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Angle Sensor Excentricity

1. General

Magnetoresistive angle sensors based on strong field operation are approximately independent of field strength. They measure mainly the direction of magnetic field lines. Ideal conditions are possible with a homogeneous parallel field. Large magnets fulfil this requirement. Costs reasons ask for a compromise between magnet size and corresponding tolerances of the angle sensor.

If sensor and magnet rotation axes are in line the sensor output characteristic will approximately follow the relation for the signal voltage V_o.

$$V_o = V_o(0) \cdot \sin 2\alpha$$

α is the rotation angle of the magnet. Tolerances occur if the sensor is placed outside the rotation axis (Fig. 1). In this case the bended field lines outside the centre are effective and they cause offset or sensitivity shifts.

Dependent on the sensor position (R_m, δ) and the mechanical angle α to be measured the following relation for the sensor output V_o has been calculated and was checked by measurements:

$$V_o = V_o(0) \sin \left(2 (\alpha + C \cdot R_m^2 \sin (2\alpha + 2\delta))\right)$$

Tab. 1 gives values of the constant C for some magnets and in general. The deviation from the standard response can be expressed as an angle deviation or tolerance

$$\Delta\alpha = C \cdot R_m^2 \sin (2\alpha + 2\delta)$$

For positions on the X, Y axes (δ = 0, 90°, . . .) no offset effect but a sensitivity change occurs with a maximum tolerance at α = +/- 45° and +/- 135° (Fig. 2)

$$| \Delta \alpha | = C R_m^2$$

For diagonal positions (x = y = -y) no sensitivity but an offset tolerance occurs (Fig. 3)

$$| \Delta \alpha | = C R_m^2 \cos 2 \alpha$$

with a maximum value at $\alpha = 0°$, +/- 90° and 180°

$$| \Delta \alpha | = C R_m^2$$

2. Single sensor system

If we assume that an encapsulated angle sensor with excentricity will be adjusted mechanically to the specified output voltage V_o ($\alpha = 0$) at $\alpha = 0$, then the tolerances at $\alpha = 0$ are set to zero.

The original offset tolerances at $\alpha = 0$ (Fig. 3) are then transformed into a tolerance

$$| \Delta \alpha | = 2 C R_m^2 \sin^2 \alpha$$

In the useful angle range of -45°. . .+45° some tolerance values of $| \Delta \alpha | / C R_m^2$ then are:

$\vert\alpha\vert$ / °. . . δ / °. . .	0	15	30	45
0 / 90 / . . .	0	0.5	0.87	1
45 / 135 / . . .	0	0.134	0.25	1

An adjusted 30° angle sensor has a maximum tolerance of

$$| \Delta \alpha | = 1/2\ C R_m^2 \quad \text{at} \ \ +/- 15°$$

and in the range between | a | = 0 and 15° the tolerance increases approx. linearly from zero to this value. Above +/- 15° the sinusoidal function given above is effective and has to be taken into account for the 70° or 90° sensors.

Fig. 4 gives the maximum tolerances at α = +/- 15° for different magnets as a function of the excentricity radius R_m.

In general a tolerance of 0.3° or 1% FS appears if R_m corresponds about to 10% of the magnetic dimensions l, w.

3. Double sensor system (KMZ 41)

In this case both sensors are influenced differently and the resulting tolerance $\Delta\,\alpha$ has to be calculated from the deviations of the two responses

System 1:

$$V_o = V_o(0) \cdot \sin(2(\alpha - 45° + C R_m^2 \cdot \sin(2\alpha + 2\delta - 180°)))$$

$$V_o = V_o(0) \cdot \sin(2(\alpha - 45° - C R_m^2 \cdot \sin(2\alpha + 2\delta)))$$

System 2:

$$V_o = V_o(0) \cdot \sin(2(\alpha + C R_m^2 \cdot \sin(2\alpha + 2\delta)))$$

If $C R_m^2$ is sufficiently small as in our case of tolerance calculation and if the angle α is calculated from the relation of the two output signals e.g. via the arc tan function, then the resulting measuring tolerance can be described by

$$|\Delta\alpha| = C R_m^2 \cdot \cos 4\alpha \cdot \sin(2\alpha + 2\delta)$$

At α = 0° / 45° / 90° /. . . the tolerances are maximum with worst case tolerances of $|\Delta\alpha| = C R_m^2$.

At α = 22.5° / 67.5° / 112.5° /. . . the tolerance is always zero. This suggests to use these position for

- measuring with highest precision (e.g. 0° of throttle position)
- adjusting the sensors (zero set)

If the sensors are adjusted in this way the maximum tolerance is limited to $C R_m^2$, while an adjust at α = 0 or 45° will double the maximum possible tolerance ($2 C R_m^2$).

