DOI:10.3969/j. issn. 1001 -4551. 2015. 12. 001

Challenge to the absoluteness of the conservation of momentum or angular momentum

WANG Qing-ming
(School of mechanical and power engineering, East China University of Science and Technology, Shanghai, 200237, China)

Abstract: Conservation of momentum and angular momentum have long been regarded as the two basic laws in physics. However, an example that does not conform to the two laws is given; that shows that none of momentum and angular momentum is an absolute conserved quantity. We found that under certain conditions, the action-reaction pair acting between two bodies touching each other changes the momentum of one body and the angular momentum of the other one. That means that the total momentum of the system is changed without any external force, and the total angular momentum of the system is also changed without any external moment. Furthermore, we found that if the momentum and the angular momentum of a system are not conserved, the two kinds of non-conservation must occur at the same time; therefore, we predict that an unknown and more general conserved quantity of the system is still conserved in this case. We anticipate our study to be a starting point for reexamining the classical physics from a new viewpoint. Additionally, we anticipate our assay to also be a starting point for searching a new propulsion mode besides rocket recoil mode for an isolated system such as spacecraft.

Key words: momentum; angular momentum; conservation law; symmetry; propulsion
Chinese library classification: O313; TH113.2

0 Introduction

Conservation of momentum and angular momentum have long been regarded as the two basic laws in physics and applied to various fields from celestial mechanics to microscopic particle physics, and these two laws have not been contradicted by any known particular experiment for hundreds of years[1-3]. But the author found a living example that does not conform to the two laws. The possibility may exist that new observation will require these two basic laws to be revised. It is very important for the study on the mechanism of propulsion of mechanical system in a special environment, so the theoretical and experimental study based on the example is necessary. This finding will lead to a great interest in physics community and engineering domain.

1 An important feature which has not been paid attention to

Suppose a rigid body has a circular motion in a rigid circular ring, as shown in Fig. 1. The mass of the body is m; a rod is fixed horizontally on the body, and the midpoint of the rod is at the center of mass of the body. Two idle pulleys are placed at each end of the rod respectively, and the pulleys keep contact with the inner wall of the ring during the circular motion. The kinematic characteristic of such a kind of the circular motion is that the revolution and rotation of the body are synchronous and in the same direction.

Suppose the distance between the center of mass of the body and the center of the revolution is r, the horizontal rod is $2l$ long, and the inner radius of the circular

收稿日期:2015 -10 -08
基金项目:国家自然科学基金资助项目(51175176)
作者简介:王庆明(1954 -),男,江西吉安人,教授,博士生导师,主要从事机械制造及其自动化、特种机器人等方面的研究. E-mail:wangqm@ ecust. edu. cn

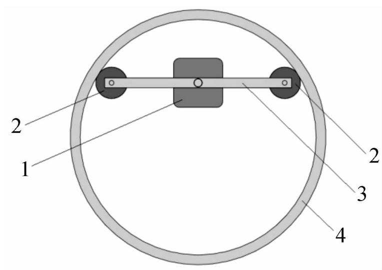

Fig. 1　a rigid body revolves in a rigid circular ring (1: body of mass m; 2: idle pulley; 3: horizontal rod; 4: circular ring)

ring is R, the body has an initial tangential velocity at one point in time, and then subjected to a tangential resistance F_f at its mass center, so it has an anti-clockwise decelerated circular motion. Define F_{nA}, F_{nB} as radius forces applied respectively by the inner wall of the ring at point A and point B. Note that two contact points between the pulleys and the ring, and the tangential friction can be ignored. The corresponding physical model is shown in Fig. 2.

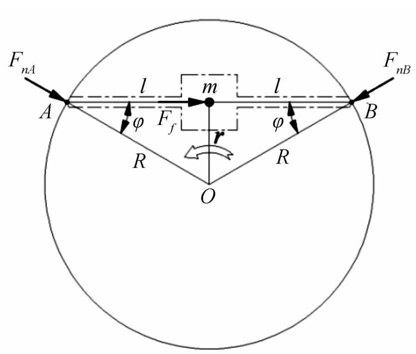

Fig. 2　Physical model

During the decelerated circular motion the body has a tangential acceleration in opposite direction of the tangential velocity, that is to say, there is an angular acceleration of the revolution, $\beta = a_t/r$, to reduce the revolutionary angular velocity, so there must be an angular acceleration, whose magnitude is also $\beta = a_t/r$, to reduce the rotary angular velocity so that the rotation with respect to the center of mass of the body can keep pace with the revolution.

