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INGENIOUS TECHNICAL SOLUTIONS AT A SAW MILL BUILT BY A ROMANIAN PEASANT CRAFTSMAN

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Abstract. In the paper we study the construction and functioning of a saw mill, empirically built in 1930th by a craftsman peasant in Sibiu area. The saw mill has a gear mechanism which allows actuation with animal traction, a rod-crank mechanism that ensures the cutting motion and a mechanism for self - advance of the wood to be cut. Kinematic analysis it is made, proving the ingenuity of the craftsman who has achieved a functional saw mill, whose advance motion is well correlated with the cutting motion. Different kinematic schemes and numerous charts are given, emphasizing the creativity of the craftsman, who empirically found the correct sizes for the mechanism's elements.

Keywords: mechanisms for saw mill, mechanisms history, kinematic of the mechanisms.

1. Introduction

People have used wood from the beginning, to make tails for hammers, spears and bows, so they had worked with cutting edges jagged rocks. Hand saws with bronze blades can be seen on frescoes from ancient Egypt. Drawings on pottery

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with hand saws, and even some saws worked simultaneously by two men, were offered by ancient Rome and ancient Greece. In the Middle Ages there were skilled carpenters, who used hand saws of various shapes and sizes such as jointers, chisels, files. At that time appeared the first types of hand operated saw mills, based on elastic rod to perform the motion for withdrawal of cutting tools. In the manuscripts of Leonardo da Vinci was found a saw mill based on crank rod mechanism, actuated by a foot pedal to rotate a flywheel by means of a rod. There is no advancing mechanism of wood. Due to the heavy work of cutting wood, people began to use the force of water. The first drawing appeared in manuscripts of the Frenchman Villard de Honnecourt, XIIIth century [1]. Agricola, in his book "De re metallica" [2] of 1556, presents several types of saw mills, actuated by water, including mechanisms based on ratchet advance. Other old saw mills (from XVI-XVIII centuries) could be seen in the books [3, 4, 5].

So that at classical saw mills have used crank rod mechanism for actuating the cutting tool and a mechanism to advance the wood whose movement is taken from the mobile yoke that bears the cutting tool. Then, it is transmitted by levers to a ratchet acting the jerky drum which wraps a chain. This chain pulls the cart carrying the wood to be cut. These principles were taken also for the saw mills built by craftsmen peasants. Four saw mills can be found in The Museum of Popular Technique in Sibiu [6, 7] and one in the Museum of Cluj-Napoca, having the same kind of crank rod mechanism, but completely different mechanisms for advance, which shows the ingenuity of the builders of the first half of the twentieth century.

These mechanisms have been studied by our group since the 80s, being published various papers [8 ... 13], from which there were selected some photos and a cinematic scheme to be presented below. In these works were made kinematic calculations, establishing clear the originality and ingenuity of the builders, which is given below more detailed for one saw mill. In [1] some old mechanisms are shown, including several saw mills. Similarly in [14, 15] details from the history of mechanisms are shown, including the mechanisms for saw mills. At this moment we do not know about other works concerning cinematic analysis of saw mills. On the internet we could find only historical, ethnographic data and modern machinery for woodworking.

2. Problem formulation

2.1 Construction of the Saw Mill – Model 1

The saw mill operated by animals, found in The Museum of Popular Technique in Sibiu, comes from the village of Gura Râului near Sibiu. There is a shed in which the saw mill it is assembled (Fig. 1) and near, in the area, it is the actuation subassembly consisting of a spit rotated by the horses, rigidly connected to a gear wheel with 86 teeth. This wheel rotates another gear wheel with 18 teeth (Fig. 2) located on the same shaft with a bevel gear with 72 teeth, coupled with a conical gear wheel with 20 teeth (Fig. 3).

Fig. 1. The shed where the saw mill it is assembled.

