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Effort and Safety Factor in the Unions of Wooden Structures Used as Carbon Mine Sustainability, Mine Case Baseli, Colombia

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Abstract

The research has been dedicated to the study of the calculation of the stresses and design conditions given by the safety factor of operation of the structural members of the mines that use wood as their main support material. Wood is a lightweight material, easily transportable and easily handled in ademe systems [1]. For this case, the structural member that is analyzed is the union between the column and the beam of the mine doors, known as the German door. For the development of the study, the geometry of standard doors commonly found in coal mining has been taken into account. The reason for the research on the proposed topic stems from the need to have a secure control over the structural sustainability of the mines, since the use and possible deterioration of the wood under operating conditions and in the mining environment is very important for human safety.

Keywords: Efforts, Mining, German door

1 Introduction

The structure under study is called the German Door and is a set of three commonly cylindrical woods, which are assembled in the shape of a trapezoid and are used as support for the mining operation [2]. The parts that make up the German door are a wood called a pencil that acts as a support beam, two woods called levers, which act as columns or parapets and a wooden lining or ceiling of the German door, in addition to some final adjustment blocks against the wall of the mine [3]. Figure 1 shows the general components of the door.

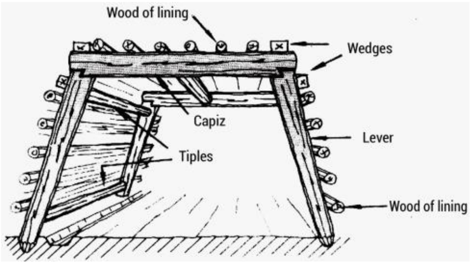

Figure 1. Parts of the German Door

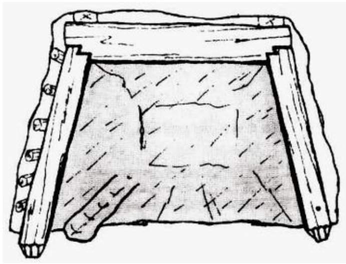

Figure 2. Door Light Area

From figure 1 it is also observed that there is an area of the gate, called the forward area, which is the area of installation of the German door structure, which is opened with explosives. Once the door is installed, the light area remains (figure 2), which is the area used for ventilation, transport, etc. calculations.

The capiz, or beam, is a cylindrical wood, which is placed in the upper part of the German door, and which, together with the levers or columns, makes the main function of the door, as it is: to support the efforts of the structure.

There are different types of pencil; -single-tooth pencil and double-tooth pencil. Figure 3 shows the detail of the single-tooth pencil and the detail of the double-tooth pencil [4]. The simple single-tooth capiz is the one studied in this research.

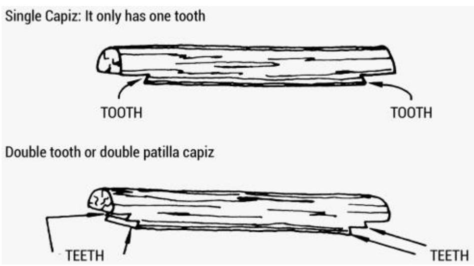

Figure 3. Simple Capiz of single Tooth and double tooth

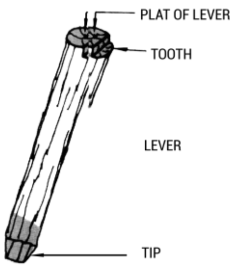

Figure 4. Column or lever

The levers, are the wood used as a column in the operation of the German door, on the columns rests the beam or pencil, the resting point of the beam on the column is called the lever plate, figure 4 shows the support column. The lever plate should be well finished and preferably sanded to avoid stress concentrator points. This is very important in the design of mine supports as more and more coal mines begin to exploit deep resources, leading to more serious support problems [5]. For the case under study, this polishing was not performed and therefore there is no relief of surface tension or notch angles.

