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# INTRODUCTION TO THE TURBULENT FLOWS THEORY – AN AXIALLY-SYMMETRIC PEACEFUL FLOWS

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*This article introduces to fluid state physics (fluid mechanics) a new interpretation of physical phenomena taking place in a fluid in motion. It introduces base of a new theory claiming that every flow has its own internal structure of motion, which is definite organization of motion, rather than a "molecular chaos", known from the fluid statics. The article introduces the new notion of structures vector fields of power and momentum and shows, every Newtonian fluid flows are dual in character. It shows that the flow of Newtonian fluid has a dual character. It demonstrates on models and further in mathematical interpretation of physical phenomena. It introduces, on the one hand, the cycloidal motion model into the fluid mechanics, on the other introduces an addition to the known, the classical model of Poiseuille laminar motion. The theory of dualism (double nature of physical phenomena) allows the description of selected characteristics of the flow, either by using the theory of cycloidal motion (semicycloidal), or by using the supplemented theory of laminar motion. The dualism theory is useful to describe each type of flows both, laminar and turbulent. This article is only an introduction to the theory. It has been assigned the number 1. It has been granted a high priority, since it contains basic concepts that will be used in others, following articles of long cycle.*

*Key words: peaceful flow, structure of vector field*

## 1. Introduction

This paper discusses the dynamic structure of axially-symmetric peaceful flow of Newtonian fluids. A model of the said structure is presented below, whereby a new, original structure of cycloidal motion is superimposed on the classical, well-known structure of laminar motion, described by means of differential equations of Navier-Stokes (Navier, Claude Louis 1785 – 1836; Stokes, George Gabriel 1819 – 1903). This approach enables a new, theoretical, mathematical and model description of laminar flow, with particular emphasis on one part of it, referred to as peaceful flow. The notion of flow structure is understood to include both; the shape of the forces (accelerations) network, creating the motion forces field, and the shape of the linear momentum (progressive velocities) network between the molecules of the fluid in motion, which are forming the stream of this fluid.

The structure of the forces field is a graphical presentation of an arrangement of forces creating that field when the fluid is in motion. It is created as a result of transformation of an external force into an internal forces of the motion. It is formed of direction lines of internal molecular forces, which are formed the field of the progressive motion fluid. The structure of the motion progressive velocities field is a derivative of the structure of the force field.

One novelty introduced by this paper to fluid mechanics is the cycloidal motion model. Its role is to visualize the molecular motion structure formation process in the fluid mass, and thus to enable a mathematical description of the process of transforming external forces into internal forces. The new model constitutes an excellent addition to Poiseuille's well known classical model of laminar flows (Poiseuille, Jean Louis Marie 1797-1869). A reverse relation is also present here. The deliberations presented below will show, that the structure of even the simplest flow is more complicated than it was claimed thus far. It is dual in character, cycloid-laminar, and consists in displaying, depending on the situation, of either create or destroy properties of the motion structure.

The new theory of dualism (dual nature) of Newtonian fluid motions has been based on two models: the classical laminar flow model and the new cycloidal flow model. This new theory shows, that the flow of the Newtonian (viscous) fluid is the sum of interpenetrating each other motions, cycloidal and laminar. Modeling of this interpenetration allows the formulation of its mathematical description. It turns out, that the cycloidal model is better suited for the description of the active forces, which form the structure of the fluid motion. The classic model is better to describe the opposition forces, which destroy the structure of fluid motion, previously worked out by active forces. The dualism theory shows, that the process of both creation and destruction of motion structures triggers an internal resistance reaction in the fluid. This resistance is triggered by forces known so far as internal friction forces.

This paper is the first one in a series of papers describing the possibilities of the new theory. The paper is not universal in character. Its task is only to present the basics of the new theory and to show, that each flow is an organized and strictly defined motion structure, rather than a “molecular chaos”, known from the fluid statics. This fragment refers only to the example best understood by researchers, i.e. to axially-symmetric peaceful flow of homogenous Newtonian fluid, over a straight-axis duct of a circular cross-section provided, that the flow is subjected to a uniform field of gravity forces. The above limitation of the model’s scope allows one to take full advantage of Poiseuille’s model for the new purposes.

The final effect of the deliberations presented here is a mathematical description of model's events, allowing to form the theoretical dependence of the linear resistance of mentioned peaceful flow, as well as to introduce a new physical term to the liquid state physics, named the threshold flow. This paper is an introduction to the new theory of dualism cycloid-laminar motion of Newtonian fluids. One of the components of this theory is the theory of turbulent flows. This theory is also an introduction to a new theory of friction and lubrication.

## 2. List of symbols

| | | | |
|---|---|---|---|
| a | – | dynamic field intensity, directional acceleration | [$m/s^2$] |
| d, ∂ | – | differential symbols | |
| f | – | function denotation | |
| g | – | gravitational, steric acceleration | [≈ 9,81 $m/s^2$] |
| h | – | distance on transverse direction to the fluid flow direction, where $0 \le h \le H$ | [m] |
| k | – | directional intensity of the gravitational field | [$m/s^2$] |
| m | – | mass of the fluid in motion | [kg] |
| t | – | time | [s] |
| x | – | distance on parallel direction to the fluid flow direction | [m] |
| y | – | distance on transverse direction to the fluid flow direction | [m] |
| z | – | sense intensity of the gravitational field | [$m/s^2$] |
| C | – | integration constant | |
| F | – | cross section area | [$m^2$] |
| H | – | height (thickness) of the analyzed layer of fluid, measured on transverse direction to the flow direction, where $H \ge 0$ | [m] |
| J | – | resistance to motion | |

| | | | |
|---|---|---|---|
| L | – | distance between cross sections | [m] |
| P | – | force | [N] [kG] |
| Re | – | Reynolds number | |
| S | – | displacement | [m] |
| U | – | fluid structure state coefficient | |
| V | – | fluid velocity | [m/s] |
| W | – | height over the reference level | [m] |
| γ | – | fluid specific gravity [gamma] | $[kG/m^3]$ $[kp/m^3]$ |
| η | – | fluid dynamic viscosity [eta] | [P = g/cm s] $[kG\ s/m^2 \approx 98{,}1\ P]$ |
| λ | – | linear resistance coefficient [lambda] | |
| ν | – | fluid kinematic viscosity [ny] | $[m^2/s]$ |
| ρ | – | fluid mass density [ro] | $[kg/m^3]$ |
| φ | – | angle of rotation of a rolling wheel (or drop) [fi] | |
| ω | – | angular velocity of a rolling wheel (or drop) [omega] | [1/s] |

Subscripts:

| | | |
|---|---|---|
| cz | – | active, builder of the motion structure |
| gr | – | terminal |
| kr | – | critical |
| max | – | maximal |
| op | – | opposition, destroyer of the motion structure |
| pr | – | threshold |
| śr | – | average |
| w | – | resultant |
| x | – | on parallel direction to the fluid flow direction |
| y | – | transverse to the fluid flow direction |
| C | – | cycloidal |
| L | – | laminar |
| N | – | normal, vertical to the duct axis |

## 3. Initial mathematical relations

An overview of mathematical dependencies is presented below. They will be used further on, when constructing the new cycloidal motion model. The investigated flow is axially-symmetric, spatial solutions will be reduced to planar solutions.