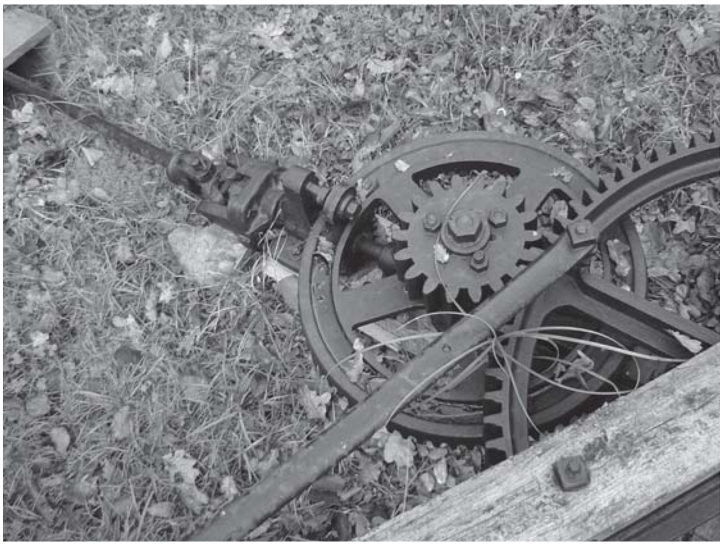

Fig. 2. The assembly of the gear wheel with 86 teeth
and respectively with 18 teeth.

The mechanism is of speed amplifier type. Through a buried cardan shaft, the movement reaches in the underground shed, by bringing about a belt pulley with diameter of 900 mm, which, via a belt, rotates another belt pulley with diameter of 300 mm. On the shaft of this wheel there are two cranks, i.e. two wheels of flywheel type, connected to two parallel rods which transmit the movement to the yoke supporting the saw mill.

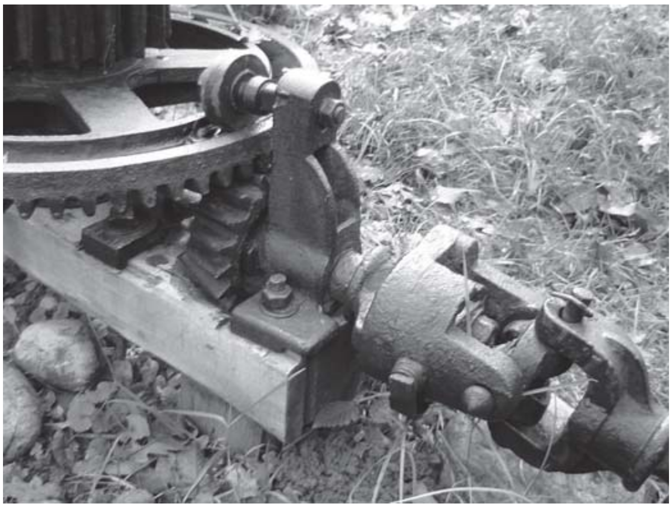

Fig. 3. The conical gear wheel with 20 teeth.

It is obvious that the peasant builder did not build alone the actuating mechanism with gearings, but he used smartly one subassembly from another machine, succeeding in adapting it to his saw mill.

2.1.1 The Functioning of the Mechanism

The kinematic scheme of the mechanism is given in Fig. 4, in which between the ordinate of C and the ordinate of A is an eccentricity e = 150 mm. The kinematic chain ABC, i.e, the rod-crank mechanism that receives the motion from the pulley with the diameter of 300 mm and by means of the connecting rod BC ensures the translation movement (the cutting) of the slide C, connected to the yoke with the tool (saw ribbon type). The dyad BCC is RRP type. C binds the slide bar CD, also on the ordinate of YC, which by dyad DEF type RRR transmits the motion to the arm FG. In G is connected through a torque fork GH, which has H a sleeve which push the friction disc to the radius HK, having the same spindle drum with the center K and radius r = 150 mm, which is wraps a chain that pulls the cart on which the log cutting, thus ensuring advance motion. GHK driveline can be assimilated to a dyad type RRR.

2.1.2. Kinematic Calculations

On the basis of Fig. 4 the equations below are written:

