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# AN INTERACTIVE LEARNING TOOL FOR MEASURING OF DISK TYPE GEAR SHAPER CUTTERS

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**Abstract:** Highly interactive self-learning tool for measuring disk type gear shaper cutters is presented in the paper. The created software tool could be used for distance learning in different engineering student courses, where gear shaper cutter characteristics are examined. A learning scenario for virtual learning and measuring of disk type gear shaper cutter is presented.

**KEYWORDS:** GEAR SHAPER CUTTER, VIRTUAL MEASUREMENT, CUTTING TOOLS, E-LEARNING

## 1. Introduction

During the past years, many research studies have been conducted to investigate interactive learning in a variety of forms ranging from the earliest days of computer based learning applications to contemporary multimedia virtual learning environments accessible via Internet. New interactive technologies provide many ways to enhance and extend educational activities. Recently, the interactive self-learning tools, simulating real experimental work, are used for distance learning for many engineering specialities [8]. Virtual simulation of the measurement cannot give the same sense of the students that they would receive using measurement instruments in traditional face-to-face practical laboratories. However, such interactive tools for virtual measurements can be used very successfully for distance and continuing engineering education [9].

In engineering education the laboratory activities are as important as the theoretical lectures [4]. For that reason in the past years appeared virtual laboratories [5, 7], which simulate real laboratory work. Virtual laboratories simulates a real set of experiments and provide a good level of realism. Students have the possibility of performing experiments at any time and from any location and can learn through a direct experience with virtual simulation of the measurements tools [10].

## 2. Virtual Laboratory in Cutting Tools

“Cutting Tools” is a bachelor’s degree course in the department of “Machine Tools and Manufacturing” in the University of Ruse [1, 3]. The main goal of the discipline is to teach the students about tools design, geometry, technological capabilities and exploitation conditions. The course contains general information about cutting tools: tools for turning, drilling, reaming, boring, milling, threading, pull-broaching, gear-cutting and abrasive machining. The theoretical material from the lectures is applied during the laboratory exercises, where students individually check, measure, draw the geometry of the tools, and define the technological parameters for exploitation and sharpening.

The virtual laboratory in Cutting tools provides the students with an environment which simulates a real set of workshops in the “Cutting Tools” course. In order to get experience close to the face-to-face learning, students need to have all kinds of interaction with all types of tools that they can come across during the real work in the “Cutting tools” course workshops. Real laboratory equipment, tooling, machine tools and measuring instruments for the whole course are replaced by corresponding virtual 3D objects. They allow students to measure interactively at their own pace.

The virtual laboratory model includes interactive tools for twelve workshops [2, 7]:

- Measuring of constructive and geometrical Turning tools parameters.
- Measuring of constructive and geometrical Drill parameters.
- Measuring of constructive and geometrical parameters of Sink tools and Reamers.

- Measuring of constructive and geometrical Milling tools parameters.
- Measuring of constructive and geometrical Thread cutting tools parameters.
- Measuring of constructive and geometrical parameters of Broaches [6].
- Measuring of constructive and geometrical parameters of Gear cutters.
- Measuring of constructive and geometrical parameters of Hob Milling Cutters.
- Turning tools sharpening.
- Drills sharpening.
- Sharpening of Sink tools and Reamers.
- Sharpening of Gear cutters.

## 3. Virtual learning scenario

The interactive learning tool for measuring Disk Type Gear Shaper Cutters conduct students in their educational process through the following stages:

**Stage 1:** Theoretical base introduction;

**Stage 2:** Viewing pictures and videos in the gallery (Fig.1);



Fig.1. Photo and video gallery

**Stage 3:** 3D Gallery view (Fig.2);

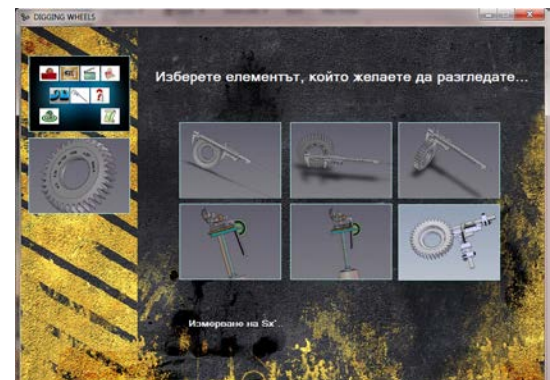


Fig.2. 3D Gallery

3D virtual models are created using *SolidWorks* in Rapid Prototyping Laboratory in University of Ruse.

