THE STUDY OF THE ROCK SHEAR TEST KINEMATICS

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Abstract: Failure of a rock mass happens when its shear resistance is exceeded. From a mathematical point of view, the failure condition is expressed by a relationship between the normal stress σ and the shear stress τ. In the paper, a virtual rock shear test device was built with in SOLIDWORKS, based on the characteristics of the press and shear plates with various inclinations from the Rock Mechanics Laboratory of the University of Petroşani. Considering that the upper plate of the press is fixed, and the lower one moves at a constant speed, we determined by numerical and analytical methods the shearing speed for various angles of inclination of the plates.

Key words: Simulation, model, shear speed, finite element, angle, shear plate.

1. ROCK SHEAR TEST

The shear strenght evaluation of rock discontinuities is determined in the laboratory by shear testing along imposed discontinuity planes. The laboratory tests are performed on standard small sized speciments obtained by coring, and are not affected by the scale effect. Testing can be performed only on samples that are homogenous and uncontaminated.

The devices used for shear tests can vary from relatively simple ones, can have various sizes and can generate different forces, but in specialized laboratories, the shear testing aparatuses can be more complex an duse samples with shear plasnes of up to 400 cm^2. Figure 1 shows the hydraulic press from the Rock Mechanics Laboratory of the University of Petroşani, prepared for performing a a shear test.

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Fig.1. Hydraulic press prepared for rock hear testing

2. THE STUDY OF THE KINEMATICS OF THE SHEAR TEST THROUGH ANALYTICAL METHODS

In the hydraulic press shown in figure 1, the bottom plate moves vertically upwards at constant speed, and the upper plate is fixed. The direct shearing of the sample is performed by two shear boxes (specimen holders). The lower shear box is driven vertically by the bottom plate. A roller low friction system is placed between the upper plate and the top shear box. This roller friction system causes a horizontal movement of the top shear box as a result of the pressure exerted by the lower shear box through the contact surfaces of the two shear boxes. The relative movement between the contact surfaces of these will cause the shearing of the sample. A schematic image of the described shear kinematics is shown in figure 2.

