© 2018 IJSRST | Volume 4 | Issue 5 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

About Measurement of Angular Velocity

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ABSTRACT

The work, based on literary studies and the author's analysis, examines the device, the principle of operation and some characteristics of different types of tachometers. Here are the ways to determine the angular velocity with these devices. Some experimental angular velocity studies have been done with these tachometers.
Keywords: measurement of angular velocity, measurement of rpm

I. INTRODUCTION

Most of the moving parts and assemblies of devices and machines perform periodic movements - rotary (rotors of electric motors, turbines, shafts, axles, flywheels, etc.), reciprocating (pistons of internal combustion engines, carriages, shuttles, etc.) complicated (units of mechanisms - eg rods) [3]. Although within a period of motion the velocity (angular ω or linear v) of these units is often uneven and characterized by its instantaneous value, for a longer interval of time motion is usually represented by the average velocity, the mechanical frequency n or revolutions n' per unit time (second or minute).

The angular velocity is defined as the angle of rotation φ (traveled angular path) per unit of time t, [1] i.e.

(1) $\omega = \varphi/t$, rad/s;

The mechanical frequency is the ratio of the number n_T of the periods T to the selected unit of time t, [1] i.e.

(2) $n = n_T/t$,

When the mechanical frequency is measured as the number of revolutions per minute, it is also called the rotation speed.

There is an equation between ω, rad/s and n, об/min (r/min или rpm) [1]:

(3) $$\omega = \frac{2\pi n'}{60} = \frac{\pi n'}{30}$$

Often the measurement of linear velocity v also comes down to measurement of angular velocity ω - measuring converter is a rotating wheel with a radius r where $\omega = v/r$.

The angular velocity is rational energy quantity and therefore to measure it can not use an external source of energy.

II. DESIGN AND PRINCIPLE OF TACHOMETERS

Angular speed meters are called tachometers. There is a wide variety of phenomena on which the work of a tachometer can be restored - mechanical, magnetoinductional, electrical, stroboscopic, etc. [1] The group of mechanical tachometers include centrifugal, clock, friction, gyroscopic, vibration, hydraulic and pneumatic rotors [1].

In Figure 1 is a schematic diagram of a centrifugal tachometer. The operation of the device is based on the use of the centrifugal inertia resulting from the rotation of a body around an axis that does not pass through its mass center. The tracer is connected to the object being measured (eg rotor of an electric motor) by pressing on the object of a suitable nozzle - rubber rollers 1 (if the rotor rotational surface is available), cone 1 '(if an accessible center hole is available) directly to the bushing 2 of the input shaft 4 of the tachometer or to the bush 2 of the gearmotor shaft 3 or multiplier used for changing the range. To the shaft 4, by means of a crankshaft mechanism CAV, there are connected in number (two, three or more), symmetrically spaced from the axis of the body 6 by mass m, connected in the points (B) of the pivot joint of the knees CB with the BAs. The presence of two or more symmetrically arranged tables is intended to lead to mutual equilibration of forces and unloading of the bearings. When rotating the angular velocity shaft, a balanced system of inertial forces F = m.z.r.mp2, acting in the radial direction and causing forces F1 directed along the axis of the shaft, emerges. At each moment these forces are equalized with the spring springs of the spring 5. As a result, the slider 7 occupies an axial position in .ωproportion to The KL-axis with arm 8 converts the translational movement of the slider into a rotational one, and the pair of tooth gear 9 - sprocket 10 enhances the rotation and transmits it to the arrow 11, which performs the reading on the scale 12. The spiral coil 13 "seals" the dead stroke in the tooth gear.

Among the main deficiencies of the centrifugal tachometer we can highlight the following: non-linear characteristic and therefore a small measuring range; greater friction, especially in case of large gear ratios of the gearbox or input multiplier, respectively - a strong influence on the measured object, including its informative parameter; the need for specially prepared and accessible surfaces on the link to the tachometer; the need to know the transmission ratio of the pair of object-input nozzle and the like.

