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TERMINOLOGICAL DICTIONARY

in the discipline «THEORY OF MECHANISMS AND MACHINES»

for students specializing in G9 «Applied Mechanics»,
G11 «Industrial mechanical engineering», J8 «Automobile transport»
and J7 «Railway transport»

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T35 **Terminological** dictionary in the discipline «Theory of mechanisms and machines» / I. Hrechka, A. Zarubina, M. Tkachuk, A. Grabovskiy. – Kharkiv : NTU «KhPI», 2025. – 55 p.

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The terms, basic concepts and definitions used in the study of the discipline «Theory of Mechanisms and Machines» are given and the interpretation of these terms and concepts is considered. The textbook corresponds to the course program «Theory of Mechanisms and Machines».

Intended for students of higher educational institutions in the field of knowledge «Mechanical Engineering» in the specialties «Applied Mechanics» and «Industrial Mechanical Engineering», as well as the field of knowledge «Transport» in the specialties «Automobile Transport» and «Railway Transport».

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INTRODUCTION

The educational publication «Terminology in the discipline «Theory of Mechanisms and Machines» (TMM) is intended for use in studying the TMM course in the preparation of bachelors of both full-time and part-time forms of study in the field of knowledge «Mechanical Engineering» in the specialty «Applied Mechanics», specialization «Hydropneumatic Automation of Oil and Gas equipment», «Logistics systems engineering», «Tool production», «Integrated mechanical engineering technologies», «Metal-cutting machines and systems», «Equipment and foundry technologies», «Equipment and pressure processing technologies», «Automated production technologies», «Engineering of mechatronic hydropneumatic systems», «Welding and related processes and technologies», «Automated modeling of technical systems»; in the specialty «Industrial mechanical engineering», specialization «Car and tractor Industry », «Machines and mechanisms of oil and gas fields», «Equipment for food, processing and chemical production», «Lifting and transport, road, construction, reclamation machines and equipment», «Computer design off-road vehicles», «Automated and robotic technological complexes in mechanical engineering», «Mechatronic systems of vehicles»; in the field of knowledge «Transport» with a specialty in «Automobile Transport», specialization «Automobiles and Automobile Industry», in the specialty «Railway Transport», specialization «Locomotives and Locomotive Industry». The purpose of studying the course «Theory of Mechanisms and Machines» is to gain knowledge about the structure of modern mechanisms and machines, about the kinematic and dynamic properties of machines as a whole and their individual parts, about the interaction of mechanisms in machines, about the properties of mechanisms and machines as control objects. When preparing a bachelor's degree, this discipline is studied among the first on which the study of special disciplines is based. The TMM discipline is taught to second and third year students. At the same time, students encounter many technical terms and concepts for the first time during their studies. In the future, these terms will form the basis of their technical vocabulary and it is very important to have a precise understanding of these terms and concepts that will be used in practical and scientific activities, both during further training and in practical activities in production and other institutions where graduates will work.

This teaching material is useful to use at the beginning of the course to familiarize yourself with its content, as well as at the final stage when preparing for tests on the topics studied.

If distance, correspondence, or self-study is necessary, the student has the opportunity to successfully master the required topics by using this educational publication as an additional explanation of the course material.

This terminological dictionary can be useful for students when studying other subjects from the «Professional Training» section, which are basic for general engineering bachelor’s training.

1. BASIC CONCEPTS

Theory of mechanisms and machines (TMM) – a science that studies the general methods of structural, kinematic and dynamic analysis and synthesis of various mechanisms, the mechanics of machines, as well as the interaction of mechanisms in machines.

Machine – a device for converting energy, materials and information.

Energy machine – a device for converting one type of energy into another. These are electric motors (ED), internal combustion engines (ICE), turbines.

Transport machine – a machine for moving various objects in space. These are cars, conveyers and lifting equipment, etc.

Technologic machine – a device for converting the shape, size, properties and condition of the starting materials and blanks. These are metal-cutting machines (MCM), forging equipment, compressors, rolling mills, foundry equipment.

Information machine – a device for converting information. These are mathematical and control devices.

Work machine – the common name for transport, technologic and information machines.

Machine aggregate – a combination of a working machine and an energy one.

Machine cycle – a period for which a certain set of works and processes is carried out, as a result of which the system comes into a state that was at the beginning of the period.

Kinematic cycle – a period during which the positions and direction of movement of the points of all parts of the mechanism or system of mechanisms, their speed and acceleration.

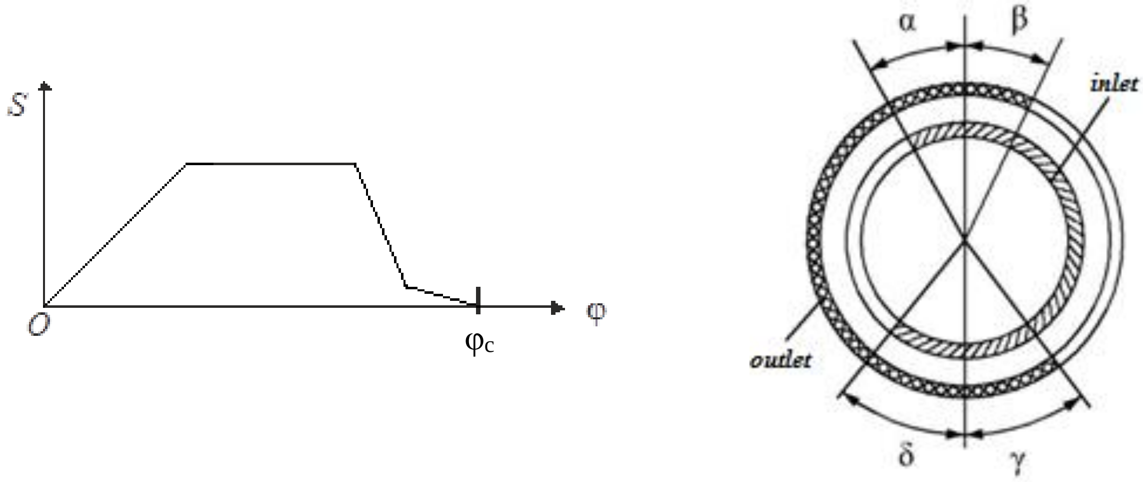
Energy cycle – the period during which the nature of the change in the power of the acting forces and moments is repeated.

Duty cycle – the period during which the set of operations of a technological machine is repeated.

Technologic cycle – the period at the end of which the manufacture of the part ends.

Production cycle – the period of time from the moment of supply of raw materials to the receipt of the finished product.

Operational cyclogram of the machine (cyclic diagram) – a graphic representation of the sequence of movement of the executive organs of the mechanism per cycle (Fig. 1.1).



a *b*

Fig. 1.1. Operational cyclogram of the machine:
a – linear cyclogram (*S* – movement of a part performing a technological operation, φ – angle of rotation of the drive shaft);
b – circular cyclogram of the operation of the valves of an internal combustion engine (α, β, δ, γ – angles of lead and delay of valve opening)

Linear cyclogram – image on which the schedule of movement of the executive body is conventionally depicted by inclined lines, and the periods of stops (immobility) – by horizontal lines (Fig. 1.1, *a*).

Rectangular and circular cyclogram – images in which the movement graphs do not show, and the intervals of the individual stages of movement or operations are distinguished by hatching or thick lines (straight or arcs of circles) (Fig. 1.1, *b*).

Cycle time – a period of time through which the sequence of movement of all the executive bodies of the mechanism is repeated.

Tact or phase – cycle intervals that determine the main state of the mechanism, for example, the tacts of movement, immobile, fuel injection, compression, exhaust gas discharge, etc.

Tactogram – a diagram of the coordination of movements of executive bodies depending on their positions.

Mechanism – a system of solids designed to transform a given motion of one or more solids into the required motions of other solids.

Link – a single part or a group of parts (bodies) rigidly interconnected, which move as a whole, that is, they are a kinematically immutable system. A link is assumed to be completely rigid. Machine components that do not fit this assumption of rigidity, such as springs, usually have no effect on the kinematics of a device but do play a role in supplying forces. Such parts or components are not called links; they are usually ignored during kinematic analysis, and their force effects are introduced during force analysis. Also define a link as the rigid connection between two or more joint elements.

Input link – a link whose movement is specified and transformed into the required movements of other links

Output link (follower) – the link that makes the movement for which the mechanism is intended.

Initial link – the link whose movement is specified, and the parameters of this movement determine the movement of all links in the mechanism (the same as the input link).

Executive link – a link that provides movement for execution by the mechanism of the technological process (the same as the output link).

Driver-link – the link for which the elementary work of the external forces applied to it is positive. This link receives movement from the engine.

Driven-link (follower) – a link for which the elementary work of external forces applied to it is negative or equal to zero. This link receives movement from the driver.

Rocker – a link making an incomplete revolution, i.e., making a rocking motion with respect to a fixed point.

Slider – a link that moves forward.

Connecting rod – a link that does not have a point of contact with a fixed link and which makes a complex movement, i.e., rotational and translational**.**

Coulisse – a movable guide of slider, forming a kinematic pair with a fixed link.

Ground, frame, base – a fixed link. In a practical machine, it usually takes the form of a stationary platform or base (or a housing rigidly attached to such a base).

Kinematic scheme – a conditional image of the mechanism on a certain scale, containing all the data necessary to perform kinematic calculations (Fig. 1.2 and 1.3).

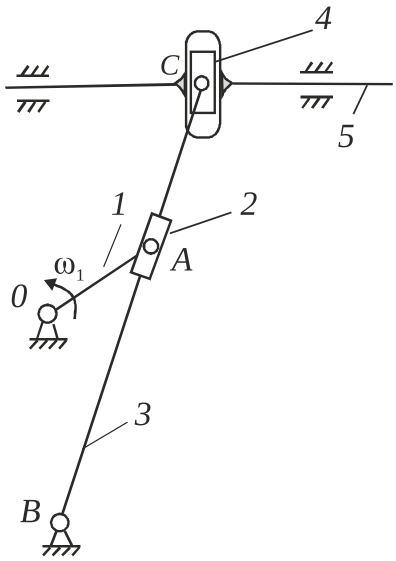


Fig. 1.2. Kinematic scheme of the hinge-lever mechanism:
0 – strut (in the kinematic scheme, highlighted by hatching); *1* – crank; *2*, *4*, *5* – sliders; *3* – rocker or coulisse – movable guide of slider

Kinematic pair – the connection of two contacting links, allowing a certain relative movement.

Element of a pair – a set of surfaces, lines and points of a link that come into contact with another link of the pair.

Prism or prismatic pair - permits only relative sliding motion and therefore is often called a sliding joint. This joint also has one degree of freedom.

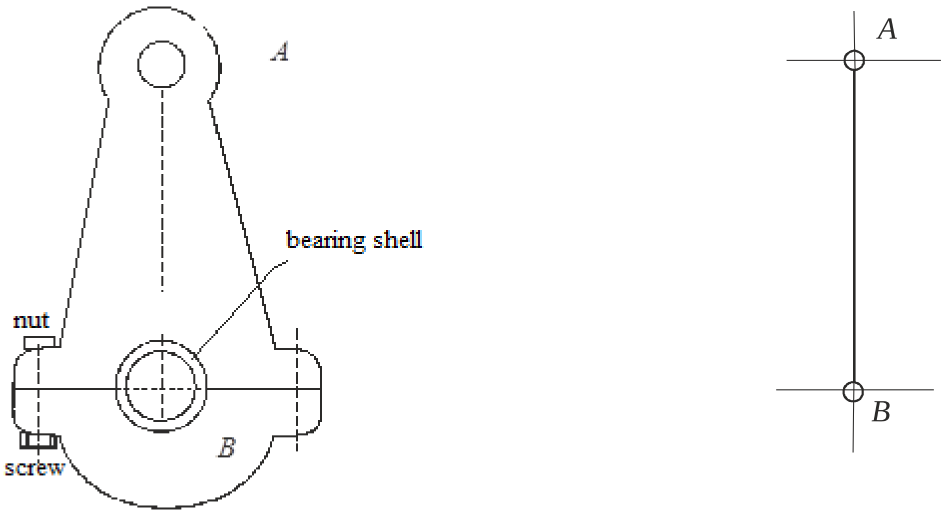
Revolute or turning pair – permits only relative rotation and is often referred to as a pin joint. This joint has one degree of freedom.

Screw or helical pair – permits both rotation and sliding motion. However, it only the helix angle of the thread. Thus, the joint variable may be chosen as either sliding or rotation, but not both. Note that the helical pair reduces to a revolute if the helix angle is made zero, and to a prism if the helix angle is made 90°.

Cylinder or cylindric pair – permits both rotation and an independent sliding motion. Thus, the cylindric pair has two degrees of freedom.

Sphere or globular pair – is a ball-and-socket joint. It has three degrees of freedom, sometimes taken as rotations about each of the coordinate axes.

Flat or planar pair – is seldom found in mechanisms in its undisguised form, except at a support point. It has three degrees of freedom, that is, two translations and a rotation.



a *b*

Fig. 1.3. Connecting Rod Image:
a – constructive; *b* – on the kinematic scheme

Closure of a kinematic pair – conditions for ensuring stable contact of the elements of the pair.

Geometric closure – closure in which the constant contact of the elements of the pair is ensured by the structural form of these elements (Fig. 1.4).

Fig. 1.4. Geometric closure of the lowest pair

Force closure – closure in which a constant contact of the elements of the pair is ensured by the force of gravity of the link, the elastic force of the spring, etc. (Fig. 1.5).

Lower pair – a pair in which the surface is an element (revolute, prism, screw, cylinder, sphere, planar).

Higher pair – a pair in which the element is a line or point (Examples include mating gear teeth, a wheel rolling and/or sliding on a rail, a ball rolling on a flat surface, and a cam contacting its follower).

Pair class – the number of limited movements imposed by a pair on the relative motion of its links.

Kinematic chain – a system of links forming kinematic pairs between themselves.

Planar kinematic chain – in which all particles describe planar curves in space, and all these curves lie in parallel planes; that is, the loci of all points are planar curves parallel to a single common plane.

Spatial kinematic chain – include no restrictions on the relative motions of the links. For example, a mechanism that contains a screw joint.

Simple kinematic chain – a chain in which each link enters no more than two kinematic pairs.

Compound kinematic chain – a chain in which there are links included in more than two kinematic pairs.

Closed kinematic chain – a chain in which every link is connected to at least two other links; the chain forms one or more closed loops and all links form at least two kinematic pairs.