Define the rotational inertia of the body is I_c, according to the rotational analog of Newton's 2nd law for a rigid body, we can write

$$F_{nB} l\sin\varphi - F_{nA} l\sin\varphi = I_c\beta \tag{1}$$

Thus

$$F_{nB} = F_{nA} + \frac{I_c R}{lr}\beta = F_{nA} + \frac{I_c R}{l\sqrt{R^2 - l^2}}\beta \tag{2}$$

If substituting β from equation (3)

$$\beta = \frac{a_t}{r} = \frac{F_f + F_{nA}\cos\varphi - F_{nB}\cos\varphi}{mr} \tag{3}$$

we can get

$$F_{nB} = F_{nA} + \frac{RI_c}{l(mr^2 + I_c)}F_f = F_{nA} + \frac{RI_c}{l[m(R^2 - l^2) + I_c]}F_f \tag{4}$$

From the equation (2) or (4), the radial force applied at the rear idle pulley is greater. Further analysis shows that if the body has an accelerated circular motion, the radial force applied at the front idle pulley will be greater, and only when the body is in uniform circular motion are the radial forces applied at the two idle pulleys equal.

Because the midpoint of the rod is at the center of mass of the body, the "equivalent mass" at point A and at point B are equal, and the tangential velocity of the body and the radius of the circle at the two contact points are also the same, so the required centripetal forces are equal. It means that when the body has a non-uniform circular motion, the redial force applied at one idle pulley will includes not only required centripetal force but also an extra force. This is an important feature which has not been paid attention to.

2　Analysis of momentum and angular momentum

From the analysis mentioned above, during the decelerated circular motion of the body, the two redial forces applied respectively at the two contact points are not equal, and F_{nB} is greater than F_{nA}. Let $F_{nB} = F_{nB1} + F_{nB2}$ and $F_{nB1} = F_{nA}$, thus, F_{nB1} and F_{nA} coalesce to form the required centripetal force for the revolution of the body, it worth noting that F_{nB} includes an extra radial force F_{nB2}, because the angular acceleration of the rotation must not be zero. In fact, the extra radial force forms a moment with respect to the center of mass of the body, so that the body can have an angular acceleration to keep the angular velocity of the rotation is synchronous with that of the variable revolution with respect to the center of the ring. Suppose the reaction of the extra radial force F_{nB2} is F'_{nB2}, when the force F_{nB2} on the pulley exerted by the inner wall of the ring changes the angular momentum of the body in a certain time interval, the force F'_{nB2} on the inner wall of the ring exerted by the pulley acts in the same time interval, according to the impulse-momentum theorem, the ring's momentum is changed.

Now, an important phenomenon that has never been noticed occurs, the action-reaction pair acting between the two bodies touching each other change the momentum of one body and the angular momentum of the other one.

Obviously, because only one body obtains an increment of momentum, the total momentum of the system consisting of two bodies is changed without any external force; and there is no internal moment being equal in magnitude and opposite in direction to the moment which changes the angular momentum of the other body, so the sum of the internal moment is non-zero, and the total angular momentum of the system is changed without any external moment.

Therefore, none of the laws of conservation of momentum and of angular momentum is an absolute law, both are relative ones; none of momentum and angular momentum is an absolute conserved quantity, both are relative ones.

It is worth noting that the increment of the momentum and of the angular momentum are both derived from the effects of a pair of internal forces in a same time interval, so the momentum and the angular momentum of a system must be not conserved at the same time, it can be described as the simultaneity of the non-conservation (SNC) of momentum and of angular momentum. Owing to the SNC, we predict that an unknown and more general conserved quantity of the system is still conserved in this case.