$$x_B = x_A + AB\cos\varphi;\; y_B = y_A + AB\sin\varphi \tag{1}$$

$$x_C = x_B + BC\cdot\cos\alpha = \text{constant} \tag{2}$$

$$y_C = y_B + BC \cdot \sin\alpha \tag{3}$$

$$x_D = x_C \,;\; y_D = y_C - CD \tag{4}$$

$$x_E = x_D + DE\cos\alpha_1 = x_F + EF\cos\beta_1 \tag{5}$$

$$y_E = y_D + DE\sin\alpha_1 = y_F + EF\sin\beta_1 \tag{6}$$

$$x_G = x_F + FG\cos(\beta_1 + 90) \tag{7}$$

$$y_G = y_F + FG\sin(\beta_1 + 90) \tag{8}$$

$$x_H = x_G + GH\cos\alpha_2 = x_K + HK\cos\beta_2 \tag{9}$$

$$y_H = y_G + GH\sin\alpha_2 = y_K + HK\sin\beta_2 \tag{10}$$

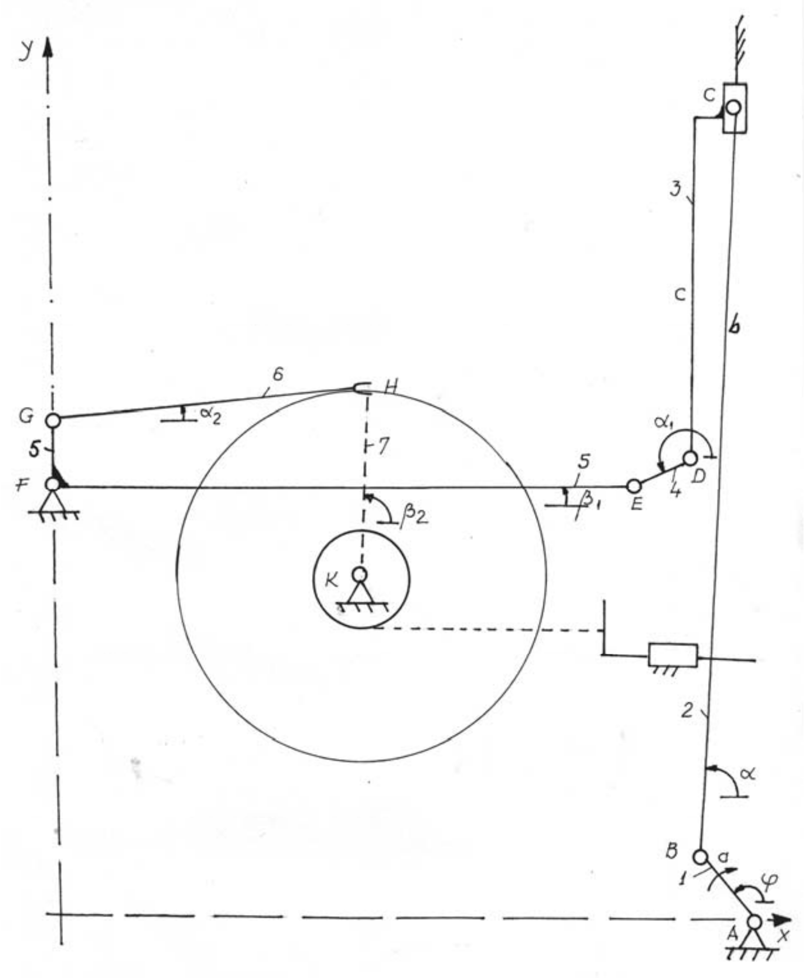

Fig. 4. The kinematic scheme of the mechanism.

It loops φ from 0 to 360, and from (1) are calculated the coordinates of B. From the eq. (2) results α and from eq. (3) can be determined $y_{C.}$ The position of D is calculated with eq. (4), and the equations (5) and (6) give α_1, β_1, and the coordinates of E. The position of G is obtained from (7) and (8) and from (9) and (10) are determined α_2, β_2 and the coordinates for H.

2.1.3. Obtained results

Measurements were made from saw mill museum yield approximate rates because many worn parts. Also, some parts are missing, being appreciated as values after the areas where fitted. The measured values were as follows (in mm): x_A= 2220; AB = 160; BC = 2100; y_F = 1140; DE = 100; EF = 2000; CD = 1000; x_K = 950; y_K = 920; FG = 160; GH = 1000; HK = 450.

Referring to Fig.5 May is observed as the tool teeth are so sharp as to race downhill chips.