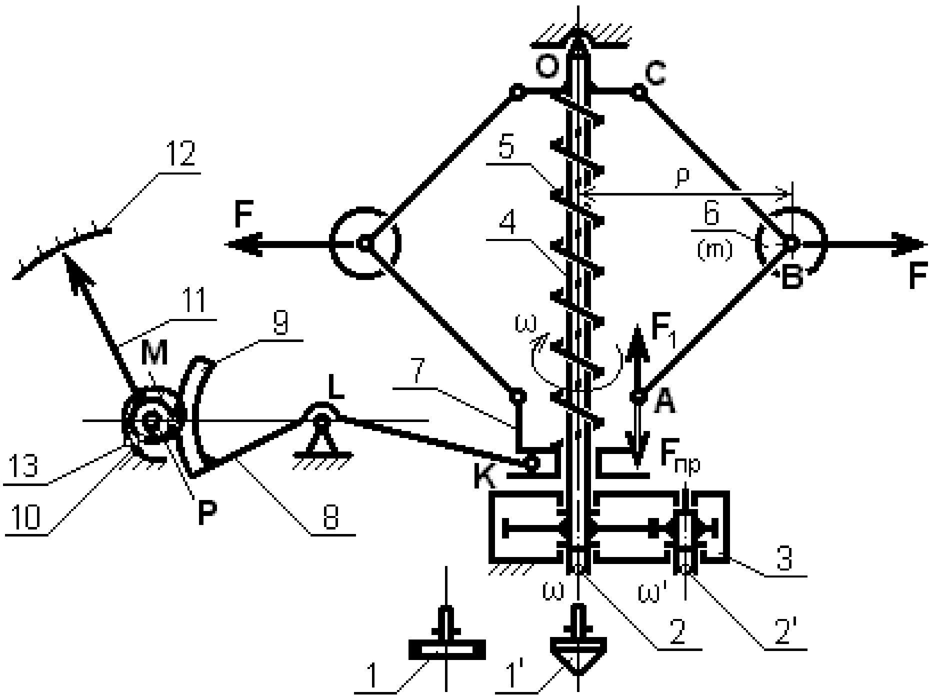

Figure 1. Centrifugal tachometer

In the case of the electric rev counter, the measured angular velocity is converted to a constant, variable or pulse current. This includes electromechanical, electric and impulse counter-clocks.

Impulse pulses are generated by the electric impulses by means of an electric or electronic key element connected to the shaft whose angular velocity is measured. The key may be mechanical contact or be non-contact (eg inductive, capacitive or photoelectric).

The average impulse current is proportional to the angular velocity. Accuracy is relatively good (0.5-1% errors).

In Figure 2 is a schematic diagram of a photoelectric tachometer [2].