### *3.1. Cycloid*

Cycloids are best known in their parametric form:

$$x = \frac{H}{2}(\varphi - \sin\varphi) \qquad [1\text{-}1]$$

$$y = \frac{H}{2}(1 - \cos\varphi) \qquad [1\text{-}2]$$

where the equation of the circle of the rolling wheel (the axial cross section of a sphere) in the starting point at the beginning of a Cartesian coordinate system

$$x^2 = y(H - y) \qquad [1\text{-}3]$$

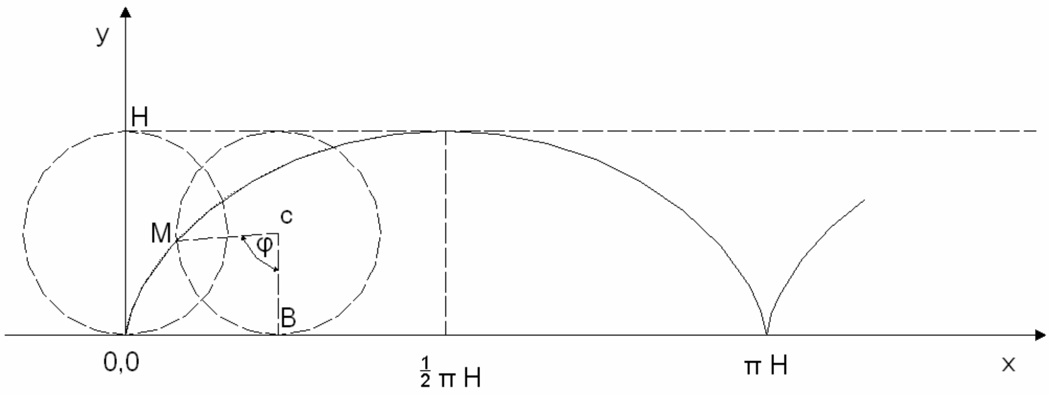


*Fig. 1/1. Cycloidal curve formed by a rolling wheel*

### *3.2. Dynamic cycloid*

A dynamic cycloid is the result of a transformation of a cycloid by placing it in a dynamic coordinate system (x, h), where $0 \leq h \leq H$. A dynamic coordinate system differs from a Cartesian coordinate system (x, y) by the fact that the measure of the ordinate (y-axis) is subject to linear refinement, in proportion to the amount of the mass of fluid involved in the motion (the abscissa (x-axis) remains unchanged), in accordance with the following:

$$y = h \cdot \left[1 + \frac{(H - h)}{H}\right] = H \cdot \left[1 - \frac{(H - h)^2}{H^2}\right] \qquad [1 - 4]$$

Definition of a dynamic cycloid

The term "dynamic cycloid" refers to a cycloid, that has been transformed by placing it in a dynamic coordinate system. In such a system the circle tracing the curve takes the form of a drop, which – rolling in a slide-free motion on a straight line (directrix) traces the dynamic cycloidal curve. A graphical representation of that curve is presented below.

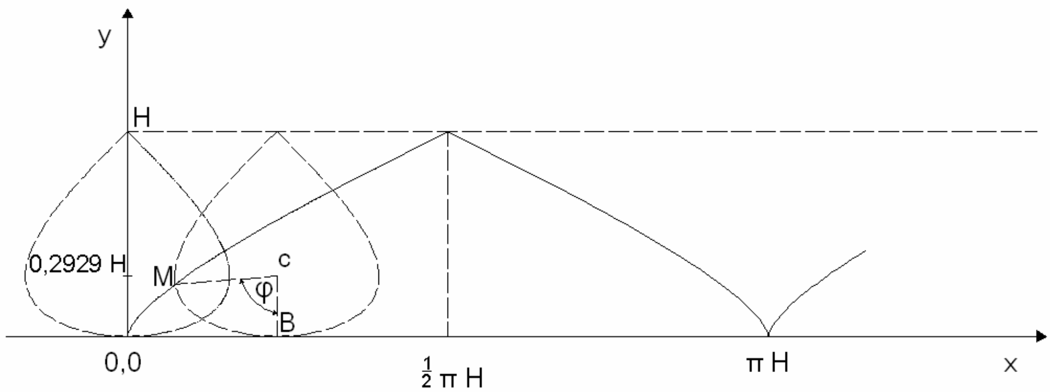


*Fig. 2/1. Dynamic cycloidal curve formed by a rolling drop.*

where the equation of the circumference of the axial cross section of the rolling drop in the starting point at the beginning of a coordinate system.

$$x^2 = y(H-y) = \frac{h}{H^2}(2H-h)(H-h)^2 \qquad [1\text{-}5]$$

$$x = \pm\frac{(H-h)}{H}\sqrt{h(2H-h)} \qquad [1\text{-}6]$$

### *3.3. Dynamic semicycloid*

The term “dynamic semicycloid” refers to a half of an arc of a dynamic cycloid traced by a rolling “drop” only in the area, where it rises over the abscissa (x-axis) - the ascending part of the function in the range 0 to $\pi H/2$.

## 4. Initial physical relations

An overview of physical relations is presented below. They will be used further on, when constructing the new cycloidal motion model.

### *4.1. Fluid as a carrier of the Earth’s gravitational field*

In physics, Galileo (Galileo Galilei 1564-1642) and Newton (Newton, Isaac 1642-1727) are considered to be the forefathers of modern dynamics. It was they who discovered, that the force on an object is determined by its acceleration rather than velocity. The acceleration of an object is the rate at which the velocity changes, or in other words, the rate of changing the rate of position in time. Furthermore, Galileo formulated another principle (principle of relativity), showing inter alia, that Earth’s motion is practically imperceptible for humans [3].

The phenomenon of constant changes in the rate of position in time is present in Newtonian fluids apparently at rest, if affected by gravitational forces. The above means (in accordance with Galileo’s principle of relativity) that the notion of “fluid at rest” makes no physical sense locally. That a space filled with fluid is a kind of an arena of physical events influenced by various organizational fields (invisible to a naked eye), creating “molecular chaos” in fluids at rest.

On Earth, the terrestrial gravitational field arms all fluid molecules with gravitons. Experience shows, that molecules armed with gravitons oscillate (vibrate) constantly. This means, that each vibrating molecule of the analyzed mass of Newtonian fluid (conventionally considered to be at rest) is a carrier of the spatial acceleration parameter $\mathbf{g} \approx 9{,}81\ m/s^2$, which translates to a directional intensity vector $\mathbf{k} = 0{,}5\ g$ and a sense intensity vector $\mathbf{z} = 0{,}25\ g$. This means that external gravitational forces create a force field in the fluid of the intensity $\mathbf{z}$. A substitution of static conditions with dynamic conditions (or fluid dispersion) does not really change that value.

In static conditions, any mass of fluid affected by the Earth’s gravitational field is shapeless. Its external boundaries are determined arbitrarily. These are phase boundaries, on the surface of which the fluid forms monolayers built of densely packed molecules, oriented in space (with the positive charge facing the object with a greater dielectric constant). In other words, a monolayer is a two-dimensional one-molecule thick layer.

### *4.2. Kinematics of motion in solid state physics*

In solid state physics, velocity is the first derivative of displacement with respect to time. Acceleration is the first derivative of velocity with respect to time and the second derivative of displacement with respect to time.

### *4.3. Dynamics of motion in solid state physics*

In solid state physics, work is a measure of energy transmitted between physical systems. It is a product of force and distance, as long as the force and the distance have the same sense and direction, and the force has a constant value.

### *4.4. Friction in solid state physics*

In solid state physics, friction refers to forces that oppose relative motion of two or more objects. These forces are generated on contact surfaces of the objects and are in the opposite direction to the velocity vector.

### *4.5. Cycloid – the curve of fastest descent*

In 1697, brilliant Swiss mathematician and physicist Bernoulli (Bernoulli Johann 1667-1748) asked the following question to his contemporary mathematicians: “Given two points A and B in a vertical plane, what is the curve traced out by a point acted on only by gravity, which starts at A and reaches B in the shortest time?”. He received numerous answers containing equations of the requested curve, but Bernoulli demanded a name for this curve, provided it was known. He received an anonymous letter from England, reading as follows: “The requested curve is a cycloid going through both points”. Having read the letter, Bernoulli exclaimed: “I recognize Newton”. And indeed, it was the ingenious English physicist and mathematician who provided the solution [2].

Remembering this event from the past is important. It not only proves that cycloid is a term known since long among mathematicians. Solid state physicists called the cycloid a brachistochrone (Greek: brachistost – *the shortest*, chronos – *time*). It is the curve between two points that is covered in the least time by a point-like body, under the action of constant gravity. An extrapolation of the above fact on to liquid state physics is presented below.

In order to develop a physical interpretation of cycloid motion, it is necessary to first determine the position of each fluid molecule at any given moment of time **t**, in a Cartesian coordinate system. For a two-dimensional motion it will be determined as follows:

$$x = f_x(t, x_o, y_o) \qquad [1\text{-}7]$$

$$y = f_y(t, x_o, y_o) \qquad [1\text{-}8]$$

where: $f_x$ , $f_y$ refer to constant time functions in a constant scalar field f (x, y).

