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DISTURBING FACTORS INFLUENCE IN ULTRASONIC SENSOR DETECTION

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Abstract:
In this paper it is presented the disturbing factors influence over the distance measuring to some objects from an ultrasonic sensor. The working environment is influenced by the wind velocity, different temperatures, oscillated humidity and different noises. For the measurements it was used a Festo ultrasonic sensor.

1. INTRODUCTION

One of the disturbing factors which influence ultrasonic detection is atmospheric attenuation. As an acoustical wave travels away from its source, the signal power decreases according to the inverse square law, where *I* is the intensity (power per unit area) at distance *d*, I_0 is the maximum (initial) intensity and *d* is the range [1].

$$I = \frac{I_0}{4\pi d^2} \tag{1}$$

There is also an exponential loss associated with molecular absorption of sound energy by the environment with α, the attenuation coefficient for medium.

$$I = I_0 e^{-2\alpha d} \tag{2}$$

The maximum detection range for an ultrasonic sensor is dependent on both the emitted power and frequency of operation: the lower the frequency, the longer the range. The maximum theoretical attenuation for ultrasonic energy is give in the next equation, where a_{max} is the maximum attenuation in dB/m and f is the operating frequency in KHz.

$$a_{\max} = \frac{f}{100} \tag{3}$$

The totality of all energy incidents upon a target object is either reflected or absorbed. The directivity of the target surface determines how much of the reflected energy id directed back towards the transducer. Since most objects scatter the signal in an isotropic fashion, the returning echo again dissipates in accordance with the inverse square law, introducing an additional 4π term in the denominator of the previous equation for intensity. In addition, a new factor K_r, must be introduced in the numerator to account for the reflectivity of the target, where K_r is the coefficient of reflection.

$$I = \frac{K_r \cdot I_0 \cdot e^{-2\alpha d}}{16\pi d^4} \tag{4}$$

This coefficient for a planar wave arriving normal to a planar object surface is given in the next equation, where I_r is the reflected intensity, I_i is the incident intensity, Z_a is the acoustic impedance for air and Z_o is the acoustic impedance for the target object. The bigger the impedance mismatch between the two media, the more energy will be reflected back to the source.

$$K_r = \frac{I_r}{I_i} = \left[\frac{Z_a - Z_o}{Z_a + Z_o}\right]^2 \tag{5}$$

Consider the expression for wave propagation speed (c) in a gas, as a function of density, ρ, and bulk modulus of elasticity, K_m and since both these parameters change with temperature, the speed of sound in air is also temperature dependent.

$$c = \sqrt{\frac{K_m}{\rho}} \qquad (6)$$

Generally speaking, three kinds of noise will affect the ultrasonic sensor performance: environmental noise, crosswalk noise, and self-generated noise.

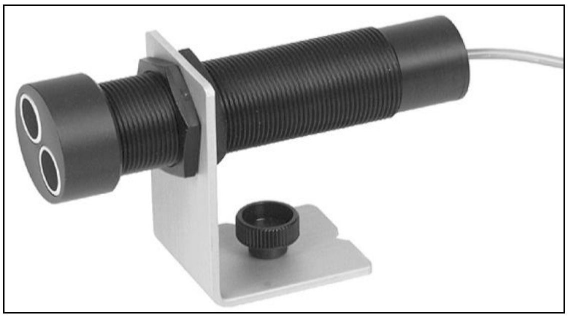
2. DEVICES USED FOR MEASUREMENTS

The ultrasonic sensor used in this instance is equipped with separate transducer elements for emitting and receiving [2].

The ultrasonic sensor is divided into the following functional groups: ultrasonic transducer, evaluation unit and output stage. In the emitting mode, the ultrasonic transducer is excited by a short voltage pulse. This pulse generates a brief ultrasonic oscillation pulse of a frequency determined by the resonance frequency of the ultrasonic transducer. The ultrasonic transducer is then switched over to the receiving mode and the reflecting ultrasonic waves (echo pulses) are received and evaluated [3].