Open kinematic chain – a chain that links included in one pair (Fig. 1.6).

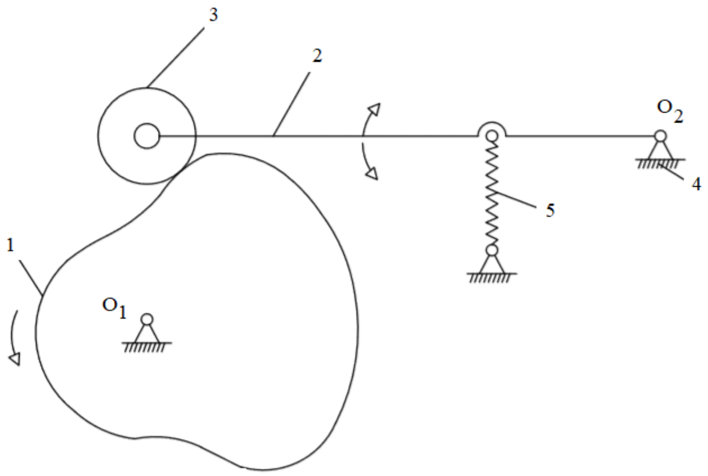


Fig. 1.5. Force closure of the highest pair:
0 – rack; 1 – cam; 2 – rocker; 3 – roller; 4 – spring

Planar mechanism – utilizing only lower pairs are called planar linkages; they include only revolute and prismatic joints. Planar motion also requires that all revolute axes be normal to the plane of motion, and that all prismatic joint axes be parallel to the plane. The planar four-bar linkage, the slider-crank linkage, the plate cam-and-follower mechanism, and meshing gears are familiar examples of planar mechanisms.

Spheric mechanism - is one in which each moving link has a point that remains stationary as the mechanism moves. Arbitrary points fixed in each moving link travel on spheric surfaces; the spheric surfaces must all be concentric. In a spheric linkage, the axes of all revolute pairs must intersect at a single point. A spheric linkage must consist of only revolute pairs, and the axes of all such pairs must intersect at a single point. A familiar example of a spheric mechanism is the Hooke universal join (also referred to as the Cardan joint).

Spatial mechanism – a mechanism in which links have non-planar trajectories or move in non-parallel planes.

Lever mechanism – a mechanism whose links are made in the form of bars and sliders and form between themselves rotational, translational, cylindrical and spherical pairs.

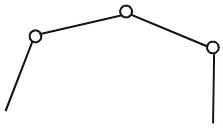
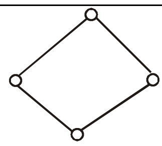
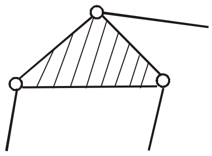
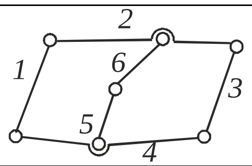
Chains	Open kinematic chains	Closed kinematic chains
Simple chains		
Compound chains		

Fig. 1.6. Types of kinematic chains

Rotatory mechanism – a mechanism whose links unite only rotational pairs.

Wedge mechanism – a mechanism whose links unite only translational pairs.

Four-bar linkage – **a** mechanism having three movable links in the form of levers, which jointed only revolute pairs.

Two-crank linkage (mechanism) –mechanism, incorporating two cranks.

Two-rocker linkage (mechanism) – a mechanism, incorporating two rockers.

Crank-rocker mechanism – a mechanism, incorporating a crank and rocker.

Crank-slider linkage (mechanism) – a four-link mechanism: three movable links (a crank, a connecting rod, a slider) and a ground).

Cam mechanism – a three-link mechanism, including a highest pair formed by a driver-link (cam) and a driven-link (pusher or rocker); it allows to get complex functions of movement of the driven link, including with stops of the driven link with continuous cam movement.

Rocker mechanism – a bar mechanism, which includes a rocker.

Gear mechanism – a mechanism consisting of links in the form of gears, designed to convert the speed of rotation (torque) of the shafts on which the gears are located.

Friction mechanism – a mechanism in which motion is transmitted or transformed using friction forces between rolling bodies - cylinders, cones, etc., pressed against each other.

Mechanisms with intermittent movement of the driven link – mechanisms in which the driven links makes periodic movement with subsequent complete stop. Such mechanisms include **cam**, **maltese**, **ratchet**, and some gear mechanisms, for example, **pinwheel and star**.

Maltese mechanism – a mechanism that converts the continuous rotation of the input (driver) link (crank) into the intermittent movement of the output (driven) link, which is called **the maltese cross**.

Ratchet mechanism – a mechanism in which the rotational movement of the rocker with the dog is converted into intermittent rotational (in one direction) movement of the ratchet.

Pinion mechanism – a gear mechanism for transmitting rotation between parallel shafts, in which one of the wheels (pinion wheel) has teeth in the form of circular cylinders – pin.

Stellar mechanism – a mechanism that provides intermittent rotational motion through engagement.

Coupler, coupling, **clutch** – a mechanism that serves to connect the shafts and transmit motion from the drive shaft to the follower. There are such types: tooth-type coupling, cam coupling, friction coupling.

2. STRUCTURAL RESEARCHES OF MECHANISMS

Structural researches – identifying patterns and structural features of the mechanism.

Generalized coordinate of the mechanism – each of the independent coordinates that determine the position of all links of the mechanism relative to the frame (ground).

Number of degrees of freedom of the kinematic chain – the number of generalized coordinates that determine the position of all links of the chain relative to some coordinate system.

Mobility (number of degrees of mobilable) of the kinematic chain – the number of degrees of freedom of this chain relative to the rack. Corresponds to the number of independent movements that can be communicated to the links of this chain relative to the ground. Mobility determined by the formula is called the Kutzbach criterion for a planar mechanism or Chebichev equation.

General bonds (constraints) in a mechanism – bonds superimposed simultaneously on all its links.

Passive connections – connections that do not affect the movement of links.

Extra degrees of freedom – degrees of freedom that do not affect the function of movement of the driven (output or executive) link.

Initial kinematic chain – the initial link (initial links) of the mechanism, forming a kinematic pair(s) with a ground (frame).

Structural group (Assur group) – a kinematic chain having a zero degree of mobility relative to the rack and not breaking up into simpler chains that meet this condition.

Structural diagram (scheme) of the mechanism – a conditional image of the mechanism on which each link is depicted in the form of a polygon or segment, with the number of sides equal to the number of kinematic pairs that include this link, and all pairs are depicted as revolute (hinges). The scheme is built without scale, and it is necessary to identify structural groups (Fig. 2.1).

Class of a structural group – a class that is determined by the number of pairs forming a closed loop of the highest order (Fig. 2.2).

View of the structural group of the second class – the view, which is determined by the number and location of the prism (translational) pairs.

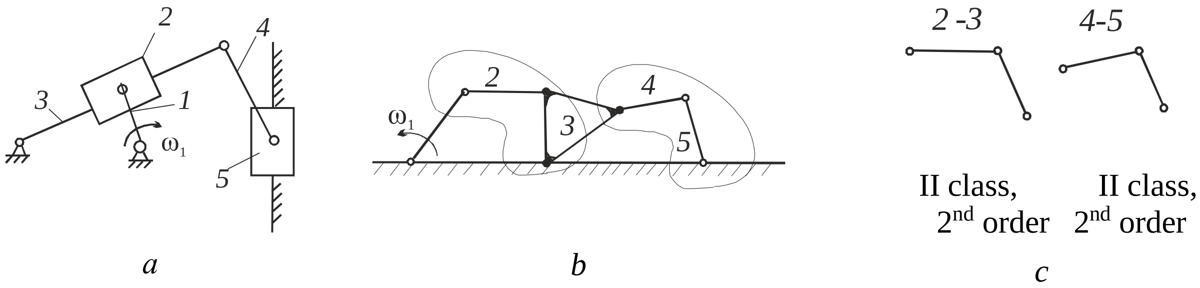


Fig. 2.1. Briquetting machine mechanism (rocker six-links mechanism):
a – kinematic diagram; *b* – structural diagram; *c* – Assur groups

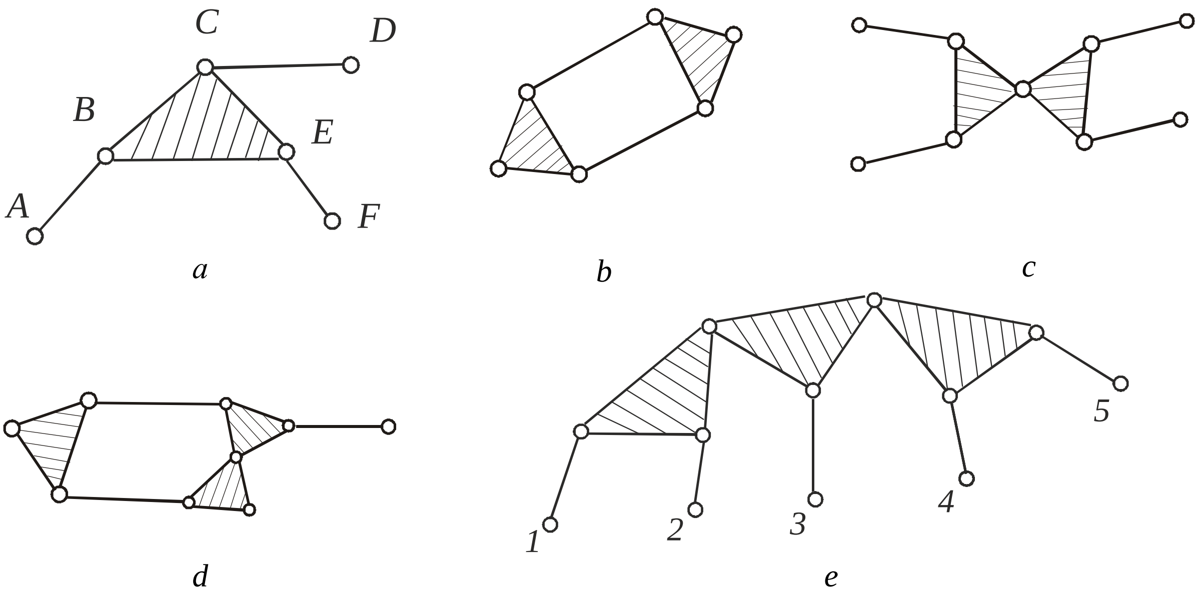


Fig. 2.2. Types of Assur groups:
a – III class, 3rd order, three-lead group, $n = 4$, $p_5 = 6$; *b* – IV class, 2nd order, $n = 4$, $p_5 = 6$; *c* – III class, 4th order, four- lead, $n = 6$, $p_5 = 9$; *d* – V class, 3rd order one-lead group; $n = 6$, $p_5 = 9$; *e* – III class, 5th order, five- lead, $n = 8$, $p_5 = 12$

Order of the structural group is the number of free elements by which the group joins other parts of the mechanism (Fig. 2.2).

Class of a mechanism is a class that is defined by the highest class of structural groups of this mechanism.

Task of the structural analysis of the mechanism is determining the structure parameters mechanism: the number of mobile links, the presence of passive connections, structural groups and their class and type, the number and type of kinematic pairs, the degree of mobility of the mechanism.

Task of structural synthesis of a mechanism is determining the structure of a new mechanism that converts a movement of the driver into the required movement of driven link and that has given properties: the number of degrees of mobility, the minimum of links with pairs of a certain type.

3. KINEMATIC RESEARCH

Kinematic research of a mechanism – the study of the law of motion of links of a mechanism without taking into account the forces that determine this movement. The goal is to determine the coordinates, velocities and accelerations of the hinge axes, as well as rotation angles, angular velocities and angular accelerations of links for a number of specific consecutive positions of the initial link (driver - link) according to a given law of its motion during the cycle of the mechanism.

Sequence of kinematic research – the sequence of consideration of structural groups, starting with the first in the order of formation of the mechanism of the structural group.

Stages of kinematic research – the procedure for determining the kinematic parameters of a mechanism, starting with the linear positions of the hinge axes and the angular positions of the links in the first stage, the linear velocities of the hinge axes and the angular speeds of the links in the second stage, the linear accelerations of the hinge axes and the angular accelerations of the links in the third stage.

Analytical method of kinematic research – a method that involves the determination of kinematic parameters by analytically solving equations that determine the values of these parameters.

Graphic-analytical method of kinematic research – a method in which equations written in an analytical form for determining kinematic parameters (displacements, velocities, and accelerations) are solved by graphical methods, namely, by constructing plans for the positions of the mechanism, speed plans, and acceleration plans with a selected rotation step of the initial link on the cycle interval mechanism work.

Plan of the mechanism – the kinematic diagram (scheme) of the mechanism at the selected scale, corresponding to a certain position of the initial link (driver).

Plans of the positions of the mechanism (combined plans of the mechanism) – kinematic schemes made in one coordinate system for a number of consecutive positions of the initial link (Fig. 3.1).

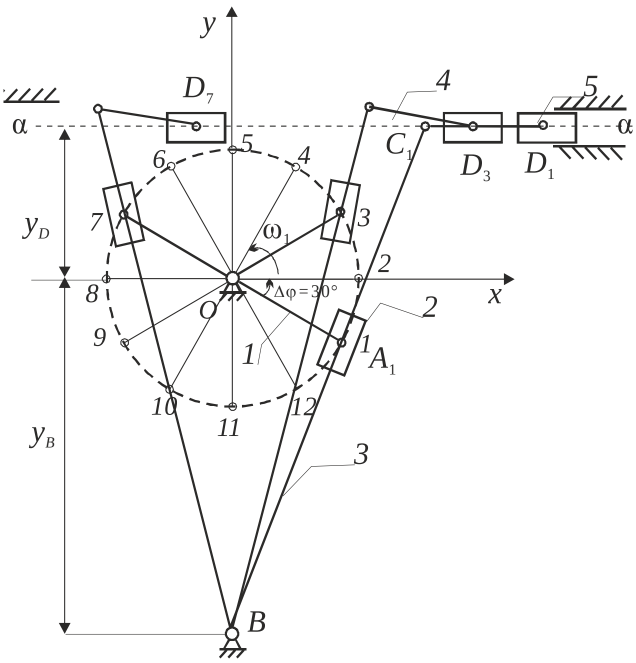


Fig. 3.1. Plans of the positions of the mechanism

Extreme position of the link – the position of the link from which it can move in only one direction.