**Stage 4:** Testing students' theoretical knowledge;

**Stage 5:** Depending on the test results, students could proceed with the practical exercise or go back to Stage 1;

**Stage 6:** Performing measurement processes with the virtual cutting tools according to predefined methodology for virtual measuring Disk Type Gear Shaper Cutters;

**Stage 7:** Filling in a report with measuring results.

#### 4. Virtual measuring of Disk Type Gear Shaper Cutters

The constructive and geometrical parameters of the disk type gear shaper cutters are presented on Fig. 3 [2].

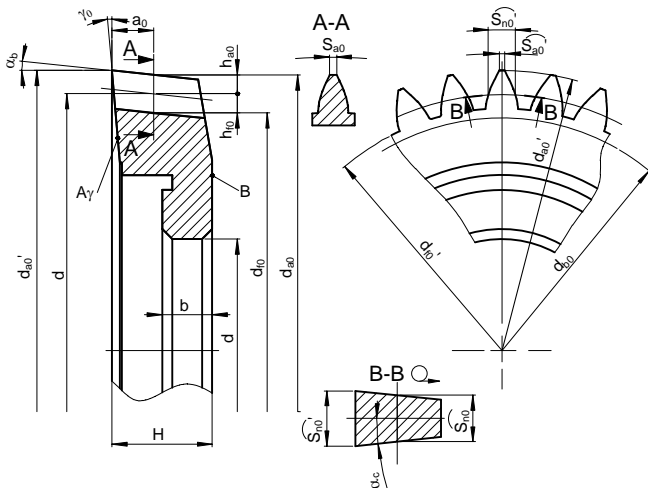


Fig.3. Disk type gear shaper cutters parameters

When gear shaper cutter tooth measurements are to be made using caliper and gear tooth caliper, the addendum, dedendum, whole depth, pitch diameter, outside diameter, root diameter, chordal tooth thickness, chordal addendum, current addendum modification coefficient, etc. must be calculated.

The measuring and calculation of constructive and geometrical parameters of the gear shaper cutters includes the following 20 steps:

**Step 1.** Determining the gear module  $m$  by reading it from the tool identification mark.

**Step 2.** Determining the pressure angle  $\alpha$  of initial tool gear rack, by reading it from the tool identification mark.

**Step 3.** Determining the number of teeth  $z_0$  by reading it from the tool identification mark, or by direct counting from the picture (Fig.4).

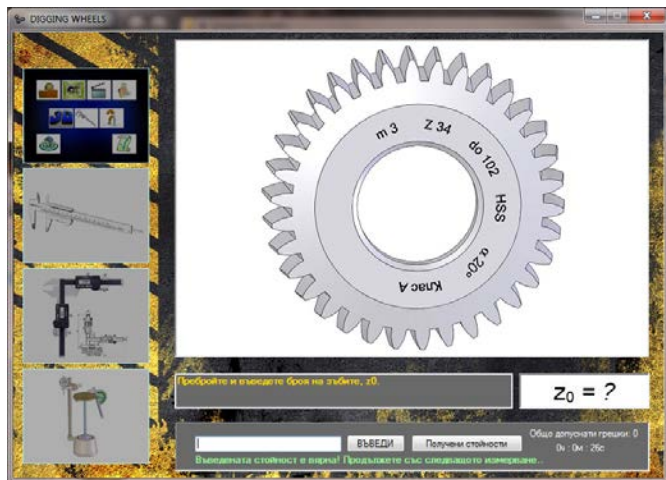


Fig.4. Determining the number of teeth (Step 3)

**Step 4.** The tooth addendum  $h_{a0}$  is determined from the formula:

$$h_{a0} = h_a^* \cdot m \quad , \text{ mm,}$$

where  $h_a^*$  is tooth addendum coefficient.

