Study of the energetics of the pole vaulting

MIHAI TOFAN, SORIN VLASE, ANGHEL CHIRU, HORATIU TEODORESCU, L. SCUTARU
Department of Mechanical Engineering
Transilvania University of Braşov
29 Eroilor Blvd., 500036 Braşov
ROMANIA

Abstract: - The study analyzes the energetic aspect of the pole vault, training in the athlete's strategy, near by pole's compressing postcritical, the application of a couple of pole's bending, maintaining verticality in the negative acceleration field. The study evaluate the contribution at the elastic potential stored in the pole by application the couple and the pole's deformations in this loading states with the purpose to identify the jump. The couple's necessary intensity is evaluated from the condition that at the pole's fixing end in the box, the moment to be null. Identify the difficulty on the deformations is caused by the differentials, hard to be showed by measuring. The access to the information upon this loading's component remains in the essence the jump's kinogram, the time to maintain verticality in the negative acceleration field.

Key-Words: - Pole vault, Couple of pole's bending, Kinogram, Negative acceleration fields, Pole's deformations, Articulated rigid bodies, Combustion law Vibe, Compressing postcritical force.

1 Introduction

A simple calculation refering to the pole vault of an world champion since 1984, Serghei Bubka, shows, regarding to his pole's vault energetics, that he applied a new strategy in his performance of 6.3 m, extraordinary at that moment. For v = 9.5 $m \cdot s^{-1}$, from the necessary potential energy, for the performing vault, the difference of energy is 13.1%!

S. Bubka feed into this energy, astonishingly, by application a couple C in the first 13/64 s, from the jump who last about 65/64 s, showed schematically in fig.1.

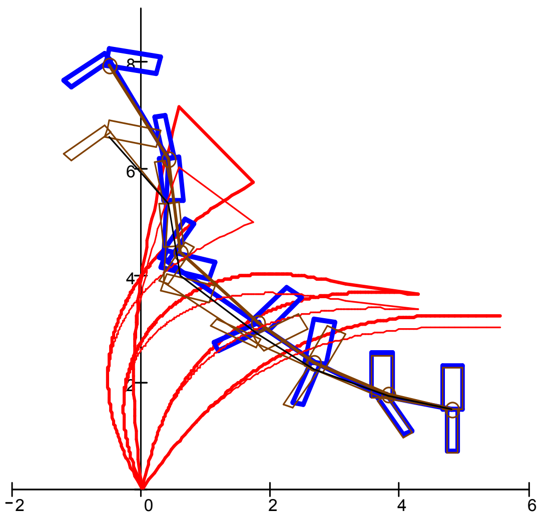


Fig. 1 The vault's model, calculation of the pole's deformations after Landau [1], on the Griner's arrangement [2] (jumps of Tadeosz Slusarski, 1968 and Serghei Bubka, 1984)

2 The model of pole's deformation suggested by Hubbard

Hubbard [3] attaches to the pole, a longer bar, over-compressed, so the end from the box, $\mathbf{A}_0$, to be retained in balance only with an over-compressing Force, presented in Fig. 2, 3.

Hubbard [3] opens the way to the importance of pole's loading with a bending Moment by applicating a couple. The identification, who stimulate the real pole's deformation, can't be build on the asymmetrical angles of contingency from the two ends, because the real deformations have practically a constant beam of curvature!

Griner [2] had build in 1984 the arrangement trained in modeling showed in Fig. 1. He gived importance to the Moment's loading, but his tries to explaine the performance in this way, were not accepted by that time trainers!

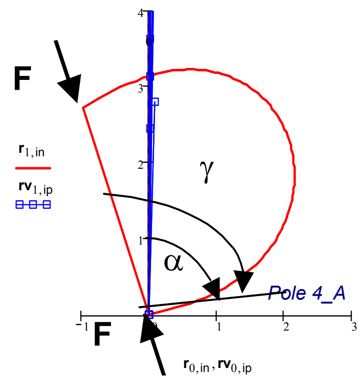


Fig. 2 The over-compressed bar of Hubbard attached to the pole

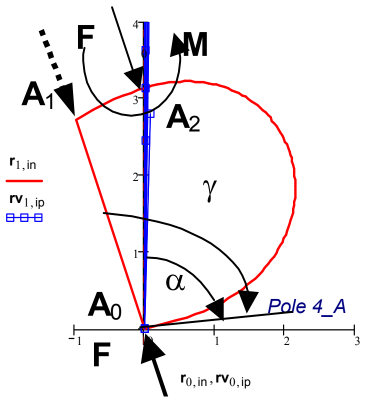


Fig. 3 If F moves from A_1 to A_2 and is inserted the couple M in this section, so that the Moment from the box of A_0 to be zero

