

# Method of displacement of closed mechanical system of bodies

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This article describes general conditions for unidirectional displacement of mechanical system of bodies when only the system's internal forces work. The paper provides theoretical justification and a practical example of this process. It also describes propulsor based on the defined principles.

## 1. Task definition

Assume there is a constrained mechanical system of bodies  $M_1, M_2, \dots, M_n$ , on which external forces do not act or they are compensated for (Fig1). All the bodies of this system are retained by internal mechanical bonds.

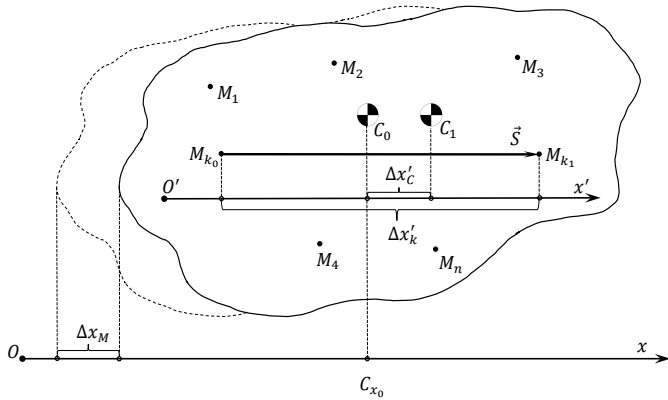


Fig. 1: Displacement of one body in the closed system.

Introduce two right-hand Cartesian coordinate systems (reference frames), as shown in Fig.1. The system  $Ox$  is an absolute fixed coordinate system. The system  $O'x'$  pertains to the mechanical system of bodies  $M_1, M_2, \dots, M_n$  and is relative for the absolute coordinate system  $Ox$ . Since the system of parallel forces acting along the X-axis is considered further below, assume that the X-axes of the absolute and relative coordinate systems are collinear and codirectional. Other axes of reference are not shown, as they are not used in the analysis.

During the time period  $\Delta t$  one of the system's body  $M_k$  with a certain mass, under the action of internal forces of the system of bodies, performs a translational straight-line displacement  $\vec{S}$  from position  $M_{k_0}$  to position  $M_{k_1}$ . Before the body  $M_k$  started moving, the system of bodies  $M_1, M_2, \dots, M_n$  was fixed in relation to  $Ox$ . The vectors of displacement  $\vec{S}$  and the X-axis of the coordinate system are collinear and codirectional. The vector of displacement  $\vec{S}$  is shown in Fig.1, as referenced to the coordinate system  $O'x'$ .

As the body  $M_k$  displace by the value  $\Delta x'_k$ , the relative center of mass  $C_0$  of the system of bodies  $M_1, M_2, \dots, M_n$  changes by the value  $\Delta x'_C$ , so the relative center of mass is in the position  $C_1$ . According to Newton's second and third laws [1], all the other bodies of the system  $M_1, M_2, \dots, M_n$ , except for the  $M_k$ , will displace relative to the coordinate system  $Ox$  in the direction opposite to the vector  $\vec{S}$ , such displacement value being  $-\Delta x'_C = \Delta x_M$ . Thus, the center of mass  $C_0$  of the system of bodies  $M_1, M_2, \dots, M_n$  remained fixed relative to the absolute coordinate system  $Ox$ , its projection on the axis  $Ox$  denoted as  $C_{x_0}$ .

Generally, the equation for displacement of particles of the closed system under review, relative to the  $Ox$  axis may be written as:

$$m_1 \Delta x_1 + m_2 \Delta x_2 + \dots + m_n \Delta x_n = 0 \quad (1.1)$$

where  $m_1, m_2, \dots, m_n$  – masses of particles (bodies)  $M$  of the system  $M_1, M_2, \dots, M_n$  and  $\Delta x_1, \Delta x_2, \dots, \Delta x_n$  – their absolute displacements from initial positions along the  $Ox$  axis.