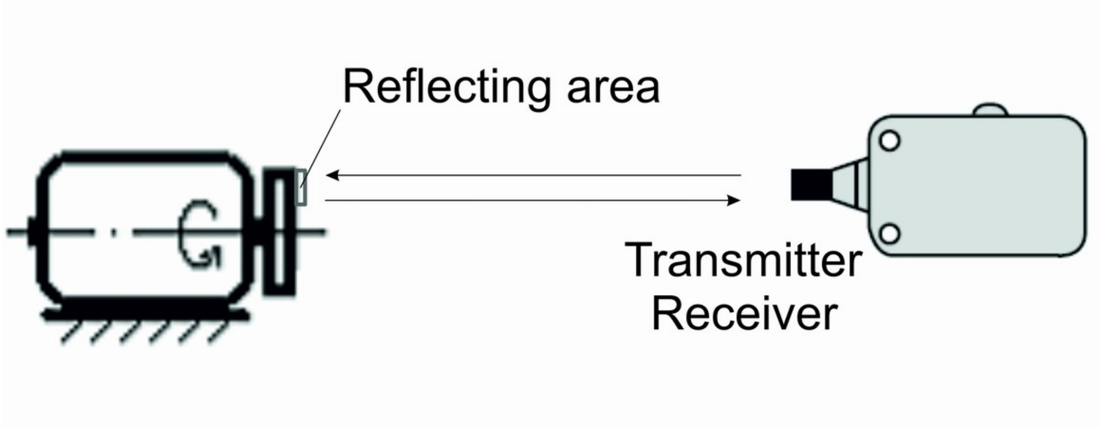

Figure 2. Photoelectric tachometer

The examined tachometers have general drawbacks - for the realization of the measurement it is necessary to interfere with the measuring object related to the provision of access to the respective surfaces, the introduction of additional elements, etc., and in the case of the instruments with immediate contact there is also a reversal of the measuring means on object and measured parameter. Of these shortcomings are deprived tachometer using a stroboscopic effect.

In Fig. 3 schematically illustrates the principle of action of the stroboscopic tachometer. A light pulse generator with a smoothly adjustable but stable frequency is required to conduct the measurement. As a source of such impulses, practically gasless discharge lamps are used, powered by electric impulses with steep fronts. For an understanding of the principle, let me assume that a single reference (see Figure 3) is applied to a disc mounted on a rotor with a constant angular speed of an electric motor. Let the reverb disk be illuminated by a short light pulse of duration. Part of the light reflected from the surface of the disk falls into the eyes of the operator. There is a nervous impulse between the eyes and a corresponding part of the brain, the perception is analyzed, and after a while the image appears on the disk. This image would disappear after a short time of about 1/15 - 1/20 from the second. Let us, however, after break time $t_{пр}$, the next light pulse again illuminates the disc exactly when it has made a full turn and the reference on it is in the same position. Everything is repeated and the operator continues to see the image of the repertoire, all the same that the disk is stationary, after which, after the same time, comes the next light pulse, and so on. There is a "standing picture" corresponding to the so- "Basic synchronicity". The same would happen if, for the time between two consecutive light pulses, the disk makes k = 2, 3 or more (k is a random integer) full turn - the "standing picture" will then correspond to the so-called "synchronic synchronization" . If for the time between two consecutive light pulses the disc does 1/2, 1/3 or for example, 1/4 full turn, we will get a "standing picture" again, but it will contain 2, 3 or 4, respectively (or 1/k) fixed benchmarks, that is, there will again be synchronicity, but with a multiple image. Since the fully immobilized "standing picture" of the basic synchronism is obtained by the equation of the pulse frequency with that of the rotating disc, the latter can be read directly from the scale of the adjustable light pulse generator. Rough mistakes can occur when confusing a basic with a synchronicity. If the frequencies of light pulses and the rotating disc are not equal but close, the picture will rotate in one or the other direction as fast as the frequency difference is greater. Such a picture would have occurred if one or both frequencies were not constant but changed. Therefore, the stroboscopic effect can only be used to measure constant frequencies *($\omega = const$)*. For a clear picture, the condition still needs to be $t_{пр} < 0{,}05\ s$. Otherwise, the image will disappear and the picture will shake.