Time t is a variable. The initial conditions are determined by the following equations: $x = x_0$; $y = y_o$ with $t = t_o$. Having determined the coordinates of any element A in consecutive moments of time t, one will receive the motion trajectory of that element. If one assumes, that the said trajectory defines displacement, then one will obtain a constant function of the components of the velocity vector of each individual element **dm**:

$$V_x = \frac{\partial x(t, x_o, y_o)}{\partial t} \qquad [1\text{-}9]$$

$$V_y = \frac{\partial y(t, x_o, y_o)}{\partial t} \qquad [1\text{-}10]$$

Similarly, components of acceleration:

$$a_x = \frac{\partial^2 x(t, x_o, y_o)}{\partial t^2} \qquad [1\text{-}11]$$

$$a_y = \frac{\partial^2 y(t, x_o, y_o)}{\partial t^2} \qquad [1\text{-}12]$$

For the axially-symmetrical flow under the action of constant gravity the description becomes much simpler, because it allows one to take into consideration lines defined on a plane. For a simple cycloid, the motion trajectory can be defined using the following system of equations:

$$S_x = \frac{H}{2}(\omega t - \sin \omega t) \qquad [1\text{-}13]$$

$$S_y = \frac{H}{2}(1 - \cos \omega t) \qquad [1\text{-}14]$$

Velocity components are defined by the following system of equations:

$$V_x = \omega \frac{H}{2}(1 - \cos \omega t) \qquad [1\text{-}15]$$

$$V_y = \omega \frac{H}{2} \sin \omega t \qquad [1\text{-}16]$$

Acceleration components are defined by the following system of equations:

$$a_x = \omega^2 \frac{H}{2} \sin \omega t \qquad [1\text{-}17]$$

$$a_y = \omega^2 \frac{H}{2} \cos \omega t \qquad [1\text{-}18]$$

In order to determine the physical mechanism of a peaceful, steady and two-dimensional flow of fluid, it is assumed that motion trajectory is determined by a dynamic cycloidal curve, which takes the following form in the constant scalar field f ($S_x$, $S_h$):

$$S_x = \frac{H}{2} \cdot \left\{ \arccos\left[\frac{2(H-h)^2}{H^2} - 1\right] - 2\sqrt{\frac{(H-h)^2}{H^2} \cdot \left[1 - \frac{(H-h)^2}{H^2}\right]} \right\} \qquad [1\text{-}19]$$

$$S_y = y = h \cdot \left[1 + \frac{(H-h)}{H}\right] = H \cdot \left[1 - \frac{(H-h)^2}{H^2}\right] \qquad [1\text{-}20]$$

where:

$$0 \le S_y \le H \qquad 0 \le S_x \le \frac{\pi H}{2} \qquad [1\text{-}21]$$

In cycloidal motion, equations describing the vector velocity field take the following form:

$$V_x = V_{max.x} \left[1 - \frac{(H-h)^2}{H^2}\right] = V_{max.x} \left[\frac{h}{H}\left(2 - \frac{h}{H}\right)\right] \qquad [1\text{-}22]$$

$$V_y = V_{max.y} \sqrt{\frac{(H-h)^2}{H^2}\left[1 - \frac{(H-h)^2}{H^2}\right]} \qquad [1\text{-}23]$$

where: $V_{max.x} = V_{max.y} = V_{max} = \omega H$ [1-24]

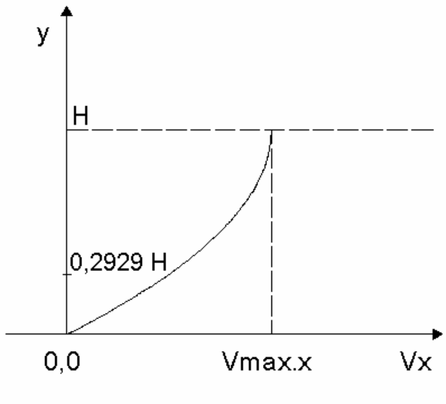


*Fig. 3/1. Distribution of velocity $V_x$ at altitude H*

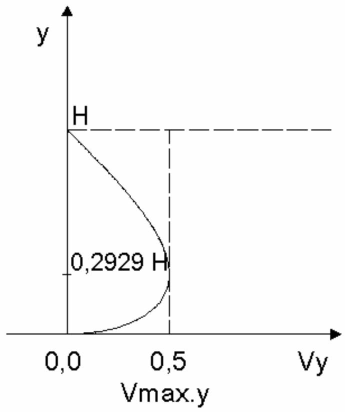


*Fig. 4/1.Distribution of velocity $V_y$ at altitude H*

The resultant vector of the local velocity attains the following value:

$$V_w = V_{max.x}\sqrt{\left[1-\frac{(H-h)^2}{H^2}\right]} = \sqrt{V_x\ V_{max.x}} \qquad [1\text{-}25]$$

Equations describing the vector acceleration field take the following form:

$$a_x = a_{max.x}\left\{2\sqrt{\frac{(H-h)^2}{H^2}\left[1-\frac{(H-h)^2}{H^2}\right]}\right\} = 2\,a_{max.x}\sqrt{\frac{V_x}{V_{max}}\left(1-\frac{V_x}{V_{max}}\right)} \qquad [1\text{-}26]$$

$$a_y = a_{max.y}\left\{1-2\left[1-\frac{(H-h)^2}{H^2}\right]\right\} = a_{max.y}\left[\frac{2(H-h)^2}{H^2}-1\right] = a_{max}\left(1-\frac{2V_x}{V_{max}}\right) \qquad [1\text{-}27]$$

where the resultant vector of local acceleration:

$$a_w = a_{max.x} = a_{max.y} = a_{max} = \omega^2\frac{H}{2} = \frac{V_{max}^2}{2H} \qquad [1\text{-}28]$$

Note: In cycloid motion, the resultant vector of internal acceleration always attains the same value $\mathbf{a_{max.C}}$. This means, that in peaceful flows the flowing mass of fluid creates a homogenous, dynamic field of centripetal accelerations, where each particle (molecule) of the fluid carries the same resultant acceleration vector $\mathbf{a_{max.C}}$. This also means that the said dynamic field of accelerations is identical to the force field of active forces.

Local values of the dynamic field of active forces (molecular forces of motion) are generated in the process of conventional slide-free rolling of drops over each phase border, and their sum is equal to the value of active forces $P_{CZ}$:

$$P_{CZ} = \int_0^m dm\cdot a_{max.C} \qquad [1\text{-}29]$$

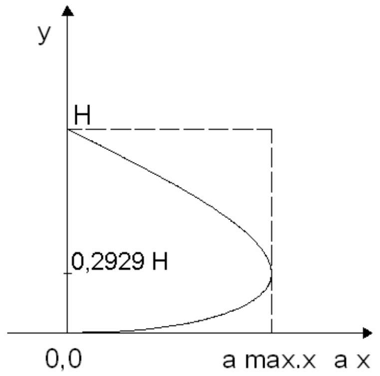


*Fig. 5/1. Distribution of acceleration $a_x$ at altitude H*

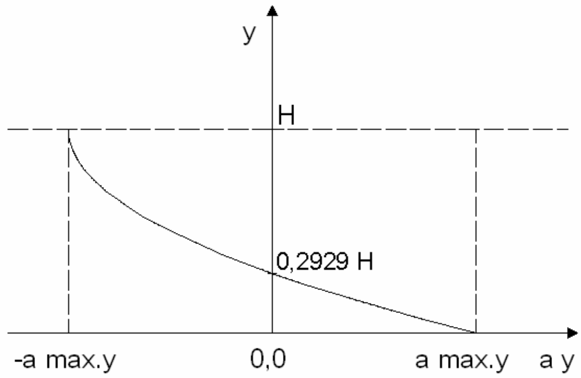


*Fig. 6/1. Distribution of acceleration $a_y$ at altitude H*

## 5. Initial definitions

### *5.1. Peaceful flow*

In what follows, peaceful flow will be discussed. The coinage of a new term into the liquid state physics is purposeful, because it introduces a division of laminar, straight-axis duct flows ($0 \leq Re <$ approx. 2300) on peaceful ($0 < Re \leq 1962$) and no peaceful ($1962 < Re \leq$ approx. 2300). A discussion of the entirety of laminar flows in the new system of the dualism theory would require more than a single paper. Therefore the description of no peaceful and other flows (including turbulent) will be presented in the next papers in the series.