Extreme position of the mechanism – the position of the mechanism at which at least one link of the mechanism occupies the extreme position.

Scale coefficient – a number showing how many units of a physical quantity are contained in one millimeter of a drawing that depicts a given physical quantity.

Velocity plan of the mechanism – a drawing on which the vectors equal in magnitude and direction to the speeds of various points of the mechanism at the given moment of the cycle (in the considered position) of the mechanism (Fig. 3.2) are shown on a scale coefficient.

Velocity plan pole – the plan point from which the absolute velocity vectors are built. Between the ends of the absolute velocities on the velocity plan are segments depicting relative velocities (Fig. 3.2 - *p*).

Acceleration plan of the mechanism – a drawing, which shows in the form of segments vectors equal in magnitude and direction to the accelerations of various points of the links of the mechanism at the moment of the mechanism's cycle of operation, i.e., in the considered position (Fig. 3.3).

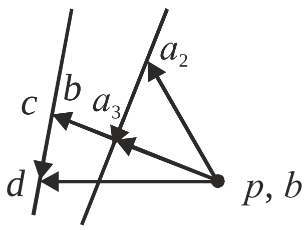


Fig. 3.2. Speed plan

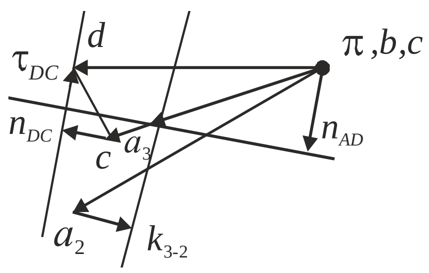


Fig. 3.3. Acceleration Plan

Pole of the acceleration plan – the point of the plan from which the vectors of absolute accelerations of the mechanism points originate (Fig. 3.3 – π).

Rule of similarity – if the points on the link form a certain figure, then the same-named points on the plans of speeds and accelerations form a similar figure, and the direction of the bypass from point to point on the kinematic diagram of the mechanism and on the plans of speeds and accelerations is preserved.

4. FRICTION IN MACHINES

Friction – the phenomenon of counteracting the movement of one body relative to another.

Force of friction – the force of resistance to the relative motion of bodies.

Friction surfaces – the surfaces by which bodies in relative motion come into contact.

Dry friction – friction of non-lubricated surfaces (Fig. 4.1).

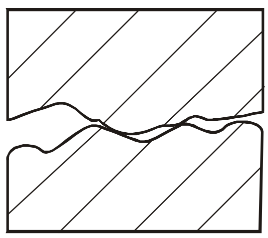


Fig. 4.1. Dry friction

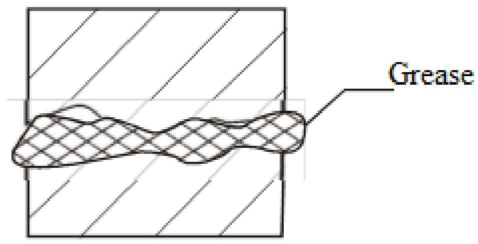


Fig. 4.2. Fluid friction

Fluid friction – friction that occurs if the friction surfaces are completely separated by a lubricant layer (Fig. 4.2).

Semi-dry (semi-fluid) friction – a combination of dry and fluid friction.

Sliding friction – the resistance to the translational (prism) movement of one body relative to another. This type of friction occurs in prism or prismatic pair, revolute or turning pair and screw or helical pairs.

Trunnion – the part of the shaft with which it is in contact with the support.

Spike – a trunnion located on the end of the shaft and perceiving a radial load.

Bearing – shaft support (neck and spike).

Heel – a trunnion that accepts axial load.

Thrust bearing – the motionless support of the heel.

Rolling friction – the resistance to rolling of one body relative to another.

Spinning friction – the resistance to rotation of one body relative to another around a common normal to the surfaces of their contact. This friction occurs when the end face of the rotating shaft comes in contact with the support in the pair «heel- thrust bearing».

Rolling friction with slippage – friction that combines the processes that occur during rolling motion, which periodically changes to slip motion.

Tribometer – a device for measuring friction in various friction pairs.

Laws of Amonton-Coulon – laws that characterize processes in the case of sliding friction:

1. The friction force arises only in the presence of a shear (moving) force.

2. Other things being equal, the friction force does not depend on the size of the friction surfaces.

3. The friction force acquires the maximum value at the moment the motion starts and is called the rest friction force.

4. The force of friction of motion is not greater than the force of friction of rest.

Rest (immobility) friction force – the maximum resistance force to relative motion that occurs at the moment the motion begins.

Strength of the movement of friction – the strength of resistance to relative motion during movement.

Rest (immobility) friction coefficient – the ratio of the rest **(immobility)** friction modulus to the normal reaction modulus between contacting bodies.

Motion Coefficient of friction – the ratio of the module of the force of friction of motion to the module of the normal reaction between the contacting bodies.

Cohesion coefficient – the ratio of the module of the greatest rest friction force of two contacting bodies to the force module, which is located normal to the friction surfaces. Corresponds to the coefficient of friction of rest.

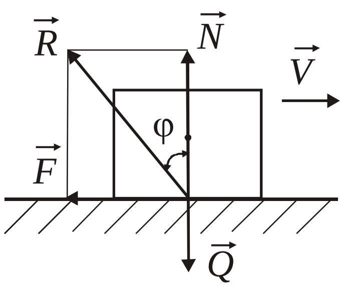


Fig. 4.3. Friction angle φ

Friction angle (φ) – the angle between the normal and total reaction vectors of the contacting bodies (Fig. 4.3).

Friction cone – the surface of a cone that will be described by the complete reaction between the contact bodies if one of the bodies is moved relative to the other in arbitrary directions of the contact plane with the other body.

Self-braking inclined plane – a plane on which the load does not slide under its own weight.

Friction circle – a circle whose radius is equal to the product of the coefficient of sliding friction by the radius of the shaft forming a rotational pair (hinge).

Rolling friction coefficient – the distance by which the normal reaction vector between the bodies shifts from its initial position at rest when rolling one body over another.

Friction materials – materials with high friction coefficients. These are leather, rubber, asbestos, textolite, etc.

Anti-friction materials – materials having low friction coefficients. These are bronze, babbitt, gray cast iron, some plastics.

Dead positions – those positions of the mechanism in which the links are unable to move due to the inhibitory effect of the friction forces. The mechanism in these positions corresponds to the conditions of self-braking.

Self-braking – a state of the mechanism in which the movement of the links is impossible at any values of the driving force due to the action of friction forces.

5. FORCE RESEARCH

Force research of a mechanism – the determination of the forces acting on the links of a mechanism, reactions in kinematic pairs and a balancing force or a balancing moment of a mechanism drive.

Ideal force research – research without taking into account friction forces.

Reactions in kinematic pairs – forces arising in kinematic pairs during movement of a mechanism under the influence of external forces.

External reactions – reactions in kinematic pairs by which the structural group joins other parts of the mechanism.

Internal reaction – a reaction in a kinematic pair formed by links of the structural group.

Principle of d'Alembert – if inertial forces are added to the external forces applied to the system, the system will satisfy the equilibrium conditions.

Kinetostatic method – the force calculation of a mechanism using inertia forces and the application of dynamic equilibrium equations, that is, a calculation based on the principle of d'Alembert.

Driving force – a force that performs positive work and is applied to the leading (initial) link (from the engine side).

Force of useful resistance (production resistance) – the force that performs negative work and arises when performing the technological function for which the machine is intended. The force of useful resistance acts on the output (executive) link on the move and is directed in the direction opposite to the speed of this link.

Forces of harmful resistance (non-production resistance) – the friction forces in kinematic pairs and the resistance forces of the environment (air, water, etc.). The work of these forces is negative.

Weight – is the force that results from gravity acting upon a mass. For the period of the cycle of movement of the mechanism, the work of these forces is zero.

Inertia – is the property of mass that causes it to resist any effort to change its motion. During the period of the cycle of movement of the mechanism, the work of inertia forces is zero.

Main vector of inertia forces – the totality of the elementary inertia forces of the particle masses of the link that arise in response to the translational motion of the link. The application point is located in the center of mass of the link. Equal to the product of the mass of the link and the acceleration of the center of mass. This vector is directed in the direction opposite to the acceleration vector of the center of mass.

Main moment of inertia forces – the set of elementary moments of inertia of the particles of masses of the link that arise in response to the rotational motion of the link. It is equal to the product of the moment of inertia of the mass of the link and the angular acceleration of the link in rotational motion. This moment is directed against the angular acceleration of the link.

Loading scheme – an image of the structural group, constructed taking into account the scale factor of lengths in the considered position of the mechanism. It shows: the main moments of the forces of inertia; and the link weights applied at the corresponding points; main vectors of inertia forces; force of useful resistance taking into account directions; reactions in kinematic pairs (Fig. 5.1).

Force plan – a closed force polygon constructed for each structural group and initial link for a specific position of the mechanism. It is a graphic representation of the equilibrium condition of a group or link and is performed on a certain scale (Fig. 5.2).

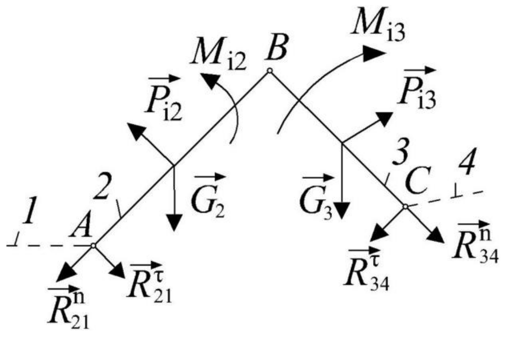


Fig. 5.1. Loading scheme

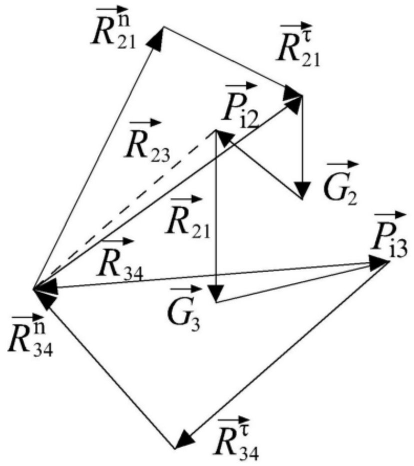


Fig. 5.2. Force plan

Force research taking into account friction forces – performed after an ideal force research. In this case, the friction forces are taken into account as known forces, which are determined by ideal reactions.

Balancing force or balancing moment – the force or moment applied to the initial link from the engine of the machine, balancing all the forces applied to the mechanism to provide the required movement.

Coefficient of performance (COP) of a machine – a value that characterizes part of the mechanical energy that is lost due to friction. It is defined as the ratio of the balancing force (moment) of the ideal force calculation to the balancing force (moment) taking into account the friction forces.

6. DYNAMIC OF MACHINES

Dynamic research (analysis) – the task of studying the patterns of movement of machines and mechanisms under the influence of applied forces.

Dynamic design (synthesis) – the task of determining the mass, moments of inertia, and, consequently, the dimensions of the links at which the links of the mechanism would move in a given mode (the kinematic characteristics of the movement mode of the mechanism and external resistance forces are specified).

Dynamic model of a mechanism (machine aggregate) – a model of a system in which one isolated selected link of the mechanism (drive link), usually the initial link, moves according to the same law as the real initial link of the mechanism; in this case, the angular velocity of the initial link is equal to the angular velocity of the model. The model is designed to study the properties of the mechanism and machine during its operation cycle (Fig. 6.1).

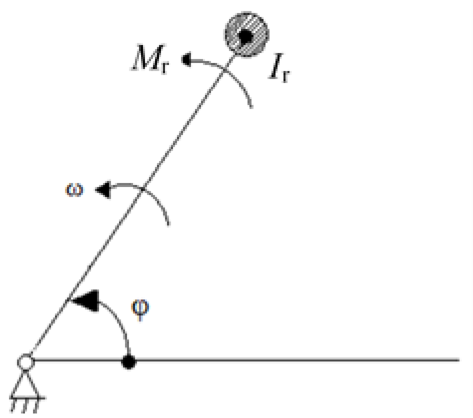


Fig. 6.1. Dynamic model of a mechanism (machine aggregate)

Direct dynamics problem – determination of the law of motion of the system under a given control force.

Inverse dynamics problem – determination of the required control force action that provides the necessary law of motion of the system.

Regulation of the machine aggregate – establishing ways to reduce dynamic loads and reduce fluctuations in the angular velocity of the initial link by selecting the parameters of control devices.

Model building – determination of the reduced force (reduced moment) and reduced mass (reduced moment of inertia) of the machine, ensuring the equivalence of the model and the real machine.

Criteria for equivalence of a model to a real machine – at each moment of the machine operation cycle, the power of the reduced force (reduced moment of force) of the model must be equal to the power of all forces acting in the machine, and also the kinetic energy of the reduced mass (reduced moment of inertia) must be equal to the sum of the kinetic energies of all moving masses of the machine.

Reduced force (reduced moment of force) – reduced force (such a conditional force (conditional moment of force) applied at the point of reduction (acting on the reduction link), the power of which (which) at each moment of the cycle is equal to the sum of the powers of all forces and moments acting in a real machine. moment of forces)

Reduced mass (reduced inertia moment) – such a conditional mass (conditional moment of inertia), concentrated on the reduction link, the kinetic energy of which at each moment of the cycle is equal to the sum of the kinetic energies of all moving masses of the machine.

Equation of motion of a machine aggregate – an equation compiled on the basis of the theorem on the change in kinetic energy, which establishes a relationship between the acting forces, moments of forces and parameters of the movement of the machine. This equation can have energy and differential form.

Operating (movement) modes of the machine aggregate – run-up, steady state, coasting (Fig. 6.2).

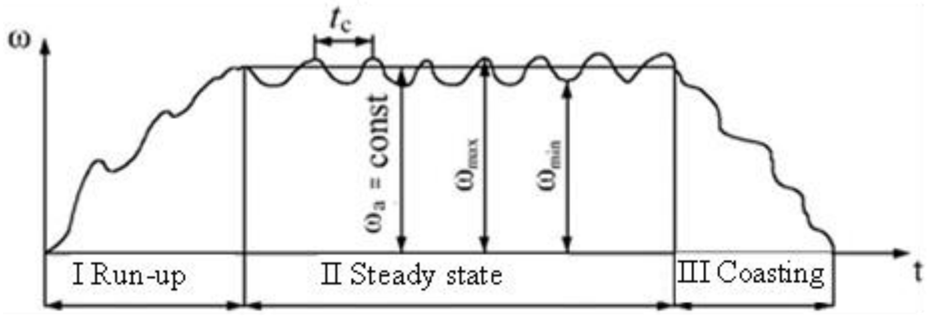


Fig. 6.2. The tachogram of the mechanism

Tachogram of the mechanism – a curve of the dependence of the angular velocity of the initial link on time (Fig. 6.2).

