# RESEARCH CONCERNING THE CINEMATIC ANALYTICAL APPROACH TO THE FLEXIBLE BARS FROM GRAPES HARVESTING MACHINE

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***Abstract***: *The paper presents a kinematical study of the elastic bars that equip the Braud-type grape harvesting machines. The deformation mode of the bars is analysed and a new method to determine the acceleration induced by bars to the vine is introduced.*

*Based on both the model and the data given by this paper the optimum-working regime can be settled for the shaking equipment.*
***Key words***: *Elastic bars, Deforming, Deformation angle.*

## INTRODUCTION

Mechanized harvesting of wine grapes by vegetation shaking is the method the most common within world viticulture practice owing to the advantages it presents as compared to other harvesting methods.

The horizontal shaking machines use parts that cause, to the vine fence, oscillations that finally reach the grapes. In this way, upon the grape-peduncle bonds tensile, twisting and bending forces are applied the resultant of which has to exceed the tensile strength of the bonds. Considering that the active parts are in direct contact with the vegetation it is necessary to settle the limits of the impact loads that are admitted by the vine.

Achieving these main harvesting objectives – an as high as possible amount of harvested grapes and an as elevated as possible protection degree of the crop – requires deep knowledge of the working part movement and especially of those movement parameters that enable determining the optimum functioning regime for the harvesting machine.

## EXPERIMENTAL MATERIAL AND METHOD

The material under study is the shaking equipment with elastic bars that is included within the BRAUD-type grape harvesting machines (Fig.1).

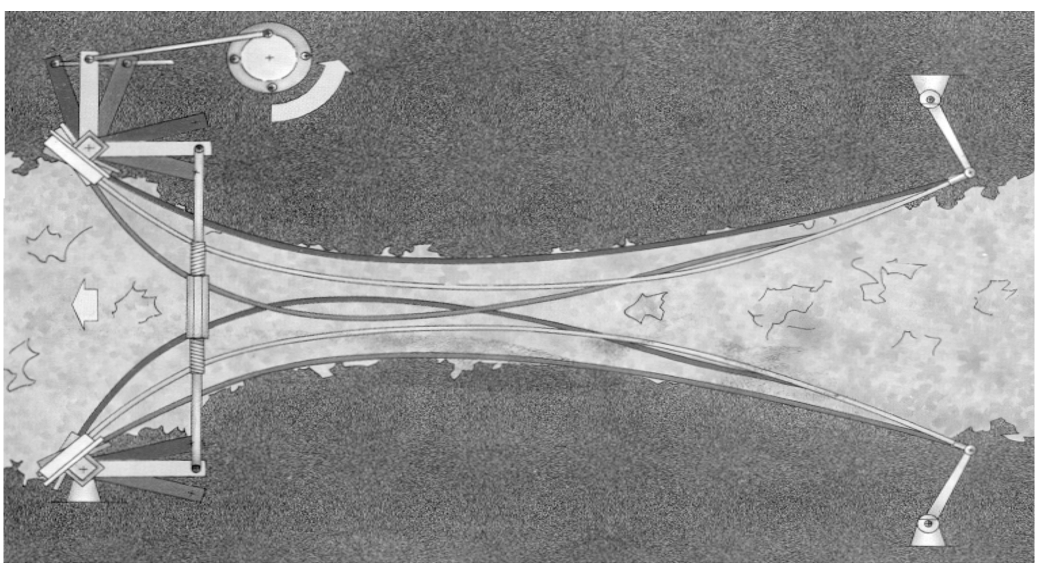

Fig.1. Shaking equipment with elastic bars

The equipment comprises an array of nylon bars with high elasticity, arranged on both sides of the vine fence. The two bar rows are kinematically connected and put out of touch with $180^0$. One end of the bar is embedded into a plate that oscillates around a fix point while the other is articulated to a balance lever.

I order to determine the acceleration applied by the bars to the vine, one has firstly to know: the deformation mode of the elastic bars as a function of the rotation angle of the oscillating plate; the trajectories described by the elastic bars as compared to the vine fence axis and the speed and acceleration of the bars as a function of the angular speed of the oscillating plate-actuation mechanism.

Since the elastic bars undergo very large strains as compared to their cross section, in order to determine the curved trajectory described by the deformed bar, the recurrence calculation principle was initially applied to the straight bars subjected to plane bending [1] Based on the force and momentum load applied to a single bar (Fig.2) a mathematic model was developed, which allowed to define the deformation mode of the bar as a function of the deformation angle θ [2].