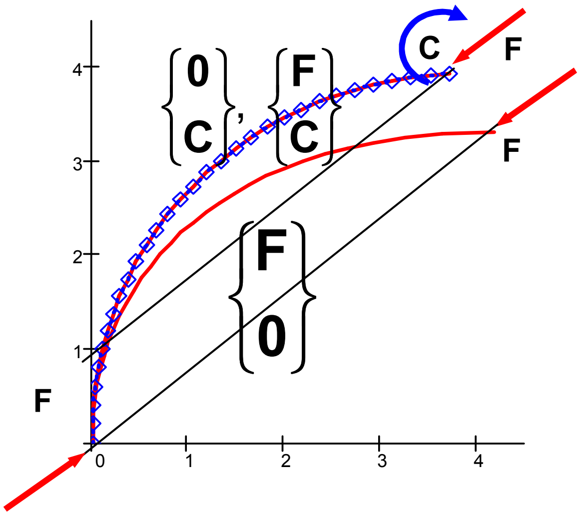


Fig. 4 The three pole's deformations, for the concentrated Force, couple and lifting screw. The last two practically are overlapped, because of the couple's intensity who dominate the effect of the compressing postcritical Force

The Balance of the bending Moment, the Hubbard's lifting screw component, applied at the pole's end, in the elastic potential, and the one with postcritical compressing.

$$MK_i := |C| + \left|\left[\left(rC^{\langle 2\rangle} - r^{\langle k_{i,2}\rangle}\right)\times \mathbf{F}\right]_2\cdot P\right|, \quad (1)$$

$$PC_i := \frac{C}{MK_i} \quad (2)$$

$$MC_i := M_{kp_{i,2}}\cdot|PC_i|, \quad (3)$$

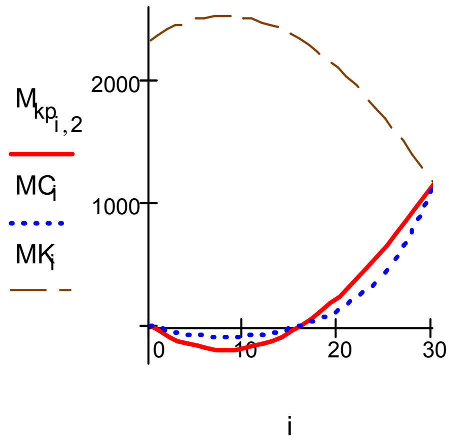
$$V_{2,h} := \frac{dq}{2}\cdot\sum_j \left|M_{kp_{j,h}}\right| \quad (4)$$

$$VC_0 := \frac{dq}{2}\cdot\sum_j |MC_j| \quad (5)$$

$$fc := \frac{VC_0}{V_{2,2}} \quad (6)$$

$$1 - fc = 0.329 \,, \quad (7)$$

$$fc = 0.671 \quad (8)$$



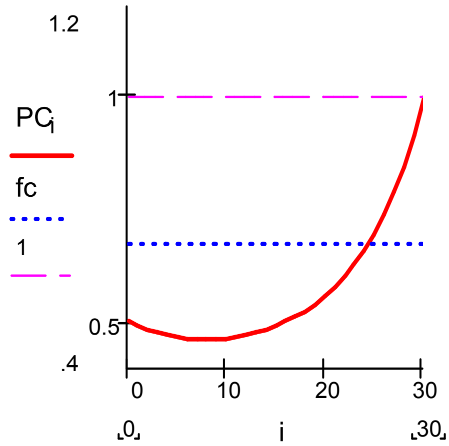


Fig. 5 The pole like Hubbard's bar, loaded with $F = 1$ and $C = 1.162$ so that in the bearing to be simple bear, only with friction! Then the mechanical's work fraction during the jump, inserted by the couple C in pole, will be 67.1% (fc) from the deformation's elastic potential, the rest of 32.9% ($1 - fc$) is associated to the postcritical compression.