2 Initial conditions

Once the parts of the German door are presented, the geometry to be simulated in the computational model is defined, Figure 5 shows the distances involved, and Table 1 shows the measures taken on site for the particular case of the Baseli Mine with concession contract 2636T in Colombia. This particular mine has been taken because it is a mine that standardizes the use of the German door with one tooth pencil.

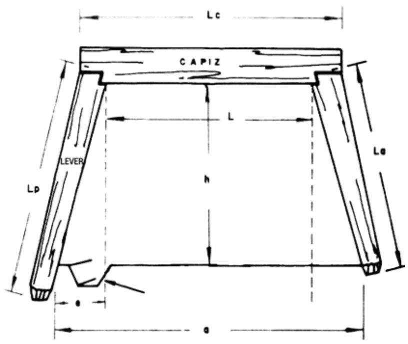

Figure 5. The geometry of the German door

Table 1. Initial conditions for the German Door

MINE BASELI	
TRAPEZOID (GERMAN DOOR)	
Base biggest	2,1 m
Base smallest	1,7 m
Height	1,8 m
Lever length	1,9 m
Recessed floor lever	10 cm – 15 cm
Door spacing	1 m
Lever diameter	10,5 cm
Capiz diameter	14,5 cm

Table 2 shows the diameter data of each wood used in the German door.

Tabla 2. Diameter of the Wood

SAMPLE	**MINE**	**USE**	**DIAMETER (cm)**
1	Baseli	Botada	10
2	Baseli	Capiz	14,5
3	Baseli	Palanca	10,5
	Upper base (m)	Lower base (m)	Height (m)
BASELI LEVEL 1	1,49	1,78	1,8

Figure 6 shows the Area diagram of the Terzagui theory, which has been used to calculate the initial load conditions. The equations show the different parameters used in the calculation of the loads, where:

B: average tunnel width. H: Average tunnel height. L: Base or width of the load parabola. C: Base or width of the zone of influence due to the effect of the angle of internal friction. Hp: Height of the loading dome. H2: Height of area 2. Kp: Terzagui constant. ϒ: Specific weight of the calculation walls. A: Door separation. Φ: angle of internal friction of the side wall rock. A1: Lateral loading area. A2: Vertical area exerting lateral stress. A3: Vertical loading area. These equations are used to calculate the initial loads of the model.

Once the areas are defined, the loads for the boundary condition are defined with the calculations of the respective volumes and densities.

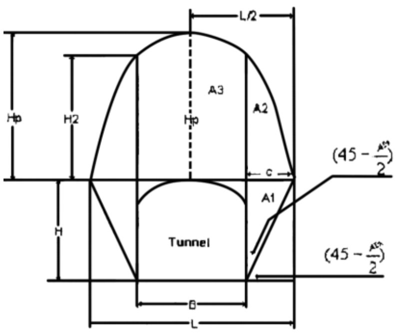

Figure 6. Area Diagram of Terzagui Theory

- Vertical Area.

$$A3 = B.\ Hp \tag{1}$$

$$Hp = Kp.\ B \quad o \quad Hp = Kp\ (B + H) \tag{2}$$

- Vertical area on the side wall of the tunnel.

$$A_2 = \left[Hp \left(\frac{L}{2}\right) cos.\left(\frac{B}{L}\right) - H2\left(\frac{B}{2}\right)\right] \quad (3)$$

$$L = B + 2c \quad (4)$$

$$C = H.\operatorname{tang}\left(45 - \frac{\varphi}{2}\right) \quad (5)$$

$$H_2 = \left(\frac{Hp}{L}\right)\sqrt{L^2 - B^2} \quad (6)$$

- Vertical area.

$$A_1 = \frac{H.c}{2} \quad (7)$$

3 Simulation of anchor teeth stresses

The anchorage teeth of the lever and the pencil are the members that are in direct contact with each other and are therefore the ones that present the greatest effort in their operation. Figure 7 and figure 8 show the meshing of the simulation point to be simulated later. Figure 9 shows the detail of the union of the column and the capiz. The simulation presented in this document has been developed with the ANSYS® software. This software uses numerical methods to solve problems because numerical methods are based on algorithms, which take the initial conditions to perform the calculations iteratively, the convenience of the method determines it, the required precision and the range of study[6]. This software is licensed at the Universidad Francisco de Paula Santander in Colombia.