Run-up – the operating mode from the moment the machine aggregate is turned on, when the angular velocity of the initial link increases from zero to a certain average value (Fig. 6.2).

Coasting – an operating mode from switching off to a complete stop of the machine aggregate, when the angular velocity drops from a certain average value to zero (Fig. 6.2).

Unsteady mode – symptoms of non-periodic, i.e. fluctuations in the angular velocity of the main shaft of the aggregate are not repeated. Run-up and exit belong to this mode (Fig. 6.2).

Steady state – the nominal operating mode of a machine aggregate, in which the angular velocity of the initial link fluctuates around a certain average value corresponding to the normal operation of the aggregate (Fig. 6.2).

Steady cycle –the period of change in the angular velocity of the initial link.

Unevenness coefficient – the ratio of the difference between the maximum and minimum angular velocity per cycle of steady motion to the average angular velocity per cycle.

Positional forces – forces acting on the links of a machine aggregate that do not depend on the angular velocity of the initial link.

Non-positional forces – forces acting on the links of a machine aggregate, which depend on the angular velocity of the initial link.

Wittenbauer method – a method for studying the motion of a machine aggregate using an energy-mass diagram, which makes it possible to ensure the required coefficient of motion unevenness by selecting the flywheel mass (flywheel).

Flywheel (fly mass) – an additional mass in the form of a wheel with a rim, installed on the main shaft of the machine to ensure the required coefficient of unevenness of motion. The main purpose of the flywheel is to limit fluctuations in angular velocity.

Dynamic synthesis – carried out during the design process of a machine and consists in determining the moment of inertia of the flywheel according to given motion conditions, that is according to a given value of the permissible motion unevenness coefficient.

7. BALANCING THE MACHINE WEIGHTS

Balancing – the process of correcting or eliminating unwanted inertia forces and moments in rotating machinery. Balancing is carried out for mechanisms whose initial link rotation speed is conditionally constant.

Balancing the mechanism – eliminating the variable effects of the mechanism stand on the foundation.

Mass balancing – balancing by distributing the masses of the links, eliminating the pressure of the rack on the foundation from the inertia forces of the mechanism links. The balancing condition is that the main vector and the main moment of inertia forces of the links are equal to zero.

Dynamic balancing – ensuring that the main vector and the main moment of inertia forces of the mechanism links are equal to zero.

Static balancing – ensuring that only the main vector of inertia forces of the links is equal to zero. It is achieved with a constant position of the center of mass of the mechanism due to the redistribution of masses so that the center of mass is located at a fixed point relative to the rack.

Moment balancing – ensuring that the main moment of inertia forces of the mechanism links is zero.

Replacement mass method – the selection of counterweight masses for static balancing.

Counterweight – a part (load) designed to fully or partially balance the forces and their moments acting in machines during their operation.

Hodograph of the main vector of inertia forces – the curve that describes the end of the main vector of inertia forces during the operation cycle of the mechanism.

Rotor – in the theory of balancing, this is the name of any rotating link. For example, the armature of an electric motor, the crankshaft of an engine or compressor, the spindle of a metal-cutting machine, etc.

Rotor imbalance – the presence of a dynamic component of the rotor's impact on the supports. Occurs in mechanisms whose initial link rotation speed is not constant.

Balancing – eliminating the harmful effects of rotor imbalance on the supports in the presence of dynamic influence. Balancing is carried out for mechanisms whose initial link rotates at a variable angular velocity.

Static balancing – determination of corrective mass to eliminate rotor imbalance.

Dynamic balancing – determination of two corrective masses to eliminate rotor imbalance.

8. GEAR MECHANISMS

Gearing (gear pair) – a kinematic pair formed by gear wheels, as well as the process of transmitting motion in a kinematic pair formed by gear wheels.

Gear transmission (gear mechanism) – a three-link mechanism, the two moving links of which are gears or a gear and a rack, which form rotational and translational (rack) kinematic pairs with a fixed link (rack), and between them a higher pair, the element of which is a line or a point (Fig. 8.1).

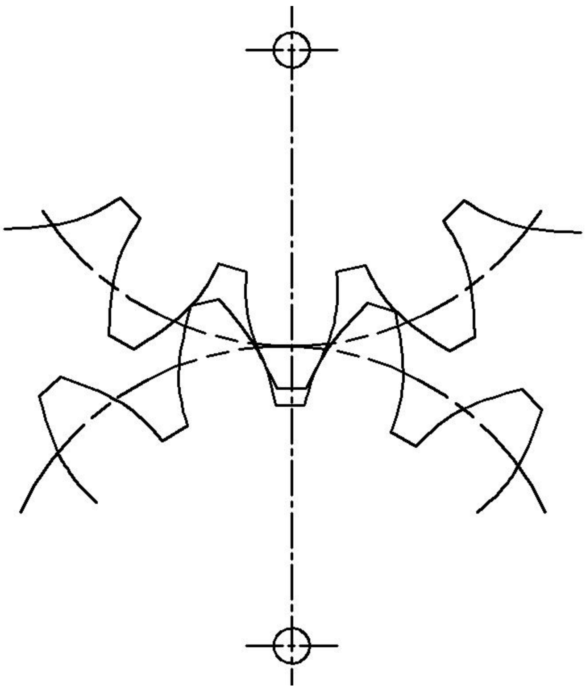


Fig. 8.1. Gear

Gear guitar – any combination of gears.

Cogwheel – an element designed to transmit movement or receive movement from another gear element using sequentially meshing teeth (Fig. 8.2).

Conjugate gear – any of two gears of a tooth-frequent transmission, which is considered in relation to the other.

Wheel – a gear wheel that has a larger number of teeth.

Gearwheel – a transmission gear that has fewer teeth.

A drive gear – a gear on a gear that turns another.

A driven gear – a gear on a gear train that is rotated by another.

An intermediate gear – a gear that meshes with two other wheels and that is driven by one of them and drives the other.

Number of teeth (z) – the number of a complete set of gear teeth.

A gear sector is a part of a gear with teeth.

The main linking theorem – the common normal, which is drawn at the point of contact of the higher pair, and which divides the center distance into segments inversely proportional to the angular velocities of the links of the pair.

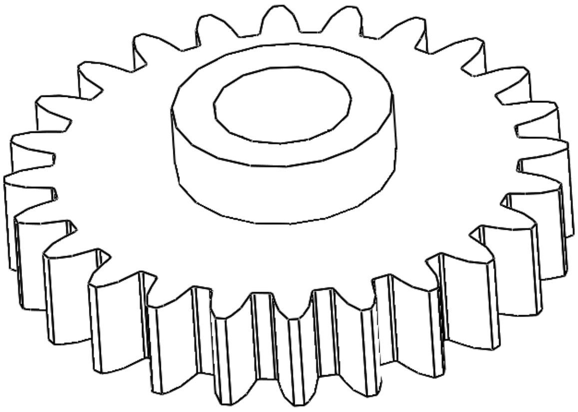


Fig. 8.2. Gear with external teeth

The pitch point – the point of contact of the initial circles of the gears, which is the instantaneous center of speed in the relative motion of the wheels.

Gear ratio – the ratio of the angular speed of the first drive gear to the angular speed of the last driven gear of the transmission guitar. The gear ratio has a plus sign if the directions of rotation of these wheels coincide, and a minus sign if they are opposite.

Transmission ratio – the ratio of the number of teeth of the larger gear wheel to the number of teeth of the smaller one (gear).

Reduction gear – a gear (guitar) in which the angular velocity of the last driven wheel is less than the angular velocity of the first driven wheel.

An overdrive gear – a gear (guitar) in which the angular velocity of the last driven wheel is greater than the angular velocity of the first driven wheel.

An inter-axial line (center line) – a straight line intersecting the axis of rotation of the wheels at right angles.

Center distance – the distance between the centers of rotation of the wheels, measured along the center line (Fig. 8.3 – distance *a*).

A tooth – a special protrusion on a link that forms a superior pair with another tooth (Fig. 8.4), or each of the elements of the gear wheel that fits into the cavities between the corresponding elements of the mating gear and which, thanks to their shape, ensure that one gear rotates the other.

The lateral surface of the tooth – an element of the highest pair of gears is the surface located between the surface of the peaks and the surface of the valleys gear wheel. This surface separates the tooth from the tooth space (Fig. 8.4 – surface L).

The active flank of a tooth – the surface that is in contact with the flank of the mating gear.

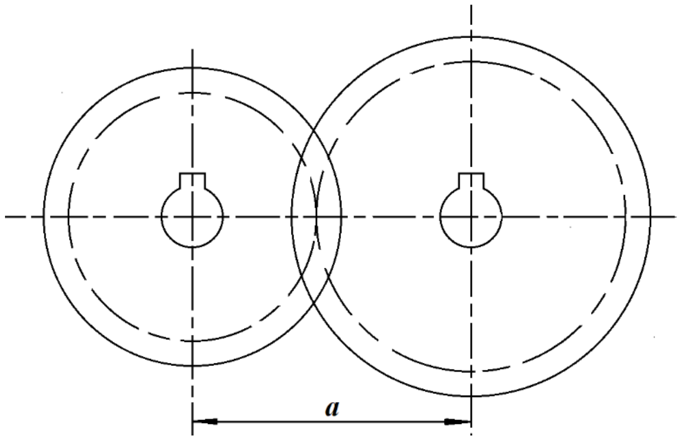


Fig. 8.3. Center distance

The apex of a tooth – the part of the surface of the apexes between the side surfaces of the teeth.

Gear tooth – the space between two adjacent teeth of a gear.

The initial surface is, in a certain gear transmission, a geometric surface described by the instantaneous axis of the relative movement of the mating gear relative to the gear in question.

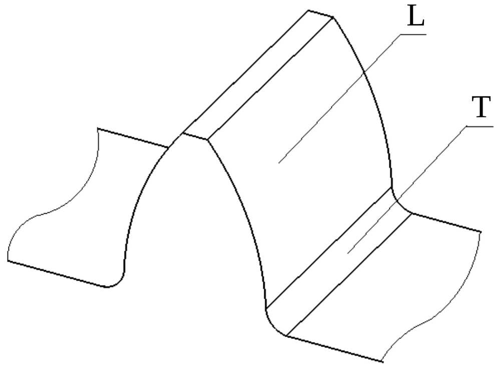
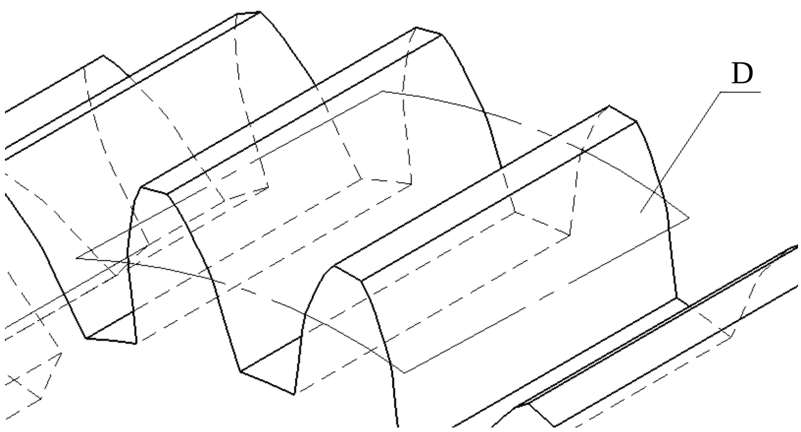


Fig. 8.4. Gear tooth

The dividing surface – an imaginary conditional surface, relative to which the dimensions of the gear are determined (Fig. 8.5 – surface D).

The vertex surface – a coaxial surface of rotation that bounds the outer edges of the outer teeth of the outer wheel or the inner edges of the inner teeth of the gear (Fig. 8.6 – surface V).



Root surface – a coaxial surface of rotation, limiting the outer edges of the cavities of gear wheels with external teeth, or the outer edges of the cavities of gear wheels with internal teeth (see Fig. 8.6 – surface C).

Fillet surface – a curved surface between the main side surface and root surface (see Fig. 8.4 – surface T).

Addendum head – part of a gear tooth between the dividing surface and the surface of the vertices.

Fig. 8.5. Dividing surface

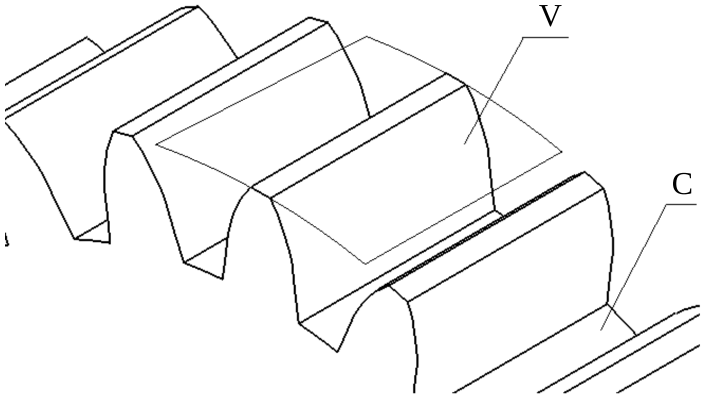


Fig. 8.6. Peak and cavity surfaces

Dedendum – part of a gear tooth between the pitch surface and root surface.

A gear with external teeth – a gear in which the surface of the cavities is located inside the surface of the peaks (see Fig. 8.2).

A gear with internal teeth – a gear in which the surface of the vertices is located inside the surface of the cavities (Fig. 8.7).

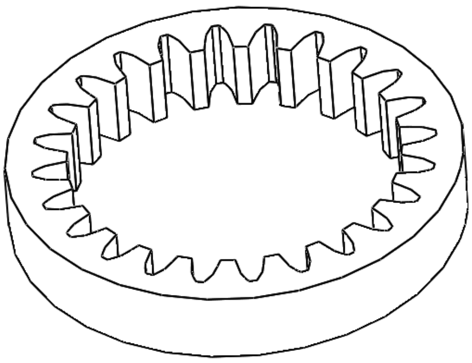


Fig. 8.7. Gear with internal teeth

Tooth line – the line of intersection of the lateral surface of the tooth and the pitch surface.

