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Graphical Methods Used to Solve Misalignment Problems of Mechanical Transmissions

Ramona-Monica Stoica[1], Daniela Voicu[2], Radu Vilău[3]

Abstract: This paper presents some graphical methods used to solve different misalignment problems of mechanical transmissions. For this purpose, it was created a mechanical transmission composed of an electric motor with a driving shaft, a coupling and a driven shaft mounted on two pillow block bearings. With the use of two dial indicators, there were measured both parallel and angular misalignment of the constituent elements and follow-up, it was realised a graphic display of the measured values, in order to determine the needed adjustments. Such alignment method has a high level of precision and it does not imply expensive devices. Misalignment of mechanical transmissions represents a broad issue in all factories, and the working personnel is constantly interested in ways to remedy such problems.

Keywords: misalignment; mechanical transmissions; graphic method

JEL Classification:

1. Introduction

In the majority of factories, regardless of the products manufactured within, all processes are performed either by mechanically driven machine parts or by other sources of movement: electric, hydraulic, pneumatic or combinations.

[1]PhD Eng., Military Technical Academy “Ferdinand I”, Bucharest, Romania, Address: Blvd. George Cosbuc 39-49, Bucharest 050141, Corresponding author: ramona.stoica@mta.ro.
[2]PhD Eng., “Dunărea de Jos” University of Galati, Romania, Address: 47 Domneasca Street, Galati, Romania, E-mail: daniela.voicu@mta.ro.
[3]PhD Eng., Military Technical Academy “Ferdinand I”, Bucharest, Romania, Address: Blvd. George Cosbuc 39-49, Bucharest 050141, E-mail: radu.vilau@mta.ro.

Specific attention is given to the alignment of machine elements which form a mechanical transmission, due to the extensive range of faults which can occur during its functioning. Regarding the alignment of mechanical parts, there are two categories: parallel and angular alignment, both in vertical or horizontal plane. Each can be determined by various methods, such as: the reverse dial indicator method, the rim and face method (with the use of dial indicators), the straightedge and feeler gauge method, laser methods etc. (Mobley, 2001; Piotrowski, 2007).

From the aforementioned, the methods which imply the use of dial indicators can be applied as graphical methods in order to determine the misalignment of two elements and the needed remedial actions.

For the demonstration purposes, considering the above, follow-up there are presented the steps which may be performed in order to verify the parallel and angular misalignment in horizontal and vertical planes.

2. Graphical method for shim determination

For the graphical determination of misalignment, it was mounted a mechanical transmission, depicted in figure 1, composed of the following:

– an electric motor with a driving shaft;

– a rigid flange coupling;

– a driven shaft mounted on two pillow block bearings;

– two dial indicators.