**Step 5.** The tooth dedendum  $h_{f0}$  is determined from the formula:

$$h_{f0} = h_{a0} = h_a^* \cdot m \quad , \text{ mm.}$$

**Step 6.** Determining the cutter tooth depth  $h_0$ :

$$h_0 = h_{f0} - h_{a0} \quad , \text{ mm.}$$

**Step 7.** Determining the cutter pitch diameter  $d_0$ :

$$d_0 = m \cdot z_0 \quad , \text{ mm.}$$

**Step 8.** The outside diameter  $d_{a0}$  in initial tool section is determined from the formula;

$$d_{a0} = d_0 + 2h_{a0} = m \cdot (z_0 + 2h_a^*) \quad , \text{ mm.}$$

**Step 9.** The root diameter  $d_{f0}$  in initial tool section is determined according to the formula:

$$d_{f0} = d_0 - 2h_{f0} \quad , \text{ mm.}$$

**Step 10.** Measuring the  $d_{a0}$  using virtual caliper.

**Step 11.** Measuring the bore diameter  $d$  using virtual caliper, shown on Fig.5.

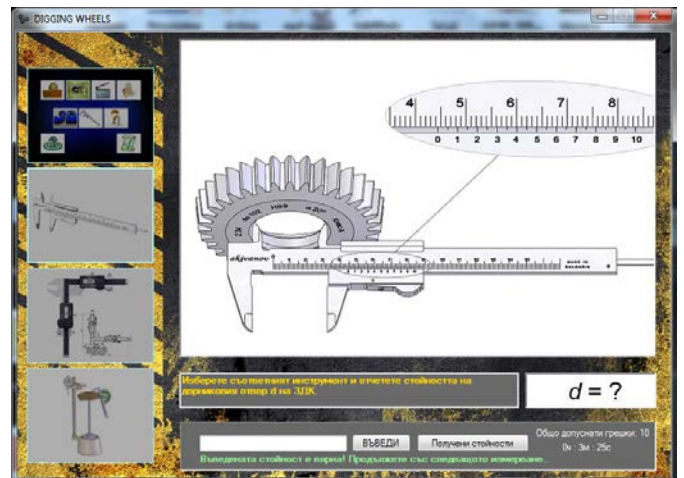


Fig.5. Measuring the bore diameter  $d$

**Step 12.** Measuring the face width  $H$  using virtual caliper.

When rake angle  $\gamma_0$  and clearance angle  $\alpha_b$  values are to be determined, the combined measuring instrument (Fig.6) must be used. That equipment allows great number of different angular and linear measurements to be easily made.

