

3D CAD Modeling Used as Support Material to Improve Understanding of Geometric Tolerances

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Abstract

Students in the mechanical and manufacturing engineering programs at the Technological University of Pereira (UTP) have had difficulty understanding GD&T (Geometric Dimensioning and Tolerances). The subject is part of the content of the subject of engineering drawing, at the beginning of the second year of study. As a contribution to improve the level of understanding, 3D illustrated models were designed with CAD modeling software. The models were migrated to students' computer, smartphone and tablet screens using a CAD viewer. The objective was to create complementary aids, in graphic form without so much text, to analyze and identify the shape, location and symbols of the GD&T. The model information and data was presented in the MBD [Model Based Definition] system. At the end, an evaluation exercise was carried out, to know the impact generated, in the improvement of the level of understanding, when using the new models and the implementation of the TIC in the teaching of the GD&T. As an evaluation model, the Likert scale was used: it is a survey model of 88 students. The data were tabulated and displayed at the end of the work.

Keywords: - MODELING, CAD, TIC, Geometric tolerances

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1. Introduction

At the Technological University of Pereira (UTP), the traditional method has been used in the teaching-learning process of the GD&T: exhibitions, text analysis, approach of exercises and introduction to the reference standards [1] and [2]. The subject is studied in the second year of career; when yet, students have not reached the skills to understand the concept of three-dimensional space. It seems to them that the types of tolerances are many and complex. Most find the subject difficult to understand. It is worth noting that, at the beginning of the study, they only have a basic level of CAD.

It is difficult to understand the characteristics and tolerance zones in a 3D environment because of the wide variety of types and the degree of complexity [3]. A problem that arises permanently is that professionals who leave the Universities do not have enough knowledge in practices with the GD&T [4]. Says the author, "Engineering programs have difficulty teaching GD&T because of their complexity." Some causes may be: little time invested in the study of the subject. The cases are varied and difficult to understand.

It results from teaching and learning because of its degree of complexity, the variety of characteristics and the extensive information contained in the theoretical statements that appear in the texts and norms. Spatial reasoning is required to conceptualize each type of tolerance in a spatial environment. It is necessary to improve the teaching processes of the GD&T. It is necessary to understand all types of tolerances in order to be applied in

production processes. With its correct application, material waste is reduced, the functionality of the elements is improved, interchangeability is facilitated and allows the standardization of a communication language between customers, designers and manufacturers [13].

At Georgia Institute, a course on part modeling, in 3D software, has helped to understand the application of GD&T. The practices help students visualize features from a three-dimensional perspective [6].

The emergence of powerful 3D modeling programs such as: Siemens Corporation NX, SolidEdge, SolidWorks, Autodesk Inventor, among others, help improve teaching processes and include specific routines to represent and designate the geometric characteristics of machine parts [7].

About 3D modeling, in general, it can be said that it allows the use of models that facilitate the interpretation of shapes and sizes of the characteristics of the parts, machines and equipment located in a space. CAD models provide ease of visualization and interpretation of components and their nominal dimensions [8].

Due to the advancement of Information and Communication Technologies (ICT), it is important to incorporate their application in this teaching-learning process of GD&T and graphic engineering.

Digital Transformation in Graphic Engineering should lead to methodological design, using Information and Communication Technologies (ICT) in the innovative teaching-learning processes of Graphic Engineering [9]. The importance of using 3D modeling serves as a guide to find answers to the following questions:

- I. Can dynamic and interactive environments be created with 3D modeling software to improve the teaching-learning process of GD&T?
- II. What effects can be achieved, in students, by including ICT in the presentation with the models?

As answers: 3D models can be designed to represent the concepts and characteristics of GD&T.

ICT can be implemented by using a model viewer for CAD, completely online. For use, you do not need to download applications or programs. The web is only accessed with the compatible browser [5]. CAD viewers allow you to view illustrated and interactive models on computer, tablet or smartphone screens to orbit, scroll, zoom and facilitate the analysis of the characteristics and symbols of the GD&T.