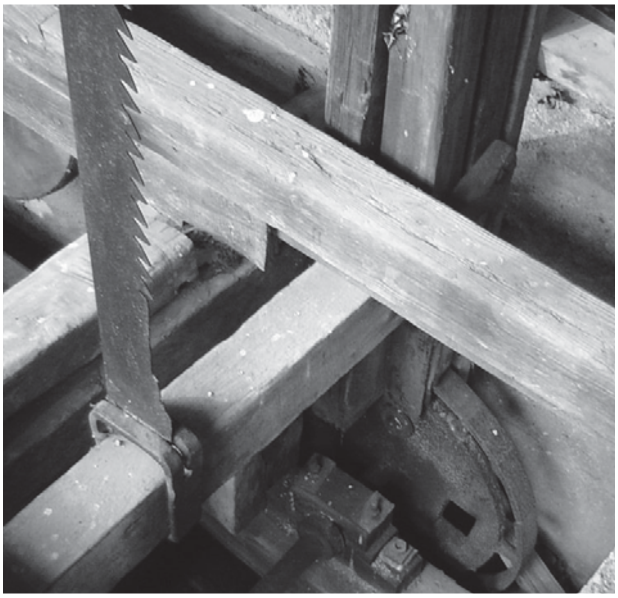

Fig. 5. The sharpness of the tool teeth.

The disc HK is rotated by the angle β_2 so that the drum in the center K and radius r = 150 mm, wrap a chain that pulls the cart with the log, resulting in advance motion (Fig. 6).

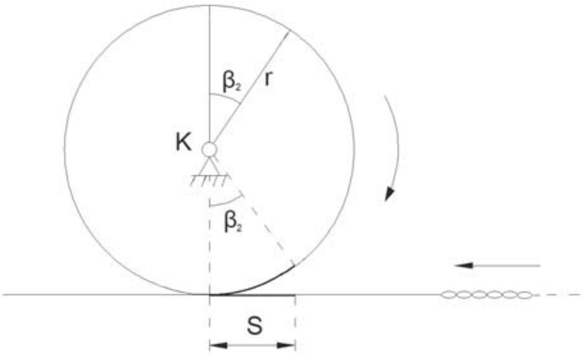

Fig. 6. The scheme of the advanced motion.

S race follows the equation:

$$S = r * \beta_2 \tag{11}$$

In Fig. 7 is shown as a diagram, where y_C show curves for (running tool) and the angle β_2 (taken here to a scale factor equal to 25, because the two curves are represented on the same diagram).

When crank AB departing from the horizontal position, with $\varphi = 0$, y Race y_C increases, then φ stockings around 100 degrees (90 not because eccentricity "e"), the race is maximum, then descends into the race cutting tool, to around φ=280 degrees, then climbed back up to starting position.

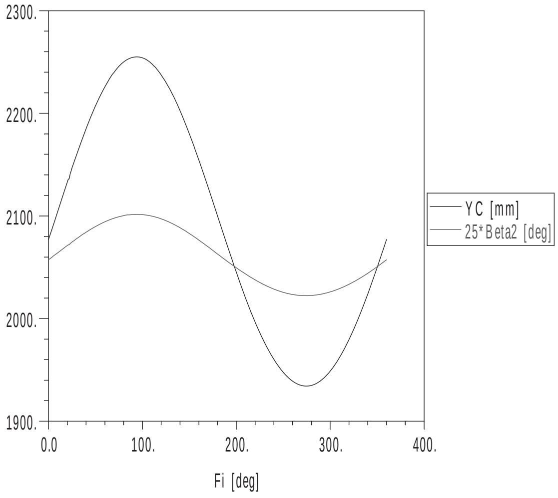

Fig. 7. The y_C diagram (the scale factor equal to 25).

Angle β_2 (which increases counterclockwise) increases until the maximum y_C is the tool retreating without splinter, and this subinterval shoe H on disk KH withdraw from the disc to the left, the carriage remains fixed. When φ = 100 ... 280, the tool descends, wood chips and falls, β_2 disk rotates clockwise and the chain is wound onto the drum, that occurs advance motion. Therefore, this saw mill feed movement is superimposed with the movement of the cutting, which is advantageous each chipped tooth having a small chip thickness compared to when the tool would suddenly splinter whole depth of cut. For φ = 280° ... 360°, the tool starts lifting without cutting, y_C increases and increase, β_2 shoe from H slides to the left.

The same conclusions are obtained for the forward stroke S, calculated with (11), given in Fig. 8.