Tab. 1 Calculation of angle sensor tolerances caused by excentricity (Fig. 1)

$\Delta\alpha = C\, R_m^2 \sin 2(\delta + \alpha)$

$R_m < 0.1\,(l + w)$

Sm_2Co_{17}-magnet all measures in mm w x h x l	C / ° / mm^2 $320/(w+l)^2$ *)	d / mm -
6 x 3 x 5	2.6	0.7
8 x 3 x 7.5	1.35	0.5
11.2 x 5.5 x 8	0.74	2.1

h = thickness
d = air gap for Hx ~ 100 KA/m
*) = l ~ w

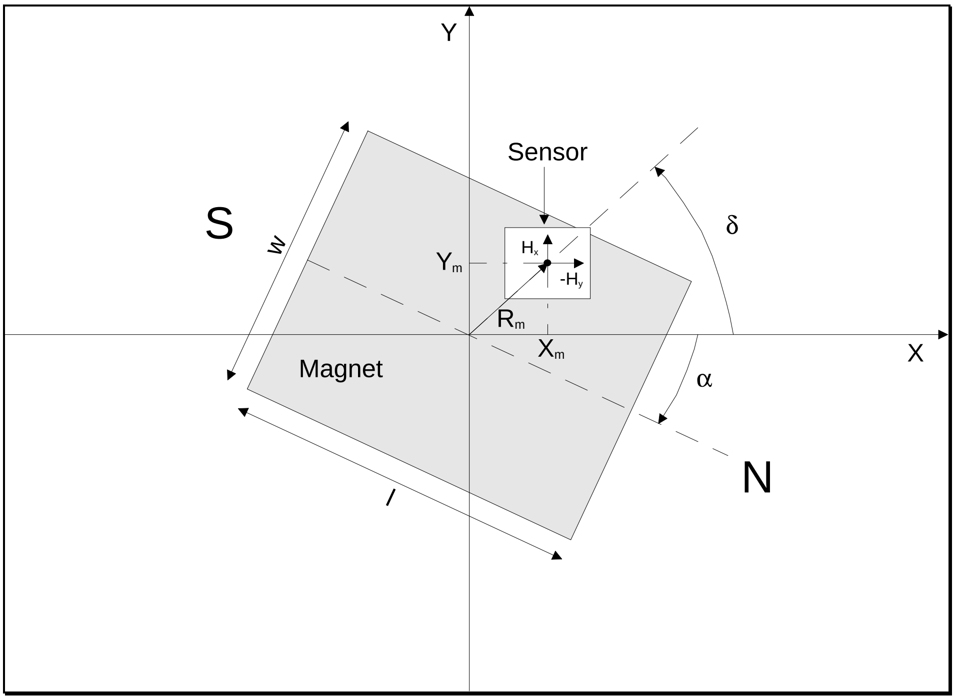