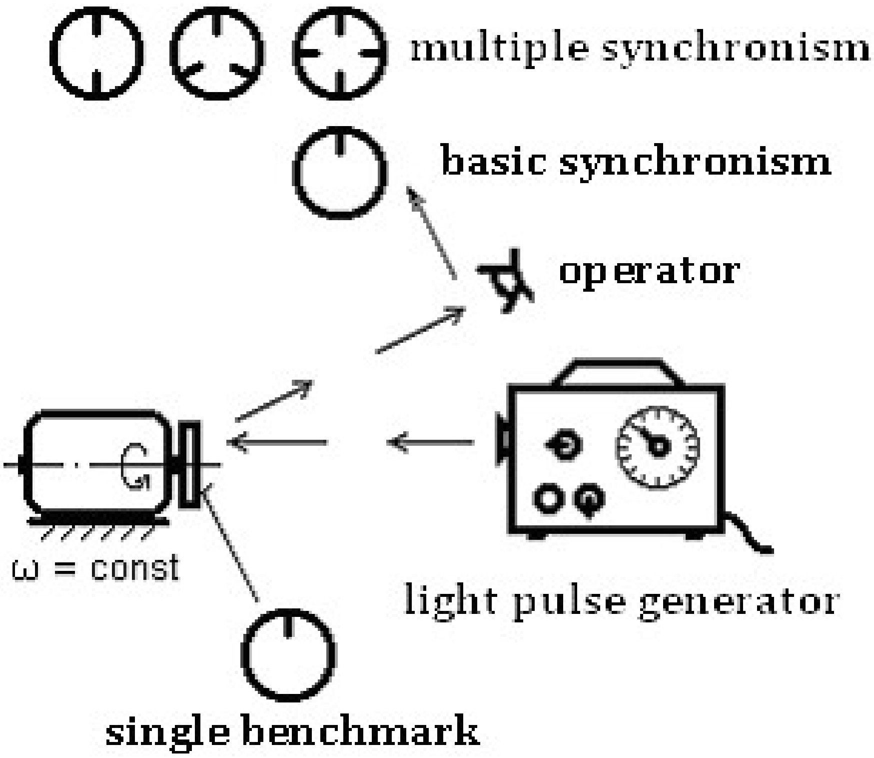

Figure 3. Stroboscopic tachometer

III. EXPERIMENTAL STAND

The technical resources used in the experiments are:

1. An electric motor with a mounted disc which is connected to an adjustable power supply device designed to control the engine speed.

2. Three tachometers operating on different principles, namely:

- ✓ centrifugal tachometer designed to measure the rotation speed n1, from 40 to 48000 rpm and a relative error of ± 2%.
- ✓ a photoelectric tachometer designed to measure the rotation speed n2, from 2,5 to 99000 rpm and with a relative error of ± 0,05%.
- ✓ a stroboscopic tachometer designed to measure the rotation speed n3 of 50 to 12000 rpm and a relative error of ± 0,05%.

IV. EXPERIMENTAL RESULTS

The results of the conducted experiments are given in Table 1, the experiments were performed 10 times and the results averaged. The graphical representation of the relative rotation n_t relations and the readings of the three tachometers n_1, n_2, и n_3 is shown on figure 4.

Table 1

№	n_t , r/min	n_1 , r/min	n_2 , r/min	n_3, r/min
1	500	512	508	502
2	600	615	609	605
3	700	718	711	704
4	800	814	814	798
5	900	919	910	903
6	1000	991	1005	1004
7	1200	1184	1215	1196
8	1400	1382	1412	1395
9	1600	1581	1611	1610
10	1800	1778	1814	1809

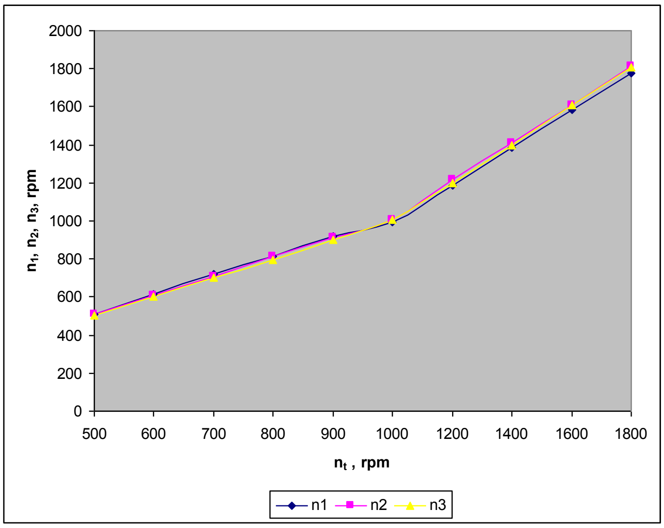

Figure 4. Graphical representation of the results

V. CONCLUSION

The results of the conducted experiments show that the closest values to the specified speed give the stroboscopic rev counter, followed by the photoelectric rev counter, and finally, the centrifugal rev counter was shown to be the most inaccurate.

VI. REFERENCES

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