When you upload the part to the viewer, a web link is generated that can be sent by e-mail. When you activate the link, the interactive model appears on the screen.

The dimensions of the tolerance zones, symbols, references and other annotations of the 3D model, can be presented in the MBD [**Model Based Definition**] system [10]. Definition Based on the Model that contains the information for a manufacturing process PMI (Process and Manufacturing Information) [10]. It is in line with the advancement of technology, in modern industry. It should be used for ASME and ISO standards when representing GD&T [9]. To evaluate the activity, with students, a survey model called the Likert scale can be used: "it is a quantitative measurement or data collection instrument used within the research" [11]

2. Methodology

They created the 3D models, in CAD, for working with GD&T. The objective was to use illustrated models as support material, combined with the use of ICT, to improve students' understanding of the topic.

The models were illustrated with different colors and shapes, to provide contrasts. Conventions, measures of tolerance zones, references and symbols were added. This information was presented in the MBD system.

For the study semester, the exercise was conducted with 88 students. First, it was studied with exhibitions, readings, study of chapters of texts and analysis of solved and proposed examples, the activity was developed within a traditional environment without the use of ICT. The main references were [7] and [12]

In a second study session, 3D models in CAD were used as complementary help material, seeking to improve the conceptualization and understanding of GD&T. Each interactive 3D model was migrated to the screen viewer of each student's computer, tablet or smartphone. The objective was to observe and analyze the model in different positions, with the purpose of achieving the spatial and conceptual understanding of the characteristics and symbols of the GD&T.

In this case, the use of ICT was implemented in the process. During the activity, students were asked to observe and analyze each data that appears in the indicator lines, which accompany the model to identify and try to understand the concept of each of the following expressions:

- Meaning of the symbol.
- Form and limits of geometric tolerance.
- Location and shape of the ideal and real surface or axis
- Reference or Datum, if applicable

At the end of the activity it was important to know the impact generated, when using illustrated 3D models and the use of ICT, in the study of the subject. Information and opinions were collected through Likert's survey model. Finally, the results of the impact when using the models were presented as a reinforcement tool.

3. 3D models used in the study

Below are the 3D models, with the types of tolerances, used in the study.

3.1. Tolerance of Righteousness

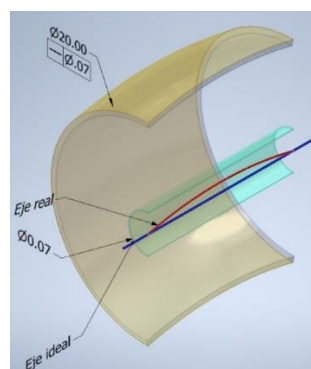


Figure 1. Straightness tolerance applied to the shaft of a cylinder. Inside the tolerance cylinder of $\text{Ø}0.07\text{mm}$, the real and ideal axes are located.

3.2. Tolerance of parallelism

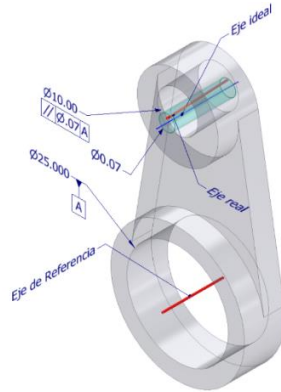


Figure 2. Parallelism tolerance applied to the shaft, of one cylinder, parallel to another reference axis A. The real and ideal shafts are contained within the tolerance cylinder with $\varnothing 0.07\text{mm}$.

