of stamping on crank presses mainly depends on two factors: skewness of the slide under the influence of an eccentric application of deforming force and the total linear elastic deformation of the construction units of the press and the stamps under load, which in turn depends on the rigidity of the construction of the press and the stamps [1].

The skewness of the slide causes beveling of the surface and obliquity of the ends of the forging, and rigidity affects the limits on the height of the forging. Skewness under eccentric load are less in crank presses, which contain two couplers (Fig. 2a,b), due to better direction of the slide and lower loads on the guides compared to crank presses with one coupler (Fig. 2c).

(**a**) (**b**) (**c**)

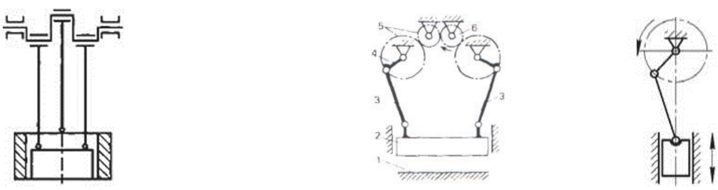


Fig.2. Kinematic schemes of crank presses. **a**,**b** with two cranks and two couplers, **c** with one crank and one coupler

Usually the stamping force coincides with the center of the slide of the press. However, due to the shape of the product or due to the method of molding, in many cases it is difficult to make the center of stamp coincide with the center of load. In stamps for gradual molding, it can be assumed that all the centers of the stamps are shifted from the center of load. When installing such a stamp in the press, an eccentric load occurs, since the center of punching and the center of load are shifted relative to each other. In the crank press with one connecting rod, the slide, when the load is displaced, has deviations, as shown in Fig. 3, in this case, the parallelism between the slider and the guides is broken. This skewness is proportional to the magnitude of the load.

To reduce the skewness of the slide, it is necessary to reduce the eccentricity of the applied load or increase the power of the press.

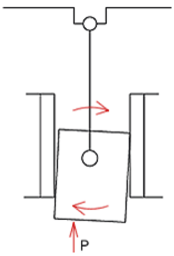
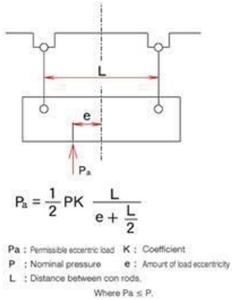


Fig. 3. Crank press with one coupler.



$$P_a = \frac{1}{2} PK \frac{L}{e + \frac{L}{2}}$$

e	Value of K
30	91
50	86
60	83
75	80
90	77
100	75
120	71
150	67
200	60
250	55
300	50

Fig. 4. Calculation of acceptable eccentric load of the crank press with two cranks.

In the case of crank press containing two cranks, the effect of load displacement will be less compared to one crank press. In case of presswork that requires accuracy, one of reasons of using of the press with two cranks is better tolerance of eccentric load. Calculation of the permissible eccentric load of the crank press with two cranks [2] is shown in Fig. 4, K – the coefficient which is taken from work [2].

Taking the total reversible deformation of the press with one coupler for 100%, one can compare it with the deformation of the press with two couplers, obtained by measuring at nominal load of identical presses with the same nominal force [3].

Crank presses with two couplers have advantages compared to presses with one coupler, due to a better distribution of forces on the slide and, accordingly, lower loads on the slide heads. Disadvantages of standard crank presses with two couplers are the complexity of the design, increase in dimensions, specific amount of metal due to the presence of the additional crank and coupler. In this regard, the choice of block diagram of the linkages for the design of the crank press is an important task.

For the choice of the structure scheme of the linkages of a crank press with two couplers and one crank we use high-class plane linkages.

2 High-class planar linkages for crank press

The famous work of L.V. Assur [4] is the first fundamental scientific work devoted to the creation of the theory of the structure of planar linkages. Taking two-binary link group as a main construction element, L. V. Assur proved the possibility of obtaining new groups of links interconnected by hinges, which as the two-binary group, turn into rigid statically definable systems if their extreme kinematic pairs are attached to a frame. L. V. Assur showed the ways of obtaining new kinematic chains with changeable closed circuit systems, composed of mobile links only, called the Assur groups of high classes.