The symmetry properties of a physical system are intimately related to the conservation laws characterizing that system, the spatial translational symmetry corresponds to the conservation of momentum, and the spatial rotational symmetry to the conservation of angular momentum[4], due to none of the momentum and angular momentum is an absolute conserved quantity. It may be reasonable to combine the space translational symmetry and space rotational symmetry to form an symmetry of spatial displacement, and the general symmetry will correspond to a conserved quantity which can more appropriately measure mechanical motion.

The discovery that both of the momentum and the angular momentum of a system may not be conserved collapses some classical ideas in physics, and it is significant in theory.

3 Experiment

The phenomenon of momentum non-conservation can be verified by a simple experiment as follow.

A movable unit shown as Fig. 3 is put in a circular container, the two idle pulleys of the unit lean against the inner wall of the container. A motor that can be controlled by remote control is fixed vertically in the center of the container; a bar is installed horizontally on the rotator of the motor as shown in Fig. 4.

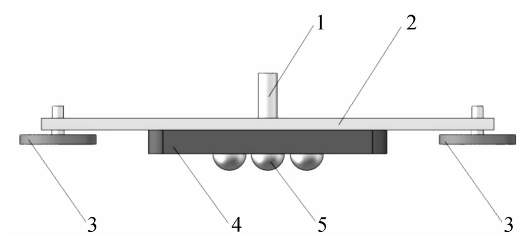

Fig. 3 Movable unit
(1: column; 2: horizontal rod; 3: idle pulley; 4: metal block; 5: balls)

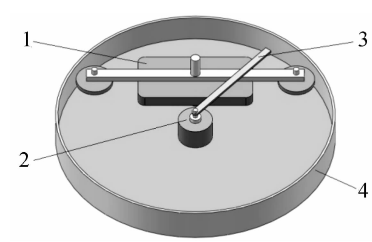

Fig. 4 Experimental device
(1: movable unit; 2: motor; 3: revolving bar; 4: circular container)

When the motor is remote controlled to start, the revolving bar pushes the column of the movable unit to drive the unit moving in a circle in the circular container, and the constraint coming from the inner wall of the circular container makes the rotation around the mass center of the moving unit must be synchronous with the revolution around the center of the container. When the motor is stopped by the remote control, the unit will continue to move depending on the inertia, then the tangential friction between the balls of the movable unit and the bottom plate of the container will slow the revolution down, so there must be a moment with respect to the center of mass of the unit to slow the rotation down, according to the foregoing analysis, the rear idle pulley of the movable unit and the inner wall of the container will be subjected to an extra force.

The experimental device as shown in Fig. 4 is placed on a foam plate floating on still water, when the motor is started and then stopped, it can be observed clearly that the experimental device will move on the water when the unit slows down and stops in the container, and the direction of the movement is always the radial direction at the contact point between the rear idle pulley and the inner wall of the container. It means that the momentum of the experimental device is changed without any external force. It cannot be seen clearly if the angular momentum of the experimental device is conserved or not in the experiment, but according to the previous theoretical analysis, the momentum and the angular momentum of the experimental device are not conserved at the same time.

4 Further discussions

The research of this paper is of practical significance, for example, it has long been noted that when a vehicle decelerates on a curve road the rear of the vehicle often sideslips outwards, the greater the deceleration, the greater the sideslip, it will be easy to lead to a traffic accident. In fact, the travel of a vehicle on a curve road can be regarded as a revolution around the instantaneous center of curvature of the road and a rotation around the centroid of the vehicle. The precondition of the running track can be kept on a curve road is the angular velocity of the revolution equals that of the rotation, the deceleration of the vehicle means the former decreases, so the latter must be decreased synchronously, so, there must be an extra force applies on the rear wheels to form an extra moment with respect to the centroid of the vehicle. If the friction between the rear wheels and the ground is not great enough to provide such a moment, the rear of the vehicle will sideslip outwards. The research results can explain convincingly this phenomenon. As an interesting experiment, there is a toy car moves circularly in a circular container placed on a foam plate floating on still water, when the car is remotely controlled to slow down rapidly, it can be seen that the floating plate moves directionally on water. It means that when the revolution of the toy car decreases, the rear of the car is subjected to an extra force to form a moment to slow down its rotation, while the reaction of the extra force changes the momentum of the system. Therefore, the system moves directionally.