It is necessary to describe such a manner of movement of particles inside the mechanical system  $M_1, M_2, \dots, M_n$ , which would enable a constant incremental unidirectional displacement of the system  $M_1, M_2, \dots, M_n$  by the value  $\Delta x_M$  per increment. Another objective of this paper is describing a propulsor, based on that.

## 2. Method of unidirectional displacement of the closed mechanical system of bodies

There is a closed, equilibrrious, constrained mechanical system of bodies  $M_1, M_2, \dots, M_n$ . One of the system of bodies is a single whole body  $M_k$  with a certain mass, performing translational straight-line displacement  $\vec{S}$  during the time  $\Delta t$ , moves from position  $M_{k_0}$  to position  $M_{k_1}$  (Fig.2). According to (1.1), all the bodies of the system  $M_1, M_2, \dots, M_n$ , except for  $M_k$ , will displace by the value  $\Delta x_M$ . This is the way a part of the mechanical system of bodies makes one increment. The absolute center of mass remained standstill. The relative center of mass changed position  $C_0$  for position  $C_1$ .

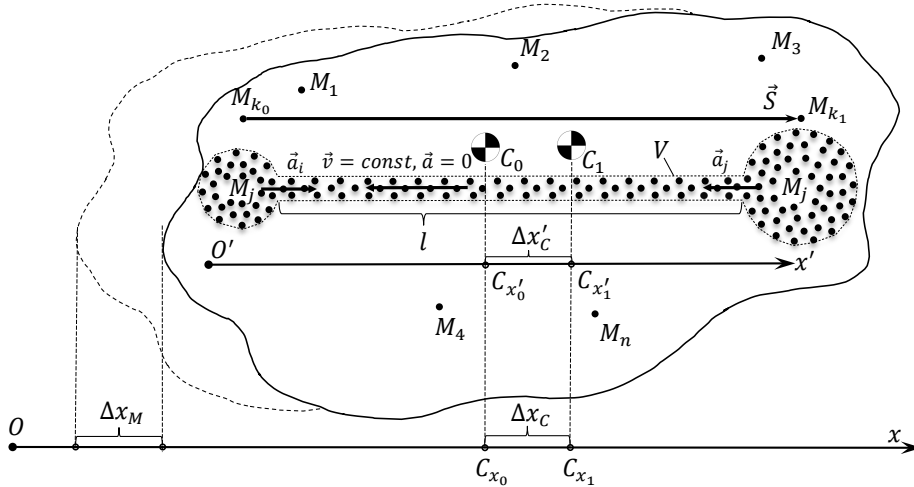


Fig. 2: Method of displacement of the closed system.

For the system of bodies  $M_1, M_2, \dots, M_n$  to make the next identical step, it is necessary to solve the problem of return of the body mass  $M_k$  from position  $M_{k_1}$  to the initial position  $M_{k_0}$  and at the same time to constantly and continuously compensate for an incipient momentum so that the system could retain instantaneous velocity within the time space when the center of mass returns from position  $C_1$  to position  $C_0$ , i.e. projected positions the system's center of mass on the axis of two

coordinate systems  $Ox$  and  $O'x'$  should coincide. Repeating such steps the system  $M_1, M_2, \dots, M_n$  can displace constantly and unidirectionally.

Admit the following solution. Assume that one of the body in the system  $M_1, M_2, \dots, M_n$  is  $M_j$  with the mass outweighing the mass of the body  $M_k$  represents a set of equal particles (elementary masses) continuously distributed in volume  $V$ , where mechanical bonds develop between each of the particles in the set (set of solid masses bonded by mechanical bonds; uniform volume of liquid, gas, plasma confined by walls), as shown in Fig. 2. In addition, assume that the right side in the system of bodies  $M_1, M_2, \dots, M_n$  contains a greater amount of such particles than the left side. The center of mass is to be transferred to the initial position  $C_0$  from position  $C_1$ . Some permanent part of volume  $V$  of the total mass of body  $M_j$  is uniformly distributed over length  $l$  and forms constant cross-section over the whole length. The remaining volume of the body mass  $M_j$  is concentrated immediately on the ends of length  $l$ . The flux of the matter (particles) is

generated on the length  $l$ , which continuously and evenly transfers in the direction of the velocity vector  $\vec{v}$ . The flux of the matter over length  $l$  had been set in motion before, and the incipient momentum was fully compensated for in any available manner to maintain the initial velocity of the system of bodies (system  $M_1, M_2, \dots, M_n$  considered as closed after the momentum compensation process is done).

