Obtaining computational models of mechanisms in geometric applications by example of mechanism of lifting signs of mold

M S Chepchurov, E M Zhukov, A M Sumskoy and D V Dudukalo

Belgorod State Technological University named after V.G. Shukov, 46, Kostyukov Street, Belgorod, 308012, Russia

E-mail: Sumskoiam@yandex.ru

Abstract. The article presents a solution to the problem of calculating and modeling the lifting mechanism of molds with the purpose of the reduction of the loading on the sliding bearings and verification of the working capacity of the mechanism as a whole. The calculation scheme is made for calculating the lifting mechanism of molds; the algorithm of operation of the mechanism is described. Mathematical modeling of the lever is conducted and the dimensions of separate links of the mechanism are calculated, the coordinates, trajectory of motion of the reference points of the mechanism are defined. A 3-D model of the lifting mechanism is executed; verification of the assembly of the model, of the operability of the mechanism is carried out as a whole.

1. Introduction
Modern development of the computing technology and software not only allows one to conduct difficult mathematical calculations of the different mechanism constructions, but also to simulate their work in virtual space [1]. Thus, the calculations of the construction of the clamping mechanism of the molds at the design stage allows one to avoid errors during its manufacture and exploitation [2,3]. These include: wear of the bearings, guides, non-closure or non-opening of the mould, etc. [4].

Such errors lead to loss of raw materials, additional and untimely servicing and repair of the equipment, to downtime of equipment and technological systems of the production line [5,8]. And as a consequence, this leads to huge economical losses for the enterprise.

We will consider the sequence of such calculations carried out in the free mathematical package of SMathStudio and its verification in 3-D modelling package FreeCAD.

The task is to calculate and simulate the lifting mechanism that the sliding bearing carries the least load during the completion of the closing movement in the structure [6,7].

Calculation stages includes composition of the calculation scheme for calculating the mechanism of lifting ejector pins, shown in figure 1.

The mechanism works as follows. In the closed position, semi-matrices 2, installed on plates 1, are closed; levers 6 and 7 are in the initial position. With the movement of the left plate 1 with the semi-matrix 2, levers 6 and 7 straighten, thereby raising the traverse 4 carrying the ejector pins 3, while the base plate is released, thus leading to the open state of the mold.

Let us determine the dimension of the levers proceeding from the dimensions of the ejector pins and the required distance of displacement (Figure 2).
Figure 1. The work of the mechanism of lifting ejector pins: 1 – plate, 2 – semimatrix, 3 – ejector pins, 4 – traverse, 5 – base plate, 6 – lever, 7 – lever.

We take the initial value of the volume of the ejector pins $L_{min}$ from the condition that they are raised during the straightening of the levers $l_{p2}$. Thus the height of the triangles ADB or CBD will be calculated using the thickness of the forming element of the mold.

Side $AB = BC = \frac{B}{2}$, where $B$ – width of the mold package.

Side $DB = L_{zn} \cdot 2$; consequently, the other side is:

$$AD = DC = \sqrt{(AB)^2 + (DB)^2} = \sqrt{\left(\frac{B}{2}\right)^2 + (2L_{zn})^2}$$

$$AD = DC = \sqrt{\left(\frac{112}{2}\right)^2 + (2 \cdot 179)^2} = 362.35 \text{ mm.}$$

From here, let us calculate:

$$l_{p2} = EB = FB,$$

$$EB = FB = \sqrt{\left(\frac{B}{4}\right)^2 + (L_{zn})^2};$$

$$EB = FB = \sqrt{\left(\frac{112}{4}\right)^2 + (179)^2} = 181.17 \text{ mm.}$$

Figure 2. Scheme of the calculation feeder mechanism of the ejector pins.
We can define the coordinates of the scheme shown in figure 2 at any moment of time. Thus, \( t_0 \) - time frame of reference upon a completely closed mold, sec; \( t_r \) - time of complete opening of the mold.

Let us consider that according to the construction of the mold during its opening, the point C is located on the stationary part of the mold not changing its position. Point A can move only along the \( x \)-axis as shown in figure 3.

Points B, D, E, F synchronously move along the X and Y axes. We can assume that the value of lifting the ejector pins \( \Delta L_{zn} \) depends on the size of the mold opening \( \Delta b_{rask} \) and \( X \) coordinates of points D, B is found from a condition that \( X_t = 0 \) and \( Y_t = 0 \). Consequently:

\[
A_x = C_x + B + \Delta b,
D_x = B_x = C_x + \frac{(B + \Delta b_{rask})}{2},
\]

from which the coordinates:

\[
F_x = C_x + \frac{|OC|}{|DC|} \cdot |FC|.
E_x = A_x - F_x - since the points E and F are located on the same horizontal plane, determine the Y - coordinates of point D:
\[
D_y = \sqrt{|DC|^2 - \left(\frac{|B + \Delta b_{rask}|}{2}\right)^2}.
\]

And accordingly the value of the angle - \( DCA = DAC = \arcsin\left(\frac{B - \Delta b_{rask}}{2}\right)\).