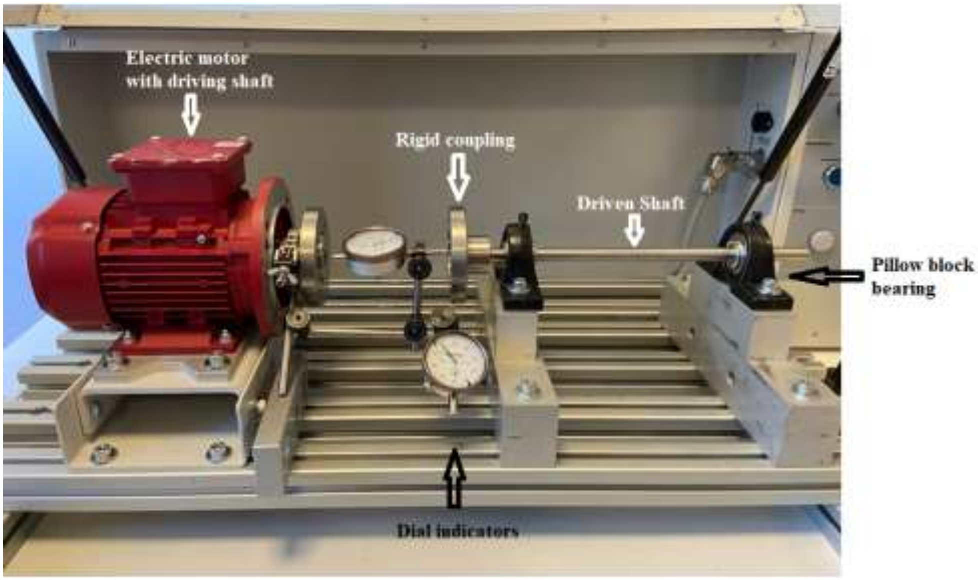

Figure 1. Components of the Mechanical Transmission

Whenever is intended to determine the misalignment between two or multiple elements, first is established the reference base, and after, there are performed the measuring steps for the consequent elements. Considering such, follow-up there are presented the phases for aligning the electric motor towards the driven shaft, by establishing the necessary height adjustment of the motor feet.

Therefore, first is performed the mechanical transmission setup, with the characteristic mounting distances between machine parts, as depicted in figure 2 [1]. The highlighted distances are essential for determination of misalignment values for the front and rear feet of the motor.

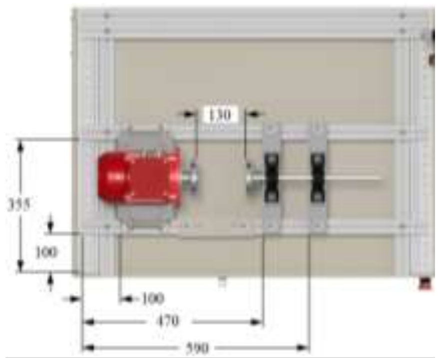

Figure 2. Mechanical Transmission Setup

The first graphical method is performed for determining the total misalignment in horizontal plane. Hence, once established the appropriate setup, there are mounted two dial indicators, one on the rim of the driving flange coupling (named motor dial indicator), positioned at 3 o'clock and the other on the rim of the driven flange coupling (named driven dial indicator), positioned at 9 o'clock.

According to specialty literature, the mathematical formulas available for the calculus of horizontal misalignment are (Didactic, 2017; Stoica, Voicu, Vilău & Barothi, 2021):

- for the driving flange coupling:

$$M_{HT} = \frac{M_H}{2} \quad (1)$$

where M_{HT} represents the total horizontal misalignment of the driving coupling, in [mm] and M_H represents the misalignment of the driving coupling, in [mm].

- for the driven flange coupling:

$$C_{HT} = \frac{C_H}{2} \quad (2)$$

where C_{HT} represents the total horizontal misalignment of the driven coupling, in [mm] and C_H represents the misalignment of the driven coupling, in [mm].

The aforementioned mathematical formulas can be applied only for horizontal alignment because any measurements in vertical plane must include the bar sag due to dial indicators mass.

The assembly consisting of the mechanical transmission and the two dial indicators was rotated until each dial indicator needle reached the opposed diametral position on the flange coupling, followed by reading the value indicated on motor dial indicator scale. It was obtained the value $M_H = 0.14$ mm. For the driven shaft was also performed a circumrotation, in order to read the value indicated on the driven dial scale, thus obtaining $C_H = -0.64$ mm.

By applying expression (1) and (2), it was determined the total axial and angular misalignment, in horizontal plane, for the analyzed flange coupling [1, 4]:

- for the driving flange coupling:

$$M_{HT} = \frac{M_H}{2} = \frac{0.14}{2} = 0.07 \text{ mm}$$

- for the driven flange coupling:

$$C_{HT} = \frac{C_H}{2} = \frac{-0.64}{2} = -0.32 \text{ mm}$$

For the graphical determination of shims thickness which must be added under engine feet, there were measured several parameters, with the use of a ruler:

○$A = 45$ mm, representing the distance between the two needles of the dial indicators, in horizontal plane;

○$B = 111$ mm, representing the distance between the driven needle and the screw bolt of front engine feet, measured in horizontal plane;

○$C = 201$ mm, representing the distance between the driven needle and the screw bolt of rear engine feet, measured in horizontal plane.

Follow-up, on a blank gridded graph there were marked the following parameters: point C at (0,0), point M at (A,0), point F at (B,0), point R at (C,0), point C_{HT} at (0, value resulted from calculus) and point M_{HT} at (A, value resulted from calculus). It was plotted a line between C_{HT} and M_{HT}, and then extended so that it passed above and below points F and R. This line represents the motor shaft axis.

