THREE-DIMENSIONAL DYNAMIC ANALYSIS OF POLE VAULTING

Julien Morlier [1] and Mariano Cid [2]

[1] Laboratoire de Mécanique Physique URA CNRS 867, Université de Bordeaux I, France
[2] Faculté des Sciences du Sport et de l'Éducation Physique, Université de Bordeaux II, France

INTRODUCTION

The pole vault is a very exciting track-and-field event which represents a great interest for scientists. In order to optimise this athletic movement, many mechanical research have been carried out. The computer simulations are much larger than the experimental studies. But, the results of these experimental studies are indispensable to improve numeric simulations. D. A. Barlow (1973) was the first to measure the forces developed by the system pole-vaulter in the pole vault box (called the pole forces) in two directions of the space, using strain gauges put directly on the pole vault box. Using the same two-dimensional approach, H. J. Gros realised a dynamic analysis of the pole vault. The force plate used in this study was placed under the box and provided, like the one used by D. A. Barlow, two components of the pole force.

Thus, our laboratory has recently developed a dynamic experimental analysis of pole vaulting. The main contribution of our work is the three-dimensional (3-D) approach of the pole vault. Moreover, two force plates were used : the first one placed on the track allowed the direct measurement of the force and torque acting by the system pole-vaulter on the runway during the last step before the take-off of the pole vaulter, owing to the second one put under the pole box, we measured the reaction force and torque acting on the end of the pole. With such an experimental system, we can compute the total impulse of the athlete before his taking-off which is an actual performance factor. Then the detailed analysis of the pole force shows the main phases of a vault.

This experimental dynamic study is of course completed by a 3-D cinematographic analysis of pole vaulting which permits the computation of the kinematic and kinetic parameters of the pole vault.

METHODS

The two force plates called "six component dynamometer" used in this experimental research were created in our laboratory and provide the three components of the force applied on the plate form and the three components of the resultant torque. In this study, we will not present the results obtained for the torque but they are necessary to compute the torque applied at the end of the pole and to quantify the influence of the material used for the tip of the pole.

The first dynamometer, integrated in the runway, is 80 cm long and 60 cm wide and is 3,4 m from the end of the box. It provides the three components of the impulsion force : the force applied by the system pole-vaulter on the track (I_x , I_y and I_z) during the last step of the athlete just before he takes off. That parameter is really important to understand better the performance in pole vaulting. Besides, the dynamometer permits to measure with great accuracy (less than 1/1000 s) the contact time of the foot to the ground during the last step. Indeed, the frequency of acquisition of the dynamometers could reach 5000 Hz.

The second force plate (40 cm long and 40 cm wide) is put under the pole box which was adapted for this experience. The box was cut into two parts (Fig. 1) : the first one is fixed on the runway and the second one which is free, is linked with the force plate in order to measure actually the three components of the pole force (F_x , F_y and F_z). The resonance frequency of the system pole vault box-dynamometer would have been less important if the box has not been cut.