The evaluation unit first of all checks whether the arriving signal is in fact the echo of the emitted ultrasonic wave. If the signal is recognized as the echo, the propagation time of the sound wave is determined. The propagation time is the time which has passed between the emission of sound and the reception of the echo. The result of this evaluation is passed on to the output stage [4].

The signal which is emitted by the output stage depends on the purpose for which the ultrasonic sensor is used. If the sensor is used as an ultrasonic proximity sensor, the occurrence of a reflected ultrasonic signal is evaluated at the receiver. In this instance, the output signal merely indicates whether an object is present or not. If the sensor is used as an ultrasonic distance sensor, then the propagation time of the sound is calculated and an electrical signal is available via the output unit, which corresponds to the distance between sensor and object.



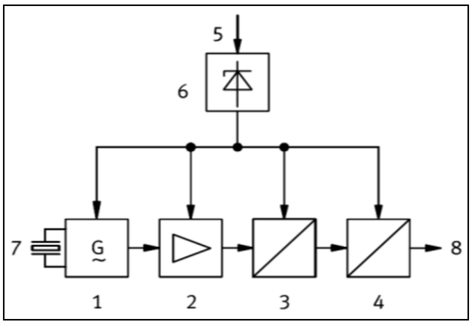


Fig. 1. The ultrasonic sensor FESTO and functional scheme.
The component elements are:
1 - oscillator;
2 - amplifier;
3 - evaluation unit;
4 - output signal conditioning;
5 - external voltage;
6 - internal constant voltage supply;
7 - ultrasonic transducer;
8 - output: current signal.

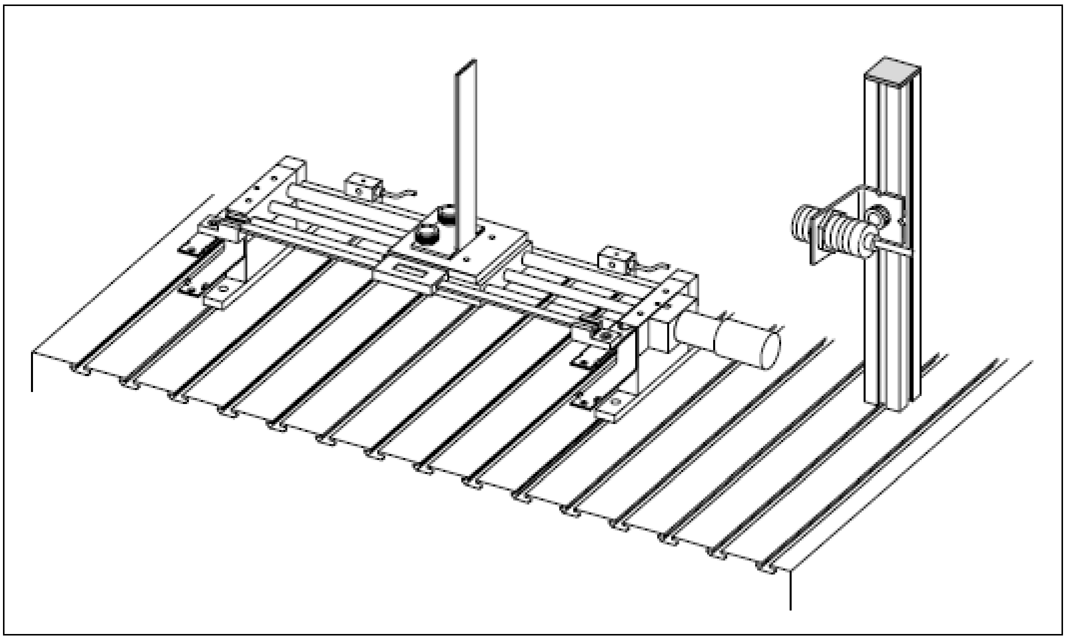


Fig. 2. Working table containing guidance subassembly with linear potentiometer and sensor.