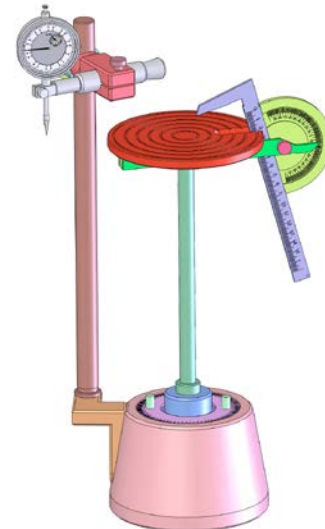


Fig.6. Virtual combined measuring instrument

**Step 13.** The rake angle  $\gamma_0$  is measured using virtual combined measuring instrument (Fig.7).

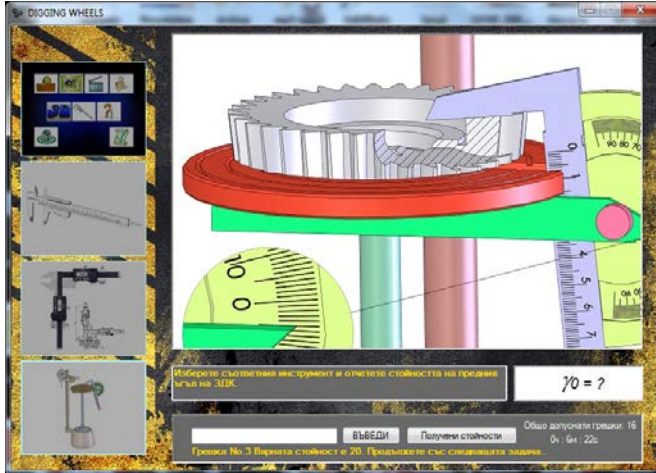


Fig.7. Measuring of rake angle  $\gamma_0$

**Step 14.** Measuring of clearance angle  $\alpha_b$ , using virtual combined measuring instrument.

**Step 15.** The dimension  $a_{oi}$  between the point of the cutting tooth and initial tool section is determined according to the equation:

$$a_{oi} = \frac{d'_{a0} - d_{a0}}{2 \cdot \text{tg} \alpha_b}, \text{mm.}$$

**Step 16.** The addendum modification coefficient  $x_{oi}$  for section standing a distance  $a_{oi}$  from initial tool section is determined according to the formula:

$$x_{oi} = \frac{a_{oi} \cdot \text{tg} \alpha_b}{m}, \text{mm.}$$

**Step 17.** The cutter tooth circular thickness  $S'_{n0}$  (Fig.3) is determined according to the following equations:

$$S'_{n0} = m \left( \frac{\pi}{2} + 2x_{oi} \cdot \text{tg} \alpha_0 \right), \text{mm.}$$

$$\text{where } \alpha_0 = \arctg \left( \frac{\text{tg} \alpha}{1 - \text{tg} \alpha_b \cdot \text{tg} \gamma_0} \right), \text{rad.}$$

**Step 18.** Determining the chordal addendum  $h$  needed to do the following measurements with gear tooth caliper (Fig.8):

$$h = \frac{d_{a0}}{2} - \frac{d_0}{2} \cdot \cos \theta, \text{mm,}$$

$$\text{where } \theta = \frac{S'_{n0}}{\alpha_0} \cdot 0.572957, \text{rad.}$$



Fig.8. Measuring the chordal thickness  $S'_x$

Students must set the third instrument - gear tooth caliper (Fig. 8) using previous results (step1-step18). To be properly set the gear tooth caliper and complete the measurement process, the student must have worked without mistakes in the previous steps. This, even in real laboratory work is not always achievable. The application includes a library of help messages to assist and guide students to successful completion of the exercise. If student enter three incorrect values, the correct value is displayed to be able to successfully continue the measurements. The misspelled value is marked in the protocol for teacher's information.

**Step 19.** Measuring the chordal thickness  $S'_x$  (Fig.8).

**Step 20.** Determining the base circle diameter  $d_{b0}$ :

$$d_{b0} = d_0 \cdot \cos \alpha_0, \text{mm.}$$

At the end of measuring process student is allowed to generate a protocol (Fig.9) that automatically include personal data, test data (time and number of correct answers) and measured data (correct and incorrect answers and the total measurement process time). The software automatically checked for incorrect values and displays them with an exclamation mark in the record table. The generated protocol is in word format file. The file is automatically locked with a password and students cannot edit the data.