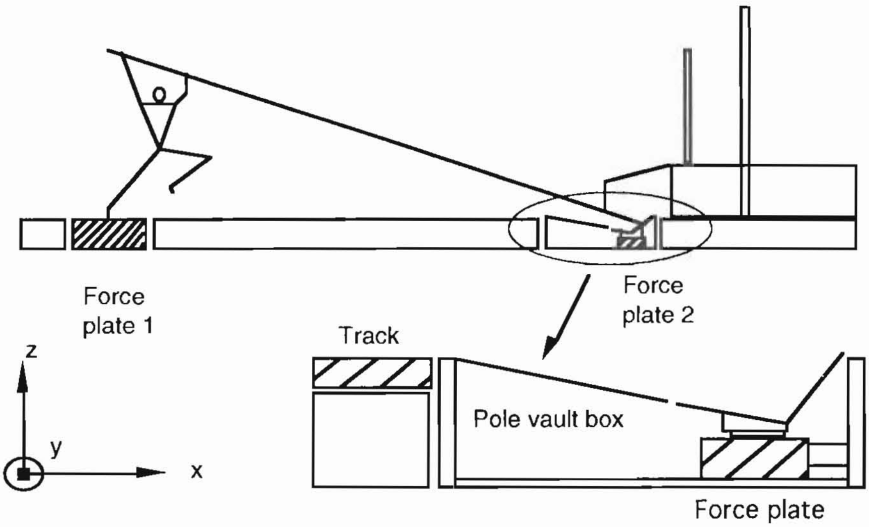

Fig. 1 : Dynamic experimental system

The signals coming from both dynamometers through a conditioning system has been recorded in a Personal Computer. Moreover, these signals were treated in order to eliminate the resonance frequency of the acquisition system (this frequency is 300 Hz for the force plate put under the box and 50 Hz for the one in the track). This dynamic experimental system allows to measure the 3-D forces applied by the pole and by the athlete on the ground and on the pole box. It also permits to calculate the duration of these actions.

RESULTS AND DISCUSSION

This paragraph will be about the results obtained for a single vault registered by this experimental system. The pole vaulter who performed that vault, is a national level athlete whose personal best is 5,40 m. Figure 2 shows the results of the pole force (F) and of the impulsion force (I) during a vault.

The detailed analysis of the z-component F_z of the pole force (which is the most characteristic one for a vault) shows the main phases of the pole vault technique : the impact of the pole in the box, takeoff and rock back, pull-up and turnover and pole release (Fig. 3).