![Figure 3](image-url)  
**Figure. 3.** Scheme for calculating the position of the points of the movement mechanism.

\[
F_y = E_y = D_y - DF \cdot \cos(\arcsin\left(\frac{B - \Delta b_{rask}}{2}\right)),
B_y = F_y = \sqrt{(FB)^2 - \left(\frac{B - \Delta b_{rask}}{2} - F_x\right)^2}.
\]

Making substitutions, we obtain:

\[
B_y = D_y - DF \cdot \cos\left(\arcsin\left(\frac{B - \Delta b_{rask}}{2DC}\right)\right) - \sqrt{(FB)^2 - \left(\frac{B - \Delta b_{rask}}{2} - C_x + \frac{|OC|}{|DC|} \cdot |FC|\right)^2}.
\]

herein:

\[
B_x = C_x + \frac{B + \Delta b_{rask}}{2}.
\]

Executing a 3D model of the sign lifting mechanism with dimensions, we determined earlier and confirmed its operability in the FREECAD software (figure 4). In this case, the earlier determined dimensions of the arm of the lifting mechanism of the ejector pins are used, including the standard
elements from a workbench library Fasteners CAD program such as bushings, washers, screws, bolts, nuts and other elements [9,10].

Figure. 4. 3D model assembly of the lifting mechanism of the ejector pins.

FreeCAD features, in particular the Exploded Assembly workstation, allows simulating the assembly process (figure. 5). After choosing the motion trajectory, connectors (nuts, bolts, flat objects etc), setting the motion vector and its characteristics for all elements of the assembly, the workstation allows one to fully and realistically animate the whole assembly process similar to the models shown in works [11,12].

Figure. 5. Exploded view of the assembly of the 3D model of the lifting mechanism of ejector pins with trajectories of movement of elements.

After checking the assembly of the model, let us execute the operability of the lifting mechanism of the mold ejector pins. The FreeCAD software of the animation workstation is used for this purpose (Figure 6), the order of this simulation is repeatedly described in various sources [13,14].
2. Conclusion
Modeling the lifting mechanism of ejector pins and its verification in the CAD system allows calculating the dimensions of the component links, obtaining the values necessary for the design of the closing mechanism of the mold, confirming the operability of the device in the whole range of performance, composing the technical specifications for the production of the device in terms of machine production. And the use of special simulation packages and special programme packages that evaluate the assembly of the mold allows for the final evaluation of the possibility of obtaining the product [15, 16].

Acknowledgments
The article was prepared within a development program of the Base University on the basis of BSTU named after V. G. Shukhov, # A-80/17.

References
[1] Puchkin V N, Atamanyuk A A, Merkulov M A, Dowgalyov A Yu, Bichurin A V, Uvarov A V, Eremyan G E, Hotenov I A and Storozenko I D 2016 Collection of Articles XI Int. Sci. and Techn. Conf. Advanced Technologies in Modern Eng. (Aravir) (Aravir mechanical-technological Institute, Armavir), pp 79-89
[2] Kozachenko N I, Pavlov E I and Danyushin LM 2014 New deejector pins of molds for injection molding of polymer products Publications from higher educational institutions. North Caucasus region. Series: Engineering science 2(177) 56-60
[3] Pershin N S, Chepchurov M S 2015 Use of metal polymers in molds for plastic molding / Bulletin of the Siberian State Automobile and Highway Academy Publishing house Siberian State Automobile and Highway University 4 86-90
[4] Dudkin V S 2013 Study of the properties of mold parts from pressure die casting Youth scientific and Technical Bulletin 8 1-9
[5] Almkuest F 2010 Wish to reduce the MLVD cycle time. Technology of lubricant of compression molds Foundry of Russia 1 10-12
[6] Tsibizov V F, Osipova N A, Kidalov N A, Zakutaev V A, Markina N V 2013 Design and and construction of model-technological equipment for the manufacture of castings by special types of casting (Volgograd: Publishing house Volgograd State Technical University) 150 p.
[7] Buryak S V, Chebykin V G, May L V, Petrov I V, Skvortsova A G, Tokarev S S, Kharitonov A A, Chunikhin T RU Patent No. 2302338 (20.07.07)
[8] Afonin B V, Velikolug A M, Voronin P V, Voronin R P RU Patent No. 2375141 (10.12.2009)
[9] Galin N E, Ogol I I, Chervach Yu B, Dammer V Kh and Hong Ru Jia 2017 Designing a combined casting mold for manufacture of a gasoline centrifugal pump body using CAD/CAM-systems IOP Conf. Ser.: Mater. Sci. Eng. 177 012025
[10] Tsygankov D, Pokhilk A 2017 The Product Design Information Imaging at the Construction Stage in 3D-model Creation Tree, Peer-review under responsibility of the scientific committee of the 27th Int. Conf. on Flexible Automation and Intelligent Manufact.
[11] Le Liu, Yanru Dun, Yiming Fang and Gongyin Li 2016 Modeling and verification of the nonlinear
system of oscillation platform of continuous casting mold driven by servo motor Adv. in Mech. Eng. 8(7) 1–9
[12] Ming-Shyan Huang, Tsung-Yen Lin, Rong-Fong Fung 2011 Key design parameters and optimal design of a five-point double-toggle clamping mechanism Appl. Mathem. Mod. 35 4304–20
[13] Praveen Mishra 2012 Review article on physical and numerical modeling of sen and mould for continuous slab casting Int. J. of Eng. Sci. and Technol. 4
[14] Xueyi Li, Shuhui Ding, Junying Wei, Quanwei Wang 2017 Research on Teaching Method of Mold Course Based on CAD/CAE/CAM Technology Int. J. of Emerging Technol. Learn. 12(07) 7224
[15] Rosentrater K, Visser J 2007 Simulation as a means to infuse manufacturing education with statistics and DOE – A case study using injection molding, ASEE Annual Conf. and Expos.
[16] Hernández P, Taboadaa S, Suáreza L, Marreroa M D, Ortegaa F, Benitez A 2015 Interactive learning tool in product development for injection moulding The Manufact. Eng. Soc. Int. Conf. 132 197-204