3.3. Perpendicularity tolerance

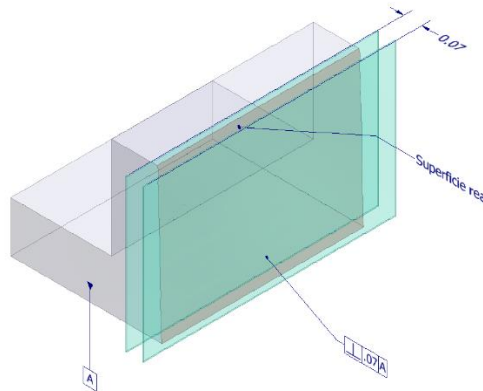
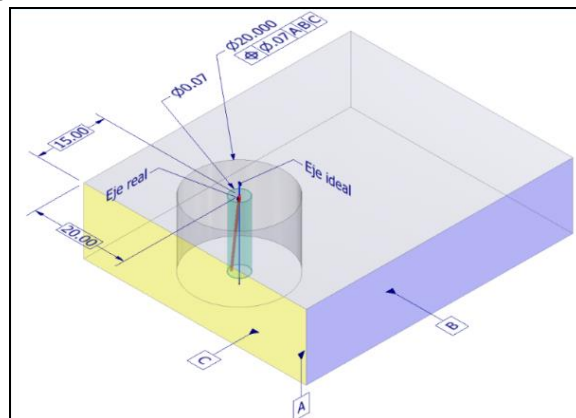


Figure 3. Perpendicularity tolerance applied to a flat surface. The actual surface is limited between two parallel planes, separated by 0.07mm . Parallel planes are perpendicular to a datum surface A

3.4. Position Tolerance



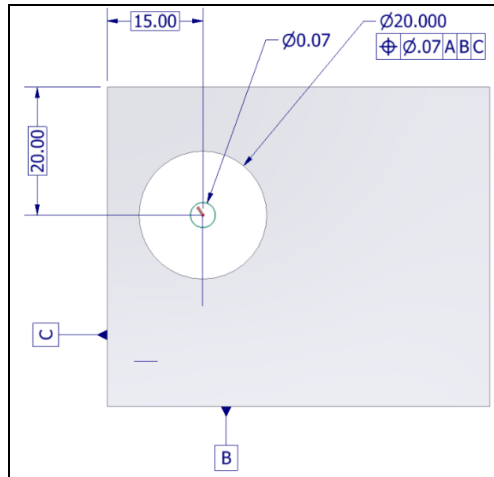


Figure 4. Location of the axis of a localized hole, with theoretically exact measurements, from the reference planes A, B and C. The tolerance cylinder of $\varnothing 0.07$ mm appears, with the real and ideal axes located within this space

3.4. Symmetry tolerance

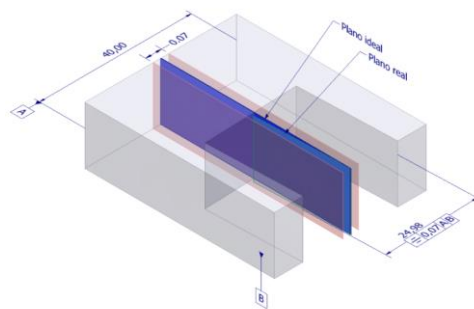


Figure 2. Symmetry tolerance applied to a true mean plane. The mean plane is between 2 parallel planes separated by 0.07 and arranged symmetrically with respect to the mean plane of reference A

3.5. Model on the computer screen



Figure 5. Model on the smartphone screen with a CAD viewer.

4. RESULTS

An anonymous survey of 88 students was conducted to evaluate the impact of 3D models, as elements of aid for the understanding of GD&. The evaluation was performed using the Likert scale. The purpose was to know the students' perception of how difficult or easy it was to understand GD&T, when using 3D models and ICT. Because it is such an extensive topic, the survey was done for four types of tolerances: Righteousness. Perpendicularity, Parallelism and Position. Before answering the survey, it was requested to carefully observe each interactive model to analyze and try to understand the concept of each of the following expressions: Symbol. Form and limits of geometric tolerance. Location of the ideal and real surface or axis. Reference or Datum, if applicable. Each student was asked to express the degree of difficulty or ease in interpreting tolerances. The following question was asked:

When observing and analyzing the interactive 3D model, how easy or difficult did you find it to understand righteousness tolerance? The same question was asked in the cases of tolerances of Parallelism, Perpendicularity and Position. Each question had only one answer out of five possible options for each type of tolerance. They correspond to the five statements of the Likert scale, with their values: very difficult (1), difficult (2), normal (3), easy (4), very easy (5). Normal means that learning and understanding is proportional to the interest and time invested in studying the subject.