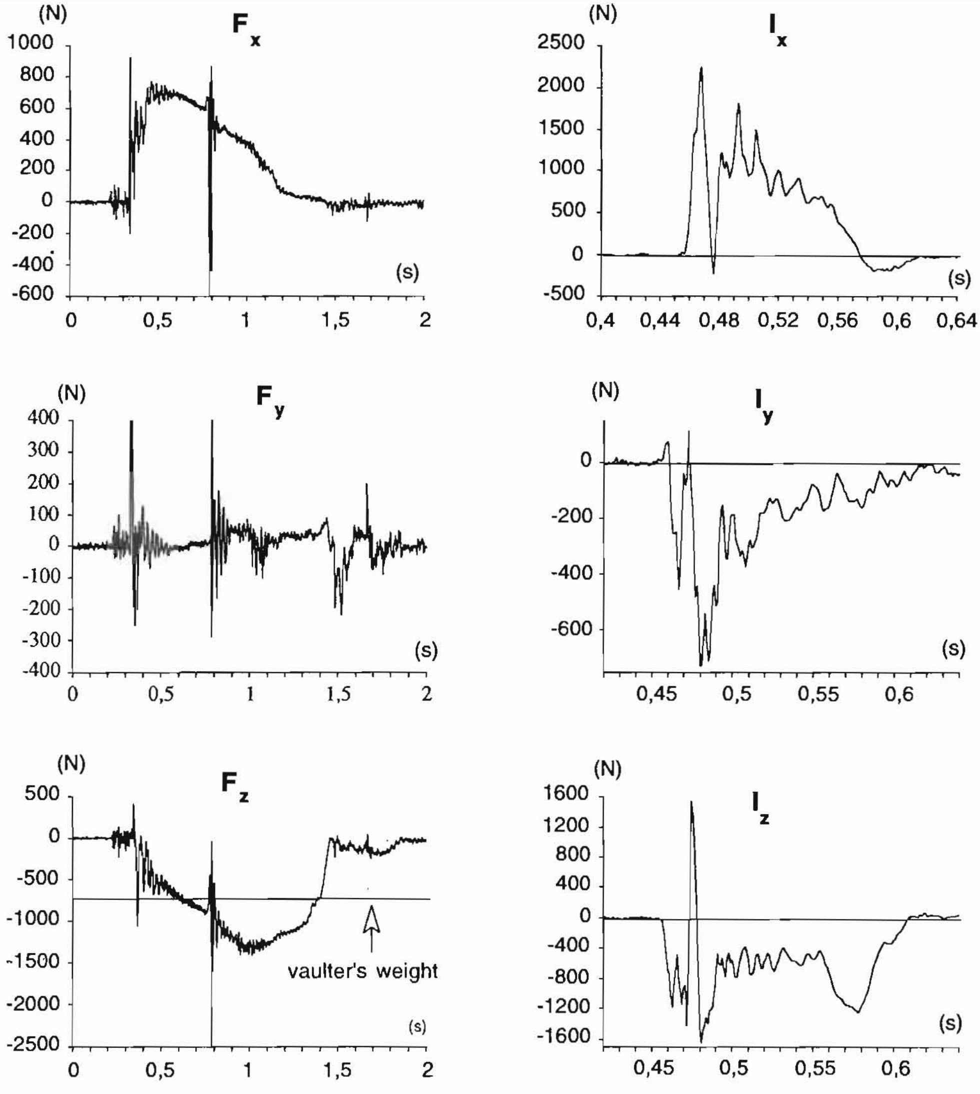

Fig. 2 : The pole force F and the impulsion force I recorded for a true vault

First, the impact of the tip of the pole on the box (pole plant) shows a vertical peak of F_Z (t = 0,35s). The shock induces oscillations in F_Z which are due to the vibrations of the system plate force - box. Just after the athlete's taking-off, there is a constant increase of the force F_Z applied on the box in the (-z) direction (0,35s < t < 1s) which is typical of the pole bending and rock back of the vaulter. At t = 0,8s, the end of the pole slides on the box, then oscillations of F_Z appear.

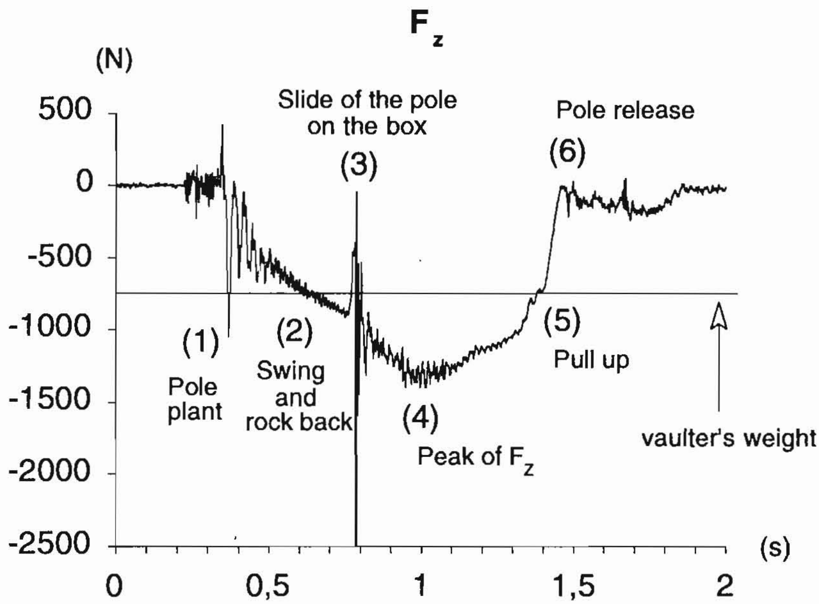

Fig. 3 : Analysis of a pole vault with F_Z

Then, after the peak of F_Z (t = 1s), the vaulter starts the pull up using the energy of the pole in order for him to get the greatest velocity in the best direction when he releases the pole, to be catapulted over the bar. That last phase of the pole vault shows that the velocity of the center of mass of the vaulter in the z-direction is decreasing (at t = 1,35s). That decrease must be as small as possible to get the best velocity when the athlete releases the pole (t = 1,5s) to clear the bar.

CONCLUSION

The development of such an experimental system must be undertaken in connection with coaches and pole vaulters in order to provide results which could be easily understood. Moreover, a 3-D experimental analysis of pole vaulting is a powerful way to improve performances and optimise each athletic movement. Finally, that system could provide numeric simulation with the evolution of the mechanical parameters measured or computed. That 3-D experimental analysis of pole vaulting will be completed with the direct measurement of the force developed by the vaulter on the pole using strain gauges and telemetry.

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