Thus, the mass of the body  $M_j$  changes its position within the

mechanical system of bodies  $M_1, M_2, \dots, M_n$  and transfers from the right to the left side, thereby changing the position of the relative center of mass. The resultant of accelerations  $\vec{a}_j$  and  $\vec{a}_i$ , which are generated during speedup and slowdown of particles at the start and end points of their motion, respectively, is zero. Hence, the forces caused by such accelerations are compensated for. Because the matter velocity over the length  $l$  is a constant, there is no acceleration and thus there is no force that can

affect of forces balance of the closed system of bodies  $M_1, M_2, \dots, M_n$ . The system of bodies  $M_1, M_2, \dots, M_n$  changes its absolute and relative center of mass on the value  $\Delta x_C = \Delta x'_C$  by transfer of matter from the right to the left side of the system and has no affect on the forces balance in the closed system of bodies  $M_1, M_2, \dots, M_n$ . The center of mass returns from position  $C_1(C_{x_1})$  to position  $C_0(C_{x_0})$ .

As soon as the left part of the system of bodies accumulates a sufficient amount of matter to form the single whole body  $M_k$ , it will again, during the time  $\Delta t$ , displace from position  $M_{k_0}$  to position  $M_{k_1}$ . According to (1.1), all the bodies of the system  $M_1, M_2, \dots, M_n$ , except for  $M_k$ , displace by the value  $\Delta x_M$ , making the next step. As soon as the body  $M_k$  arrives at the position  $M_{k_1}$ , it joins the body  $M_j$ . Then the cycle repeats. Thus the system  $M_1, M_2, \dots, M_n$  performs incremental unidirectional displacement.

System  $M_1, M_2, \dots, M_n$  performs incremental unidirectional displacement infinitely time, restricted only by the energy stored inside this system, its center of mass does not remain at the start point, resource of mass of the system not consumed at displacement, its center of mass unidirectional displaces without action on that system outside forces, so we can talk about *displacement of the closed system of bodies (particles)*.

Let us consider an example illustrating the idea described above. This experiment is easy to conduct mentally because its components can be fairly often encountered in equipment and machinery.

A flatcar 1, which can freely move on rail tracks, carries two containers with water (Fig.3). The containers communicate with each other through pipe 2 of uniform cross section. Water from container 3 constantly and continuously pumped through pipe 2 to container 4 by pump 5. The flatcar's speed relative to the rail tracks is zero at this point in time. When water in pipe 2 was set in motion to achieve the velocity  $\vec{v}$ , the flatcar was braked and then the brake was released.

Consider the flatcar and all the objects thereon as a closed system of bodies, in which the external gravity force is compensated by the external force of support reaction from the rail tracks. Let us regard the platform as a system of parallel forces. Introduce a coordinate system as shown in Fig.3, directing the

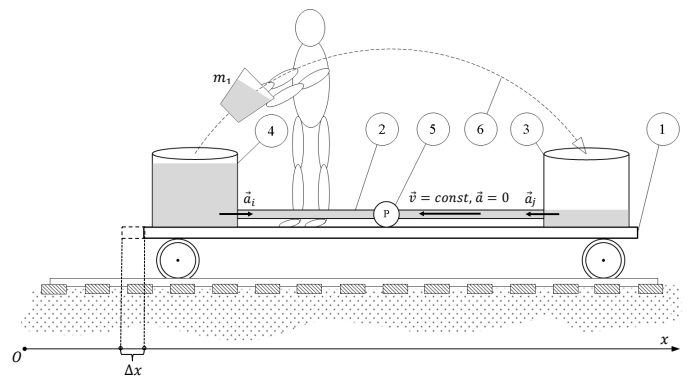


Fig. 3: A flatcar moving. 1 – flatcar; 2 – pipe; 3,4 – container; 5 – pump; 6 – toss trajectory.

axis  $Ox$  perpendicular to external forces. Disregard friction force and air resistance, considering their minor values.