Tooth profile – the line of intersection of the lateral surface of the tooth with an arbitrary plane, which also intersects the dividing surface (Fig. 8.8). Depending on the plane intersecting the side surface, end, normal and axial profiles are considered.

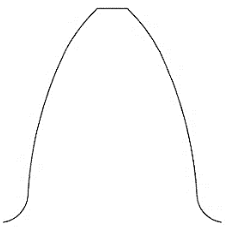


Fig. 8.8. Tooth profile

A simple gear transmission – a three-link mechanism consisting of 2 gear wheels and a rack.

A complex gear transmission – a mechanism that consists of several gears connected in parallel or in series to one another. They are subdivided into: gear mechanisms with fixed axles of all wheels; mechanisms, the axles of individual wheels of which move relative to the rack.

A spur gear – a gear with parallel axes of the wheels (Fig. 8.9).

Bevel gear – a gear with intersecting wheel axes (Fig. 8.10).

Hyperboloid Gear – gear Drive with crossing wheel axles (Fig. 8.11).

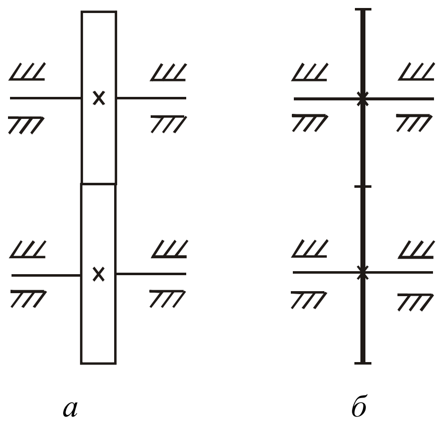


Fig. 8.9. Cylindrical broadcast: *a* – wheels in engagement; *b* – wheels on the kinematic diagram

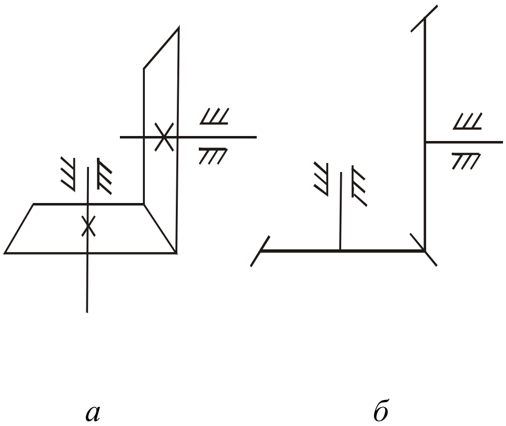


Fig. 8.10. Bevel gear: *a* – wheels in engagement; *b* – wheels on the kinematic diagram

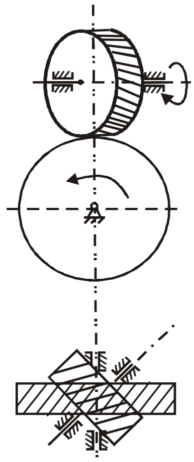


Fig. 8.11. Hyperboloid gear train

Helical gear, hypoid gear, worm gear – types of hyperboloid gears.

A worm gear – a special case of a hyperboloid gear, in which a small cylindrical or toroidal wheel (worm) has helical teeth.

Hypoid gearing – a gearing consisting of conical-shaped wheels, the axes of which are crossed and spaced apart.

A rack – a segment of a gear having a radius equal to infinity.

Ring gear – a complete set of wheel teeth located on the body of the wheel.

External gearing – a transmission in which both wheels are gears with external teeth (Fig. 8.12, *a*).

Internal gearing – a transmission in which one of the wheels is made with internal teeth (Fig. 8.12, *b*).

Rack and pinion gear (rack and pinion) – a gear train consisting of a gear wheel and a gear rack (Fig. 8.12, *c*). Rack and pinion gearing is considered a gear transmission of external gearing.

A spur gear – a wheel in which the tooth line is parallel to the axis of rotation (Fig. 8.13, *a*). This definition applies to spur gears.

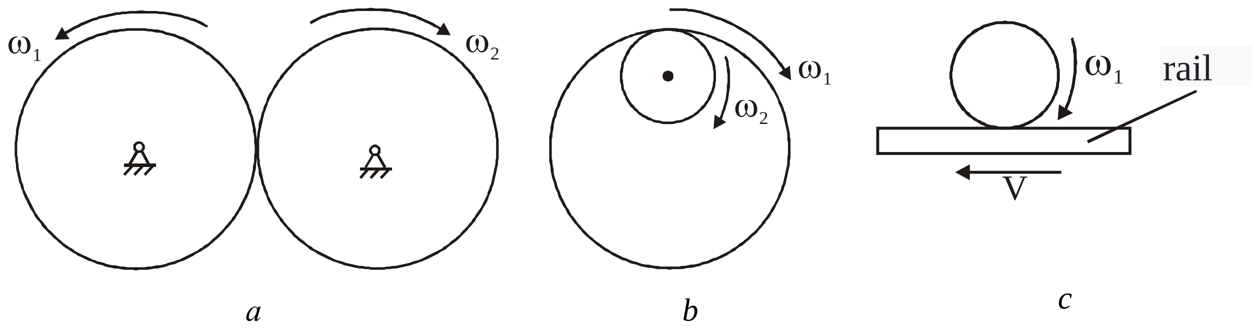


Fig. 8.12. Cylindrical gears:

a – external gearing: $i_{12} = \frac{\omega_1}{\omega_2} < 0$; *b* – internal gearing: $i_{12} = \frac{\omega_1}{\omega_2} > 0$;

c – rack and pinion gear: $i_{12} = \frac{\omega_1}{\omega_2} = \infty$ or $i_{21} = 0$

A spur bevel gear – a bevel gear whose tooth lines are straight forming lines of the pitch cone (Fig. 8.13, *b*).

A helical gear – a cylindrical gear in which the tooth line is a helical line (Fig. 8.13, *c*).

A chevron gear – a cylindrical gear, the width of which consists of sections with the opposite direction of the line of teeth, the so-called left teeth and right teeth (Fig. 8.13, *d*).

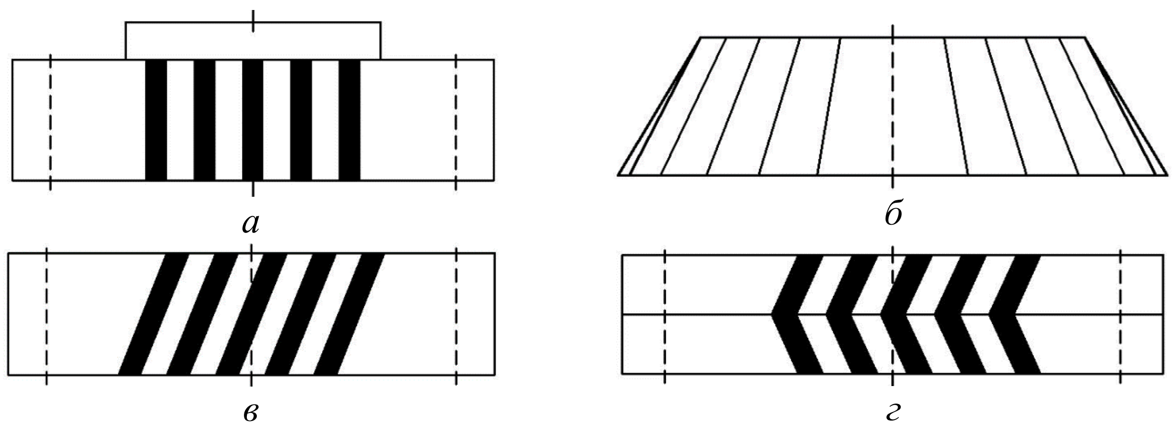


Fig. 8.13. Position of the tooth line on the gear:
a – spur gear; *b* – spur bevel gear; *c* – helical gear; *d* – chevron gear

The end section of the tooth – a section perpendicular to the axis of rotation of the wheel (Fig. 8.14).

The normal cross section of the tooth – a section perpendicular to the tooth line (see Fig. 8.14).

Pitch (operating) circle (r_w – the radius of the starting circle) – a mental circle rigidly connected to the gear wheel. The initial circles of the gears in mesh touch each other at the meshing pole and roll over one another without sliding (Fig. 8.15).

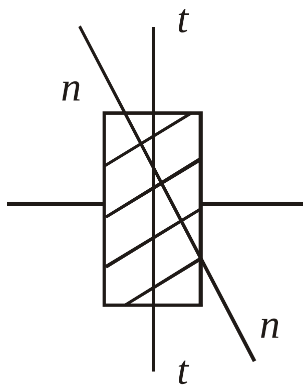


Fig. 8.14. End *t-t* and normal *n-n* tooth sections

Outside circle (r_a – the radius of the circle of the apexes) – a circle passing through the boundary points of the apexes of the teeth (see Fig. 8.15).

Root circle (r_f – the radius of the cavities of the teeth) – the circle that limits the cavities of the teeth. Separates the tooth from the wheel body (see Fig. 8.15).

Reference circle (r – the radius of the pitch circle) – the circle on which the wheel has a standardized module. This circle is the basis for determining the dimensions of the gear (see Fig. 8.15).

Base circle (r_b – the radius of the main circle) – a circle whose development is an involute. (see Fig. 8.15).

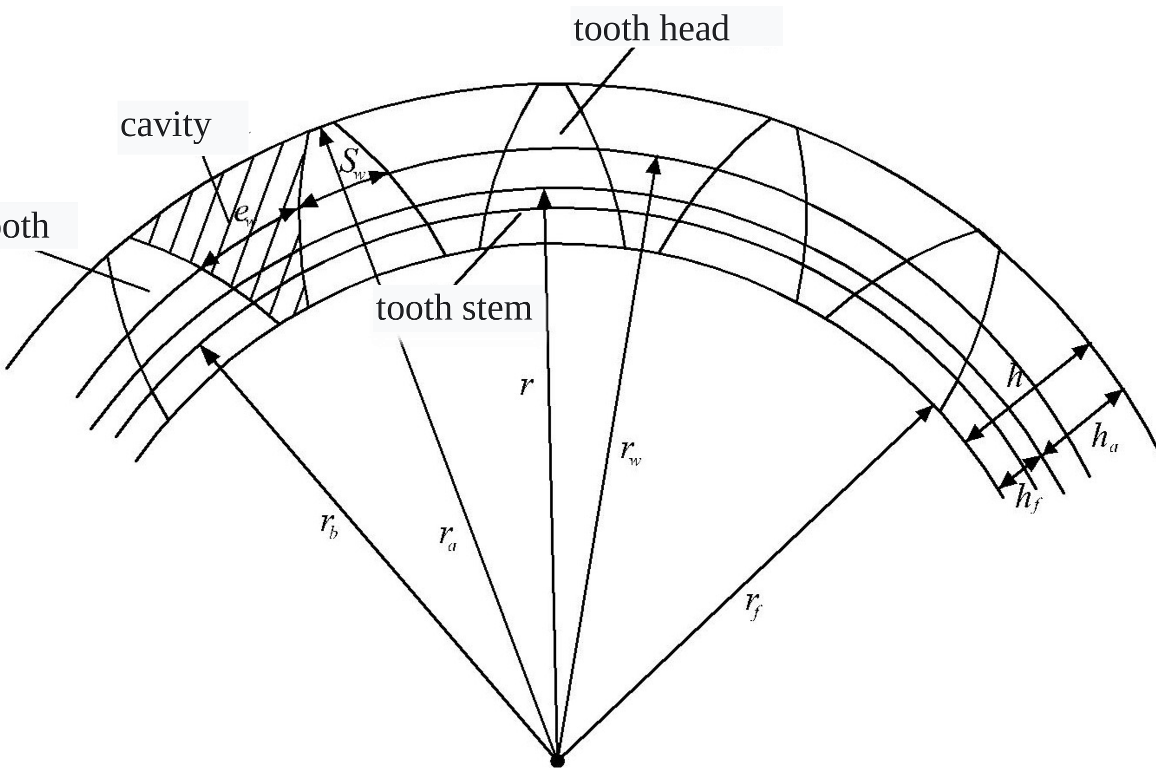


Fig. 8.15. Elements and parameters of a spur wheel

Tooth thickness (*S*) – the distance between opposite tooth profiles along the arc of the concentric circle of the gear wheel (see Fig. 8.15).

The width of tooth space (*e*) – the distance between the left and right side surfaces of two adjacent teeth along the arc of the concentric circle of the gear wheel (see Fig. 8.15).

Tooth height (*h*) – the distance between the circle of the peaks and the circle of the valleys (see Fig. 8.15).

The height of the addendum head (h_a) – the radial distance between the vertex circle and reference circle (see Fig. 8.15).

The height of the tooth stem (h_f) is the radial distance between the root circle and reference circle (see Fig. 8.15).

Teeth pitch (*p*) – the length of the arc along the pitch, initial or other circle of the wheel between the same points of adjacent teeth.

Angular pitch (τ) – the central angle of the concentric circle of the wheel: $\tau = 2\pi/z$.

The condition of close contact – the condition for ensuring two-sided contact of the side surfaces of the teeth without lateral clearance.

Modulus – the part of dividing the gear pitch along a certain circle by the number π. Module units **are millimeters.**

Standard module (*m*) – the part of dividing the gear pitch along the pitch circle by the number π ($m = p / \pi$). In the future, the module.

Radial clearance – the radial distance between the circle of the tops of one of the gears and the circle of the bottoms of the other ($c = c \cdot m$).

Radial clearance coefficient (c^*) – the ratio of the radial clearance to the gear module. Standard value $c^* = 0.25$.

Addendum head height coefficient (h_a^*) – the ratio of the height of the tooth head to the gear module. Standard value $h_a^* = 1{,}0$.

Dedendum height coefficient (h_f^*) – the ratio of the tooth root height to the gear module. Standard value $h_f^* = 1{,}25$.

A cycloid – a flat curve that is formed by a point on a circle and that rolls along a stationary straight line without slipping.

Cycloidal gears – wheels whose tooth profiles are cycloids.

Cycloidal gear train – a gear train consisting of cycloidal gears.

Novikov gearing – a gear in which the convex profile of one wheel interacts with the concave profile of the other. The tooth profile is formed by the initial generating contour, the teeth of which are profiled by circular arcs.