3 The kinematics study of two articulated rigid bodies

The columns approximation was executed, absolutely the same, like approximation of Burcă [1] with two duals combustion law Vibe [3,4]. We accentuate one more time, how easy can be realized an excellent application of this exponential functions on arrangements or filmed images readings. In consequence, we have access to the speeds and mostly of the angular accelerations of the two rigids, and final to the inertness forces developed by athlete.

The dynamics control of the jump becomes immediately accessible, lighting to good performances approximation of this test in the developed forces margins by an athlete trained in the spirit of this obstruction strategy of rotation in the strong negative acceleration jump field, realizing a supplementary loading by pole's bending.

Combustion law Vibe, in interval [0,1]:

$$C = ln(10^3),\quad C = 6.908\,, \tag{9}$$

$$f(t,m) = 1 - e^{-C\cdot t^{m+1}}\,. \tag{10}$$

Combustion speed Vibe, derivative with t:

$$w(t,m) = C\cdot(m+1)\cdot t^{m}\cdot exp(-C\cdot t^{m+1})\,. \tag{11}$$

Combustion acceleration Vibe:

$$W(t,m)=C\cdot(m+1)\cdot t^{m}\cdot exp(C\cdot t^{m+1})\cdot\left(\frac{m}{t}-C\cdot(m+1)\cdot t^{m}\right). \tag{12}$$

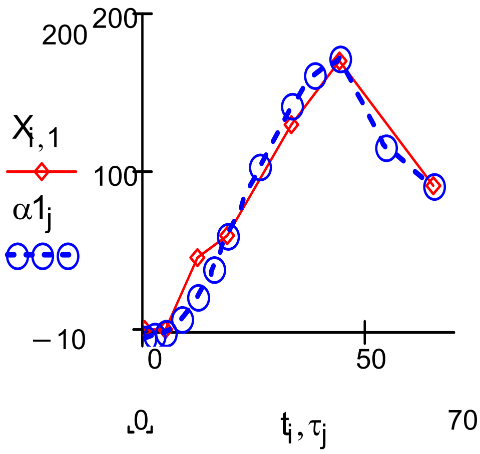


Fig. 6 Superior body position

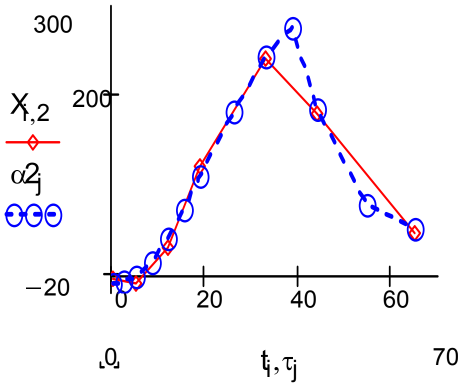


Fig. 7 Inferior body position (I)

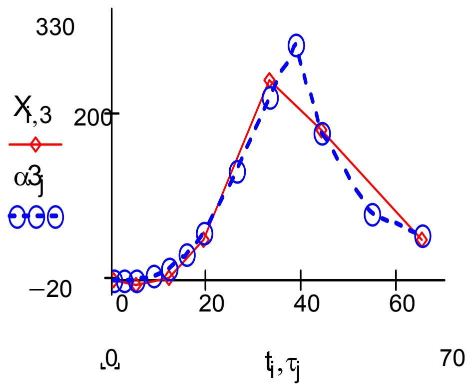


Fig. 8 Inferior body position (II)