Transfer of water from container 3 to container 4 does not change the flatcar's initial (zero) speed. Throughout the transfer process, water flow rate in pipe 2 is a constant and there is no acceleration. Hence there is no force that may affect the momentum of the flatcar system. The resultant of accelerations  $\vec{a}_j$  and  $\vec{a}_i$  is zero. The generated forces are mutually compensating and have no effect on the flatcar's momentum. This is how the center of mass of the flatcar's system changes while its momentum remains unchanged.

Imagine that there is a man on flatcar 1, who bails water with mass  $m_1$  with a bucket from container 4 and masterfully tosses it into container 3 along trajectory 6, thus changing the relative center of mass of the flatcar system. According to (1.1), displacement of mass  $m_1$  causes the flatcar to displace by the value  $\Delta x$ . Each toss of mass  $m_1$  will cause the flatcar to displace incrementally by the value  $\Delta x$ . Thus the man is able to constantly displace the flatcar system along the rail tracks without interaction on by outside forces (within the earlier discussed system of parallel forces acting along  $Ox$ ).

### 3. Propulsor

Fig.4 shows the propulsor whose base 1 can be secured to the body of an object being displaced [2]. A closed hollow pipe 2 of dielectric material is attached to base 1. Pipe 2 contains a multitude of

solid masses 3 in the form of spheres from magnetic materials. Pipe 2 has equally spaced solenoids 4 strung on it. Solenoids 4 are switched on and off by controller 6. Controller 6 implements the preset algorithm for toggling between solenoids 4, which is described in more detail later. The magnetic field produced by solenoids 4 moves mass-spheres 3 inside pipe 2. Solenoids 4 should be spaced at a minimum distance from one another and ensure the maximum smoothness of motion of mass-spheres 3. Power source 7 supplies power to controller 6 and electric magnets 4 via power line 5.

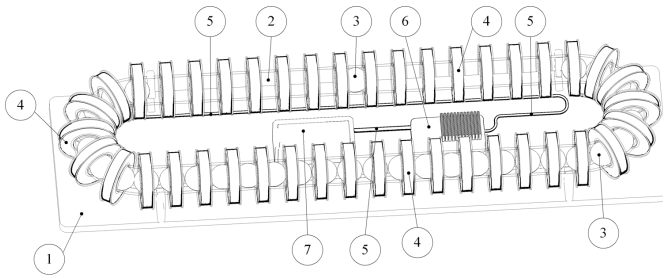


Fig. 4: Propulsor. 1 – base; 2 – pipe; 3 – mass-spheres; 4 – solenoids; 5 – power line; 6 – controller; 7 – power source.

The solenoids are switched in a manner ensuring that mass-spheres fill the pipe compactly over the lengths D-E-F-G-A-B, and provide even and continuous (relative to the pipe walls) motion of the chain of mass-spheres (Fig.5). On the length B-C the solenoids cause mass-spheres to move with positive acceleration and on the length C-D with negative acceleration, such accelerations being equal by module. B-C and C-D are equal in length. There is always only one mass-sphere between points B and D. Inside the pipe, mass-spheres move clockwise in the direction of the velocity vector  $\vec{v}_m$ .

Let us regard the propulsor/moved object system as a closed system of bodies. Project the vector of velocity of mass-sphere motion inside the pipe  $\vec{v}_m$  on axis  $Ox$  and denote it as  $\vec{v}_x$ . Denote the velocity-related projection of mass-sphere acceleration on axis  $Ox$  as  $\vec{a}_x$ . The diagrams depicted in Fig.5 show a change in the projection of mass-sphere velocity  $\vec{v}_x$  and a change in the projection of mass-sphere acceleration  $\vec{a}_x$ , depending on the coordinate of mass-spheres on axis  $Ox$ . The upper diagram shows variations in vectors  $\vec{v}_x$  and  $\vec{a}_x$  that occur as masses move from point A

to point E. In the lower diagram the direction is reverse – from E to A.