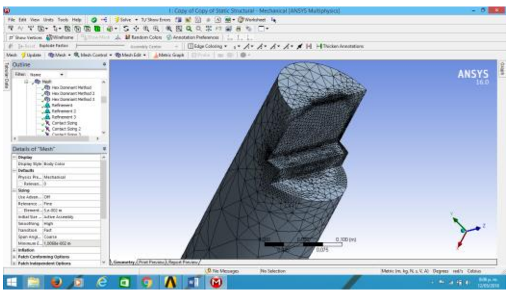

Figura 7. Detail of Pencil Tooth Meshing

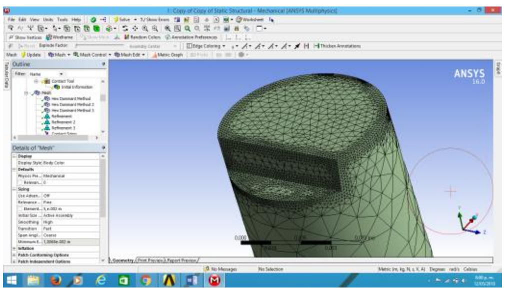

Figura 8. Lever Tooth Meshing Detail

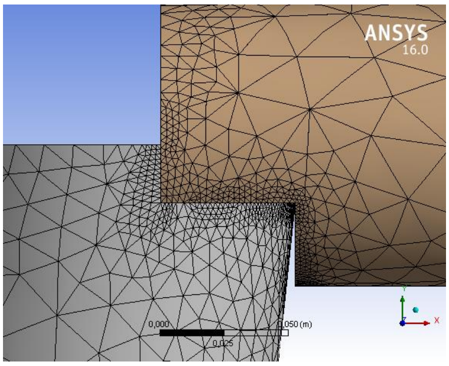

Figura 9. Detalle de la Unión

The figures show the type of mesh used, which is a triangular wedge element type with 6 nodes, this mesh has been refined to the ratio 0.5 in the areas of highest contact. For the simulation no stress relief has been done, i.e. no rounding of the profiles on the selvedges or sanding of the lever plate area, this no stress relief is possibly the cause of the plasticity that is achieved in some points of the pencil tooth in figure 9, this plasticity is due to the contact of the two surfaces, pencil - lever. Figure 10 shows the distribution of stresses on the pencil tooth, and Figure 11 shows its equivalent distribution of stresses on the Lever tooth.

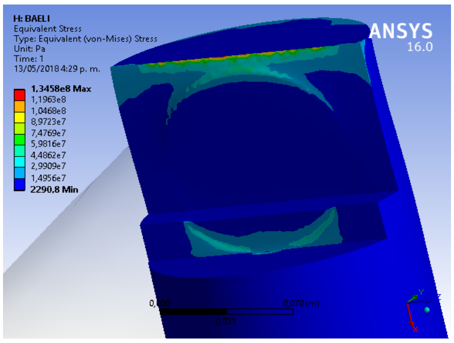

Figure 10. Stress distribution on the Capiz tooth

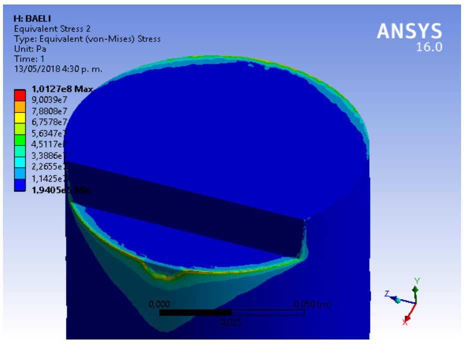

Figure 11. Stress distribution on the lever tooth

Analyzing Figure 10 and Figure 11 together, it is observed that the distribution of forces is good and safe for the operation of the mine under study, this due to the fact that in almost all the graph of the tooth, the average value of 25 MPa for the pencil tooth and 21 MPa for the lever tooth prevails, these forces are presented in blue in the graph, this being an indication that the stresses at no time have exceeded the creep values of the material, the creep values of the material have been used as boundary conditions for numerical simulation and have been previously calculated in a stress test on the universal machine and obtained a value of 4.8 GPa.