There were marked two vertical discontinuous lines, along points R and F. Points on y axis, where these lines intersect the motor shaft axis, represents the shims thickness needed for horizontal alignment. The value related to point R represents parameter G_{HR} (shim thickness for rear feet), and the value related to point F represents parameter G_{HF} (shim thickness for front feet). The complete graph is depicted in figure 3 (Stoica, Voicu, Vilău & Barothi, 2021).

As it can be observed from the graph, the resulted values of shim thickness are $G_{HF} = 0.7$ mm and $G_{HR} = 1.48$ mm. Positive values imply the movement of engine towards 3 o'clock, whereas negative values imply the movement of engine towards 9 o'clock.

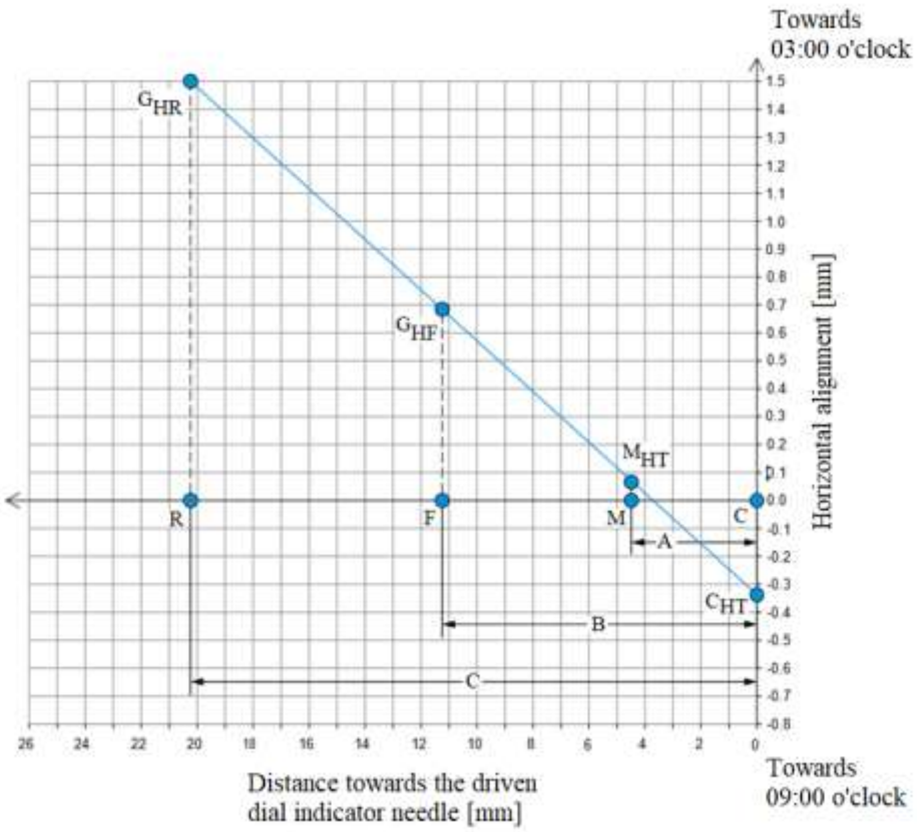

Figure 3. Horizontal Alignment of Machine Parts by Graphical Method

For vertical alignment of transmission elements there were used the following mathematical formulas [1]:

- for the driving flange coupling:

$$M_{VT} = \frac{M_V - M_{Vg}}{2} \quad (3)$$

where: M_{VT} [mm] represents engine total misalignment in vertical plane, M_V [mm] represents the engine misalignment in vertical plane, M_{Vg} [mm] represents the value shown by the dial indicator, wherewith it was corrected the total misalignment, as effect of gravity force.

- for the driven flange coupling

$$C_{VT} = \frac{C_V - C_{Vg}}{2} \quad (4)$$

where: C_{VT} [mm] represents driven element total misalignment in vertical plane, C_V [mm] represents driven element misalignment in vertical plane and C_{Vg} [mm] represents the value shown by the dial indicator, wherewith it was corrected the total misalignment, as effect of gravity force.