Definition of peaceful flow

The peaceful flow, in a uniform gravitational force field, is a flow that induces – within a homogenous mass of fluid – resistances of cycloidal motion equal to resistances of laminar motion, where active forces (cz) are equal to opposition forces (op), which could be expressed as follows:

$$J = J_{cz} + J_{op} \qquad \text{where} \quad J_{cz} = J_{op} \qquad [1\text{-}30]$$

$$P = P_{cz} + P_{op} \qquad \text{where} \quad P_{cz} = P_{op} \qquad [1\text{-}31]$$

### *5.2.Linear resistance of flow*

The object of the following analysis is linear resistance of peaceful flows of Newtonian fluid. The definition of this resistance is well known. First introduced in 1856 by Darcy (Darcy, Henry Philibert Gaspard 1803 – 1858), it was subsequently transformed into a formula known as the Darcy – Weisbach equation (Weisbach, Julius Ludwig 1806 – 1871)

$$J = \lambda \frac{1}{2H} \frac{V_{śr}^2}{2g} \qquad [1\text{-}32]$$

The original version of Darcy's formula was as follows [4]:

„With a steady turbulent flow of real fluids through straight-axis, circular cross-section ducts, head losses are directly proportional to the square of mean velocity of the flow and the length of the duct, and inversely proportional to the diameter of the duct; furthermore, head losses depend on a certain value, referred to as linear resistance of flow **λ**".

The above formula was subsequently extended by Darcy's followers to include the whole range of flows, and the coefficient **λ** became subject to analyses of many researchers, such as

Moody (Moody, Lewis Ferry 1880 – 1953), Blasius (Blasius, Paul Richard Heinrich 1883 – 1970), Nikuradse (Nikuradse, Johannes 1894 – 1979) and others. The said analyses resulted in a single theoretical formula, introduced on the basis of Poiseuille's physical model (see below). Taking a step further, the said formula was derived on the basis of Newton's classical internal friction hypothesis, expressed as follows:

$$dP_N = \eta \frac{dV}{d(H - h)} dF \qquad [1-33]$$

The formula of the coefficient **λ** derived theoretically on the basis of Newton's hypothesis from Darcy – Weisbach formula (for an indefinitely high number of layers, where Σh = H), has so far proven true only with regard to steady peaceful flows of Newtonian fluids ($0 < Re \leq 1962$) through straight-axis ducts of a circular cross-section in a uniform gravitational force field. For other kinds of flows, the value of the coefficient **λ** is determined empirically.

**6. Classical laminar flow theory**

Since long, Newton's classical internal friction theory and Poiseuille's mathematical-physical model have provided a basis for theoretical interpretation of parametric dependencies of laminar flow. An overview of these dependencies is presented below [4]:

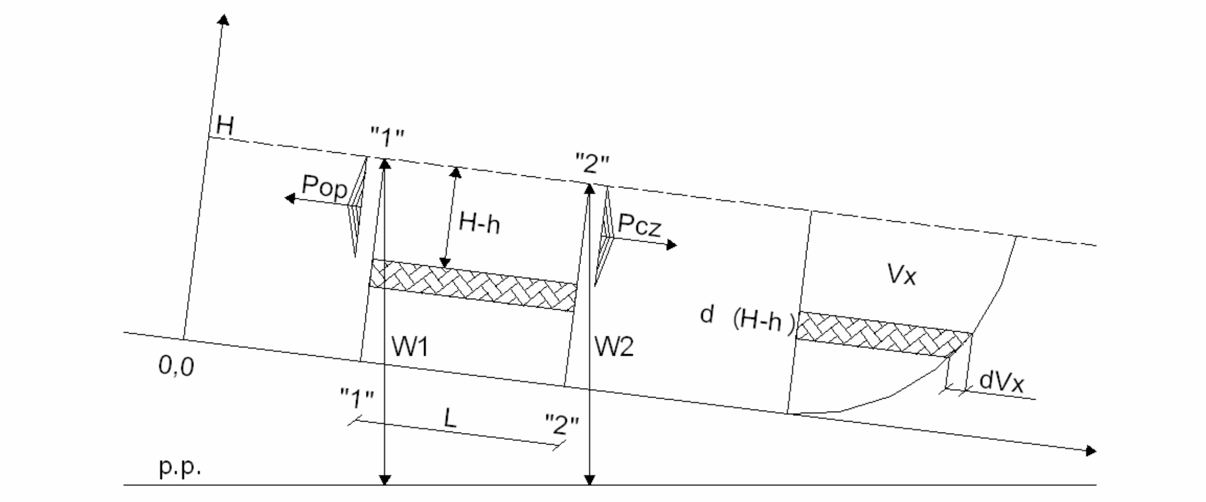


*Fig. 7/1. Distribution of flow forces and velocities*

Active forces are measured by the value of the component of the gravity force along the axis of the duct:

$$P_{cz} = \text{(gravity) x (energy line slope)} = \pi L (H - h)^2 \gamma J \omega H \qquad [1-34]$$

where:

$$J = \frac{1}{L}\left[\left(W_1 + \frac{p_1}{\gamma}\right) - \left(W_2 + \frac{p_2}{\gamma}\right)\right] \qquad [1-35]$$

Opposition forces result from fluid viscosity and are opposite to active forces:

$$P_{op} = -2\pi(H - h) L \eta \frac{dV_X}{d(H - h)} \qquad [1-36]$$

When the values $P_{cz}$ and $P_{op}$ are added, one arrives at the following classical equation:

$$\pi L (H - h)^2 \gamma J + 2\pi(H - h) L \eta \frac{d V_X}{d(H - h)} = 0 \qquad [1-37]$$

When discussing fluid motion, it is more convenient to use the fluid kinematic viscosity **ν**, rather than the fluid dynamic viscosity **η**, whose dependency is expressed as follows:

$$\nu = \frac{\eta}{\rho} \qquad [1-38]$$

After an integration of both sides of this classical dependency:

$$V_x = -\frac{g\,J}{4\nu}(H-h)^2 + C \qquad [1-39]$$

$$\text{dla: } h = 0; \quad V_x = 0; \quad C = \frac{g\,J}{4\nu} H^2 \qquad [1-40]$$

$$V_x = \frac{g\,J\,H^2}{4\nu}\left[1 - \frac{(H-h)^2}{H^2}\right] \qquad [1-41]$$

$$V_{max} = \frac{g\,J\,H^2}{4\nu} \qquad [1-42]$$

Mean velocity (vertical distribution of velocity in a tube is described by a parabola)

$$V_{śr} = \frac{1}{2} V_{max} = \frac{g\,J\,H^2}{8\nu} \qquad [1-43]$$

Reynolds number:

$$Re = \frac{2\,V_{śr}\,H}{\nu} = \frac{2\,V_{max}\,R_h}{\nu} \qquad [1-44]$$

The resultant coefficient of linear resistance of flow (Darcy – Weisbach formula):

$$\lambda = \frac{64}{Re} \qquad [1-45]$$

### *6.1. Comments on the classical laminar flow theory*

A critical review of Poiseuille's model and its mathematical description discloses some "paradoxes" embedded into it, i.e. embedded assumptions which – although contradicting the reality – lead to conclusions supported by experience.

One of them is the fact that classical modeling was based on the phenomenon of phase boundary roughness, which is not reflected in the mathematical description of the phenomenon. This means, that mathematical description of the model takes into account only relatively small friction forces within the stream of fluid, resulting of the fact of relative sliding of the laminas inside the mass homogenous fluid, simultaneously ignoring the high resistance on the rough side surface (on the phase boundary, on the duct's wall), despite the fact, the high resistance on the model wall the flow exist, irrespectively of the wall's "slipperiness".

