



24th COBEM - 2017



24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM-2017-0950

ANALYSIS OF FIT SYSTEM IN THE PROGRAMMING ENVIRONMENT MATLAB

Felipe Marques Farias Filho

Universidade Federal da Paraíba (UFPB), Cidade Universitária, João Pessoa PB, Brazil
fmfariasfilho@hotmail.com

Romualdo Campos da Fônsaca

romumetromec@ct.ufpb.br

Cícero da Rocha Souto

cicerosouto@cear.ufpb.br

Abstract. *This work consists in the development of a routine to analyze normalized fits according to the NBR 6158/95, using the programming language MATLAB. The final product of this work is an executable program, provided with a normalized fit it shows the fit data, hole and shaft data, which compose it. This information is displayed in detail for a specific analysis, and graphically for a fast analysis. Besides that, it is capable to do probability calculations with the statistical data acquired from the fit, which is interesting to predict outcomes in case of mass production. As secondary objective, students interested in learning about the NBR 6158/95, metrology and fit systems can also use this tool to help with their studies. It is presented as results the user interface, highlighting the areas of inputs and outputs.*

Keywords: *Metrology, Fit systems analysis, Statistical Process Control, NBR 6158/95, MATLAB.*

1. INTRODUCTION

The majority of the mechanical parts manufactured in the word industry are interchangeable. A part is interchangeable when in a group of similar parts, any can be selected randomly for assembly and the mechanism functions satisfactorily (Bjorke, 1978). Inside the specifications of any mechanical part is the tolerance, as there are no perfect manufacturing process. The basic concept for dimensional tolerance is the admitted variation for a determined dimension (Duarte, 2012). The tolerance specification in the detailing stage of the product is maybe one of the major project activities, because it directly affects the quality and cost of the product. A wrong specified tolerance can affect the quality of a product, generating costs related to errors in its main function or by generating secondary problems (Umaras, 2010). In addition, tolerance is important to the fit of a mechanical. A two parts fit is defined by the difference between their effective dimensions before the mating, therefore it depends on the tolerances established for the dimensions of these parts. Tolerance and fit systems were created to limit and normalize the tolerances and fits of mechanical parts, like the DIN 7182 and the NBR 6158/95. These norms like any other normalizing process also guarantee quality, security and efficiency. The objective of this work was to create a program in MATLAB capable of analyzing a normalized fit according to the NBR 6158/95, which is the enforced norm in Brazil, and informs its data.

2. MATLAB LANGUAGE CHOICE

MATLAB is a language widespread across the engineering courses (Gilat, 2012). It is considered compacted when compared to other programming languages. However, it is not open source, which restrain its availability.

3. PROGRAM DEVELOPMENT

The result of this work is displayed in Fig. 1, the user interface. It contains the following components: normalized fit input box, status box, hole data, shaft data, arithmetic fit data, statistical fit data, graph and probability calculations area.