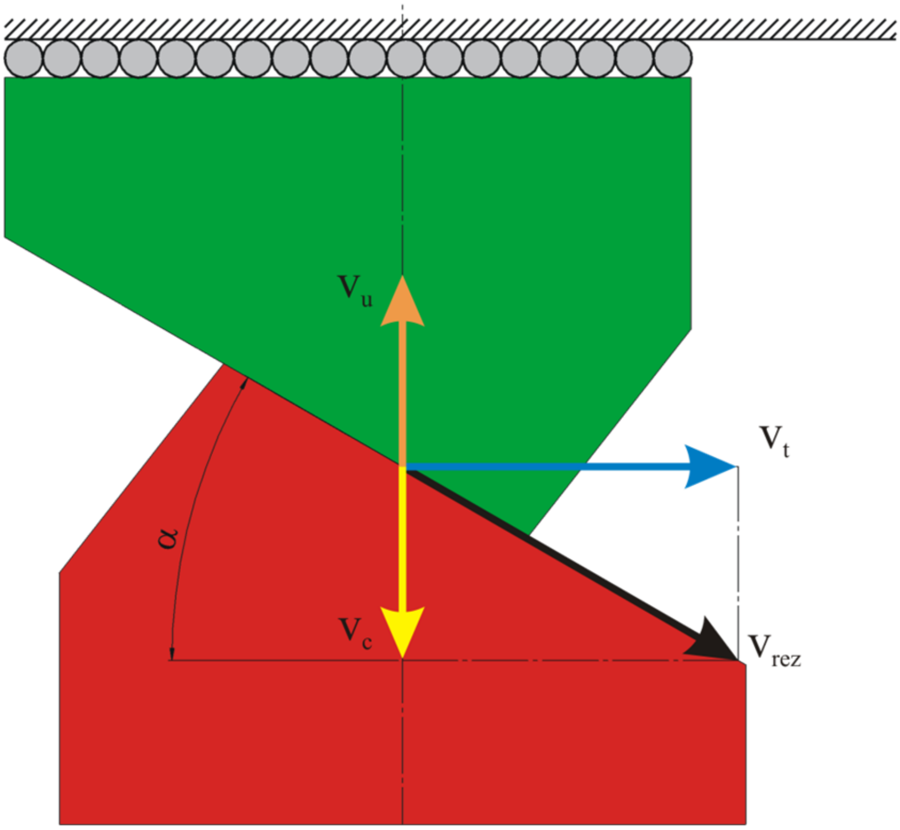

Fig.2. Shear kinematics schema

In figure 2 it is shown that the two shear boxes have an angle of inclination α. Considering that the climb velocity of the lower shear box moving upwards v_u is known, both the translation velocity v_t can be determined by calculation (this is the horizontal velocity of the upper shear box) as well as the resultant velocity v_{rez} (which is the actual shearing velocity).

$$v_t = \frac{v_u}{\tan(\alpha)} \tag{1}$$

$$v_{rez} = \frac{v_u}{\sin(\alpha)} \tag{2}$$

$$v_c = v_u \tag{3}$$

Based on equations (1) and (2) the variation diagrams of the translation velocity v_t and the resultant velocity v_{rez} were traced as function of the angle of inclination α, as shown in figure 3. An upwards velocity v_u = 2 mm/s of the lower shear box was considered. The analysis of the variation graphs of the two velocities indicates that a higher angle of inclination causes a lower shear rate, while a lower angle of inclination causes a higher shear rate.

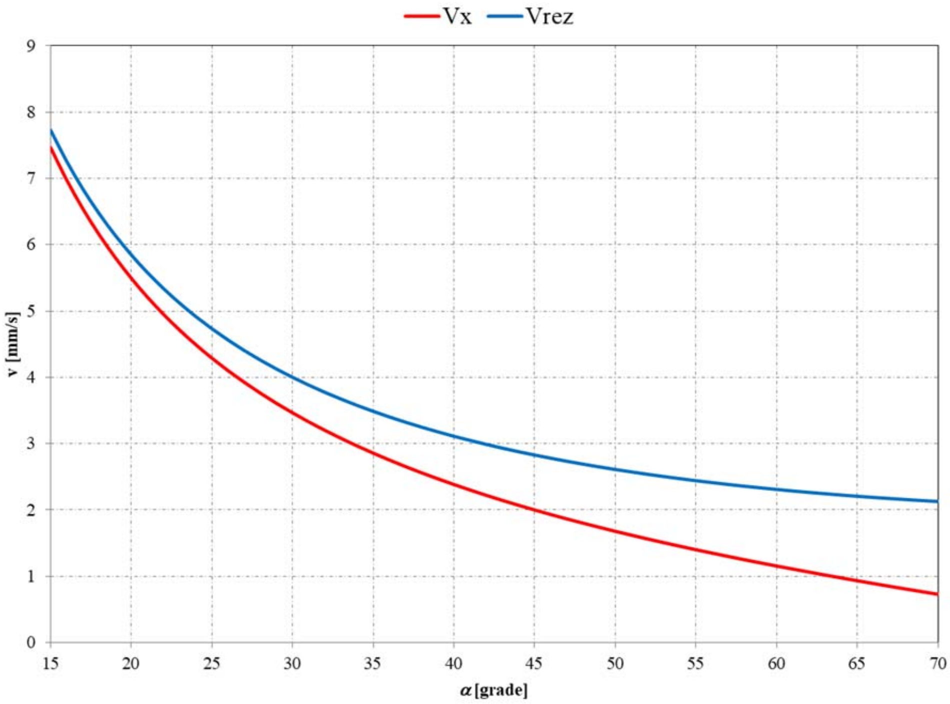

Fig.3. Variation diagram of v_t and v_{rez} function of angle α

3. THE STUDY OF THE KINEMATICS OF THE SHEAR TEST THROUGH THE NUMERICAL METHOD

A virtual model of the actual hydraulic press from the rock mechanics laboratory of the University of Petroșani was built in SOLIDWORKS, at true scale, as can be seen in figure 4. It is an assembly that consists of the following parts:

1 - hydraulic unit;
2 - hydraulic unit piston;
3 - lower shear box;
4 - upper shear box;
5 - horizontal guide rail of the upper shear box.