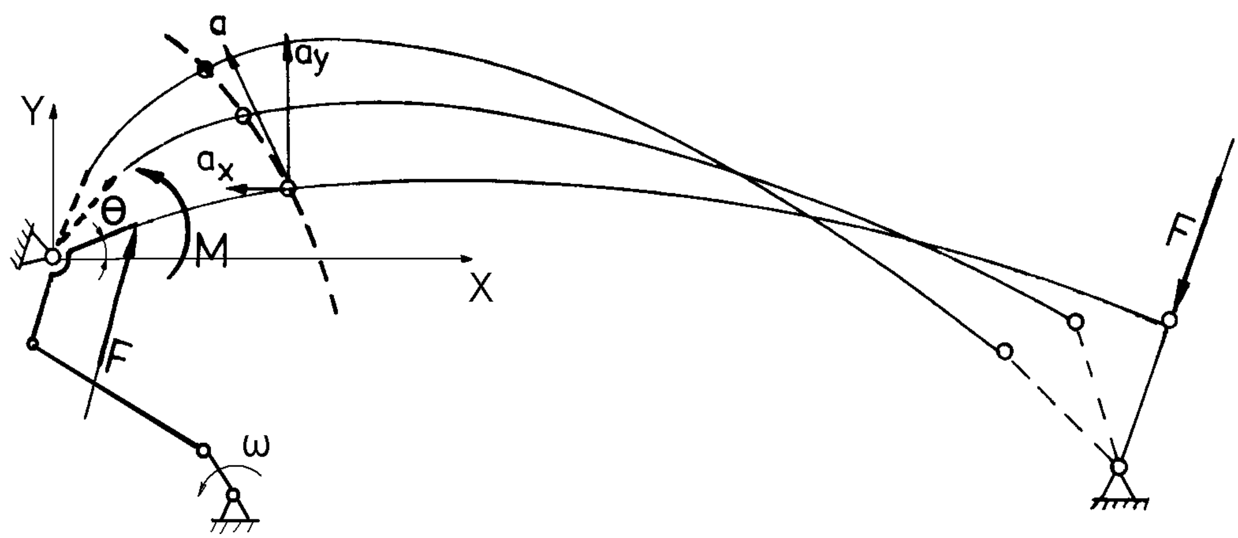


Fig. 2. The forces and momentums that act on the elastic bar during its deformation

The model enables to determine the coordinates for several points of the elastic bar, not matter how large the bar is. For experimental purposes, a number of M equally spaced characteristic points, designated by $P_1$; $P_2$; …$P_j$;….$P_M$, are assumed (Fig. 3.).

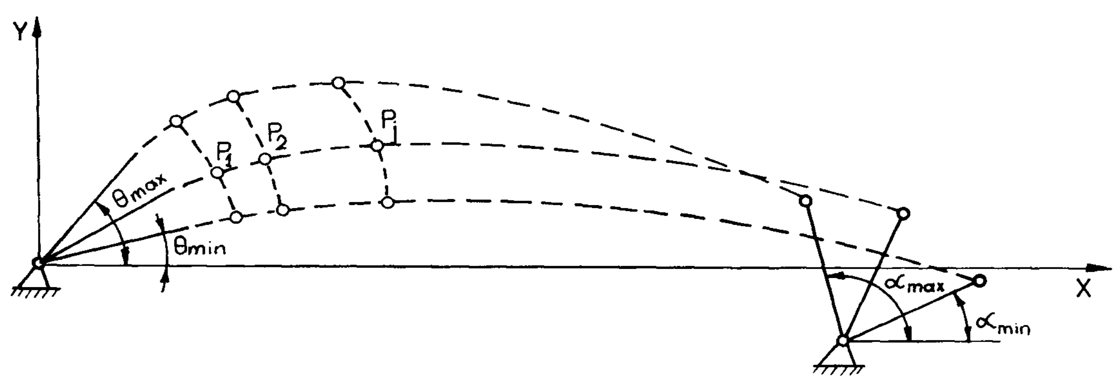


Fig. 3. Trajectories developed by the characteristic points

Knowing the coordinates $X_j$ and $Y_j$ for different values of the angle θ, the trajectory of any point of the bar can be plotted. By means of the least square fitting method, the third order polynomial equations can be determined that use the following correlations:

$$\begin{cases} X_j(\theta) = a_1\theta^3 + b_1\theta^2 + c_1\theta + d_1 \\ Y_j(\theta) = a_2\theta^3 + b_2\theta^2 + c_2\theta + d_2 \end{cases} \quad (1)$$

Based on these relationships and the variation law of the deformation angle, $\theta = f(\omega) = f(t)$ resulting from the kinematical analysis of the actuation mechanism, after derivation as a function of time, both the speeds and the accelerations are obtained for any point of the elastic bar.