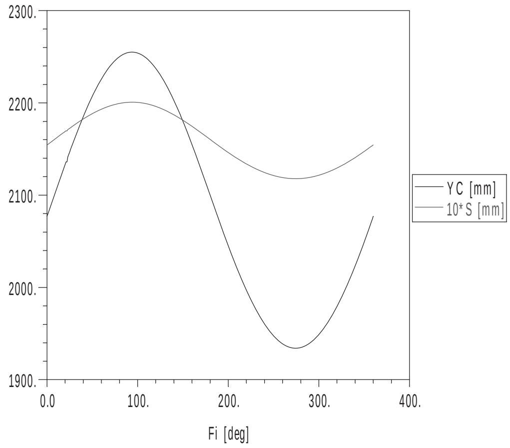

Fig. 8. The forward stroke S diagram.

Referring to Fig. 9 shows that the forward stroke is 8 mm, which is normal for tree cutting. It is possible for the element to have been FG holes, so that the position of F to be set by moving the pin in the holes of G, according to the essence of the cut wood. In the museum, this area is damaged.

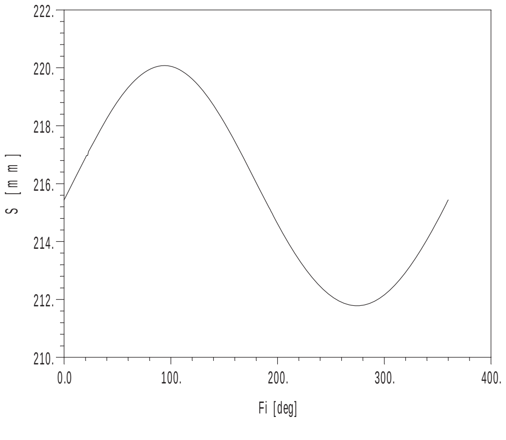

Fig. 9. The forward stroke for tree cutting.

The above findings demonstrate ingenuity special craftsman who built this sawmill.

2.2. Another constructive solution – Model 2

In [4] shows a perspective drawing of the sawmill when it was brought to the museum (it was already old former owner, therefore from the beginning had some damaged parts), drawing partially given in Fig. 10 (drawn from nature by architect C. Neagu [7]).

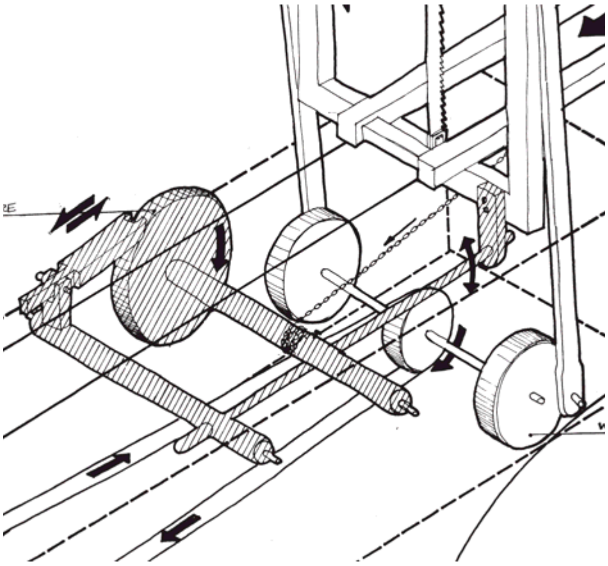

Fig. 10. The perspective drawing of the sawmill when he was brought to the museum.

It is noted that the yoke tool link rigid bar long (EF Fig. 4), which rotates the shaft of F and crank FG, i.e. chain DEFG is a rigid, disappearing torque of E and bar, so E and D overlap. This solution is not correct since the point D performs a translation on the ordinate of C, but also must be rotating in relation to the joint in the saw mill F. It is possible to have a play in the ED, ED to that bar be slid into place in the body of the tool-holder yoke of the E. The kinematic scheme in this case is given in Fig. 11 where there is a dyad RPR.
Writing the following relationships:

$$S_5=\sqrt{(x_D-x_F)^2+(y_D-y_F)^2} \tag{12}$$

$$x_F-x_D+S_5\cos\beta_1 \tag{13}$$

$$y_F=y_D+S_5\sin\beta_1 \tag{14}$$

$$\beta_1=\tan^{-1}\left(\frac{\sin\beta_1}{\cos\beta_1}\right) \tag{15}$$

With (12) is calculated stroke S_5, which is now variable, from (13) and (14) gives cos β_1 and sin sin β_1. And in (15) yields the angle β_1.