The distance between sensor and obstacles is set with a guidance subassembly with linear potentiometer. This assembly also contains a spindle drive unit, one geared motor, a mountable vernier caliper, a signal switching unit, an analog connection unit, a motor control unit, and two proximity sensors. For the measurements of air velocity, differential pressure, temperature, and humidity it was used the portable Multi-Function Anemometer TA460.

Fig. 3. Anemometer TA460.

3. MEASUREMENTS

For the simulation of the wind velocity it was used a ventilator. The measurements were made on two values of velocity, at 10 and 15 meters per second. The velocities were applied in three directions, one perpendicular on the ultrasonic wave and two parallel with ultrasonic wave (one of them in emitted wave way, and another in received wave way).

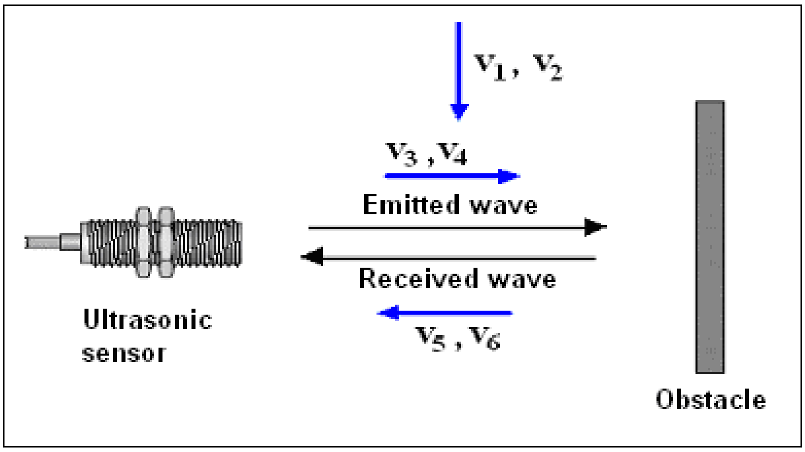


Fig. 4. The applied velocities on the ultrasonic wave.

v_0 – 0 (zero);
v_1 – velocity perpendicular on the ultrasonic wave; v_1= 10 m/s;
v_2 – velocity perpendicular on the ultrasonic wave; v_2 = 15 m/s;
v_3 – velocity parallel with the ultrasonic wave, having the emitted wave way; v_3= 10 m/s;
v_4 – velocity parallel with the ultrasonic wave, having the emitted wave way; v_4= 15 m/s;
v_5 – velocity parallel with the ultrasonic wave, having the received wave way; v_5= 10 m/s;
v_6 – velocity parallel with the ultrasonic wave, having the received wave way; v_6= 15 m/s.

Table 1. Response time variation on the wind simulation

Distance	Response time for v_0	Response time for v_1	Response time for v_2	Response time for v_3	Response time for v_4	Response time for v_5	Response time for v_6
d (mm)	t (s)	t (s)	t (s)	t (s)	t (s)	t (s)	t (s)
20	$0,1143 \cdot 10^{-3}$	$0,1152 \cdot 10^{-3}$	$0,1157 \cdot 10^{-3}$	$0,1149 \cdot 10^{-3}$	$0,1138 \cdot 10^{-3}$	$0,1073 \cdot 10^{-3}$	$0,1149 \cdot 10^{-3}$
80	$0,4386 \cdot 10^{-3}$	$0,4354 \cdot 10^{-3}$	$0,4245 \cdot 10^{-3}$	$0,4211 \cdot 10^{-3}$	$0,4235 \cdot 10^{-3}$	$0,4233 \cdot 10^{-3}$	$0,4215 \cdot 10^{-3}$
140	$0,7782 \cdot 10^{-3}$	$0,7848 \cdot 10^{-3}$	$0,7788 \cdot 10^{-3}$	$0,7932 \cdot 10^{-3}$	$0,8372 \cdot 10^{-3}$	$0,7797 \cdot 10^{-3}$	$0,8014 \cdot 10^{-3}$
200	$1,1296 \cdot 10^{-3}$	$1,1163 \cdot 10^{-3}$	$1,1472 \cdot 10^{-3}$	$1,1703 \cdot 10^{-3}$	$1,2994 \cdot 10^{-3}$	$1,1696 \cdot 10^{-3}$	$1,218 \cdot 10^{-3}$