Involute gears – wheels whose tooth profiles are outlined by the involute of a circle.

Involute gear – a gear consisting of involute gears.

The involute of a circle – the trajectory of any point on a straight line that rolls without sliding along a stationary circle. In the theory of gearing, the circle that defines the involute of the tooth profile is called the main circle (Fig. 8.16).

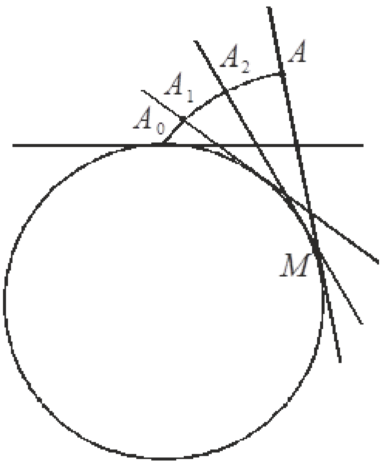


Fig. 8.16. Formation of the right branch of the involute

The profile angle of the involute at a given point – an acute angle formed by the tangent to the involute at a given point and the radius vector of the involute of this point.

The angle of deployment – the angle formed by the initial and current radius vectors.

The involute angle (angle involute) – a function of the difference between the tangent of the angle of rotation and the angle itself.

The copying method – a method of manufacturing gears in which the working edges of the tool correspond in shape to the surface being processed (cutting a gear with a profiled disk or finger cutter) (Fig. 8.17 and 8.18).

The rolling (bending) method – a method according to which the tool and the workpiece, due to the kinematic chain of the machine, perform two movements - cutting and bending (cutting with a hob cutter, tool rack, cutter). The cutting tool and the workpiece are given such movements relative to each other that reproduce the engagement process (Fig. 8.19).

Gear cutter – a special gear wheel that has cutting edges along the profiles of its teeth for the manufacture of gears using the rolling method.

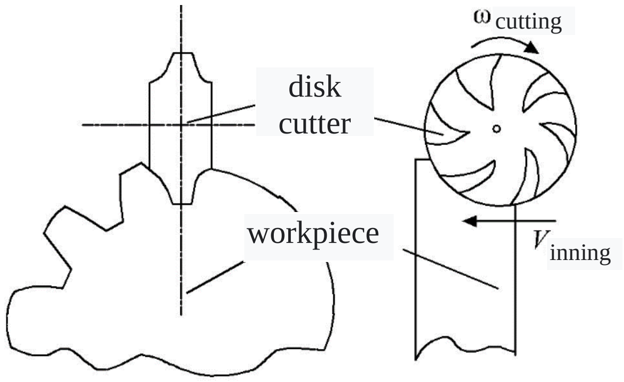


Fig. 8.17. Gear cutting
copying method with a disk cutter

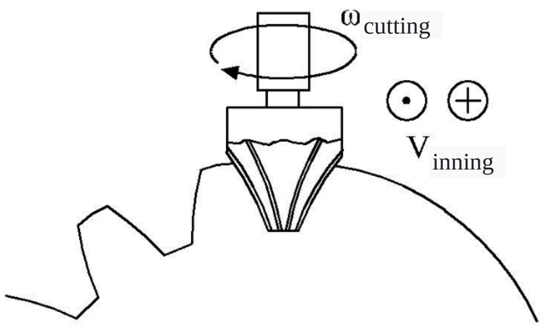


Fig. 8.18. Finger cutting

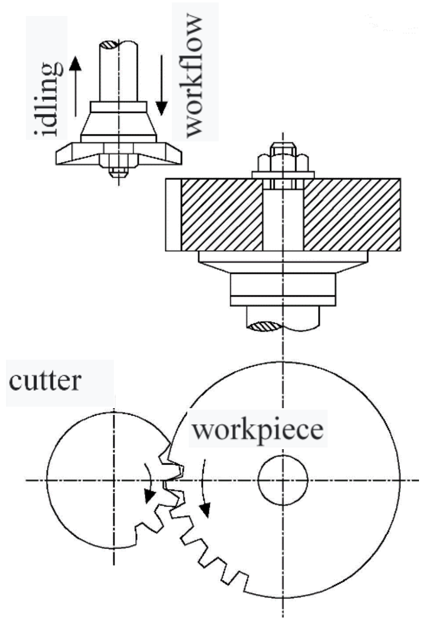


Fig. 8.19. Cutting a wheel using the rolling method (tool – cutter)

A hob cutter – a screw with a trapezoidal thread, the profile of which in the normal section coincides with the profile of the tool rack. Serves for the manufacture of gears using the rolling method.

Tool rack – a gear rack with cutting edges along the side surfaces of the teeth. Used for the manufacture of gears using the rolling-in method.

Initial contour (IC) – the contour of the rack teeth, obtained in a section by a plane perpendicular to the side surface of the tooth (Fig. 8.20). Used as a basis for determining standard tooth sizes for involute gears. (The dimensions of the original contour are established according to DSTU ISO 1122–1:2006).

The initial generating contour of the rack (IGC) – the contour of the rack teeth, obtained in a section by a plane perpendicular to the side surface of the gear-cutting tool.

The dividing line of the rack – a straight line along which the thickness of the rack tooth is equal to the width of the cavities $S = e = \pi\, m/2$ (Fig. 8.21).

Zero setting of the tool – the setting at which the pitch line of the IPC touches the pitch circle of the wheel being manufactured.

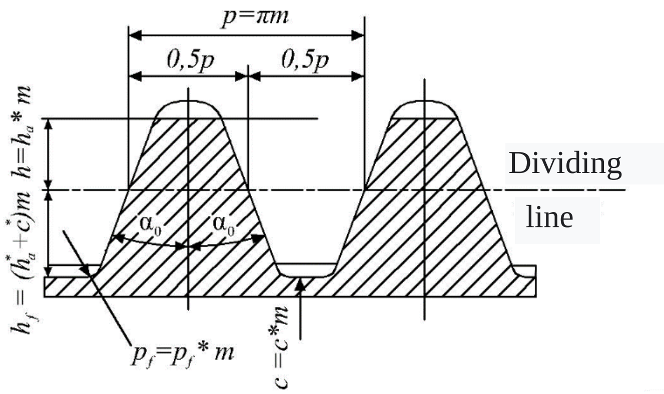


Fig. 8.20. Profile of the original contour

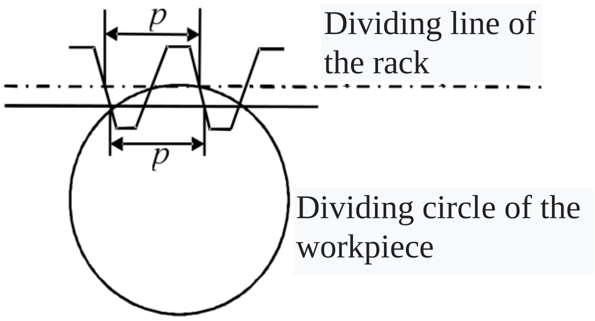


Fig. 8.21. Position of the rack and cut wheel

Positive installation – an installation in which the dividing line of the IPC is moved away from the dividing circle.

A negative setting – a setting in which the dividing line of the IPC intersects the dividing circle.

Displacement of the initial contour of the generating rack – the distance X along the normal between the pitch circle of the cut gear and the pitch line of the original generating contour: $X = x \cdot m$. The displacement of the original generating contour is accepted: positive, if the dividing line of the original contour does not intersect or touch the pitch circle of the gear; negative if the dividing line of the original generating contour of the rack intersects the dividing circle of the gear; zero if the dividing line of the original generating contour of the rack touches it.

The displacement coefficient of the original circuit (x) – the ratio of the displacement of the original generating circuit to the standard module.

Equalization offset ($\Delta y \cdot m$) – the amount by which the tooth height of a rack-and-pinion tool for the wheel being cut is reduced in order to obtain a standard radial clearance in the working gear. (In machine gearing – the distance between the boundary producing straight rack and the circle of the vertices of the wheel being cut).

Equalization coefficient (Δy) – ratio of equalization bias to design modulus.

Zero gear – a wheel that is cut with zero displacement of the original contour; The pitch thickness of the tooth in this case is equal to half the pitch.

Positive gear – a wheel that is cut with a positive offset of the original contour; the pitch thickness of the tooth in this case is more than half the pitch (for external teeth).

Negative gear – a wheel that is cut with a negative offset of the original contour; The pitch thickness of the tooth in this case is less than half the pitch (for external teeth).

Perceived displacement ($y \cdot m$) – the distance between the pitch circles, measured along the center line with no backlash.

The perceived displacement coefficient (y) – the fraction of the perceived displacement divided by the standard gear module.

Positive gearing – a gearing in which the coefficient of perceived displacement is positive (the pitch circles do not intersect or touch), $x_1 > 0$; $x_2 > 0$; $y_m > 0$; $y > 0$; $a_w > a$, where a – the center-to-axle distance of a gear whose wheels are cut without displacement.

Zero gear transmission – a transmission in which the coefficient of perceived displacement is zero (the pitch circles touch), $x_1 = x_2 = 0$ or $x_1 = -x_2$; $\alpha_w = \alpha_0 = 20°$; $\Delta y = 0$; $y = 0$; $r_{w1} = r_1$; $r_{w2} = r_2$.

Negative gearing – a gearing in which the perceived displacement coefficient is negative (the pitch circles intersect), $x_1<0$; $x_2 < 0$ or $x_1 <|-x_2|$; $y_m < 0$; $y < 0$; $a_w < a$.

The active tooth profile – the part of the tooth profile through which interaction occurs with the tooth profile of the paired gear.

Line of action (N_1N_2) – geometric location of the contact points of the profiles on a fixed plane (Fig. 8.22).

The active part of the engagement line (ab) – the part of the engagement line that extends placed between the boundary contact points of the active profiles of the gear teeth (see Fig. 8.22).

Engagement pressure angle (α_w) – an acute angle formed by the engagement line and a straight line perpendicular to the center line.

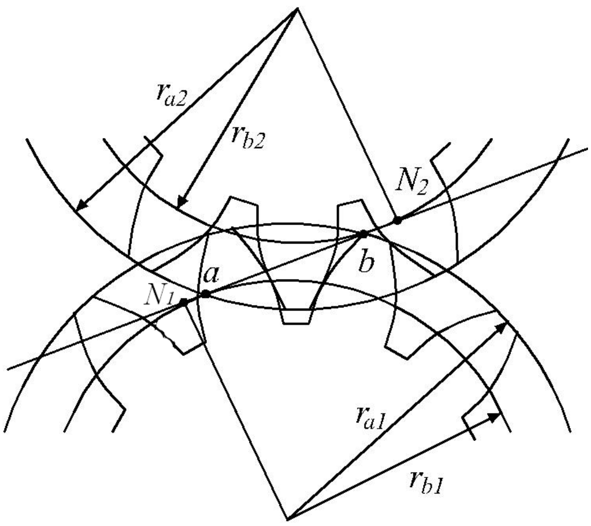


Fig. 8.22. Engagement line N_1N_2

The overlap angle of the gear – the angle of rotation of the gear from the position of the tooth entering the mesh until it disengages (engagement time).

The end overlap angle – the angle of rotation of the cylindrical gear gear from the position of the entry into the engagement of the end profile of the tooth until it disengages.

The axial overlap angle – the angle of rotation of the gear of a cylindrical gear, at which the common point of contact of the teeth will move along the tooth line of this gear from one of the ends limiting the working width of the rim to the other.

Qualitative indicators of engagement – geometric indicators that characterize the operation of the gear mechanism, namely: absence of cutting of teeth, ensuring overlap in engagement, wear resistance, bending and contact strength.

Overlap coefficient (ε_α) – the ratio of the overlap angle of a transmission gear to its angular pitch. Takes into account the continuity and smoothness of gearing in the transmission.

The end overlap coefficient – the ratio of the end overlap angle to its angular pitch.

The axial overlap coefficient – the ratio of the axial overlap angle to its angular step.

Specific slip coefficient (ν) – the ratio of the sliding speed at the contact point to the tangential component of this speed.

Specific pressure coefficient (γ) – the ratio of the calculated module to the reduced radius of curvature of the profiles.

Cutter interference – a phenomenon in which the head of the cutting tool cuts into the leg of the wheel being cut. When cutting a zero gear with a standard contour ($x = 0$; $\alpha = 20°$) the minimum number of teeth that will not be trimmed by a rack tool, $z_{\min} = 2h_a^*/\sin^2\alpha$; $z_{\min} \approx 17$ (Fig. 8.23).

Tooth sharpening – with increasing displacement coefficient x tooth thickness S_a at the top it will decrease. If $x_{\max}$ sharpening of the tooth occurs ($S_a = 0$). To prevent the top of a pointed tooth from chipping, there is the following condition: the thickness of the teeth around the circumference of the tops should be $S_a \geq 0{,}2\ m$.

Correction of gears – correction of gearing in order to improve transmission quality.

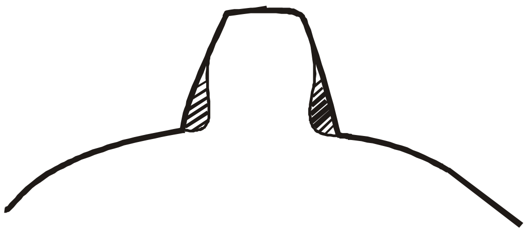


Fig. 8.23. Tooth trimming

The Kudryavtsev coefficient system – a system of tool displacement coefficients for the manufacture of wheels, ensuring maximum contact strength of teeth. Recommended for closed gears.

The TKBR coefficient system – a system of tool displacement coefficients for wheel manufacturing, ensuring equalization of specific slip coefficients and thereby increasing wear resistance. Recommended for open gears.

Enclosed gears – gears located in a tight housing and operating with lubricant.

Open gears – gears located in a loose housing and operating without liquid lubrication.

A blocking contour – a set of curves constructed in coordinates x1 and x2, limiting the choice of design displacement coefficients x1 and x2, defining the zone of their permissible values (Fig. 8.24).

Complex gear mechanisms – mechanisms consisting of several gears connected in parallel or in series with each other. They are divided into: gear mechanisms with fixed axles of all wheels; mechanisms in which the axes of individual wheels move relative to the rack.

An ordinary gear mechanism – a sequential connection of several pairs of gears, on each of the fixed axes of which one wheel is placed (Fig. 8.25).

A stepped gear mechanism – a sequential connection of several pairs of block wheels (Fig. 8.26). It also consists of single wheels, namely input and output.