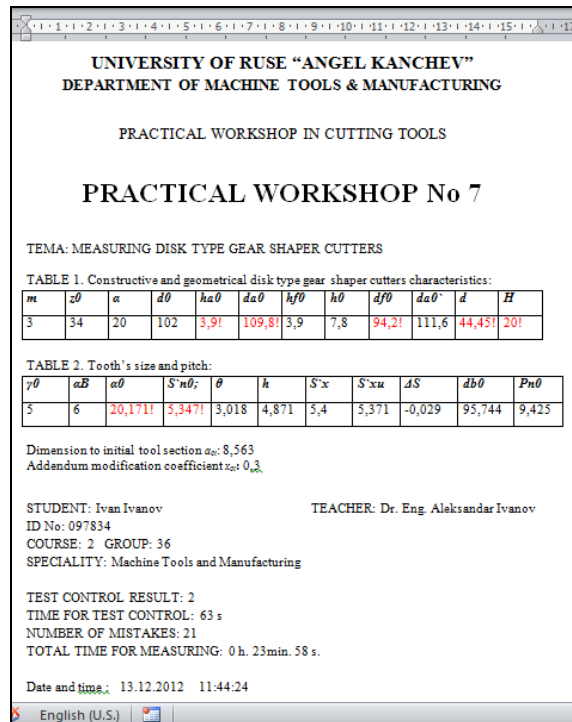


Fig.9. Generated Protocol

## 5. Virtual vs real laboratory work

- **Monitoring and student progress tracking** - Limitations of traditional classroom practices make it impossible to monitor what every student is doing and what students really have (or have not) learned. The interactive tool includes efficient mechanisms for monitoring and processing what students know. The software records every action and results made by student in the measurement section. Teachers can track individual student progress in the protocol and help student of specific problems, where his results are not so good.

- **Different types of user access levels** - Two types of users can use the interactive learning tool for measuring disk type gear shaper cutters – students and teachers. After registering (Fig.10), every student receives access to the student modules, which have been presented in the previous sections.

Fig.10. Registration Form

The teacher is registered as an administrator and access administrator's module. He can edit learning materials - such as test questions and etc. He designs the test system, which randomly generates different type of tests. The idea is to test student theoretical knowledge before the measurement section. The measurement section is not accessible till the test is not passed. If the student did not pass the test, he has to return and learn again. During the test control student cannot access learning materials because they are forbidden.

- **Flexible education matches specific user needs** - Depending on students test and measuring results, learning process can be adjustable. Student's results are evaluated according to the formalized criteria and dynamic reconstruction of the planned learning process is possible. When student has difficulty with solving a task or choosing the right measuring tools for the specific measurement, the application help him how to continue.

- **Wide variety of instruments in different measuring ranges** - In the measurement section, the students have to choose not only the right virtual tool for the specific measurement but also this one with the right measuring range. Students have opportunity to learn to be familiar with working with different kind of measuring tools and to learn how to use them. Providing such a wide variety of different measuring tools for every student in the real laboratory is very difficult and expensive due to lack of time and insufficient number of available technological equipment and tooling technology for simultaneous operations of all the students in the lab. In the virtual lab it is easier and the cost is lower in comparison to the cost of the real laboratory equipment. Using virtual instrument is also without risk of injury compared to work in the real world, where different possible accidents are happened.

- **Learning anytime, learning anywhere** - The interactive tool is published online and provides more efficient use of educational resources, because it is available 24 hours a day with unlimited access to students, unlike the real laboratory that can be used one or two semesters for a few hours a day.

- **Innovative more excited 3D learning** - Traditional ways of educating engineering students have well-proven advantages, but there are problems with keeping students involved and engaged in the classroom. Today students are more engaged and excited using 3D interactive learning tools than using traditional learning materials. 3D measuring provides a wide range of experiences, some of which are impossible to try in the real laboratory because of distance, cost or danger. When students are excited about their learning, they are more motivated and self-disciplined and their results are better.

## 6. Conclusion

New technologies are already powerful means to complement traditional engineering teaching, and they are bound to modify deeply both teaching and learning.

The proposed highly interactive self-learning tool for measuring the constructive and geometrical parameters of the disk type gear shaper cutters increases the level of understanding of the students through interactive 3D virtual models and enable students to have free, safe and remote access and possibility of performing experiments at any time and from any location.

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