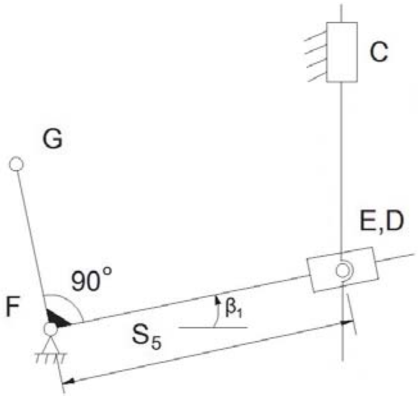

Fig. 11. The kinematic scheme - the dyad RPR.

Fig. 12 shows how the stroke S_5 varies (i.e. the length EF), which means that the E, D, EF bar that slides into the slot.

In other words, in this case, the mechanism is working correctly, the diagram of the variation of S with φ. It is nearly identical to that of the Fig. 9.

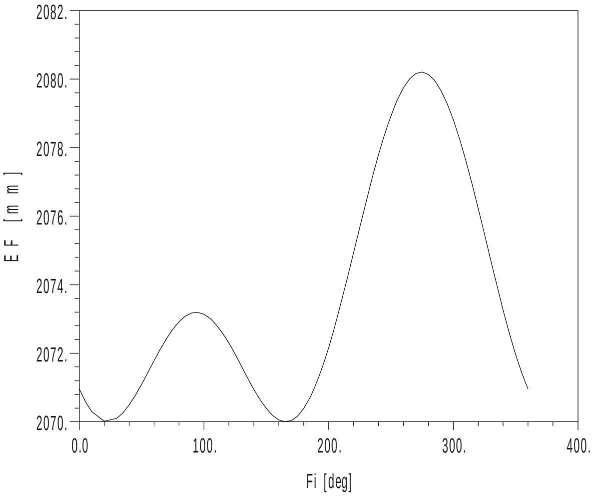

Fig. 12. The diagram for S_5 stroke.

2.2.1. Choosing the Dimensions of the Mechanism

The manufacturer started from the kinematic chain with gearing, set the length of the drawbar based on the force provided by the horses, put the cranks in motion and acted the saw mill with the tool. The difficult problem was to determine the lengths of the chain elements forming the kinematic motion of advance. It is obvious that he has seen saw mills made by others, but the mechanism for advance is original, being different than other saw mills from the museums of Sibiu and Cluj-Napoca. It is clear that he has never had any drawings or engineering calculations, everything being based on his ingenuity.

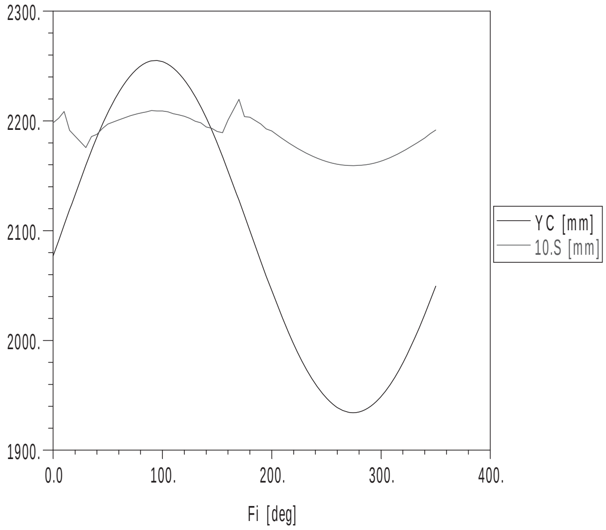

Fig. 13. The variation of the advance race with disturbances around φ = 20 degrees and φ = 160 degrees.

The variation of β_2 is also disturbed (Fig. 14).

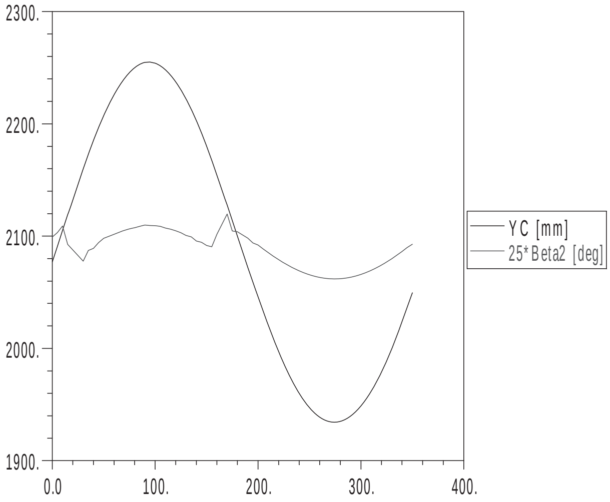

Fig. 14. The variation of β_2 parameter.