Subsequently, the methods of structural analysis of Assur groups of high classes were significantly developed. However, general and practically acceptable methods that meet the requirements of uniformity of the structural classification of high classes

Assur groups and methods of their kinematic and dynamic research were developed in [5-9].

The ideas of L.V. Assur were most fully developed in the works of I.I. Artobolevskii. In these fundamental studies, the definition and classification of high classes plane linkages were first introduced [10–12]. The most complete items of the structural analysis of plane linkages of high classes according to the classification of I.I. Artobolevskii are set forth in monograph [13]. Planar linkages of high classes, due to the presence of changeable closed hinged-lever contours, possess wide kinematic and dynamic capabilities of reproducing a given law of movement of the working body. Moreover, in high-classes planar linkages, it is only due to the mechanical properties of the mechanism that it is possible to implement complex program trajectories of one, two, or more working elements from one engine located on the frame, which leads to a significant simplification of the control system. The use of high-class plane linkages in machines and manipulators of industrial robots improves the positioning accuracy of the latter due to the rigidity of the construction itself, increases the load-carrying capacity due to the distribution of forces along the contours of the mechanism, provides ease of maintenance and control through the installation of drives on the frame, provides any complex trajectory of movement of working units. The use of high-classes planar linkages for the design of various mechanisms and devices allows expanding significantly their functionality [14].

2.1 Structural Assur groups high classes

Assur group is a kinematic chain, when it is attached to the original mechanism or detached from it, a new mechanism is formed which has the same number of degrees of freedom as the original one" (Fig. 5), [13].

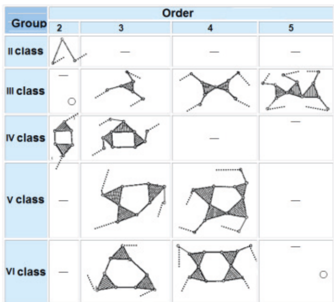
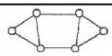
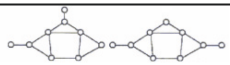
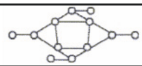
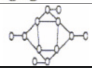
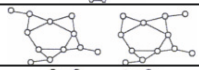
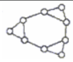
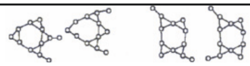
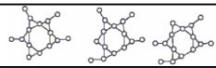
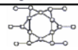


Fig. 5. Assur group.

The Assur group, containing changeable closed loop "k", $k \geq 3$, composed of moving links and kinematic pairs only, is called Assur group of high class. Links that form changeable closed loop, called loop links. Class k $(k \geq 4)$ k of Assur group high class equals the number n_k of loop links. The number of elements of external kinematic pairs, by means of which the group joins the leading link or frame, determines the order r of the Assur group [13].

For detailed study of the structure of Assur groups high classes, we use the method of developing of the changeable closed loop by I. I. Artobolevskii [13].

Table 1. Assur groups classes IV, V and VI

k	№	r	L	H	n	P_5	Structure schemes
IV	1	2	0	2	4	6	
	2	3	2	1	6	9	
	3	4	4	0	8	12	
V	1	3	1	2	6	9	
	2	4	3	1	8	12	
	3	5	5	0	10	15	
VI	1	3	0	3	6	9	
	2	4	2	2	8	12	
	3	5	4	1	10	15	
	4	6	6	0	12	18	

The method is based on changeable closed loops, composed of movable loop links only with the number $n_k > 4$. The number of relative degrees of freedom W of such loops is equal to the number of loop links $W = n_k$. Therefore, in order to get Assur group of k-th class from the changeable closed loop with the number of loop links n_k, it is necessary to apply S_e of external constraints on the loop $S_e = n_k$ so, that it meets all the above requirements for the existence of Assur group high-class. For the case $n_k = 4$ we put on the loop links 4 external constraints $S_e = 4$ with a help of: a) two external hinges; b) one external hinge and two binary links; c) four binary links. Herein, it should be taken into account, that two loop links with external hinge can't be close to each other, but loop links with one binary link can be placed in any order. Otherwise, Assur groups of high classes split into simple Assur groups of II and III classes. Thus, we obtained all four possible types of Assur groups class IV, which are summarized in Table 1, where k – Assur group class; r - group order equal to the number of external hinges; L – number of binary links; H- number of external hinges of non-binary links loop links; n - number of moving links; P_5– number of kinematic pairs of class V.