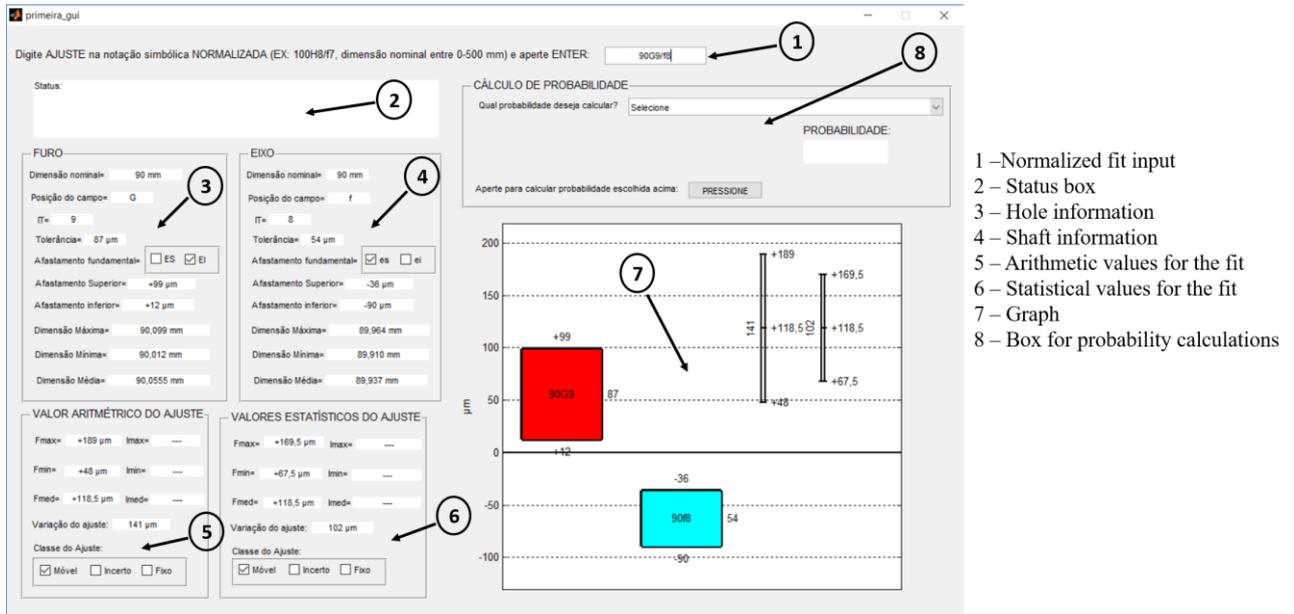


Figure 1. User interface

As an example for the user interface it was used the normalized fit 90G9/f8 as input. Specifically inserted in the area of the item 1 of Fig. 1. The results are displayed in the areas of the items 3 to 7, which will be explained in the next section.

The development of the program started with the determination, division and ordering of the demanded functions for it. This resulted in the guiding of the project and the tasks that should be covered: receive normalized input; decode input; export data about the hole, shaft, arithmetic fit, and statistical fit; graph synthesis; probability calculations and export the probability results. This development guide is displayed in Fig. 2.

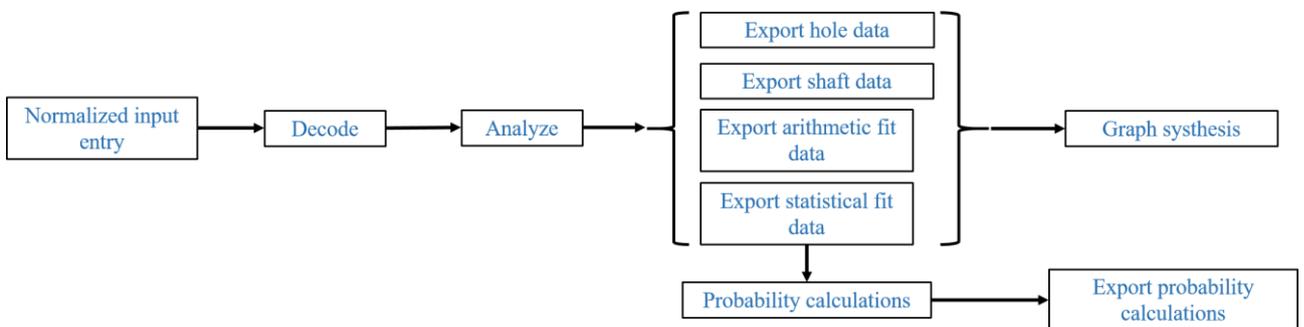


Figure 2. Development diagram

3.1 Input of normalized fit and decoding

The program receives as input normalized fits according to the NBR 6158/95, like 90G9/f8. The fit can be into two parts: hole and shaft. Each one can be split even more into the following data: nominal size, fit tolerance zone and international tolerance grade (IT).