## EXPERIMENTAL RESULTS

Within the experimental calculations and verifications, the constructive data of the shaking equipment from a BRAUD 2720 machine were used. The bars have round cross section with a 30 mm-diameter and a 1700-mm length, from which 90 mm are embedded into the oscillating plate. In the case of the cross-section and the material under use, the elasticity longitudinal modulus is E = 4840 N/mm$^2$.

The theoretical results concerning to the deformation mode of the bars under static regime, are shown in Fig.4 for different values of the deformation angle.

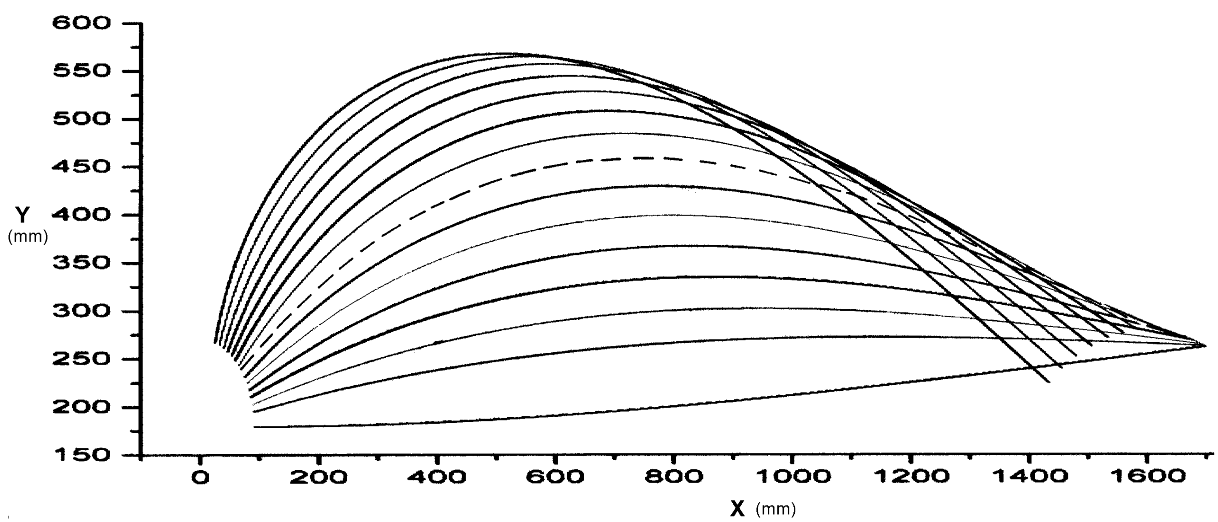


Fig. 4. Variation of the deformed bar shape as a function of the deformation angle

Table 1

Coefficients of the equation that defines the shape of deformed elastic bar

| Angle θ (deg.) | $Y=aX^3+bX^2+cX+d$ | | | |
|---|---|---|---|---|
| | ax$10^{-7}$ | bx$10^{-4}$ | cx$10^{-1}$ | dx$10^{2}$ |
| 0 | 0.00003 | 0.28 | 0.046 | 1.78 |
| 10 | -0.00009 | -0.62 | 1.49 | 1.86 |
| 20 | 0.634 | -3.17 | 4.08 | 1.78 |
| 30 | 1.05 | -5.11 | 6.13 | 1.82 |
| 40 | 1.59 | -7.31 | 8.20 | 1.88 |
| 50 | 2.25 | -9.62 | 10.2 | 2.05 |
| 60 | 3.12 | -12.2 | 11.6 | 2.25 |
| 70 | 4.04 | -14.5 | 12.5 | 2.56 |

For calculation accuracy, the elastic bar was divided into thousand equal parts, in such a way that for the curves shown in Fig.4, third degree polynomial equations have been determined, the coefficients of which are given in Table 1

Experimental measurements were performed on a laboratory stand, considering the bars both under static and dynamic regime. For this purpose 16 characteristic points were chosen, which are spaced at 100 mm. For the above two regimes, Tables 2 and 3, respectively present theoretical and experimental (measured) values corresponding to some of the points.

The verifications performed under dynamic regime aimed to plot the trajectories followed during a complete rotation of the actuation mechanism. The stand has enabled the measurement of the coordinates X and Y of the considered points, corresponding to the position of deformed elastic bar at both maximum and minimum values of the angle θ, for two angular rates: : $\omega_1$=24.713 $s^{-1}$($n_1$=236 rot/min) and $\omega_2$=44.191 $s^{-1}$($n_2$=422 rot/min), respectively.