At $n_k = 5$ we have $S_e = 5$, and for $n_k = 6$, $S_e = 6$ and all possible types of Assur groups classes V and VI are also summarized in Table 1. Similarly, Assur groups of classes VII, VIII and higher are obtained.

2.2 Structural formulas of high classes Assur groups

Taking the number of changeable closed loops $N = 1$, from [13] for all Assur groups of high classes we have:

$$n_k = S_e = L + 2H,\ r = \mathrm{L} + H \tag{1}$$

Special case:
a) Let $H = 0$, $\mathrm{L} = r$, then $S_e = r$; when distributing one binary link to each loop link, we get Assur group of high classes with uniformly distributed binary links, in all other cases there are groups with non-uniformly distributed binary links along loop links;
b) Let $H = r$, $\mathrm{L} = 0$, then $S_e = 2r$; we get non-binary link Assur groups of high classes. It follows that for the Assur group of high classes

$$r \le r \le S_e \ge 2r \tag{2}$$

$$\frac{S_e}{2} \le r \le S_e \tag{3}$$

Taking into account, that order r of Assur group – is a whole number, we get dependencies between class k and order r in one-loop Assur groups:

a) For even classes $\frac{k}{2} \le r \le k$

$$r = \frac{k}{2}, \frac{k}{2} + 1, \ldots, k - 1, k \tag{4}$$

b) For odd classes $\left(\frac{k+1}{2} \le r \le k \right)$

$$r = \frac{k+1}{2}, \frac{k+1}{2} + 1, \ldots, k - 1, k \tag{5}$$

Then the number of different orders r of one-loop Assur groups:
a) For even classes

$$r = \frac{k}{2} + 1, \ldots, k - 1, k\,; \tag{6}$$

b) For odd classes

$$r = \frac{k+1}{2} \tag{7}$$

From (1) with account of ($k = n_k$) we define the dependencies between the class, the order, and the number of binary links and external hinges of the non-binary loop links of single-loop Assur groups:

$$\mathrm{L} = 2r - k \;\; ; \;\; H = k - r \tag{8}$$

a) For even classes Assur groups:

$$\mathrm{L} = 0,2, \dots, k-2, k \;\; ; \;\; H = \frac{k}{2}, \frac{k}{2} - 1, \dots, 1, 0 \tag{9}$$

b) For odd classes Assur groups:

$$\mathrm{L} = 1,3, \dots, k-2, k \;\; ; \qquad H = \frac{k-1}{2}, \frac{k-1}{2} - 1, \dots, 1, 0 \tag{10}$$

Further, the number of different numbers of binary links l and non-binary loop links with external hinge h of one-loop Assur groups will make:
a) For even classes

$$l = h = \frac{r}{2} + 1 \tag{11}$$

b) For odd classes

$$l = h = \frac{k+1}{2} \tag{12}$$

Since the Assur groups include loop links and binary links, then the number of moving links n and kinematic pairs of V class p_5 is determined by the following dependencies:

$$n = n_k + \mathrm{L} \;\; ; \quad p_5 = n + r \tag{13}$$

or

$$n = 2r \;\; ; \qquad p_5 = 3r \tag{14}$$

Using formulas (1-14), we can get all possible Assur groups IV, V and VI and higher classes and of different orders.

2.3 Planar linkages of class IV for crank press

Thus, Assur groups of high classes differ in class, order, and distribution of external links along loop links. By attaching one or more external hinges of the Assur group high classes to the driving links, and all other external hinges to the frame, we obtain a high-class planar linkage with one or many degrees of freedom. The hinge point of the Assur groups attached to the driving link we will call driving point. Choosing different external hinges of the Assur group IV class (Table 1) for the driving point A, we will get 7 different planar linkages of class IV with driving link 1 (Fig. 6), structural formulas for which are:

l(1)→IY(2,3,4,5), l(1) →IY(2,3,4,5,6,7), l(l) →IY(2,3,4,5,6,7,8,9).