Thus, by modifying a single length, EF, from 2000 mm to 2150 mm, the results become completely different; Fig. 13 shows the variation of the advance race with disturbances around $\varphi = 20°$ and $\varphi = 160°$, so that the operating of the saw mill is no longer correct. Again, this is further proof of the manufacturer's ingenuity.

3. Conclusion

The construction and operation of a saw mill from the Museum of Popular Technique in Sibiu, originating from the Gura Râului village, was studied. The saw mill has been already studied in other papers, but here, the correlation between the cutting movement and the motion of advance is more detailed. Calculations and diagrams have proven that this correlation is correct, the two movements being simultaneous, thus increasing the operation productivity and the tool life. Based on the diagrams obtained from the relations written by the method of projections, the ingenuity of the manufacturer's constructive solutions is resulted. It is also shown how a small change in the length of a bar from the kinematic chain of advance can disrupt the proper functioning of the mechanism, thus the manufacturer's empirically established dimensions are correct. Since the saw mill is in an advanced state of wear, with some parts being damaged, a drawing, made shortly after the saw mill was assembled in the museum, was studied, finding that the mechanism can also work in this variant, but only if a bar is able to slide into a recess of the mobile saw mill. The overall conclusion is that this saw mill demonstrates the ingenuity of the craftsmen from our villages around the years 1930-1940.

References

[1] Taimina, D., *Exploring Linkages.* Cornel University. [http://kmoddl.library.cornell.edu/linkages/]

[2] Agricola, G., *De re metallica*. Soner Publishing Company and publisher University of North, Baia Mare 1994.

[3] Berthelot, CF., *La mecanique applique aux arts*, Venezia, 1782.

[4] Bockler, GA, *Theatrum / machinarum / Novum / exhibens / aquarias*, 1662 Coloniae Agrippinae.

[5] Ramelli, A., *La machine capitano del Agostino Ramelli*, Paris, 1588.

[6] Bucur, C., *Evolution and Systematic Typology in Traditional Installations in Romania, in: Cibinium, from 1974 to 1978*, Sibiu, 1979, pp. 111-198.

[7] Palada, Del., *Installations of Wood Carving Museum Complex*. In: Communication Studies and the history of civilization popular in Romania, vol. II, Sibiu, 1981, pp. 199-208.

[8] Popescu, A., *Contribution to the Performance Evaluation Mechanisms Created over Time*. PhD Thesis (cond. Del. Prof. dr. Ing. Iosif Tempea), "Politehnica" Bucharest, 2007.

[9] Popescu, I. - *Ingenious Mechanism used over Time in Romanian Folk Technique*, Technical Publishing House, Bucharest, 1983.

[10] Popescu, I., *In Art History*, Vol. I-VI, Sitech Publishing House, Craiova, 2002.

[11] Popescu, I., Popescu, A., *Romanian Folk Ingenious Mechanisms for Sawing*. In Mechanisms and Manipulators, vol. 3, no. 1/2004, pp. 13-18.

[12] Popescu, I., Popescu, A., *From the History of the Mechanisms*. Sitech Publishing House, Craiova, 2008.

[13] Popescu, I., *Mechanisms of Romanian Popular Technique in the European Context*. Sitech Publishing House, Craiova, 2011.

[14] Ferguson ES, *Kinematics of Mechanisms from the Time of Watt*, eBook, 2008. [http://www.mirrorservice.org/sites/gutenberg.org/2/7/1/0/27106/27106-h/27106 -h.htm]

[15] Ferguson, ES, *The Mind`s Eye: Nonverbal Thought in Technology*. In: Science, vol. 197, no. 4306, August 26, 1977.

[16] [http://www.mee.tcd.ie/neuraleng/pmwiki/uploads/Teaching.4E1/Ferguson_NonverbalThoughtinTechnology.pdf]