Fig.1 : Angle sensor with excentric sensor positon

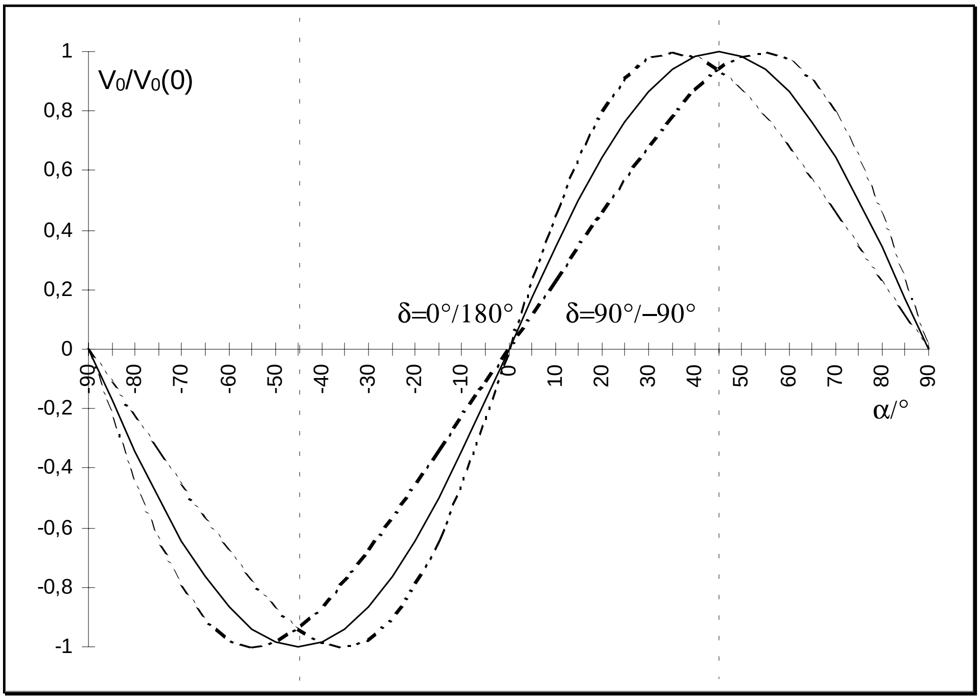

Fig.2 : Response tolerances for sensor position on x,y axes

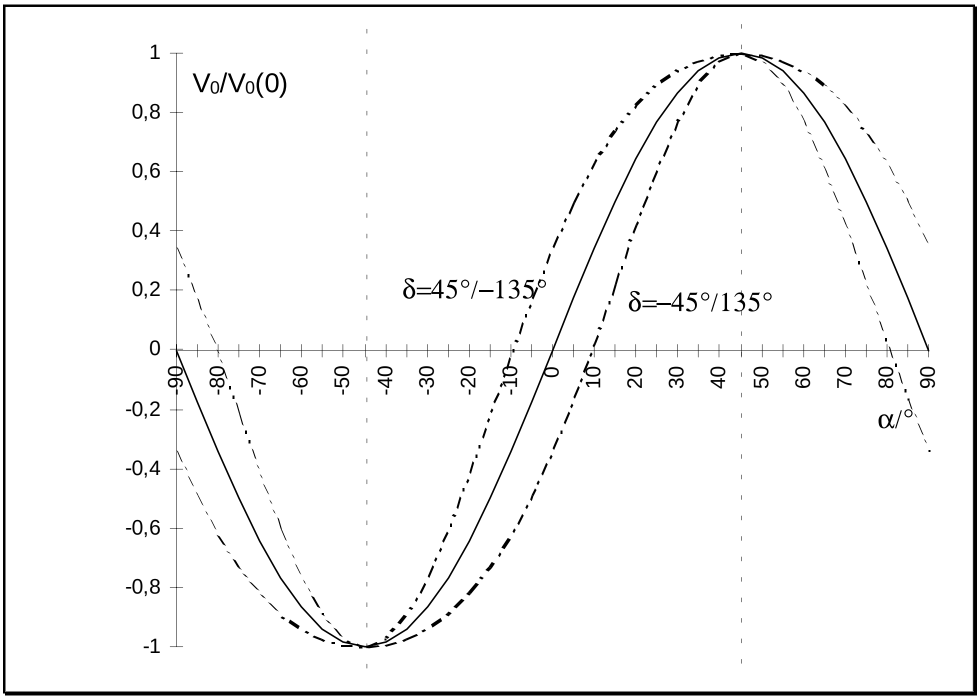

Fig.3 : Response tolerances for sensor position diagonales

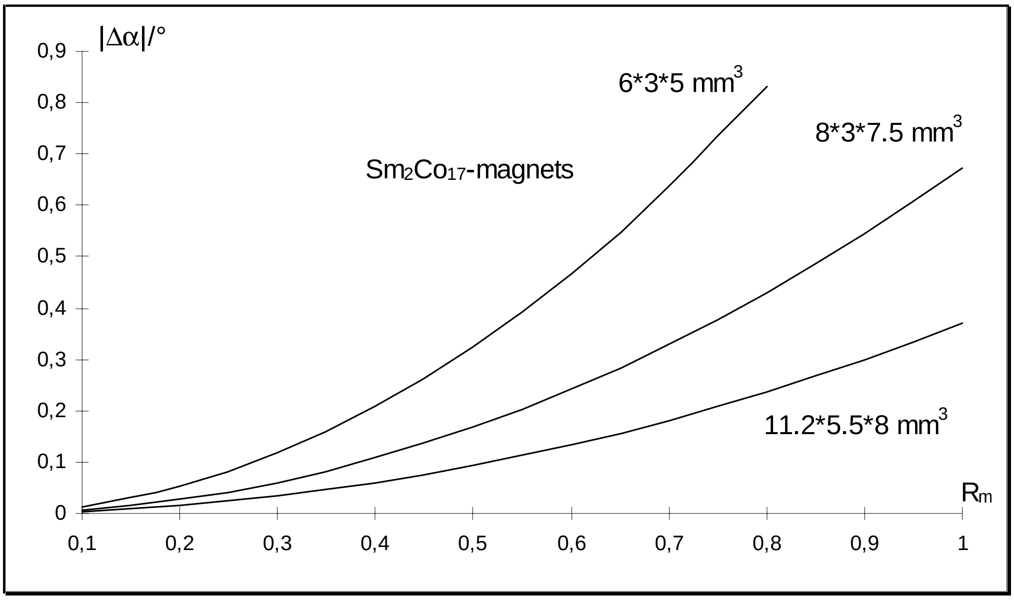

Fig.4: Maximum angle tolerances $\Delta\alpha$ caused by exentric magnetic field sensor position at 30° angle sensors