

STRAIGHTNESS FUNDAMENTALS

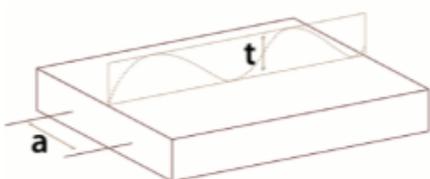
WHY MEASURE STRAIGHTNESS

The evaluation of straightness deviation is employed primarily in monitoring the form of cylindrical and conical surface parts. It can also be used to control line elements in one direction on flat surfaces.

In the mechanical area the evaluation of straightness is very important. In fact, "In machine tool guiding systems the straightness is fundamental for warranting the tolerance observation of the produced parts. In the manufacturing of hydraulics equipment parts it is also necessary to observe straightness and flatness specifications; the respect of tolerances is fundamental in aircraft wing subassembly, etc." [1].

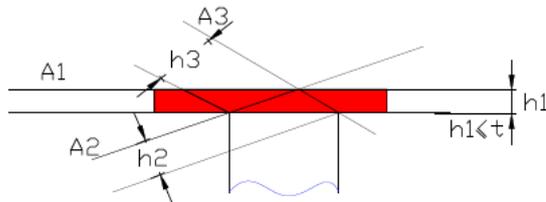
DEFINITIONS (according to ISO 1101) AND GENERALITIES [2]

- Straightness is a property of a nominally straight line. It characterizes a line (edge, median line, line on a surface) in what concerns its deviation from an ideal straight line, but it is not sufficient to characterize a surface in global terms.
- The straightness tolerance is the maximum acceptable linear dimension, t , of the tolerance zone where the line location must be considered.
- The tolerance zone, in the considered plane, is limited by two parallel straight lines at a distance t from each other, only in the specified direction, at any distance a .



Definition of the straightness tolerance zone of a given line on a surface

- In the evaluation of the straightness geometric deviation for an element with a given tolerance, the straightness must be in accordance with its specification when the element is contained between two straight lines that are distant from each other by a value less than or equal to the specified tolerance value. The orientation of the straight lines must be chosen so as to minimise the distance between them.



Definition of a straightness tolerance zone

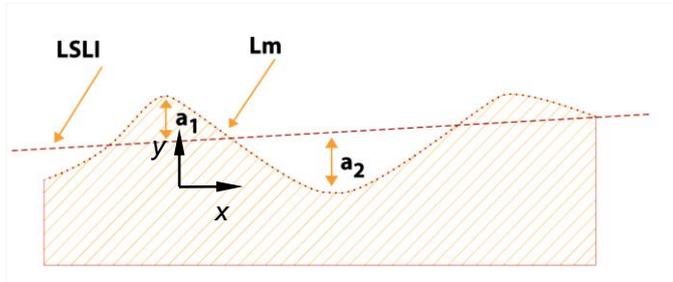
- When determining the tolerance zone orientation it is necessary to establish a reference line – an associated line adjusted to the straightness profile, according to specific conventions, for which the deviation and the straightness parameters are referred. The technical specification ISO/TS 12780-1:2003 considers two procedures for determination of the reference line:
 - The minimum zone reference line method (MZLI), that best meets the tolerance zone definition
 - The least squares reference line method (LSLI), which provides a good approximation for the straightness deviation, although overestimating it, but it is currently the most commonly used in measurement equipment at industrial level.

PROCEDURE FOR DETERMINING THE STRAIGHTNESS DEVIATION

The least squares reference line method (LSLI) is now used to assess the straightness deviation of a given line on a surface of the workpiece. According to ISO/TS 12780-1, the procedure can be described by the following steps:

- Determine the extracted line, L_m , containing the extracted points of a surface (x_i, y_i) in the selected direction.

- ii) Adjust to this line a straight line for which the sum of squares of the local straightness deviations, a_i , is minimal - least squares reference line (LSLI). Local straightness deviations, a_i , will be given by the distances from the extracted points of L_m line to the reference line, LSLI.



Least squares reference line (LSLI) [ISO 12780-1]

- iii) Calculate the shortest distance of each extracted point (x_i, y_i) to the straight line LSLI using the following equation:

$$a_i = \frac{y_i - mx_i - b}{\sqrt{1 + m^2}}$$

where m is the LSLI slope and b its intercept.

- iv) Straightness deviation can be defined by the sum of the value of the maximum positive local straightness deviation, a_1 , with the absolute value of the maximum negative local straightness deviation, a_2 - peak-to-valley straightness deviation (STRt).
- v) The STRt value must be compared with the straightness tolerance value, to verify if the element straightness deviation is in accordance with the corresponding specification.

[1] Restivo, T., Rodrigues, J., Chouzal, F., Menezes, P., Online Virtual System for Straightness Evaluation, Experiment@ International Conference (exp.at'13), 2013 2nd proceedings, IEEE Xplore, 192 – 193, DOI: 10.1109/ExpAt.2013.6703068

[2] Maria Teresa Restivo, Fernando Gomes de Almeida, Maria de Fátima Chouzal, Joaquim Mendes e António Mendes Lopes, "Laboratórios de Instrumentação para medição/Instrumentation for Measurement Laboratories", bilingual edition, Editora UPorto, ISBN: 978-972-8025-67-0, Fevereiro 2008, (e-book).