Geometric concentricity and coincidence links were established between the component parts of the assembly.

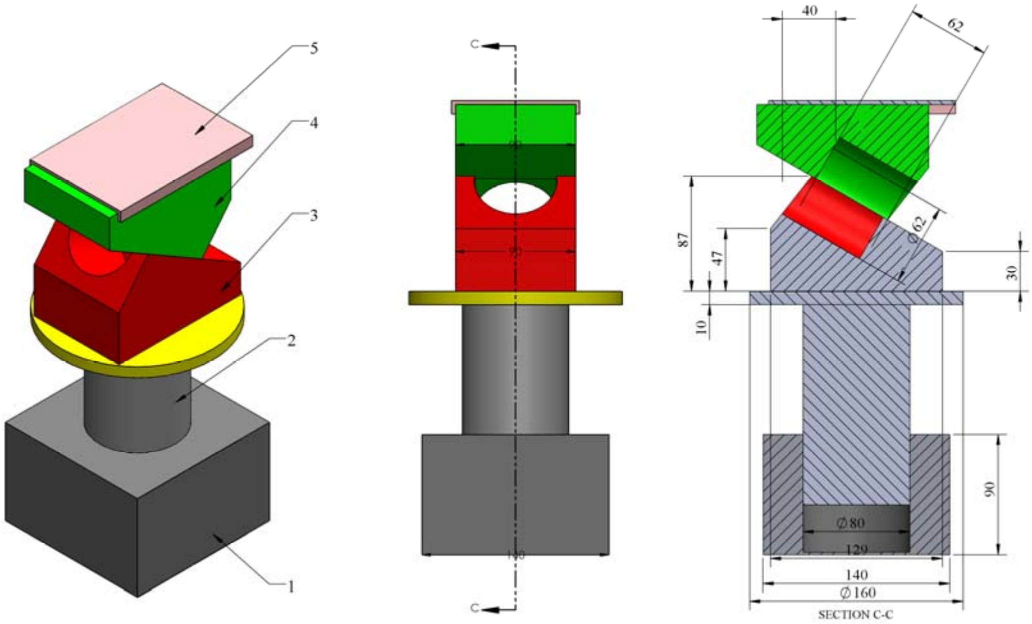

Fig.4. Virtual model of the hydraulic press (inclination angle of 30°)

The study of shear kinematics was carried out by numerical methods using the *Motion Study* menu with the *Motion Analysis* option of SOLIDWORKS. Shear boxes with inclination angles of 30° and 60° respectively were used. The movement of the bottom plate was achieved using a linear actuator as can be seen in figure 5.

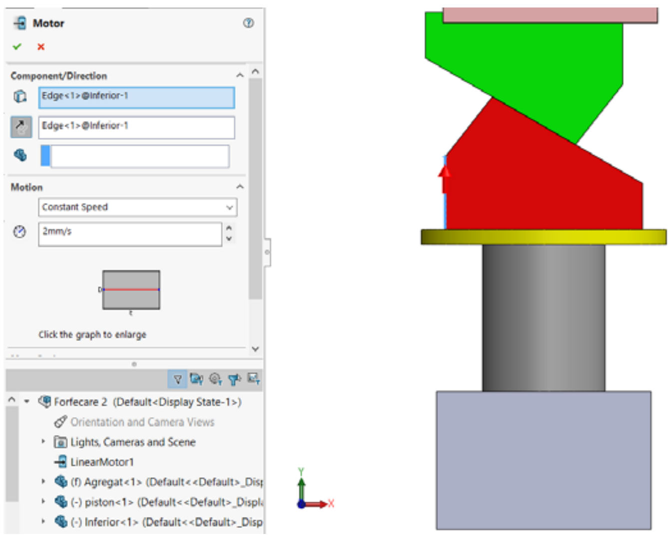

Fig.5. Setup of the bottom plate movement

In order to be able to calculate and plot the shear velocity diagram (v_{rez}) a coordinate system was attached to the lower shear box (figure 6).