Another paradox is the fact, that in solid state physics slide friction depends on the pressure force acting perpendicular to the direction of the friction. The pressure force is not determined in Newton's hypothesis. It is simply not there.

The above indicates that the classical model is incomplete. On the other hand one should remember, that dependencies derived from it are unquestionable, because they have been confirmed empirically. Thus, one can use them to search for model supplements, rather than model changes. Such a development, consisting of introduction of cycloidal motion to the model, is presented below.

**7. The structure of peaceful flow in a new interpretation**

The dynamic structure of peaceful flow is created as a result of transformation of external force into internal forces of motion, forming progressive motion of a fluid mass and motions its individual particles. The shape of the structure created in this way is determined by the shape of vector fields of forces (accelerations) and linear momentum (progressive velocities), each considered separately. In the analyzed case, the structure of velocity field of translational motion is generally known. It takes the form of the paraboloid and is identical both in Poiseuille's classical model and in the new cycloidal motion model.

The shape of the structure of the force field, forming the paraboloid structure of the velocity field of progressive motion has not been described so far. Friction forces caused by relative movement of laminas, resulting from Newton's hypothesis, do not create such a structure. They are merely a measureable effect of the interaction of a not-yet-determined force field. Assuming, that the same rights apply to both, solid and liquid state physics, a conclusion may be drawn, that Newton's hypothesis and Poiseuille's classical laminar flow model based on it must be supplemented by pressure forces causing friction within the fluid, acting transverse to the lines of momentum of each lamina (in the analyzed case – perpendicular to the axis of the flow).

Forces perpendicular to the direction of momentums are a novelty in fluid mechanics. They cannot be found neither in Newton's hypothesis, nor in differential equations of Navier-Stokes. They can only be found in the mathematical-physical description of the new cycloidal motion model. The trouble is, that these forces appear only on the wall of the duct and in its axis. They do not permeate the entire mass of the fluid in motion and in general they do not belong in Poiseuille's model. We cannot find these forces until a statement of fact, that in the new model the transfer of forces is possible only follows a dynamic semicycloid, not a full cycloid line, transverse forces are released in the fluid. This fact constitute the missing element of Poiseuille's model, as will be presented in detail below.

Despite the fact, that in the cycloidal motion model the direction of forces is different from the perpendicular direction (with the exception of forces on the duct's wall and axis), in both models these forces generate the same effect of sliding friction between laminas. The foregoing results from the definition of friction forces which are opposite to the velocity Vx of progressive motion which field shape – as shown above – is exactly the same (parabolic) in both models.

Therefore, in the analyzed case one deals with interpenetration of two structures of field of forces (accelerations), which jointly form a paraboloidal structure of the field of momentum (progressive velocities) of progressive motion. This implies full separation of the force field of motion from the momentum field generating fluid flow, even though momentum and force fields together form the joint vector field.

The above does not mean that molecular forces creating field forces (fluid molecules, each armed with a unit of directional acceleration of motion) do not create motion. That would contradict Newton's laws (but not the hypothesis). In the analyzed case these forces create oscillatory motion of molecules. This motion is not accidental. It is a two-directional oscillation, one way along the lines of the dynamic semicycloid and second way along the lines that are perpendicular to direction lines of motion. The said oscillation is superimposed on the "molecular chaos" of the gravity field. The relationship between the vector of unitary directional acceleration of motion, denoted as $\mathbf{a}_{\mathbf{max}}$, and the vector of directional gravitational acceleration, denoted as **z**, is discussed below as well.

The oscillation on the duct's wall and in its axis is highly specific. It is a unidirectional oscillation. This specific nature determines the fact, that in the analyzed case it is the wall and the axis that constitute the boundary of the dynamic vector field of motion.

### *7.1. Directional oscillatory motion*

Before proceeding with further deliberations, it is worthwhile to once again take a look at the trajectory of oscillatory motion, determined in the cycloidal model by the dynamic cycloid which – look at equations [1-19] and [1-20] – takes the following form in a continuous scalar field in a rectangular coordinate system f ($S_x$, $S_y$):

$$S_x = \frac{H}{2} \cdot \left\{ \arccos\left[ \frac{2(H-h)^2}{H^2} - 1 \right] - 2\sqrt{\frac{(H-h)^2}{H^2} \cdot \left[ 1 - \frac{(H-h)^2}{H^2} \right]} \right\}$$

$$S_y = y$$

If the parameter H denotes the distance between the wall and the axis of a duct of a circular cross-section, then it is easy to notice that a full motion along the arc of the cycloid is impossible. The only possible motion is semicycloid, on the path from the wall to the axis, i.e. a motion that stays within the following limits - look at equation [1-21]:

$$0 \le S_y \le H \qquad\qquad 0 \le S_x \le \frac{\pi H}{2}$$

The above results from mathematical rules, and specifically from the fact, that determinability of the arcus cosine function is possible only within the range [0, πH], as a result of which the determinability of the $\mathbf{S_x}$ function is limited to the range [0, πH/2].

A similar situation is encountered on the opposite side of the duct's axis. Since the discussed type of motion is fully symmetric in relation to the axis (an axially-symmetric flow), then such an interpretation will lead to a conclusion that super-concentration of oscillatory motion and formed it forces have arisen on the axis of the duct. This super-concentration blocks the said motion and causes a destruction of the cycloidal motion structure (or semicycloidal, in this case). The foregoing has not been observed empirically, which means that Nature knows how to launch a mechanism of discharging such super-concentration. The Nature creates specific mechanism of transverse oscillatory motion, perpendicular to the directional lines of momentum, transverse penetrating through the entire mass of the fluid in motion. Transverse forces causing this motion are the missing element of Poiseuille's model.

And this is the space for the birth of the new dualism theory. This theory assumes, the Newtonian (viscous) fluid in motion create 2 force fields; an active forces field and a opposition forces field. Their intensity is determined by the value of the characteristic vector of unit directional acceleration $\mathbf{a_{max}}$, being the sum of two unit acceleration vectors of oscillatory motion:

– semicycloidal $a_{max.C}$
– laminar $a_{max.L}$
– where; $a_{max} = a_{max.C} + a_{max.L} = 2\, a_{max.C} = 2\, a_{max.L}$. [1-46]

Conventionally, the vector $\mathbf{a_{max.C}}$ draws the path of "ascent" in the mass of the fluid in motion, following the arch of dynamic cycloid in the range [$0 \le \mathbf{S_h} \le H$, $0 \le \mathbf{S_x} \le \pi H/2$]. It is a carrier (quantum) of energy within the fluid, transformed from the forces of external influences. It creates a dynamic force field of cycloidal motion, whose intensity is determined by the value of the vector of unit active force $\mathbf{dP_{cz}}$ = dm $a_{max.C}$.

In its turn, the vector $\mathbf{a_{max.L}}$ draws the path of "descent" in the mass of the fluid in motion, following the line perpendicular to the axis of the duct, in the direction of the flow, in the range [$0 \le \mathbf{S_h} \le H$, $\mathbf{S_x} = 0$]. In this way, it generates a dynamic force field of laminar motion, whose intensity is determined by the value of the vector of unit opposition force $\mathbf{dP_{op}}$ = dm $a_{max.L}$.