Students were also asked to make anonymous comments about the activity developed using the initial texts and examples and the perceived difference when using the new 3D models. The tabulated data are shown in Table 1 and Figures 6 and 7.

	Very easy	Easy	Normal	Difficult	Very difficult
Straightness	13	25	18	17	15
Perpendicularity	14	23	20	13	18
Parallelism	12	21	22	19	14
Position	15	25	20	15	13

Tabla 1, Number of students and responses for each of the 4 types of tolerances

The information in Table 1 is shown tabulated in the graphs in Figures 6 and 7.

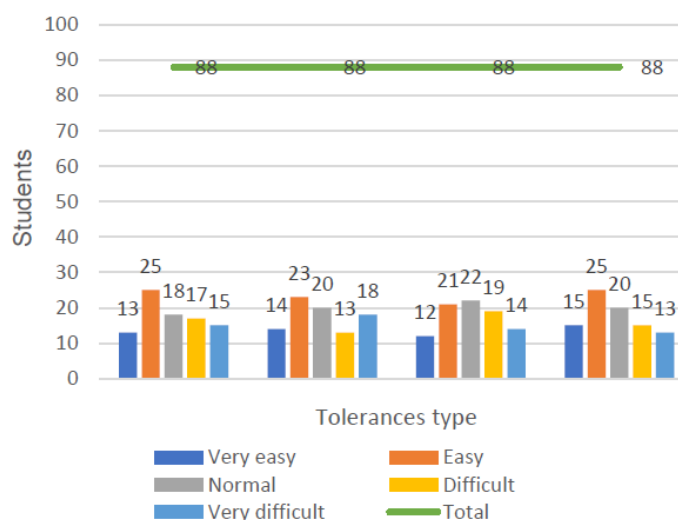


Figure 6. Tabulated data in Table 1

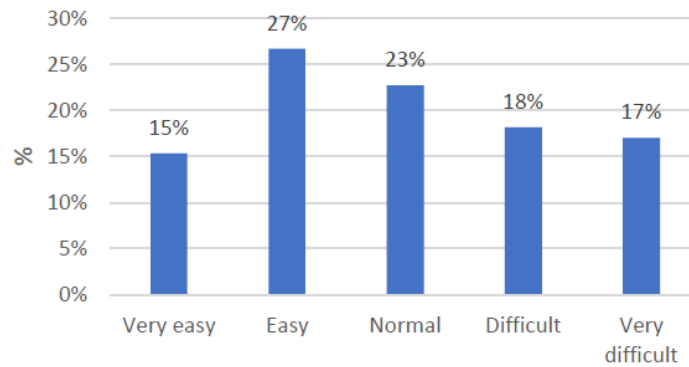


Figure 7. Average of the percentages for the 4 types of tolerances recorded.

5. Conclusiones

Adding the results of the 4 types of tolerance, you can see:

- Very easy + easy varía desde 38% to 45%
- Normal ranges from 18% to 22%
- Very difficult + difficult varia de 28% to 33%
- An increase in the level of understanding was detected in the 4 cases recorded
- The increase was not as flattering as expected, as the number of students who found it difficult and very difficult remains high (28% to 33%).

The trend of the average values, of the result, reached a similarity with the averages of results in the evaluation of the subject of Engineering Drawing in the second year: A low average of students, achieved high level of understanding (very easy). A low average showed great difficulty in understanding (very difficult)

The results indicate that it is necessary to continue in the search for new strategies to advance in the process of improving understanding.

Student comments and suggestions:

- The study time is insufficient because it is such a varied and extensive subject
- Some agreed that studying the subject with the traditional method, reading texts and analyzing 2D exercises, looks boring and difficult to understand.
- The types studied are better understood using 3D models in a dynamic environment. Thus, the piece can be observed from different angles, facilitating the identification and positions of geometric features
- Some suggested that, the next course be worked by making measurements directly, in the physical elements in the laboratory

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