For the propulsion of an isolated system, the law of conservation of momentum entirely excludes all ways except rocket recoil mode, while our research gives a possibility of finding new methods of propulsion for an isolated system such as a space vehicle. Considering the work hours of a space vehicle is expected to be as long as possible, while the transportation of fuel from the ground to the space is expensive, the propulsion operated on solar cells will be very attractive, the results of this study will inspire great enthusiasm in engineering domain.

5 Conclusions

(1) Suppose a noncircular rigid body keeps contact with the inner wall of the ring at two contact points being symmetrical with respect to the mass center of the body, when the bodies has a uniform circular motion in the ring, the two redial forces applied respectively at the two contact points are equal, but if the circular motion is nonuniform, the two redial forces will not be equal, it means the body is acted on by an extra radial force at one contact point.

(2) Because the "equivalent mass" at two contact points are equal, and the velocity and the radius of the revolution of the body at the two contact points are also the same, so the required centripetal forces at two contact points are equal, leading to the extra radial force forms a moment with respect to the center of mass of the body so that the body can has an angular acceleration to keep the angular velocity of the rotation is synchronous with that of the variable revolution with respect to the center of the ring. Meanwhile, the reaction of the extra radial force acting on the inner wall of the ring changes the momentum of the ring.

(3) In the living example given by the paper, the action-reaction pair acting between the two bodies touching each other change the momentum of one body and the angular momentum of the other one, it means that the total momentum of the system is changed without any external force, and the total angular momentum of the system is changed without any external moment.

(4) If the momentum and the angular momentum of a system are not conserved, the two kinds of non-conservation must occur at the same time; so we predict that an unknown and more general conserved quantity of the system is still conserved in this case.

(5) The research of this paper is of practical significance.

6 Acknowledgments

This research was supported by National Natural Science Foundation of China under grant No. 51175176.

参考文献(References):

[1] HEWITT, P. G., Conceptual Physics[M]. 11th ed. Boston: Addison-Wesley, 2010.

[2] David Halliday, Robert Resnick, Jearl Walker. Fundamentals of Physics[M]. 9th ed. New York: Wiley, 2009.

[3] HUGH D. Young, Roger A. Freedman[M]. University Physics, 9th ed. Boston: Addison-Wesley, 1996.

[4] ELLIOTT, J. P. and Dawber, P. G., Symmetry in physics principles and simple applications[M]. London: Macmillan, 1979.

[**编辑**:罗向阳]

对动量或角动量守恒的绝对性的质疑

王庆明

(华东理工大学 机械与动力工程学院,上海 200237)

摘要:动量守恒和角动量守恒长期以来被认为是物理学基本守恒定律。在此给出一个不符合这两个定律的实际例子,表明动量和角动量都不是绝对的守恒量。我们发现在一定的条件下,两个相互接触的物体之间的作用力和反作用力引起其中一个物体的动量变化和另一个物体的角动量变化,这意味着系统的总动量在无外力的情况下发生变化,同时系统的总角动量在无外力矩的情况下也发生改变。我们还发现如果系统的动量和角动量不守恒,这两种不守恒必须同时发生,因此我们预言系统的某个未知的和更一般的守恒量在此情况下仍然是守恒的。我们预计这个研究将是从一个新的视角重新审视经典物理学的起点。另外,我们预计我们的试验对于为空间飞行器一类的孤立系统的推进寻找火箭反冲方式以外的新方法也是一个起点。

关键词:动量,角动量,守恒定律,对称性,推进

中图分类号:G642;O313　　**文献标志码**:A　　**文章编号**:1001-4551(2015)12-1529-05

本文引用格式:

王庆明. 对动量或角动量守恒的绝对性的质疑[J]. 机电工程,2015,32(12):1529-1533.

WANG Qing-ming. Challenge to the absoluteness of the conservation of momentum or angular momentum[J]. Journal of Mechanical & Electrical Engineering, 2015,32(12):1529-1533.