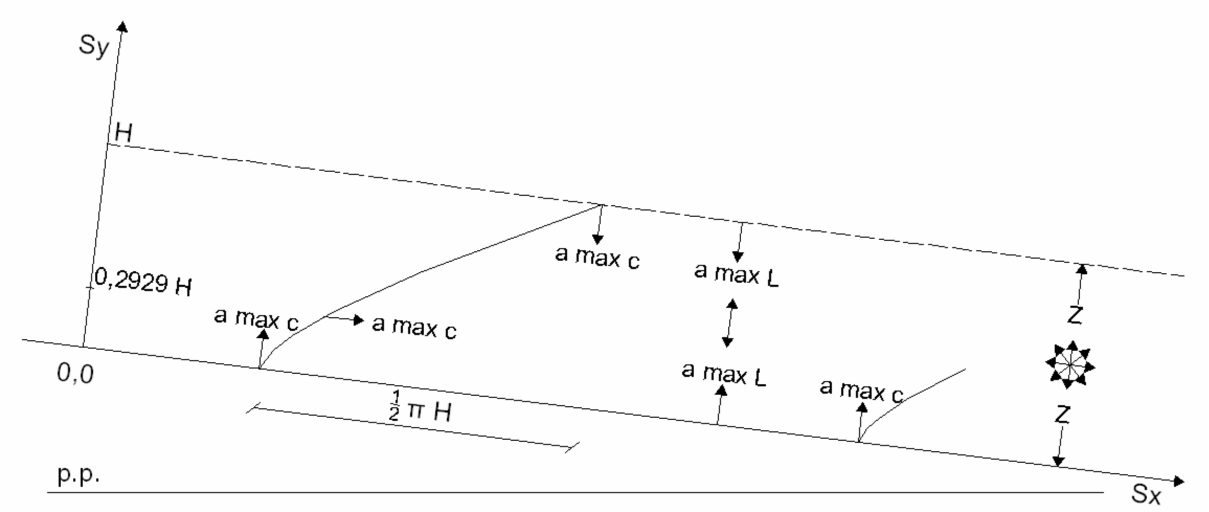


*Fig. 8/1. Structure of field of forces (accelerations) in axially-symmetric peaceful flow*

### *7.2. Dualism theory of Newtonian fluid flows*

The new theory of cycloid-laminar dualism suggests, the dynamic motion restores order to "molecular chaos" in fluids by the creation motion structures. The theory also talks about external forces that cause the flow and discovers (importantly) internal forces created as a result of external influences. One particular novelty is transverse forces (perpendicular to the axis). Thus far they have not been addressed in theoretical deliberations despite the fact that the transverse oscillatory motion in the dynamic force field of the fluid (being the result of the said transverse forces) has been known to practitioners since long.

In the approach proposed by the dualism theory, the transverse motion is the result of the migration of the molecular force of fluid $\mathbf{dP_{cz}}$ on the path from the wall to the axis of the duct, following a semicycloid (a half of a dynamic cycloid) and the return of the force $\mathbf{dP_{op}}$ on the path from the axis to the wall, perpendicularly to the directional line of the momentum. Since the said migration takes place in Newtonian (viscous) fluid environment, it is accompanied by motion energy losses related to flow resistance. In the analyzed case, in a homogenous environment with the omnipresent vector $\mathbf{a_{max}}$ ascending motion resistances are equal to return motion resistances. The ascending motion is cycloidal, the descending motion is transverse (perpendicular to the directional line of the momentum).

The new theory proposes an alternative into the phenomenological approach of describing the transport of fluids. This is a microstructural approach, consisting in the deductive analysis of each fluid molecule flow. This is difficult because the structure of the fluid in motion is unstable. Everything that is built with active force $\mathbf{dP_{cz}}$ is immediately destroyed with the opposition force $\mathbf{dP_{op}}$.

### *7.3. Binary physical state of fluid molecules*

The new theory of cycloid-laminar dualism talks about a binary physical state of the molecules of the fluid in motion, which in a micro-scale means that the molecule either directs its oscillatory motion, or oscillates in a chaotic way. In a micro-scale, pulling individual molecules from the state of "molecular chaos" in the fluid and embedding them in the structure of motion is not gradual, but abrupt (discrete). This means that there exists a threshold molecular force $\mathbf{dP_{pr}}$, which causes this abrupt change. The said force is the product of the molecule's mass dm and the threshold directional acceleration $\mathbf{a_{max.pr}}$. Below it will be demonstrated that $a_{max.pr} = 0{,}25$ g.

In a macro-scale, individual physical states of individual molecules are not phenomenologically measurable, because the fluid (as a physical body), consists of an indefinitely great amount of molecules of the mass dm, creating a continuum that fills in a certain enclosed area of the mass m. Each change of this kind is fractional, and the participation of molecules creating the structure is determined by the coefficient **U** of the state of the structure of the fluid in motion, where $0 \leq U \leq 1$. In a macro-scale, these changes remain invisible even if the value U is close to one. This results from the fact that the ensemble of molecules in a fluid is not a classical ensemble, but its range (it has only two values: 0 and 1) and is devoid of the measure of an random event.

Therefore, for the purposes of further deliberations the coefficient **U** has been considered to be a substitute measure, allowing one to transfer phenomenologically non-measurable events from the micro-scale to the macro-scale. As a result, the notion of unit acceleration of oscillatory motion gains a substitute definition, expressed by means of the following relations:

– $a_{max.C} = U\, a_{max.pr}$ [1-47]

– $a_{max.L} = U\, a_{max.pr}$ [1-48]

where $a_{max} = 2\, U\, a_{max.pr}$ [1-49]

### *7.4. Basis for modeling the structure of peaceful flow of Newtonian fluids*

It has been assumed that the fluid, as a physical body, consists of an indefinitely great amount of point particles (molecules) of the mass **dm**, creating a continuum that perfectly fills in a certain enclosed area (phase space). From this assumption it follows that:

1. In Earth's conditions the entirety of the analyzed mass of fluid is always a carrier of the terrestrial gravitational field, whose value is determined by the spatial scalar **g** ≈ 9,81 m/s$^2$ and the vector of reverse intensity of the gravitational field **z** = 0,25 g. In static conditions the said mass is filled by "molecular chaos". Only the mass' boundary is created by a directionally arranged monolayer of the intensity z = 0,25 g.
2. In dynamic conditions, the "molecular chaos" of the static gravitational field is gradually systematized by means of the field of forces (accelerations) of a strictly determined structure. This systematization consists in directing the oscillatory motion of an increasing number of fluid molecules, growing in line with the growth of the dynamics of the flow. In this way the structure of the field of forces (accelerations) and its derivative in the form of a field of momentum (translational motion velocity) is created.
3. The linear momentum of a point particle (molecule) of the fluid is the product of its mass **dm** and the progressive motion velocity $\mathbf{V_x}$. The direction and the sense of the momentum matches the direction and the sense of the velocity $V_x$. In the analyzed case, the field of momentum takes the shape of a paraboloid, and in the longitudinal profile of the flow – the shape of a parabola.
4. The active force of the point particle (molecule) of the fluid $\mathbf{dP_{cz}}$ is the product of its mass **dm** and the directional acceleration $\mathbf{a_{max.C}}$. The force of opposition $\mathbf{dP_{op}}$ is the product of its mass **dm** and the directional acceleration $\mathbf{a_{max.L}}$, where $a_{max.C} = a_{max.L}$. In a longitudinal axial profile, the joint flow directional transfer route lines of molecular forces take a sawtooth shape, where the face of each tooth is profiled perpendicularly to the directional lines of the momentum. The sense of the active forces is partially centripetal, partially matching the sense of the momentum, and never opposite to the momentum. The sense of the forces of opposition is always centripetal and perpendicular.
5. In the range of peaceful flows, both forces (active and opposition) are equal. Their effects manifest themselves by the directional oscillatory motion of individual fluid molecules which – within the mass of the fluid – become carriers of energy provided from the outside. Oscillatory motion is visible experimentally, the flow of forces is not shown in the flow, because everything that is built with active force $\mathbf{dP_{cz}}$ is immediately destroyed with the opposition force $\mathbf{dP_{op}}$.

6. The progressive motion of the fluid is created due to the surplus of the work of “ascent” over the work of “descent”. This results from the fact that the path of “ascent” along the arch of the dynamic semicycloid (using the active force) is longer than the path of “descent” perpendicularly to the axis of the duct and the direction of the flow (using the force of opposition).
7. In a micro-scale (molecular-scale) the process of systematization of the oscillatory motion of individual molecules is not gradual, but abrupt (discrete), although in a macro-scale the process of pulling individual molecules from the state of “molecular chaos” in the fluid is not experimentally visible.
8. In the dynamic structure of peaceful flow of Newtonian fluids the momentum field is separated from the forces field, even though both fields overlap, creating one joint vector field.
9. The structure of the field of momentum and the structure of internal friction forces are derivatives of the structure of the force field.
10. The boundary of the dynamic vector field of the motion are determined by the wall and the axis of the duct.