Table 2

Coordinates of the points from the bar deformed under static regime

| Point from the bar | $\theta=10^0$ | | | | $\theta=50^0$ | | | |
|---|---|---|---|---|---|---|---|---|
| | X (mm) | | Y (mm) | | X (mm) | | Y (mm) | |
| | theoretic | measured | theoretic | measured | theoretic | measured | theoretic | measured |
| 1 | 187.31 | 186.0 | 31.82 | 31.5 | 127.87 | 127.0 | 320.18 | 319.0 |
| 3 | 385.62 | 384.5 | 57.58 | 56.0 | 295.41 | 294.0 | 428.21 | 427.0 |
| 5 | 584.82 | 585.0 | 75.40 | 74.5 | 485.30 | 484.5 | 489.43 | 488.5 |
| 7 | 784.51 | 782.0 | 86.41 | 85.0 | 684.10 | 683.0 | 508.19 | 507.0 |
| 9 | 984.43 | 983.0 | 91,80 | 90.0 | 883.26 | 882.0 | 492.18 | 491.0 |
| 11 | 1184.42 | 1181.5 | 92.78 | 91.5 | 1078.6 | 1076.5 | 449.47 | 448.5 |
| 13 | 1384.41 | 1382 | 90.61 | 89.0 | 1269.15 | 1268.0 | 389.52 | 388.5 |

Table 3

Coordinates of the points from the bar deformed under static regime

| Point from the bar | X (mm) | | | Y (mm) | | |
|---|---|---|---|---|---|---|
| | theoretic | measured | | theoretic | measured | |
| | | $n_1$ | $n_2$ | | $n_1$ | $n_2$ |
| $\theta_{min}=8^0$ | | | | | | |
| 1 | 187.61 | 188.0 | 188.0 | 29.95 | 28.5 | 28.0 |
| 3 | 386.11 | 386.0 | 386.0 | 54.30 | 53.0 | 51.5 |
| 5 | 585.38 | 586.0 | 585.0 | 71.29 | 69.0 | 67.5 |
| 7 | 785.09 | 792.0 | 791.0 | 81.96 | 79.5 | 76.5 |
| 9 | 985.01 | 986.5 | 987.0 | 87.37 | 86.0 | 83.5 |
| 11 | 1185.13 | 1186. | 1187.5 | 88.70 | 86.5 | 84.0 |
| 13 | 1384.99 | 1385.0 | 1386.0 | 87.02 | 86.0 | 84.0 |
| $\theta_{max}=55^0$ | | | | | | |
| 1 | 115.97 | 114.0 | 112.0 | 330.09 | 332.5 | 334.0 |
| 3 | 277.96 | 273.5 | 271.0 | 445.97 | 448.5 | 450.5 |
| 5 | 466.61 | 462.5 | 460.5 | 510.59 | 517.0 | 521.0 |
| 7 | 665.41 | 660.0 | 659.5 | 528.69 | 538.0 | 542.5 |
| 9 | 864.22 | 859.0 | 854.0 | 509.47 | 517.5 | 519.5 |
| 11 | 1058.33 | 1052.5 | 1048.5 | 462.20 | 469.5 | 471.5 |
| 13 | 1246.83 | 1241.5 | 1238.5 | 394.97 | 399.0 | 400.5 |

It is noticeable that under static regime the experimental shape of the deformed elastic bar only slightly differs from the theoretical one. The differences become larger under dynamic regime, due to inertia forces occurring at the end of the strokes. As an effect of these forces, the bar has two tendencies: to increase its deformation degree, particularly in the area between points 5 and 9 (located at distances of 500 and 900 mm, respectively from the oscillating plate) for $\theta_{max}$ and to decrease its deformation degree in the same area, for $\theta_{min}$.

Under dynamic regime, the average deviation of the measured values from the theoretical ones is 2.4 %, and increases with the rotation speed of the actuation mechanism up to 5 % in the area of maxim deformation.

## CONCLUSIONS

The kinematical analysis of the elastic bodies, which are highly deformed during their motion, cannot be performed by means of classical well-known methods belonging to the resistance of materials. In the present case, the application of the recurrence calculation principle, to straight bars subjected to plane bending, allowed determining the deformed shape of the bars as a function of the movement of the actuation mechanism.

The experimentally measured coordinates of the points from the deformed elastic bar revealed differences, as compared to theoretical results, which were insignificant under static regime and tolerable under dynamic regime.

Based on the present data, the parametric equations can be determined for the space covered by any point from the bar, and then its speed and acceleration can be determined as a function of the angular rate of the actuation mechanism.

## REFERENCES

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