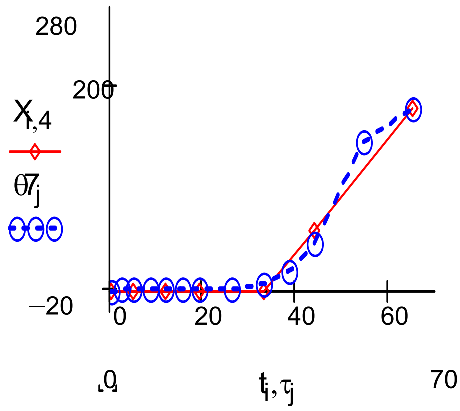


Fig. 9 Twist around personal axis

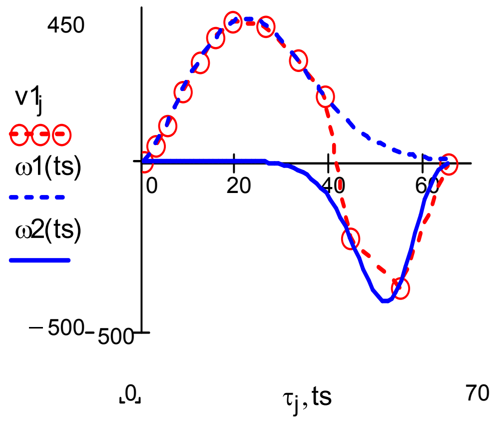


Fig. 10 Angular speed (I)

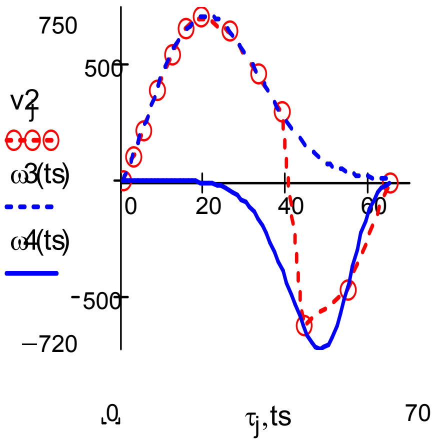


Fig. 11 Angular speed (II)

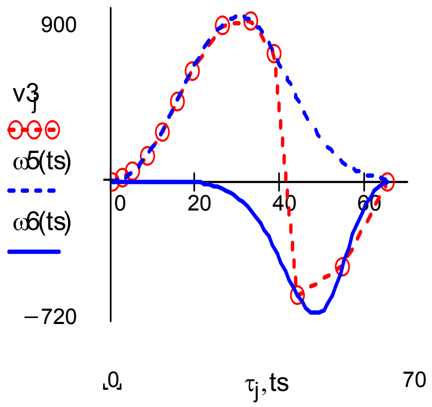


Fig. 12. Angular speed (III)

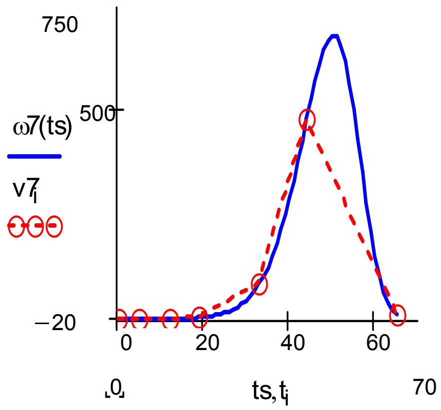


Fig. 13 Angular speed (IV)

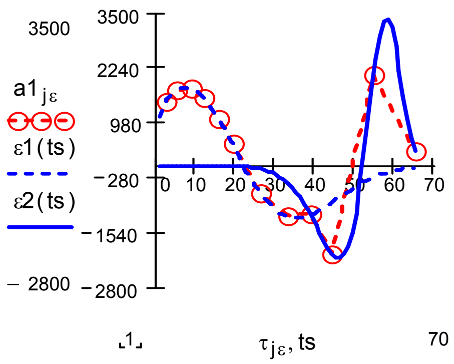


Fig. 14 Angular acceleration (I)

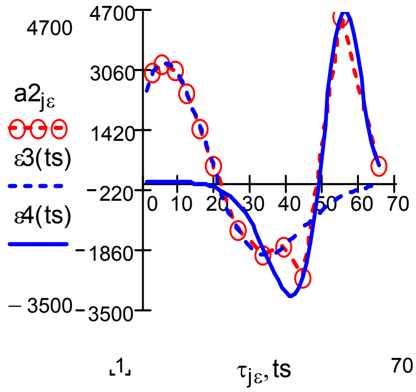


Fig. 15 Angular acceleration (II)