If the convex phase space of the fluid is filled with homogenous point particles (molecules), then the basic values used to describe the dynamic phenomena taking place within it are the overlapping vectors of dynamic directional acceleration $\mathbf{a_{max}}$ and longitudinal velocity $\mathbf{V_x}$, which may be represented graphically by means of arrows.

In the proposed mathematical-physical model, the description of the evolution of the convex phase space, irrespectively of its complexity, has been reduced to the description of the motion of a single point of that space in the direction determined by the encountered arrows of the velocity vector (the first temporal derivative of the changes to the shape of the phase space), in the force field determined by the encountered arrows of the acceleration vector (the second temporal derivative of the changes to the shape of the phase space).

**8. Links between the classical laminar motion theory and the new cycloidal motion theory**

Physical dependencies in semicycloidal and transverse motion imply that on the side surface there appears normal (i.e. directed perpendicularly from the side surface to the interior of the fluid mass) dynamic, centripetal pressure, induced by the fluid motion. The said pressure is created by unit centripetal forces, which:

- have not been defined thus far
- the sense is directed centripetally (away from the wall), as a result of it there are no forces exerting pressure on the wall which remains “perfectly smooth”.

***8.1. Transformation of dependencies of Newton’s internal friction hypothesis***

In accordance with the accepted basis of modeling a steady peaceful flow of fluids, unit forces of motion resistances are in proportion to unit centripetal forces $\mathbf{dP_N}$, which means that they have already been defined by one of Newton’s dependencies, which – for a single layer of the thickness H – is expressed with the following formula:

$$dP_N = \eta \, \frac{V_{max}}{H} \, dF \qquad [1\text{-}50]$$

The above definition is similar to the definition shown in equation [1-33]. That is still the Newton’s definition, but so formulated, that is no longer fit to build the model laminar flows.

The above definition may be formulated in an engineer’s unit system. As a rule, contemporary physics uses SI units. Having made transformations from the engineer’s units system (kilogram-force – **kG**) to the SI system (kilogram-mass – **kg**), the resultant dependencies of Newton’s internal friction hypothesis take the following form:

$$dP = dP_N \frac{a_{max}}{g} \frac{dm}{dm} = dP_N \frac{a_{max}}{g} = \eta \frac{V_{max}}{H} dF \frac{a_{max}}{g} \qquad [1\text{-}51]$$

The above dependency allows one to modify Newton's internal friction hypothesis, which – in his own words – can be formulated as follows [4]:

"*The* flow *resistance which arises from the lack of slipperiness of the parts of the liquid, other things being equal is,* in the Earth's gravitational field, *proportional to the velocity with which the parts of the liquid are separated from one another* and the intensity of force field created inside the liquid in motion"

A modification of Newton's internal friction hypothesis lends credibility to the classical theory of laminar motion. It introduces to the analysis a force that is perpendicular to the direction of the displacement of laminas. Thus, it makes the definition of sliding friction in the fluid closer to the definition of sliding friction forces known from solid state physics. From this moment on, both in fluid state physics (fluid mechanics) and in solid state physics the sliding friction forces depend on the friction coefficient and normal pressure force. The above becomes a contribution to the general theory of friction and lubrication, pointing to mechanisms of origin of friction forces.

### *8.2. The description of the peaceful flow vector field*

The extension of Newton's internal friction hypothesis allows one to analyze parametric dependencies in semicycloidal oscillatory motion. For comparative purposes, the said analysis has been made in the same order as presented above, in the laminar motion analysis.

– mean velocity adopted from the classical deliberations (vertical distribution of velocity in a tube is described by a parabola) - look at equation [1-43]:

$$V_{śr} = \frac{Q}{\pi H^2} = \frac{1}{2} V_{max} = \frac{g J H^2}{8 \nu}$$

– characteristic relations of the dynamic vector field:

$$V_{max} = 2 \omega \frac{H}{2} = 2 V_{śr} = \frac{g J H^2}{4 \nu} \qquad [1\text{-}52]$$

$$\omega = \frac{V_{max}}{H} = \frac{2 V_{śr}}{H} = \frac{g J H}{4 \nu} \qquad [1\text{-}53]$$

$$a_{max} = \omega^2 \frac{H}{2} = \frac{V_{max}^2}{2 H} = \frac{2 V_{śr}^2}{H} = \frac{g^2 J^2 H^3}{32 \nu^2} \qquad [1\text{-}54]$$

### *8.3. Parametric dependencies resulting from the analysis of semicycloidal motion*

The extension of Newton's internal friction hypothesis allows one to analyze parametric dependencies in semicycloidal oscillatory motion. For comparative purposes, the said analysis has been made in the same order as presented above, in the laminar motion analysis.

The resultant of active forces of semicycloidal motion (in accordance with Newton's second law of motion):

$$P_{cz} = \text{(mass) x (vector field intensity)} = \pi \rho L H^2 a_{max} \qquad [1\text{-}55]$$

The resultant of opposition forces (resulting from viscosity, opposite to the resultant of active forces of semicycloidal motion (in accordance with Newton's updated internal friction hypothesis):

$$P_{OP} = -2 \pi H L \eta \frac{V_{max}}{H} \frac{10 a_{max}}{g} \qquad \text{where: } \eta \left[ \frac{kG \cdot s}{m^2} = \frac{98{,}1 g}{s \cdot cm} \right] \qquad [1\text{-}56]$$

When the values $P_{cz}$ and $P_{op}$ are summed, the following classical equations are obtained:

$$\pi \rho L H^2 a_{max} = 2 \pi H L \eta \frac{V_{max}}{H} \frac{10 \ a_{max}}{g} \qquad [1\text{-}57]$$

$$\pi \rho L H^2 \frac{V_{max}^2}{2H} = 2 \pi H L \eta \frac{V_{max}}{H} \frac{10 \ a_{max}}{g} \qquad [1\text{-}58]$$

$$\frac{2 V_{max} R_h}{\nu} = 1962 \frac{a_{max}}{g/2} = 1962 \frac{U \cdot a_{max.pr}}{g/4} \qquad [1\text{-}59]$$

$$Re = 1962 \frac{a_{max}}{g/2} = 1962 \frac{U \cdot a_{max.pr}}{g/4} = 1962 \ U \qquad [1\text{-}60]$$

## 9. Definition of threshold Reynolds number

The notion of Reynolds threshold number $\mathbf{Re_{pr}}$ is understood as a characteristic value of Newtonian fluid flows which separates peaceful flows from no peaceful flows (both flows being laminar). It is a new value which is assumed to function in the same way as other characteristic values of this kind, such as:

- boundary Reynolds number $Re_{gr}$, separating laminar flows from turbulent flows
- critical Reynolds number $Re_{kr}$, separating supercritical flows from subcritical flows.

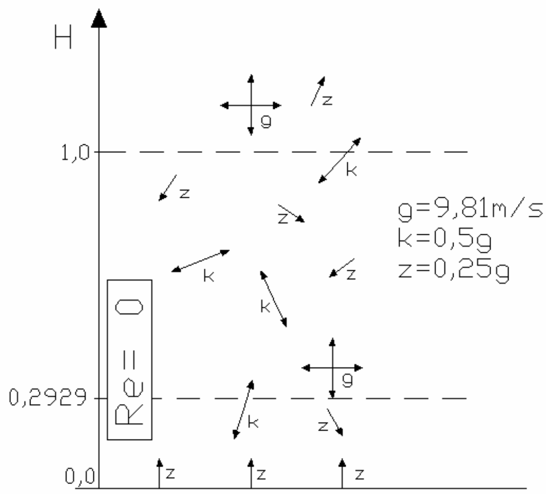


*Fig.9/1. Static state*
*Molecular chaos*

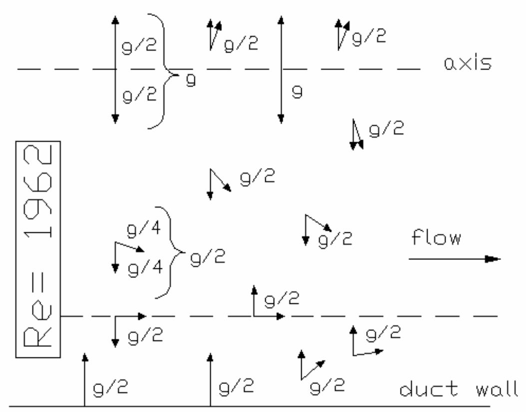


*Fig. 10/1. Dynamic state*
*Full structure of motion*

Definition of threshold Reynolds number $\mathbf{Re_{pr}}$

The threshold Reynolds number refers to the characteristic number used to describe of the dynamics Newtonian fluid flows. It is a value at which the fluid attains full “molecular order”, and the state **U** of the fluid’s structure takes the value U = 1,0.