It should also be noted that in some points of contact of the teeth, there are zones of plasticity, these appear in red, this is an indication that in the selvedges or points of stress concentration, the value of the material creep was exceeded, this is a very normal condition of the behavior of the wood when used in structural members that come into contact, as in this case [7].

It is normal to observe in structural applications of wood, as traces appear on them, when these are in contact with another member of any other material or of the same; this is a slight crushing that exceeds the limit of creep. In some cases, it not only occurs in points where there is contact between two materials, but also in places where the stress concentrator is at high angles close to 90 degrees, as in the case of the teeth under study, i.e. no stress relief was performed in the geometry by rounding off the wood or structural member.

Figure 12 shows the average safety factor found at the German Door, which is greater than n = 5; this makes the diameter of the wood used in the Door safe, considering that the safety factor is the relationship between capacity and demand and is perhaps the most common design acceptance criterion used in engineering [8]. At no point in the central body of the Figure are there any red points indicating values close to zero. In general, numerical simulation shows a safe design for the study.

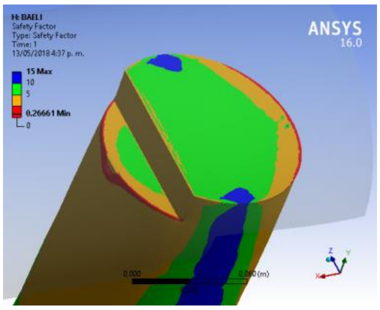

Figure 12. Lever Tooth Safety Factor

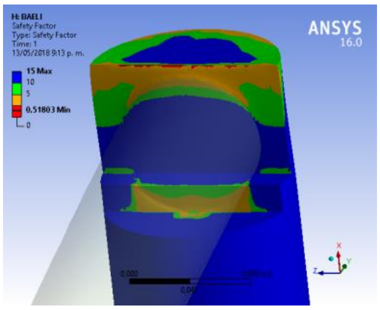

Figure 13. Capiz Tooth Safety Factor

Figure 12 and Figure 13 show the red point of the Safety Factor, indicating that at this point a zone of plasticity was reached, a condition of mechanical behaviour normally expected and already known from the wood. This is probably due to the fact that the wood was not stress relieved for installation and was installed at an angle of around 90 degrees.

5 Conclusions

The results shown in figure 10 and figure 11 indicate that the stresses encountered are well below the limits of proportionality or ultimate strength and creep of the material, a condition represented by the blue tonality in the distribution of stresses of the structural elements of the above-mentioned figures. Pointwise, the stresses of 25 MPa for the pencil tooth and 21 MPa for the lever tooth are well below 4.8 GPa, wood strength obtained through laboratory testing. This allows us to state that the designs and assemblies of the German doors of the Baseli mine are adequate, since the dimensions and properties of the wood selected for the capiz and the levers generate forces below the strength of the material and the forces encountered are in a safe working area.

It is important to mention that in some points of contact of the teeth, there are zones of plasticity; these appear in red in figure 10 and figure 11. This is an indication that in the selvedges or edges or points of stress concentration, the value of the creep of the material was exceeded, this is a very normal condition of the behavior of the wood when it is used in structural members that come into contact, as is the case here; sometimes it even occurs not only in points where there is contact between two materials but also in places where the stress concentrator occurs in high angles close to 90 degrees.

From figure 12 and figure 13, it can be concluded that the average safety factor found is greater than 5, and does not show areas marked with red indicating critical safety factor values. This reinforces the statement about the effectiveness of the design and allows us to consider as safe the diameter of the wood used in the door under study for both the cap and the levers.

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