A gear block – a rigid connection of two wheels with a shaft (Fig. 8.26).

An epicyclic gear mechanism – a gear mechanism in which at least one gear has a movable axis of rotation.

A planetary gear mechanism – an epicyclic gear mechanism, the degree of mobility of which is equal to one (Fig. 8.27).

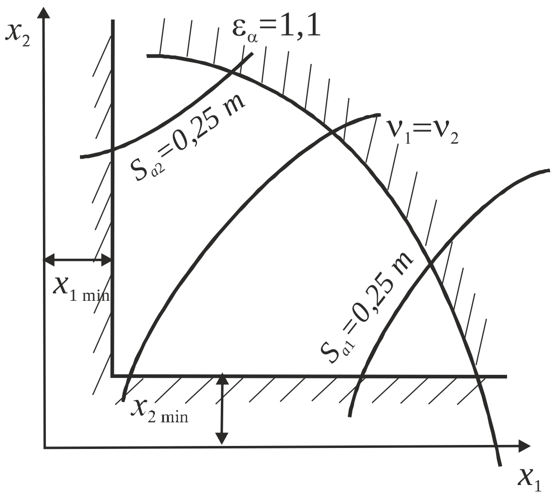


Fig. 8.24. Blocking circuit

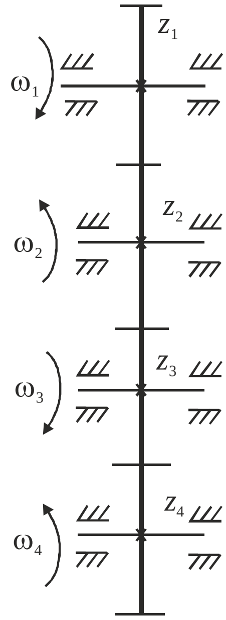


Fig. 8.25. Private gear

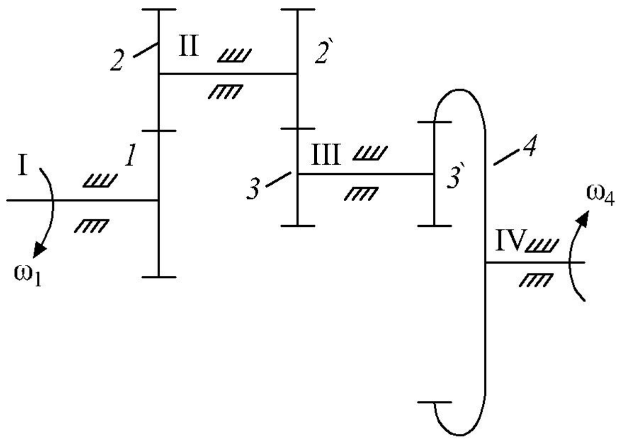


Fig. 8.26. Step transmission

Planetary gearbox – reduction planetary gear train (see Fig. 8.27).

The differential gear mechanism – an epicyclic gear mechanism, the degree of mobility of which is equal to two (Fig. 8.28).

A satellite – a wheel whose axis is movable in the rack system (see Fig. 8.27, *c* – wheel *2*).

The satellite block is paired wheels with a moving axle (see Fig. 8.27 – wheels *2-2*ꞌ).

The carrier is a link on which the movable axes of the gear wheels H are located (see Fig. 8.27 – *H*).

Central or sun wheels are wheels rotating around fixed axes, included in planetary or differential mechanisms (see Fig. 8.27, 8.28 – wheel *1*).

The support wheel is a stationary wheel included in the planetary gear mechanism (see Fig. 8. 27 – wheel *3*).

The motion reversal method (Willis inversion method) is a mental communication to all links of the movement mechanism in the opposite direction from the movement of the selected link in order to solve practical problems by «stopping» the required link, for example, a carrier in a planetary mechanism or a cam in a cam.

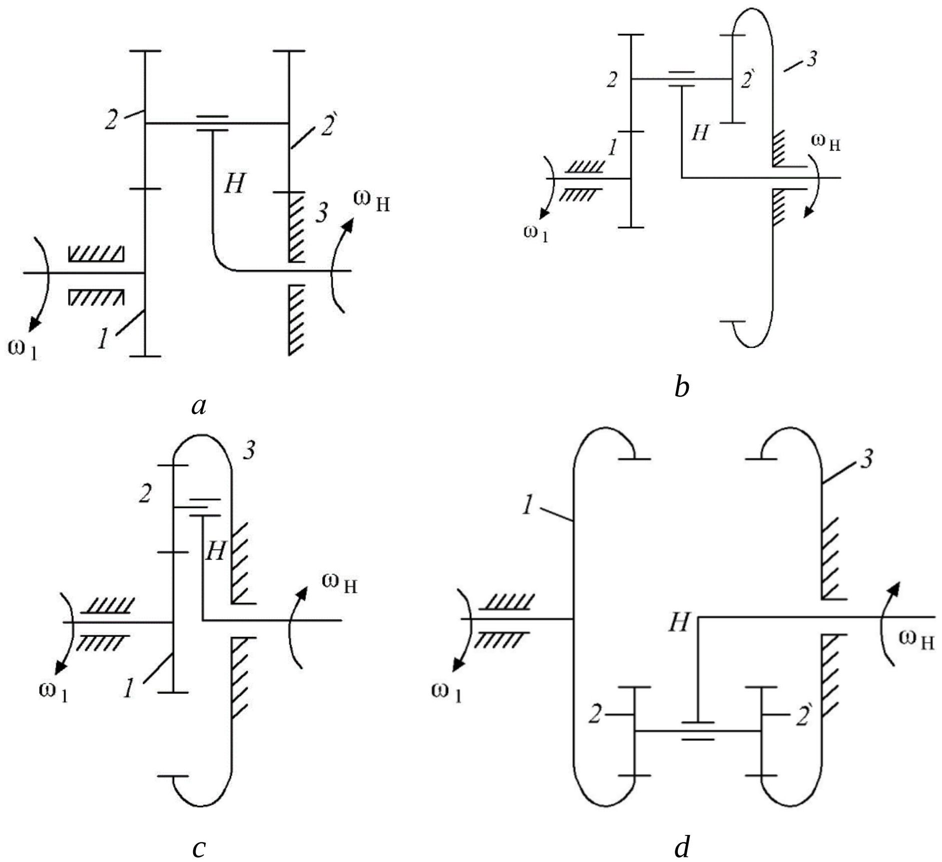


Fig. 8.27. Two-stage planetary gearbox:
a – type A–A; *b* – type A–J; *c* – type $\overline{\text{A} - \text{J}}$; *d* – type J –J;
A – external gear; J – internal gearing

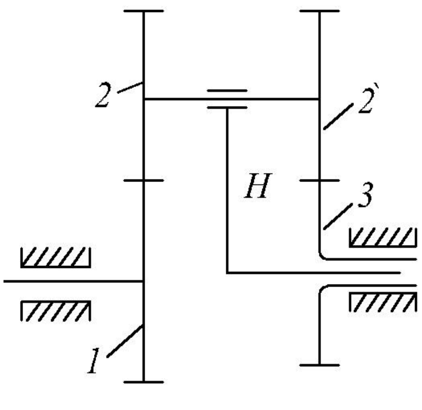


Fig. 8.28. Differential mechanism

A reversed mechanism – a mechanism that has been mentally transformed by the method of reversing movement, i.e., with the required link «stopped».

The task of synthesizing a planetary mechanism – a task that consists in selecting, according to the selected scheme of a planetary mechanism, the number of teeth of its wheels so as to satisfy the following conditions: have the required gear ratio, fulfill the conditions of coaxiality, proximity and assembly.

Alignment condition – a condition under which the interaxle distances between the satellite (satellites) and the central and support wheels must be equal.

Adjacent condition – a condition under which the circles of the tops of the teeth of two adjacent satellites should not touch.

Assembly condition – the condition under which, when assembling the satellites, the teeth of each of them must fall into the recesses of the central wheels.

9. CAM MECHANISMS

The cam mechanism – a three-link mechanism, which includes an upper pair formed by the driving link (cam) and the driven link (pusher or rocker arm) and allows obtaining complex laws of motion of the driven link, including with stops of the driven link during continuous cam movement (Fig. 9.1).

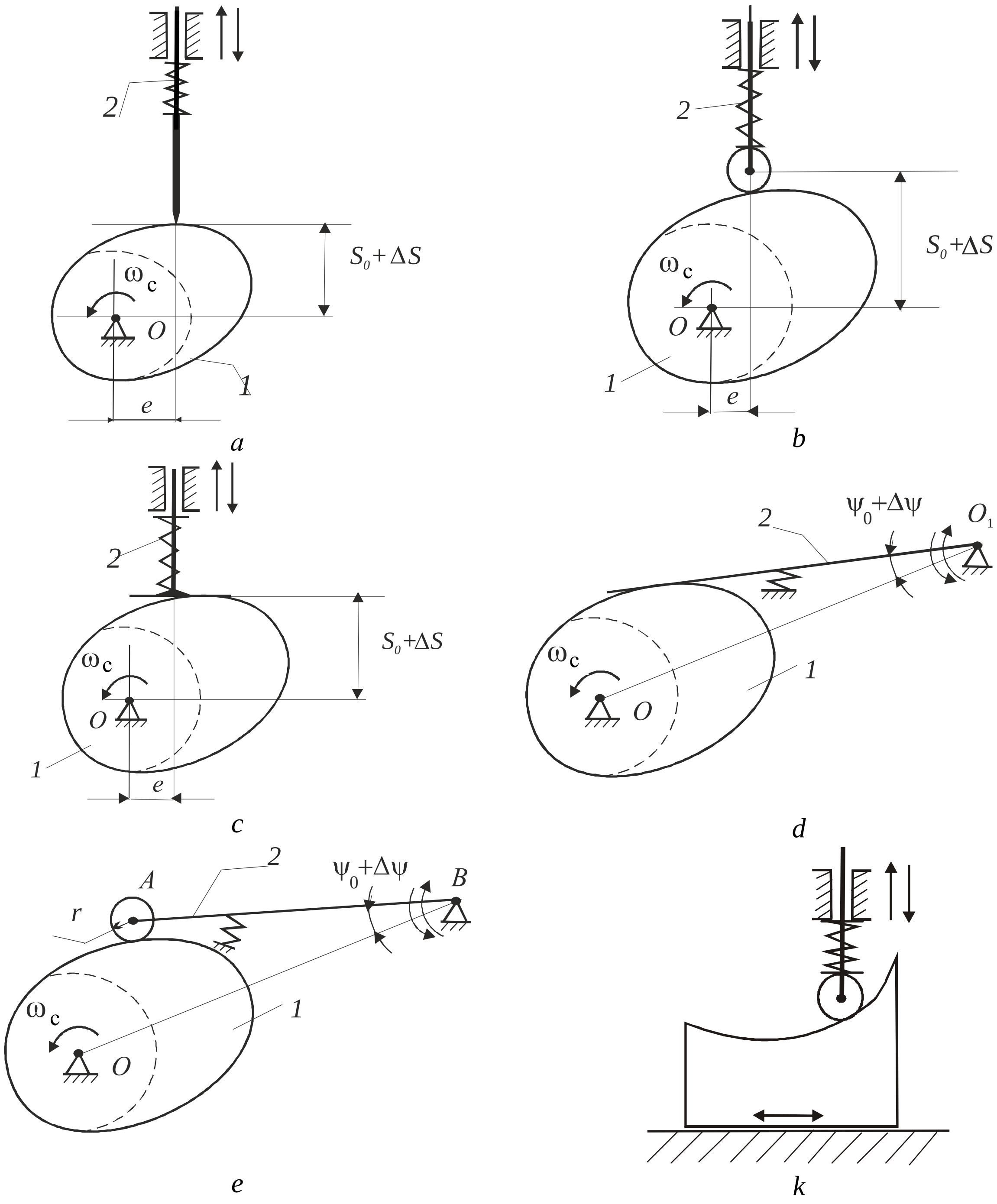


Fig. 9.1. Types of cam mechanisms:
1 – cam; *2* – pusher or rocker

A pusher – a driven link making a translational motion.

A rocker arm – a driven link that performs a reciprocating rotational movement for an incomplete revolution.

The cam profile – an element of the higher pair with variable curvature.

The main characteristic of the cam mechanism – the law of motion of the driven link, set by the position function and determined by the cam profile.

The purpose of the cam mechanisms – to convert the rotational or translational movement of the cam into a reciprocating movement (for a rocker arm) or a reciprocating movement (for a pusher).

The advantages of cam mechanisms – the ability to obtain an intermittent movement of the output link, including those with stops (dwells), and the ability to ensure accurate dwellings of the output link.

A roller – a link of the cam mechanism, which does not affect the nature of the movement of the driven link and serves to replace sliding friction in the higher pair with rolling friction in order to reduce the wear of the elements of the higher pair (Fig. 9.1, *b*, *e*, *f*).

Force-closing – the use of a spring to ensure constant contact of the upper pair of the cam mechanism (see Fig. 1.5 and 9.1).

Geometric closure – the use of a constructive solution to ensure the constancy of the contact of the upper pair, for example, the groove in which the roller of the driven link is located (Fig. 9.2).

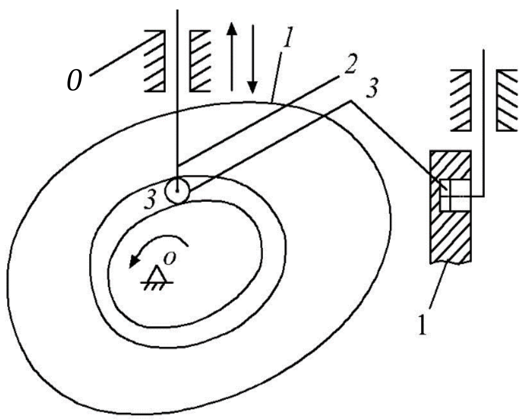


Fig. 9.2. An example of a form-fit – a roller in a cam groove: *0* – rack; *1* – cam; *2* – pusher; *3* – roller

The task of the analysis of the cam mechanism – the task, which consists in determining the parameters of the movement of the driven link from the existing cam profile.

The problem of the synthesis of the cam mechanism – the problem, which consists in determining the cam profile according to the given law of motion of the driven link.

A flat pusher, a flat rocker arm (a disc pusher or a rocker arm with a plate) – a cam mechanism in which the driven link element is made in the form of a plane (look Fig. 9.1, *c, d*).