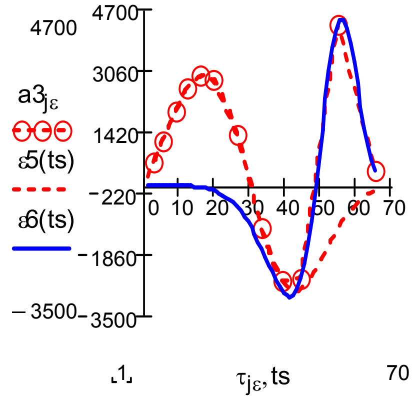


Fig. 16 Angular acceleration (III)

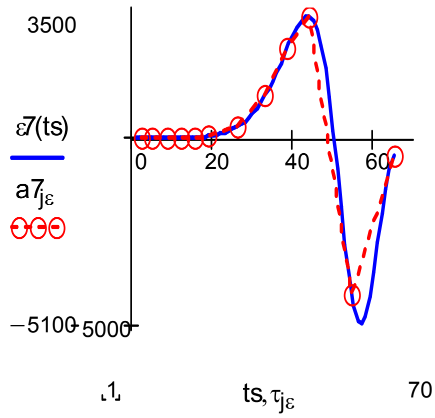


Fig. 17 Angular acceleration (IV)

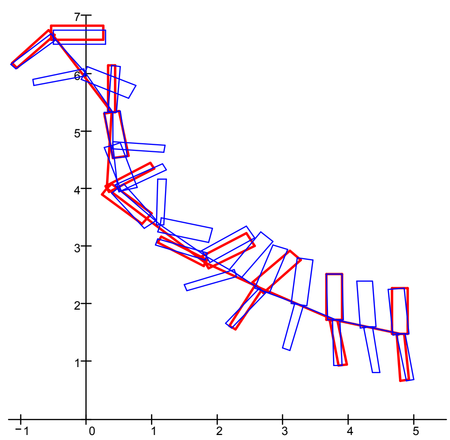


Fig. 18 Extension by interpolation (I)

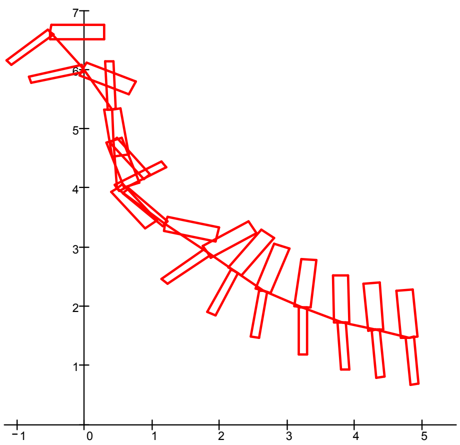


Fig. 19 Extension by interpolation (II)

4 Conclusions

Increasing with 13% the energy stored in the pole, towards the one released from the jumper's running, it is necessary the application enduring ≈ 13/64 s, ≈ 65/64 s, the approximate time of the jump, till after the second position from fig.1.The jumper must not give up to the inertness Force, the negative acceleration field specific, in what he is sinking, being one with the pole at the 0.75 m, just to apply the couple C.

The training only in this way brought to S. Bubka (1984) the surprising medal.

T. Slusaraki (1978) didn't resisted to oppose the inertness in the negative acceleration field about ≈ 5/64, fig. 1.

The major difficulty to identify the pole's loading state from analyzing the deformed filmed image is because the couple **C** necessary to resist the solid's rotation in the strong negative acceleration field is very big, hard to defeat.

But a couple of bending so big, hides by the bar's bending the effect of compressing postcritical induced by the inertness force. Because of that reason appears the practical impossibility to identify the loading state. The bending and compressed pole with the screw in contradistinction with the simple bending circular, by the couple, can not be practicaly noticed. The two deformed are practically congruent, like we tried to show in the fig. 4, and also because of the big intensity of the bending couple, all the deformations have one symmetrical axis, so they are similar. The images from fig. 2, 3, used at the significant illustration of the Hubbard's concept are too thin, the bar is too flexible to be used in sports. We do not know any techniques to measure exactly the image's deformation's beam of curvature. Possible remains the tensometer's measure, but this one brings many dificulties too.

The sportsman's and the coach's honesty remains interesting arguments.

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