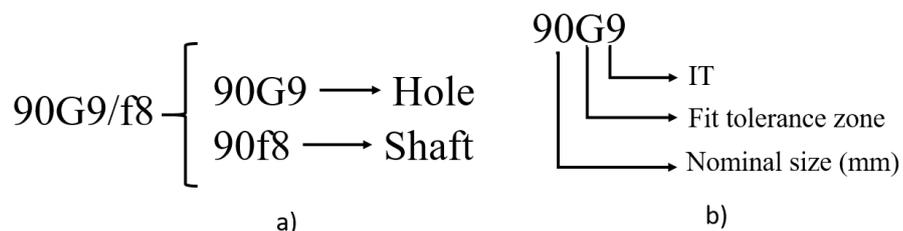


Figure 3. Decoding of the input 90G9/f8

The tolerance varies in function of the IT and the nominal size. Specifically, the tolerance is directly proportional to the nominal size and IT, in other words, the bigger the nominal size or IT, the bigger is the tolerance, The IT can vary between 1 to 18, accordingly to the application. The currently version of the program only works with nominal size up to 500 mm, because in this interval include most of the frequently used values, the values used in the conventional mechanics.

One or two letters indicate the tolerance zone. For shafts, it is used lower case letters and for the holes, it is used upper case letter. The tolerance zone is contained between two lines, representing the maximum and minimum limits of size, defined by the magnitude of the tolerance and its relative position in relation to the zero line (ABNT, 1995a).

3.2 Analysis

3.2.1 Shaft and hole data

In the analysis, the information about the hole and shaft acquired on the previous stage: nominal size (D), tolerance zone and IT. With this information, at first are acquired the all the data related to the hole and shaft: tolerance, specification of the fundamental deviation, numerical values of the deviations, limits of size and the mean size.

The maximum limit of size (D_{\max} for holes and d_{\max} for shafts) is the biggest value tolerated for a size, so that a part is still considered good for use. Similarly, the minimum limit of size is the smallest value tolerated for a size, so that the part is still considered good for use. The mean size is the arithmetic mean of the limits of size. The tolerance the difference between the maximum and minimum limit of size:

$$T = D_{\max} - D_{\min} \quad (1)$$

The deviations can be positive or negative and classified in upper and lower deviation. The upper deviation (ES for holes and es for shafts) defined as:

$$ES = D_{\max} - D \quad (2)$$

And the lower deviation (EI for holes and ei for shafts) is given as:

$$EI = D_{\min} - D \quad (3)$$

Replacing Eq. 2 and Eq. 3 in Eq. 1, results in:

$$T = ES - EI \quad (4)$$

The fundamental deviation defined as the deviation closest to the nominal size, therefore, is the deviation with the lowest absolute value. The fundamental deviation can be the upper and the lower deviation, depending on their values.

Both tolerance and fundamental deviation are acquired through the NBR 6158/95, where their values are tabled in function of the nominal size and the IT. Besides the value of the fundamental deviation, it also informs if it is the upper or lower. Hence, with one of the deviations and tolerance, using Eq. 4, calculate the other one. With the values of nominal size and deviations, the limits of size can be calculates using Eq. 2 and Eq. 3.

3.2.2 Data of fit between hole and shaft

Using the data found of the hole and shaft, it is possible to analyze the data of the fit. The definition of fit is described as the resulting relation of the difference, before assembly, between the sizes of the two elements, which are going to be mounted (ABNT,1995a).

This way the maximum and minimum limit sizes for the fit will be calculated by the following equations:

$$D_{\max} - d_{\min} \quad (5)$$

$$D_{\min} - d_{\max} \quad (6)$$

If the Eq. 5 has a positive value it is considered to be a maximum clearance (F_{\max}), otherwise if it has a negative value it is considered to be a minimum interference (I_{\min}). Similarly, if the Eq. 6 has a positive value it is considered to

be a minimum clearance (Fmin), otherwise if it has a negative value it considered to be a maximum interference (Imax). Then is calculated arithmetic mean between the values of Eq. 5 and Eq. 6, if it is positive is considered a mean clearance (Fmed), if it is negative it is considered a mean interference (Imed). The subtraction between the values of Eq. 5 and Eq. 6 is the fit tolerance zone (VA), or alternatively, the sum of the hole and shaft tolerances is also the fit tolerance zone.