In the analyzed case of steady, an axially-symmetric peaceful flow of homogenous Newtonian fluid through a straight-axis duct of a circular cross-section under the action of constant gravity, the intensity of the dynamic, centripetally directed vector field ($\mathbf{a_{max}}$) achieves a double the value of the natural terrestrial gravitational field, which can be expressed as follows:

$$\text{dla:} \quad a_{max.} = 2 a_{max.pr} = 0{,}5 \ g = 2 \ z \qquad [1\text{-}61]$$

$$Re_{pr} = 1962 \qquad \text{gdzie}: Re_{pr} \neq Re_{gr} \ ; \quad Re_{pr} \neq Re_{kr} \qquad [1\text{-}62]$$

**10. Summary and conclusions**

1. The subject of this article is an axially-symmetric peaceful flow of homogenous Newtonian fluid, over a straight-axis duct of a circular pipe, in a homogeneous gravitational field of natural forces. This flow is caused by the external forces, which are transformed into 2 kinds of internal forces; internal active force, the builder of internal motion structure and internal opposition force, the destroyer of internal motion structure, previously built by internal active force.
2. Internal forces are ordered. Inside the fluid mass in motion, these forces are developing the internal structure of molecular motion. This structure can be modeled, visualized, and theoretically described in mathematic formulas. To do this, the new theory was introduced to fluid state physics (fluid mechanics). The theory suggests, that Newtonian fluid flows are dual in character. The dual character of the flow allows one to describe selected features of flows by means of the cycloidal (semicycloidal) motion theory, and others by means of the amended laminar motion theory.
3. The review of actual achievements of fluid mechanics [1] and the innovative analysis of kinematics cycloidal motion are the inspiration for the new theory of cycloid-laminar dualism of Newtonian fluid flows. The highlight of this new theory is the transformation of dependencies of Newton's internal friction hypothesis.
4. In the light of the new dualism theory, the structure of flow created by 2 organizational fields: force field of cycloidal motion (field of active forces) and force field of laminar motion (field of opposition forces). The intensity of both fields are equal which is expressed in relation $\mathbf{a}_{\mathbf{max.C}} = \mathbf{a}_{\mathbf{max.L}}$. With this arrangement, the structures of force fields are unstable. Everything built by active forces is immediately destroyed by the opposition forces. The only stable and measurable result of motion is the structure of the momentum field (velocities), a derivative of the structure of the field force with respect to time.
5. Modeling of force fields was based on 2 physical models of motion; cycloidal and laminar. The route of forces transfer in the cycloidal motion model is longer, than the transfer route of the same forces in the laminar motion model. This means, the work (work = force x distance) taking place in the force field of cycloidal motion is greater than the work taking place in the force field of laminar motion. The result from the above difference is the phenomenon of progressive form of fluid flow.
6. In an axially-symmetric peaceful flow through a circular pipe, the visualization of the unstable structure of force motion fields allows to show the direction lines and sense arrows of the field forces (accelerations).

   In a transverse section, this is the perpendicular plane to the line directions of momentum, fully covered with molecules performing oscillatory motion with equal intensity $\mathbf{a}_{\mathbf{max}}$. This motion is orderly, which is graphically illustrated by the sense arrows on the force directional lines. The arrows denoting the sense of the active forces are partially centripetal, and partially match the sense of the momentum. The arrows denoting the sense of the opposition forces are always centripetal, perpendicular to the line direction of momentum.

   In an axial longitudinal profile, the joint flow directional transfer route lines of molecular forces takes a sawtooth shape, where the face of each tooth is profiled perpendicularly to the directional lines of the momentum.
7. In an axially-symmetric peaceful flow through a circular pipe, the visualization of stable structure of velocities field is well known, because the distribution of progressive velocities is fully measurable. This structure (in a steady flow) is a derivative of the

structure of the field force, with respect to time. Directions of the field lines are parallel to the axis of the duct. In an axial longitudinal profile, the velocity distribution is parabolic.

8. The structure of internal friction forces (in a steady flow) is also a derivative of the structure of the field force. Directions of these forces are parallel to the direction of the momentum. Their sense arrows are on the contrary the sense arrow of momentum.
9. The resistance internal flow (internal friction forces) results mostly from Newtonian fluid viscosity. The viscosity suppresses the oscillatory motion of molecules triggered by both; active forces (cycloidal motion field) and opposition forces (laminar motion field). In the laminar motion the fluid viscosity provokes an additional friction between sliding relative to each other laminas.
10. The growth in the resultant flow resistance is directly proportional to the participation of molecules covered by the motion structure. The said participation is defined by the coefficient **U** of the state of fluid in motion structure, where $0 \leq U \leq 1$. The molecules outside the motion structure create the "molecular chaos", typical for static fluids. This participation of "molecular chaos" decreases as the fluid motion dynamics grows.
11. A half of the structure of a peaceful flow is created by "new molecular bricks", representing molecular motion active forces $\mathbf{dP_{cz}}$. The other half is created by gravitons, applied to proper molecules, constituting "regain molecular bricks" of the Earth's gravitational field. Once they are arranged in order, they change on the molecular opposition forces of motion $\mathbf{dP_{op}}$.
12. On the walls and in the axis of the duct the arrows of the field force intensity are always centripental. In this way, the fluid in motion separates its dynamic vector field from its surrounding by means of a liquid boundary, being one of the elements of the flow structure. The boundary structure is similar to the structure of a static monolayer of the fluid.
13. The new dualism theory introduced supplements into the Newton's internal friction hypothesis, which:
    - directly indicate, the existence of fluid motion force field, which is described by the characteristic vector of the intensity $\mathbf{a_{max}}$, indirectly indicate, the existence of perpendicular pressure forces to the direction of the momentum, which provoke the friction between sliding relative to each other laminas
    - suggest, that in case of the lack of gravitational force, the laminar flows do not occur, and all flows have the structure of turbulent flows - nowadays this suggestion has not found an experimental confirmation.
14. The article introduces a new notion of threshold Reynolds number $\mathbf{Re_{pr} = 1962}$, which separates peaceful flows from no peaceful flows (both flows are laminar). In the case of a threshold flow the share of molecules covered by the motion structure is 100% (**U** = **1**). All gravitons of the mass of the fluid in motion are fully covered the motion structure and converted to directional acceleration vectors of laminar motion $\mathbf{a_{max.L}}$ = **0,25 g**.
15. The new dualism theory confirms theoretically known phenomenon, that in the quiet flow of the internal friction grow in proportion to the average flow velocity. The classic description expresses it in direct relation $J = f(V_{śr})$. The new description of cykloidal motion expresses it indirectly, that the force of internal friction grows in proportion to fluid structure state coefficient value $J = f(U)$.

## 11. Issues to address in Paper 2

Paper 2 will contain more new informations about the possibilities of the theory on cycloid-laminar dualism of Newtonian fluid flows. Emphasis in this case will be placed on no peaceful flows, more complex in their structure, than peaceful flows discussed above. The sophistication of motion dependencies will increase.

The deliberations will continue to focus on a selected example of a steady an axially-symmetric flow of no peaceful Newtonian fluid through a straight-axis duct of a circular cross-section, under the action of constant gravity. This will enable simple comparison of peaceful and no peaceful flows. The highlight of Paper 2 will be a precise, theoretical calculation of Reynolds number, resultantly determined by the value $\mathbf{Re_{gr} = 2302}$. It will be tantamount to fully opening the previously locked door to the theory of turbulent flows.

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