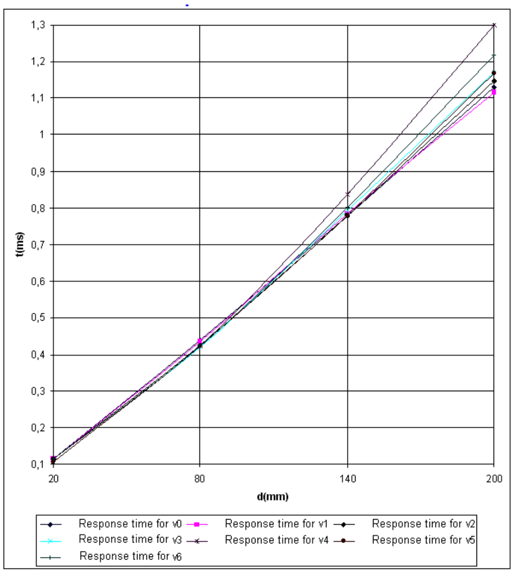


Fig. 5. Response time in function with distance.

For a plane obstacle, placed at distance d=100mm over the sensor, was made measurements at different temperatures of the environment.

Table 2. Response time variation in function with environment temperature

Temperature T(^oC)	Response time t(s)
-15	$0{,}6233 \cdot 10^{-3}$
-10	$0{,}6154 \cdot 10^{-3}$
-5	$0{,}6098 \cdot 10^{-3}$
0	$0{,}6028 \cdot 10^{-3}$
5	$0{,}5988 \cdot 10^{-3}$
10	$0{,}5937 \cdot 10^{-3}$
15	$0{,}5882 \cdot 10^{-3}$
20	$0{,}5831 \cdot 10^{-3}$
25	$0{,}5785 \cdot 10^{-3}$
30	$0{,}5714 \cdot 10^{-3}$

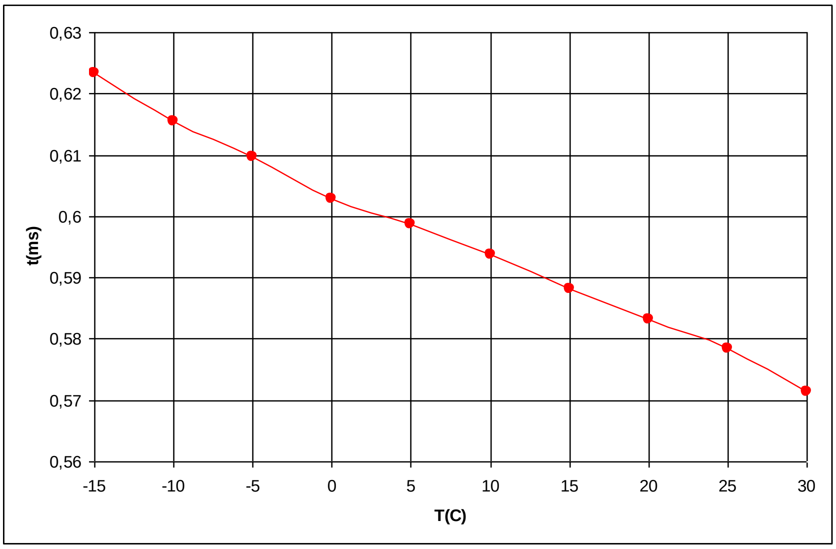


Fig. 6. Response time in function with temperature.

5. CONCLUSIONS

Ultrasonic detection is influenced of the temperature, the wind velocity, the shapes of the obstacles due to the values of the measurements. Anyway, the sonar and ultrasonic sensor are used in different types of applications due to the low cost and high precision compared with other distance sensors.

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