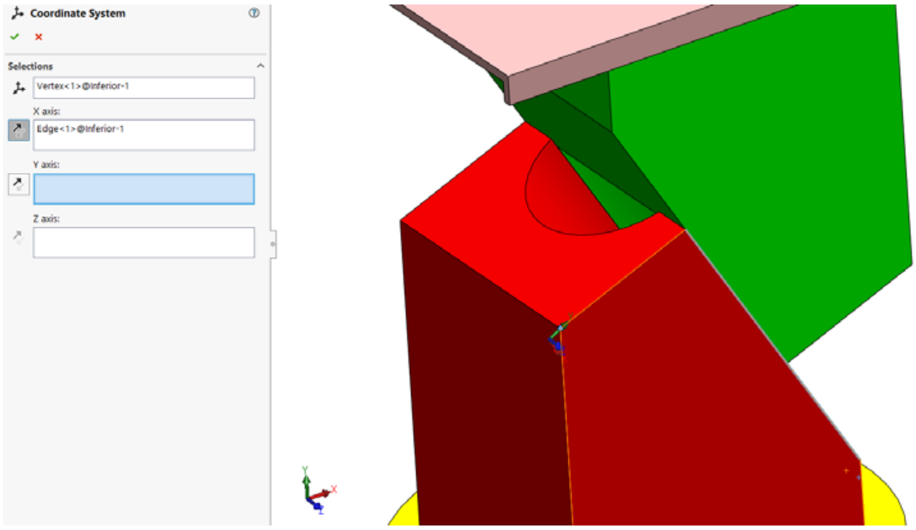

Fig.6. The coordinate system attached to the lower shear box

As previously stated, the calculations were performed considering two angles of inclination of the shear boxes, 30° and 60°, respectively. Figure 7 shows the variation graphs of the climb (v_u), translation (v_t) and shear (v_{rez}) velocities for the angle $\alpha = 30^{\circ}$.