Chains of mass-spheres on the lengths G-A-B, D-E-F move evenly and continuously, relative to the pipe walls. On these lengths there are always an equal number of similar mass-spheres per time unit. As evident from the diagrams, values  $\vec{a}_x$  acting on the pairs of lengths G-A, A-B and D-E, E-F are equal by module, but opposite in direction, which means the resultant forces are mutually compensating. The chain of mass-spheres on the length F-G moves evenly and continuously. Projection of the velocity vector  $\vec{v}_x$  on axis  $Ox$  is a constant. No acceleration and related force are produced. The chain of mass-spheres moving on the lengths D-E-F-G-A-B, therefore, does not affect the balance of the closed propulsor/moved object system. Speedup of the chain of masses on the length F-G at the start of the propulsor and slowdown of the chain at the propulsor's shutdown generate a momentum vector directed along  $Ox$ . This momentum is compensated by any possible method to maintain the initial velocity of the propulsor/moved object system (system regarded as closed after the momentum compensation process is done).

As a mass-sphere moves from point B to point D, it changes the relative center of the

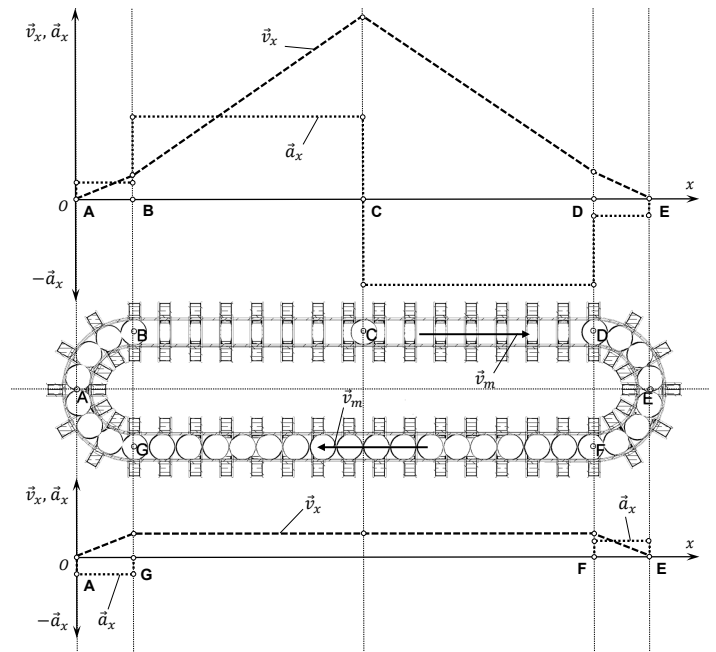


Fig. 5: Velocity and acceleration changing diagrams.

propulsor/moved object system. According to (1.1), displacement of a mass-sphere causes the propulsor/moved object system to displace by a certain value  $\Delta x$ .

After a mass-sphere reaches the end point D, the next mass-sphere in the chain arrives at point B and the cycle repeats. Thus, the propulsor and object attached thereto perform constant incremental displacement to the left side (by the scheme on Fig.5).

By applying (1.1) to the propulsor under review, define the value of motion of the propulsor/moved object system relative to axis  $Ox$  by one step, as follows:

$$\Delta x = -\frac{m_k}{M} \Delta x'_k \quad (3.1)$$

where  $m_k$  – mass of one sphere moved between points B and D;  $M$  – total mass of all the bodies of the propulsor/moved object system;  $\Delta x'_k$  – change of displacement coordinates of mass-sphere.

## References

1. B.M. Yavorsky, A.A. Detlaf, A.K. Lebedev, Physics Handbook. For engineers and university students. 8<sup>th</sup> revised edition, 2007 (in Russian).
2. V.M. Ledin, Propulsor exploiting accelerating bodies: patent 2467202, Russian Federation. No.2011108667/11(012462); application of 09.03.2011; published 20.11.12, Bulletin No.32 (2012).