The needle pusher – a cam mechanism in which the driven link element is sharpened (look Fig. 9.1, *a*).

The cyclogram of the cam – a graphic representation of the dependence of the function of the position of the driven link on the angle of rotation of the cam (if the cam performs rotational movement) during the cycle of operation of this mechanism (for example, for the angle of rotation 2π) (Fig. 9.3)

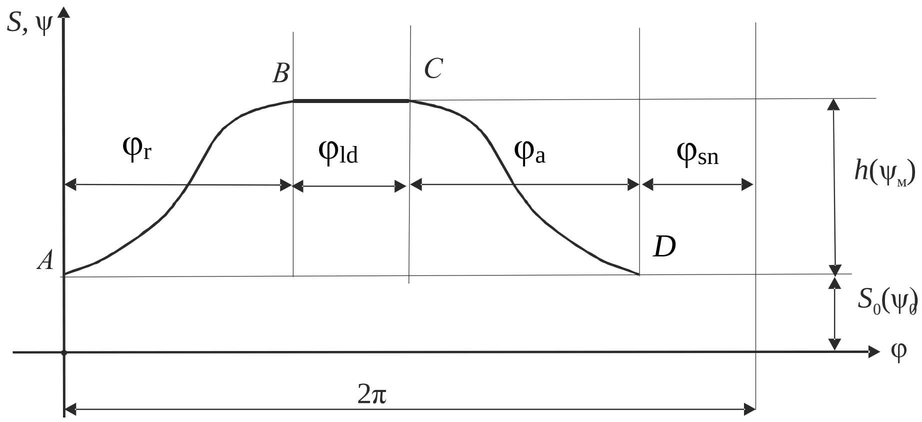


Fig. 9.3. Cam output position function

Phases of movement of the driven link (Fig. 9.3):

The phase of removal (φ_r) – the part of the cycle corresponding to the increase in the displacement function of the driven link. During this phase, the follower moves from the position closest to the center of the cam to the position farthest from the center.

The approach phase (φ_a) – a part of the cycle corresponding to a decrease in the movement function of the driven link. In this phase, the follower moves from the position furthest from the center of the cam to the position closest to the center.

The long-distance holding phase (φ_{ld}) – the part of the cycle at which the position function is constant and maximum. This phase corresponds to the cam profile outlined by a circular arc.

The near standing phase (φ_{ns}) – the part of the cycle in which the position function is constant and minimal. The cam profile providing this phase is outlined by a circular arc.

Analogue of the speed of the driven link ($S^{/}$) – the first derivative of the follower movement along the cam angle.

Analogue of the acceleration of the driven link ($S^{//}$) – the second derivative of the follower movement along the cam angle.

Center (theoretical) cam profile (T) – a profile that in the cam coordinate system describes the center of the roller as it moves along the cam working profile (Fig. 9.4).

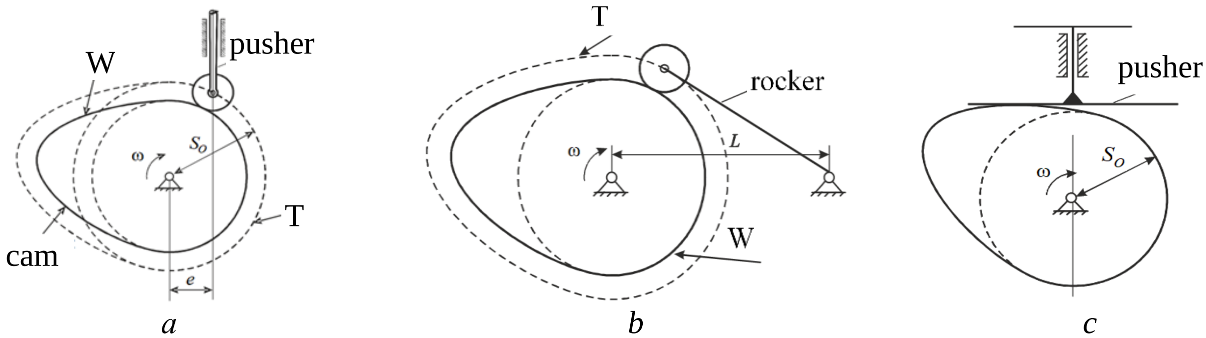


Figure: 9.4. Center and working profiles in cam mechanisms:

a – with a roller pusher; *b* – with a roller rocker; *c* – with a flat pusher

Working (practical) cam profile (W) – cam profile along which the roller is rolling.

Followed link motion law – a function that determines the parameters of the driven link motion. As a rule, it is set in the form of an analogue function of the acceleration of the driven link (Fig. 9.5).

Cam mechanisms with hard blows – mechanisms in which the function of an analog of acceleration has an instantaneous jump by an infinite amount (Fig. 9.7).

Cam mechanisms with soft impacts – mechanisms in which the function of an analog of acceleration has an instantaneous jump by a finite amount (Fig. 9.6).

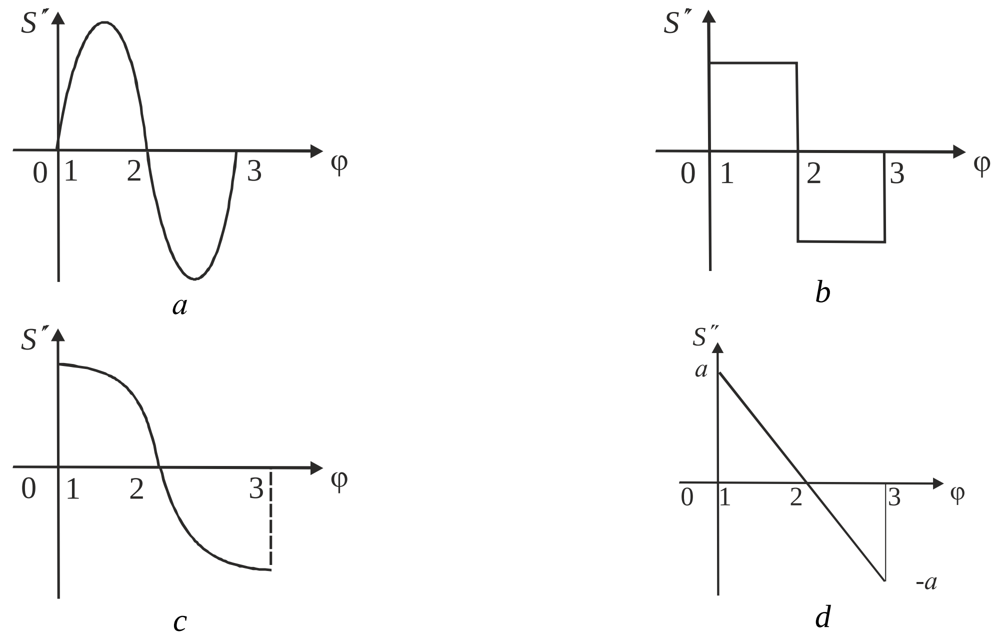


Fig. 9.5. Functions of pusher acceleration analogs:

$$a - S'' = a\sin k\varphi;\ b - S'' = \pm a;\ c - S'' = a\cos k\varphi;\ d - S'' = a\left(1 - 2\frac{\varphi}{\varphi_r}\right)$$

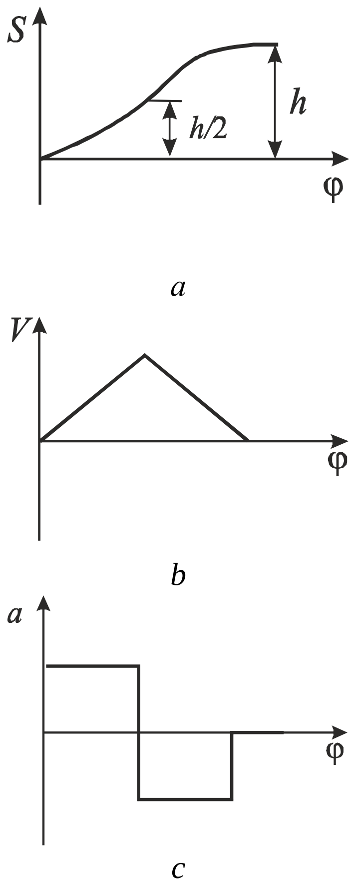


Fig. 9.6. Function with «soft» impact

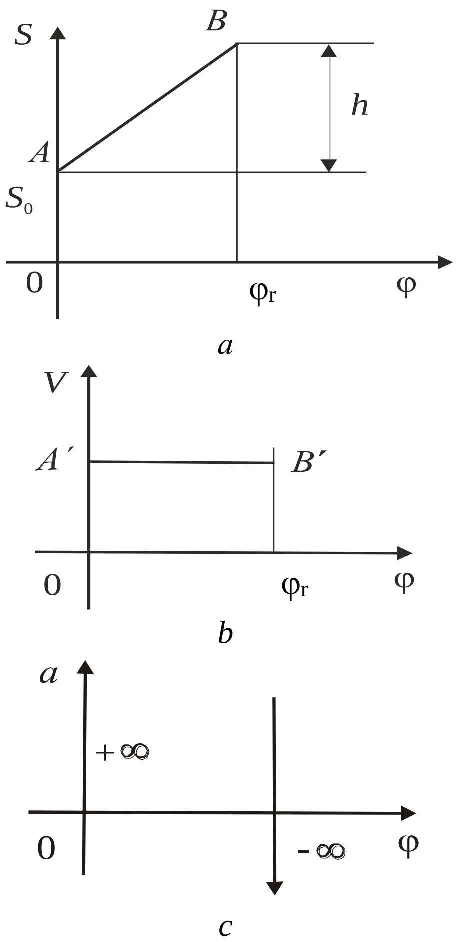


Fig. 9.7. Function with «hard» hits

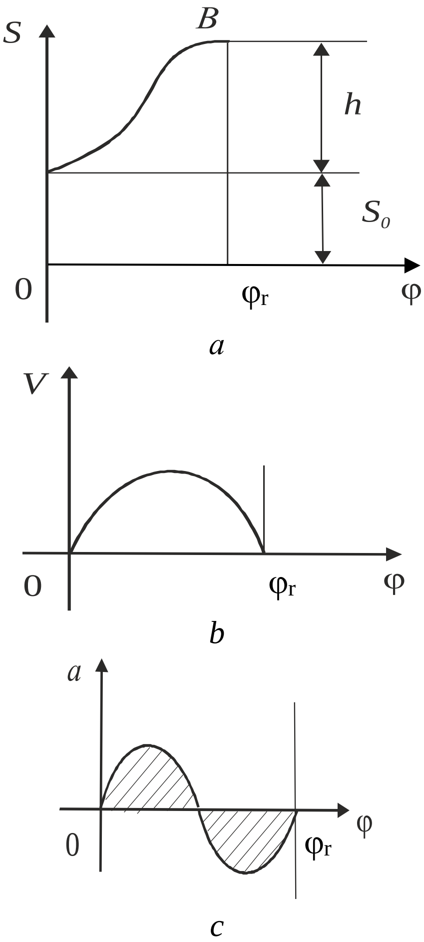


Fig. 9.8. Shockless function

Shockless cam mechanisms – mechanisms in which the function of an analogue of acceleration does not have instantaneous jumps, i.e. it changes smoothly (Fig. 9.8).

The angle of pressure of the cam mechanism (ϑ) – the angle formed by the total force of pressure of the cam on the driven link, directed along the common normal at the point of contact of the higher pair, and its effective component directed along the absolute speed of the point of the driven link. This angle has the following limitations: 30 ° – for cam mechanisms with a pusher; 45 ° – for rocker mechanisms. It is relevant only for cam mechanisms equipped with a roller (Fig. 9.9 and 9.10). For cam mechanisms with a poppet driven link, this angle is zero.

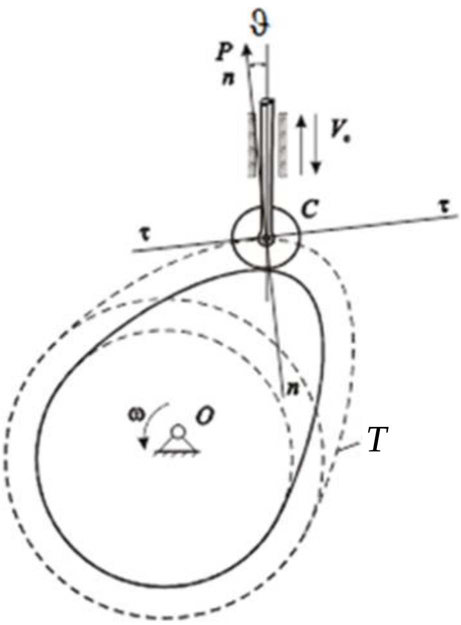


Fig. 9.9. Pressure angle in a cam mechanism with a roller follower moving translationally

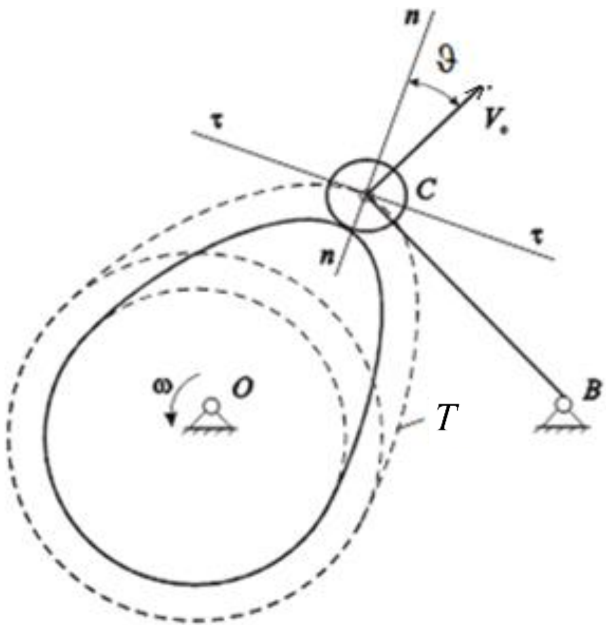


Fig. 9.10. Pressure angle in the cam mechanism with the roller on the rocker arm

Cam washer radius – the maximum radius of a circle that can be inscribed into the cam profile from the center of its rotation.

Eccentricity (*e*) – displacement of the axis of movement of the pusher relative to the axis of rotation of the cam.

Free parameters of the cam mechanism – design parameters that determine the dimensions and strength characteristics of the mechanism. These include the radius of the cam washer, eccentricity, and roller radius.

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CONTENT

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