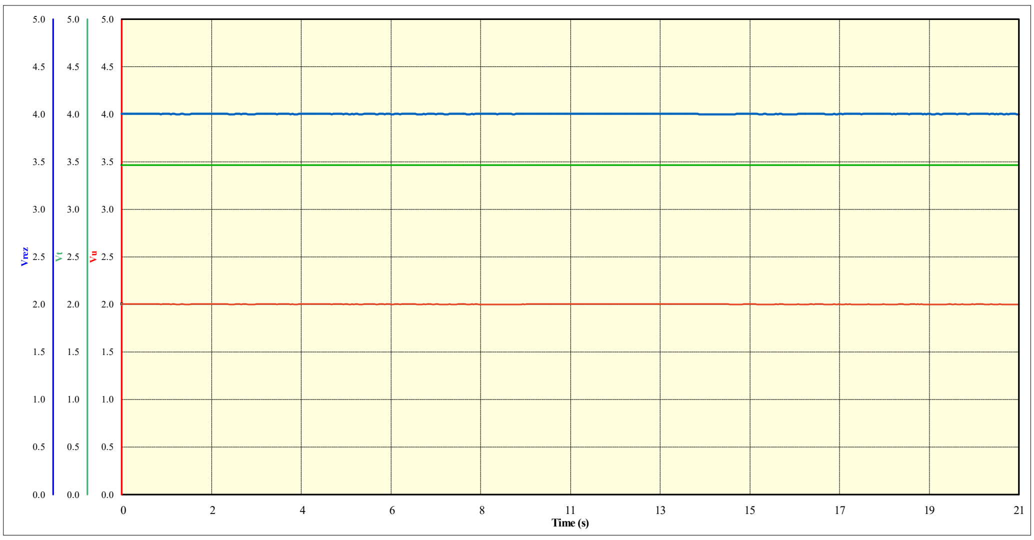

Fig.7. Velocities variation for $\alpha = 30^{\circ}$

Analyzing figure 7, it can be seen that for the angle $\alpha = 30^{\text{o}}$, the translation and shearing velocities are both constant for the 21 second duration of the simulation. We underline that the only imposed velocity was the climb velocity v_u, with a value of 2 mm/s. The values of the resultant velocity were determined as a result of the movemet of the upper shear box, which is a consequence of the geometric connections it has with the lower shear box and with the horizontal guide rail.

Figure 8 shows the variation graphs of the climb (v_u), translation (v_t) and shear (v_{rez}) velocities for the angle $\alpha = 60^{\text{o}}$.

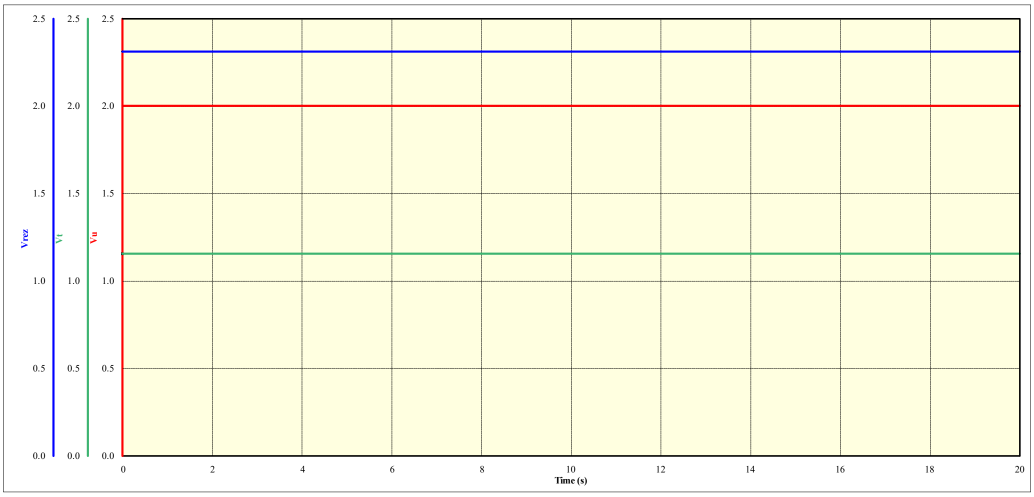

Fig.8. Velocities variation for $\alpha = 60^{\text{o}}$

CONCLUSIONS

Following the determinations made, the results obtained both for the study by analytical methods and for the one by numerical methods are identical. They highlight the fact that in the case of shear boxes with different inclination angles, the actual shearing velocity is determined by this angle and by the velocity of the active plate of the press. Thus, a higher inclination angle causes a lower shear rate, and a lower shear angle causes a higher shear rate. In other words, the shear velocity is inversely proportional to the angle of inclination. This aspect is particularly important in the case of hydraulic presses that do not allow variable velocities for the active plate, as is the case with the press from the Rock Mechanics Laboratory of the University of Petroşani. The solution required to change the shearing velocity is in this case that of using wedges with various inclinations to be placed between the shear boxes and the plates of the press.

At the same time, the obtained results are important for the simulation setup of the shear test using Geomechanica Irazu software. In this software, for the case of shear simulation based on the model of the press presented in the first paragraph, two velocities must be imposed, one vertical to the lower plate and one horizontal to the upper plate (this results by calculation and is depending on the velocity of the lower plate and the angle of inclination).

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