- angular velocity of the connecting rod:

$$\omega_2 = \frac{v_{By}\cos\theta - v_{Bx}\sin\theta}{L_2}$$

The developed algorithm has been integrated into a computer-aided design system, enabling:

- automated calculation for Group I and Group II (Type 1);
- visualisation of link trajectories using Matplotlib;
- optimisation of mechanism parameters based on trajectory analysis.

Conclusion. This research has developed software for kinematic analysis of crank-slider mechanisms based on Assur groups.

1) The mathematical model of the crank-slider mechanism includes:
- position, velocity, and acceleration equations for Assur Groups I and II;
- algorithms for solving equation systems using Cramer's method;
- formulas for optimising calculations.

2) The software library has been implemented in Python, providing:
- high calculation accuracy (error < 0.1%);
- efficient execution of kinematic analysis;
- visualisation of motion trajectories of executive tools.

3) Integration with computer-aided design systems enables:
- accelerated mechanism design process;
- improved calculation accuracy;
- optimisation of mechanism parameters based on trajectory analysis.

Thus, the programme demonstrates high efficiency compared to traditional methods such as Turbo Pascal implementation. The use of modern Python libraries (NumPy, Matplotlib, SciPy) ensures not only high calculation accuracy but also convenient visualisation of results, significantly simplifying data analysis and interpretation.

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PROGRAMME FOR THE CONSTRUCTIONS OF THE SURFACE OF A TRUNCATED PYRAMIDS

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Keywords. Truncated pyramid, development, DXF format, geometric calculations, construction algorithms, programme, trapezoidal faces, parallelogram faces, assembly allowances, CAD compatibility.

The relevance of this work stems from the need for precise and efficient design of surface developments for complex geometric forms to enable subsequent physical manufacturing.

Research Objective. To develop software for the automated construction of the surface of a truncated quadrangular pyramid with the ability to generate developments in DXF format compatible with modern CAD systems. Unlike existing solutions, the proposed algorithm ensures correct construction of developments for arbitrary truncated pyramids, accounting for asymmetric sections and assembly allowances, significantly expanding the application scope of the software solution in industrial and architectural design.

Material and Methods. Mathematical foundations for development construction.

Results and Discussion. A truncated quadrangular pyramid (frustum) is a geometric figure bounded by two parallel rectangular bases and four lateral faces. The lower base is defined by dimensions, b; the upper section by dimensions c, d:

$$c = a - 2\Delta x, \quad d = b - 2\Delta y,$$

where Δx and Δy are the offsets of the cutting plane relative to sides a and b respectively, and h is the pyramid height.

The lateral faces of the truncated pyramid can be trapezoidal or parallelogrammatic depending on the symmetry of the section. With symmetric offsets ($\Delta x = \Delta y = 0$), the faces are isosceles trapezoids; with asymmetric offsets ($\Delta x \neq \Delta y$), they are parallelograms.

The length of the lateral edge l is calculated as:

$$l = \sqrt{\left(\frac{a-c}{2} + \Delta x\right)^2 + \left(\frac{b-d}{2} + \Delta y\right)^2 + h^2}.$$

The angle of inclination β_a relative to the Y-axis is determined as:

$$\beta_a = \arctan\left(\frac{h}{\frac{a-c}{2} + \Delta x}\right).$$

The coordinates of the upper section vertices are calculated as follows:

The proposed development construction algorithm includes the following steps [1]:

1) parameter input: The user specifies base dimensions (a, b), cutting plane offsets (Δx, Δy), pyramid height (h), and assembly allowances (f_1, f_2, f_3).

2) geometric parameter calculation: Edge lengths, inclination angles, and vertex coordinates are computed.

3) development formation: The development is split into left and right parts with allowance f_1 to prevent element overlap.

4) DXF file generation: Two files are created – «Piram_L.dxf» (left part) and «Piram_R.dxf» (right part), containing geometric objects on layers «cutting» (main contours) and «marking» (allowance markings).

Specialised algorithms for handling complex geometric forms:

- contour self-intersection check
- angle correction for asymmetric sections
- coordinate calculation for trapezoidal and parallelogram faces

The programme is implemented in Pascal due to the following advantages:

- availability of RAD tools for rapid UI creation
- convenience of text file handling via standard functions («WriteLn», «AssignFile», «Rewrite»)
- procedural syntax suitable for implementing geometric algorithms

Programme structure includes:

- form «TMainForm» with components for parameter input («TEdit», «TLabel», «TButton»)
- geometric parameter calculation module
- DXF file generator with manual format structure writing

Special attention is paid to calculation accuracy – vertex coordinates are written with six-digit precision using parameter «cod := 6», critical for correct physical assembly [2] .

Consider an example of a truncated pyramid with parameters: $a = 200\text{mm}$, $b = 300\text{mm}$, $c = 150\text{mm}$, $d = 250\text{mm}$, $\Delta x = 10\text{mm}$, $\Delta y = 20\text{mm}$.

Left edge length l:

$$l = \sqrt{\left(\frac{200-150}{2}+10\right)^2 + \left(\frac{300-250}{2}+20\right)^2 + h^2}.$$

Angle β_a inclination:

$$\beta_a = \arctan\left(\frac{h}{\frac{200-150}{2}+10}\right).$$

Coordinates of point 5 (left part):

$$x = -213.246549, \quad y = 16.074042.$$

Example coordinates from DXF files:

- «Piram_L.dxf»: «10 -213.246549, 20 16.074042» (left part)
- «Piram_R.dxf»: «10 213.246549, 20 16.074042» (right part)

These points form a pair symmetric about the Y-axis, ensuring coincidence during physical assembly.

The programme implements several methods for integrating development parts:

1) **allowance zones**:

- allowance f_1 shifts left and right parts to opposite sides of the X-axis
- allowances f_2 and f_3 are added to coordinates to create connection zones

2) connection markings:

- text labels on «marking» layer (red colour)
- lines and polylines for guide markings

3) geometric alignment:

- symmetric shifting of left and right parts
- accounting for edge inclination angles to ensure face parallelism

Conclusion. The developed programme for constructing the surface of a truncated quadrangular pyramid addresses the urgent task of automated design of surface developments for complex geometric forms. The proposed algorithm ensures:

- Precise geometric parameter calculation of the truncated pyramid using analytical formulas and trigonometric functions
- Correct development construction for arbitrary configurations, including symmetric and asymmetric sections
- DXF file generation compatible with modern CAD systems, with layers «cutting» and «marking»
- Accounting for assembly allowances, ensuring precise element alignment during physical manufacturing

Experimental verification showed that the programme correctly generates developments for various truncated pyramid configurations, and DXF files successfully import into AutoCAD and other CAD programmes for further processing. Symmetry of coordinates in left and right development parts guarantees precise element alignment during assembly.

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