For the vertical measurement, the two dial indicators were mounted at 6 o'clock and 12 o'clock, respectively, and it was performed a bar sag measurement, resulting the values $M_{Vg} = C_{Vg} = 0.03$ mm.

Considering the same values for parameters A, B, C as in horizontal plane, there were established: point C at (0,0), point M at (A,0), point F at (B,0), point R at (C,0), point C_{VT} at (0, value resulted from calculus) and point M_{VT} at (A, value resulted from calculus).

Following the same graphical steps as for the horizontal alignment phase, it resulted the representation from figure 4, from which can be extracted the values of needed shims thicknesses (Stoica, Voicu, Vilău & Barothi, 2021).

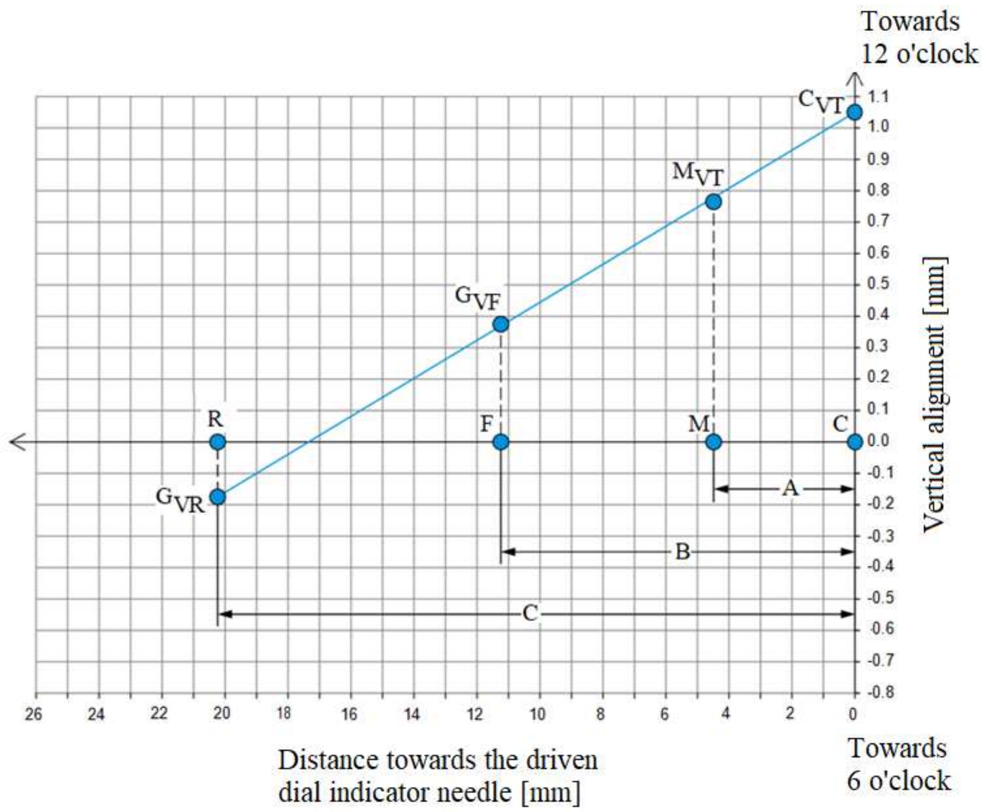

Figure 4. Vertical Alignment of Machine Parts by Graphical Method

3. Conclusions

Misalignment of mechanical parts can influence the functioning period of a mechanical transmission and it often is between main causes for faulty functioning or frequent maintenance actions.

Graphical methods are an alternative to the straightedge feeler gauge method, in order to obtain high precision measurements or to the laser methods, which are an expensive solution. Also, both parallel and angular misalignments in a plane can be determined by performing a single mounting of the dial indicators.

As a disadvantage, the graphical method implies a certain training of the personnel, regarding the usage of dial indicators and measurement techniques, and the understanding of the graphical steps implied by such methods.

4. Acknowledgement

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