To calculate the statistical data of the fir firstly is obtained the statistical fit tolerance zone (VAe) with:

$$VAe = \sqrt{(T^2 - t^2)} \tag{7}$$

The result of VAe must be round to an integer, according to the NBR 5891/2014 (ABNT, 2014b). With the result for VAe and Fmed (or Imed) it is possible to use the equations below:

$$F_{med} (or I_{med}) + \frac{VAe}{2} \tag{8}$$

$$F_{med} (or I_{med}) - \frac{VAe}{2} \tag{9}$$

If the value of Eq. 8 is positive it is considered to be the maximum statistical clearance (Fmaxe), otherwise if it is negative it is considered to be the minimum statistical interference (Imine). Similarly, if the value Eq. 9 is positive it is considered to be the minimum statistical clearance (Fmine), otherwise if it is negative it is considered to be the maximum statistical interference (Imaxe).

3.3 Graph synthesis

The program creates a graph, presented in Fig. 4. It is a syntheses of all information obtained of the hole, shaft arithmetic values for the fir and statistical values for the fit. Therefore, all information in items 3 to 6 in Fig. 1, which were explained in the previous section.

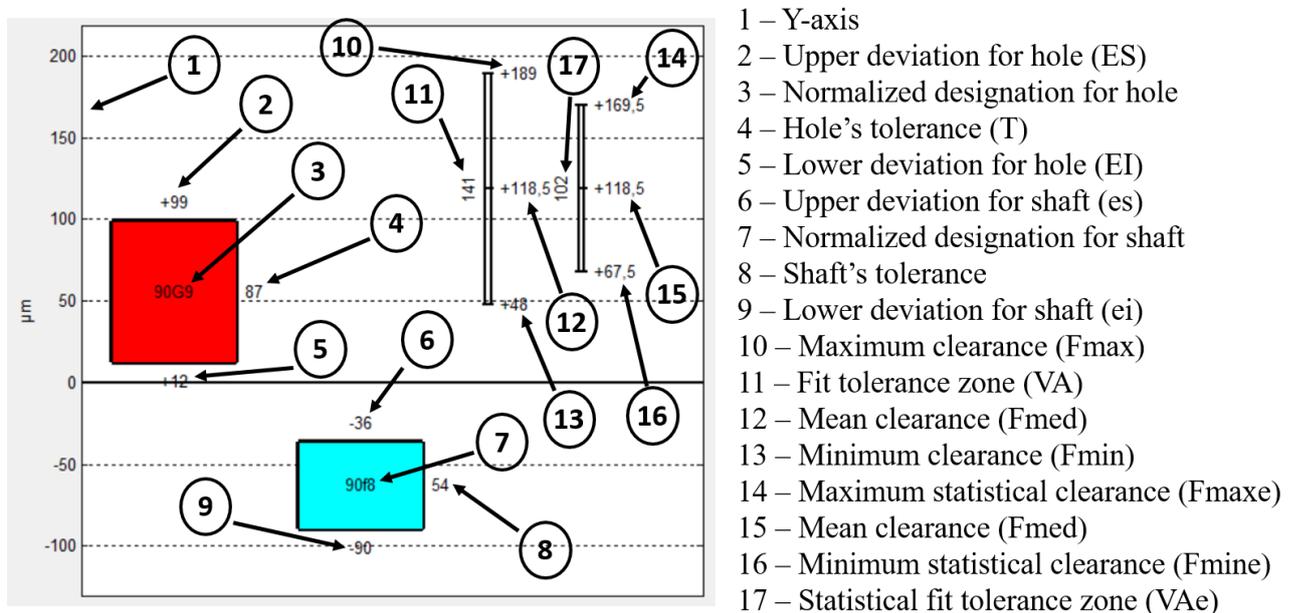


Figure 4. Graph for the 90G9/f8 fit

The origin of the y-axis in the graph represents the nominal size, and the other values represent sizes varying away from the nominal size. These sizes are positive, when they are bigger than the nominal size and they are negative when they are smaller than the nominal size. The scale of the y-axis is micrometers (µm).

The red rectangle and the three numbers around it represent the hole data. The number above the rectangle correspond to the ES, the one below is the EI. The value besides the rectangle is the T. At the center is the normalized designation for the hole.

Analogously the blue rectangle and the three numbers around it represent the shaft data. The number above the rectangle correspond to the es, and the one below the ei. The value besides the rectangle is t. At the center of the rectangle is the normalized designation of the shaft.