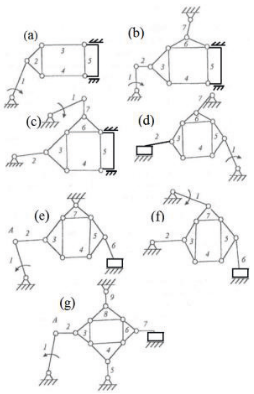


Fig. 6. Planar linkages IV class.

On the basis of obtained planar linkages of class IV (Fig. 6), one can design new crank presses. The use of planar linkages of class IV, due to peculiarities of their structural configuration, allows expanding significantly functionality of crank presses. Designer, depending on the task, can choose necessary scheme of planar linkage of class IV (Fig. 6) for the design of a new crank press. We are interested in the scheme of the planar linkage of class IV, shown in Fig. 6a. Let's choose the scheme of the planar linkage of class IV (Fig. 6a) for designing of a slide-crank press (Fig. 7).

As mentioned above, crank presses with two couplers have great advantages compared to presses with one connecting rod, thanks to a better distribution of forces on the slide and, accordingly, lower loads on the guide slide.

In this regard, the choice of the scheme of planar linkages IV class (Fig. 7) for the design of the new crank press is reasonable.

To develop a new crank press with two couplers and one crank, the planar linkage IV class was synthesized [18].

Fig. 8 shows the kinematic scheme of the new crank press based on the planar linkage IV class.

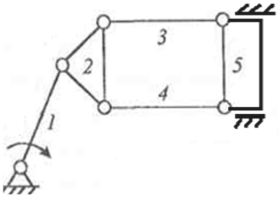


Fig. 7. Planar linkage IV class.

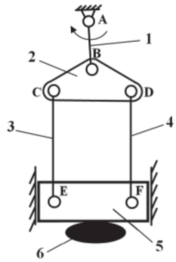


Fig. 8. Kinematic scheme of the new crank press.

The mechanism of the crank press consists of crank 1, link 2, having three rotational kinematic pairs B, C and D, two couplers 3 and 4, and also the slide 5. The slide 5 has two rotational kinematic pairs E and F, with which the rods 3 and 4 are connected, respectively. The three-pair link 2, the couplers 3, 4 and the slide 5 form between each other a quadrangular closed changeable loop CDEF. The linkage of the crank press works as follows. At full rotation the crank 1 through the three-pair link 2 and rods 3 and 4 transmits the movement of the slide 5, which in turn affects the processed object 6. With that, at the moment of contact of the slide 5 with the object under the process 6 the couplers 3 and 4 are in a parallel position, which ensures an even distribution of loads both on the processed object 6 and between the links of the press. A prototype of the new crank press is made (Fig. 9)

Fig. 9. Prototype of the new crank press.

Testing of the prototype of the new crank press showed a good distribution of the efforts applied during the presswork and a better tolerance (viability) of the eccentric load.

3 Conclusion

Crank presses with two couplers have great advantages compared to presses with one connecting rod, due to the better distribution of forces on the slide and, accordingly, lower loads on the guide slide. Disadvantages of the typical crank presses with two couplers are the complexity of the design, increase in dimensions, metal intensity due to the presence of the additional crank and connecting rod. In this regard, the choice of the block scheme of the linkage for the design of crank press is an important task.

To select a block scheme of the linkage of a crank press with two couplers and one crank, high-class planar linkages were used.

The use of planar linkages of high class in crank press improves the accuracy of presswork due to the rigidity of the structure of construction, increases the nominal force due to the distribution of forces along the loop of the mechanism. The new crank press based on planar linkage IV class has been designed and its prototype has been made. The tests of the prototype of the new crank press, which showed its performance and the practical absence of its jamming, were carried out.

An important result of the work is the justification for the use of high-class planar linkages for designing of the new crank presses.

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