The two vertical bars to the left and the four numbers around it represent the arithmetic data for the fit. The values to the right of the bars are respectively from up to bottom: The Fmax, Fmed, Fmin. The value to the left of the bars represent the VA.

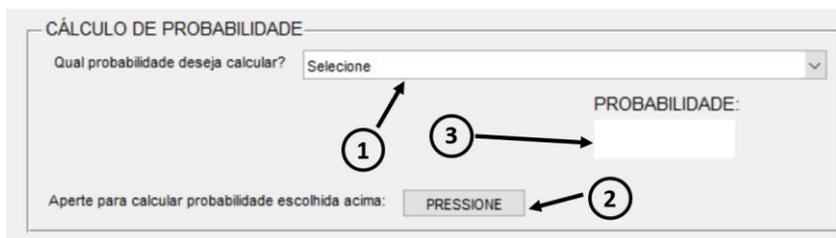
In a similar way, the two vertical bars to the right and the four values around it represent the statistical data for the fit. The data to the right of the bars are respectively from up to bottom: The Fmaxe, Fmed and Fmin. The value to the left of the bars represent the VAe.

3.4 Probability calculations

The probability calculations are based in the normal probability plot reduced form 0 to z. Firstly, the type of probability is selected from the following options:

- a. Probability of clearance fit.
- b. Probability of interference fit.
- c. Probability of clearance fit above a determined value.
- d. Probability of clearance fit bellow a determined value.
- e. Probability of clearance fit between two values.
- f. Probability of interference fit above a determined value.
- g. Probability of interference fit bellow a determined value.
- h. Probability of interference fit between two values.

In Fig. 5 is in detail the box for probability calculations. Only the options “a” and “b” do not need input, all the other options need input data. Specifically for options “c”, “d”, “f” and “g” it only need one input data. For options “e” and “h” it necessary two input data. After the selection of probability and input entry (or not) and press the button “PRESSIONE” and the output will be displayed in “PROBABILIDADE” as percentage.



- 1 – Choose the type of probability to calculate.
- 2 – Button to confirme choice and input.
- 3 – Result.

Figure 5. Box for probability calculations

In Fig. 6 is an example to demonstrate the use of the box for probability calculations. The analyzed fit was 90G9/f8, the same one used in Fig. 1, Fig. 3 and Fig. 4. The selected option was “e”, therefore it was necessary to enter two input data: +70 μm e +120 μm . The result obtained was 49,78 %, which means that if parts were mass manufactured with the 90G9/f8 specifications about 49,78 % of them would have a fit clearance varying between +70 μm e +120 μm .

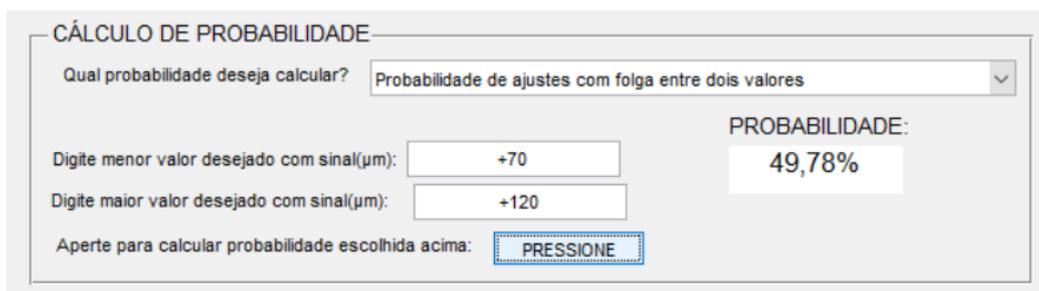


Figure 6. Example of probability calculation

4. CONCLUSION AND RESULTS DISCUSSION

The presented work showed the creation of a program with a clear and lean user interface, which determines the data from a normalized fit using the Integrated Development Environment (IDE) of MATLAB. As suggested improvement, it is possible to update the program to work with dimensions up to 3150 mm, instead only up to 500 mm. Another important matter is the development possibility of a function, linked to this program, capable to choose a normalized fit suitable according to some specifications like nominal size and limits of size.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

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