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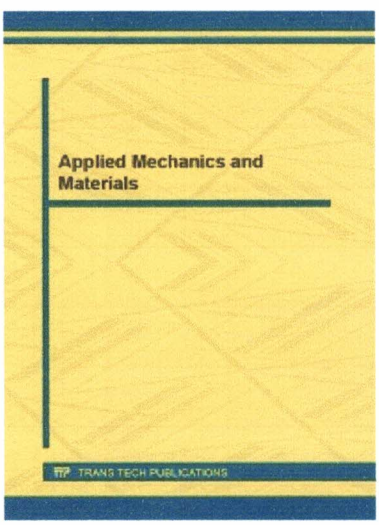

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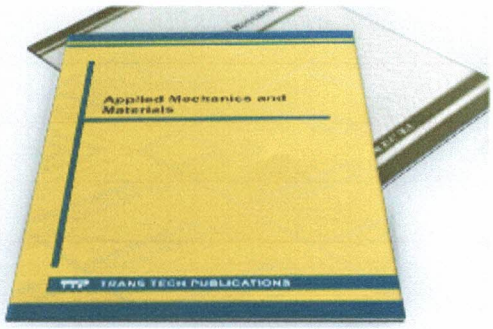

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Preface

In this volume collected articles presented at Uttaradit Rajabhat University International Conference on Science and Technology 2018 (URUICST 2018. August 2-3, 2018, Uttaradit Thailand). The main topics of issue are technologies in the food processing and agriculture, pharmacology and biotechnologies, technologies for production of renewable energy, advanced materials and chemical technologies in the environmental engineering, designing in mechanical engineering and information technologies.

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Theory Mathematics and Physics Model Fitting of Kinematic Parameter for Usain Bolt 100 Metres Sprint at Beijing Olympic Games 2008

Nichapat Thongsit[1a], Yosita Sangnok[1b], Wannee Wannapak[1c], Kan Khoomsab[2a], Surachest Iamsamang[2b], Sirada Sangnok, Jetsadaporn Pakamwang[3a] and Artit Hutem[4*]

[1]Petpittayakom School, Ni-Muang Sub District, Muang District, Phetchabun, Thailand 67000

[2]Biology Program, Faculty of Science and Technology, Phetchabun Rajabhat University, Phetchabun, Thailand 67000

[3]Computer Science Program, Faculty of Science and Technology, Phetchabun Rajabhat University, Phetchabun, Thailand 67000

[4]Physics Division, Faculty of Science and Technology, Phetchabun Rajabhat University, Phetchabun, Thailand 67000

[1,a]nichaaapat0882@gmail.com, [1,b]yosiyosita123@gmail.com, [2,a]topkan13@hotmail.com, [2,b]topthesun1978@gmail.com, [3a]Jetsadaporn.pa@gmail.com [4]artithutemdee@gmail.com, *E-mail: artithutemdee@gmail.com, Fax: 056-717-123, Mobile: 086-9909536

Keywords: Usain Bolt runner, kinematic parameter, mathematical and physics model, sport physics

Abstract. In this paper, we develop a mathematical and physics model or formula of time-dependent displacement, time-dependent velocity, time-dependent acceleration, time-dependent kinetic energy and time-dependent mechanical power of Usain Bolt in the 100 m sprint at Beijing olympic games 2008. We use data of distance, velocity and time of Usain Bolt from Mackata Krzysztof and Antti Mero analysis kinematic parameter of Usain Bolt to compare the mathematical and physics model. The mathematical has the same velocity and acceleration as the physics model has. As shown in the book entitled Introduction to sport biomechanics of Roger Bartlett (pp.83-92).

Introduction

Currently Sport science is very extraordinary particularity, for athletes and trainers. It is a discipline that studies how the healthy human body works while exercising, and how sport and physical activities promote our whole body more healthy.

According to K. Mackata and M. Antti (2013) [5], the step length is the main factor has an influence in running speed in the 10 and 20 meters sections of the entire 100 meters distance. And his anthropometric advantage is not dubious and it is one of the factors that make him faster. O. Helene et al. 2010 [3] extend the analysis of Eriksen et al. to model Bolt's time-dependence velocity of the Beijing 2008 and Berlin 2009 records. JJ Hernandez Gomez et al. 2013 [4] had shown the theoretical model of the kinetic performance of the 100 m world record sprint of Usain Bolt at Berlin is developed, presuming a drag force proportional to u and to u^2 (u is the horizontal velocity(speed)). They studied and compared physical characteristics, time, velocity, stride length and stride frequency in Beijing. From their journal, we will calculate the function of time series and compare the time-dependent displacement, time-dependent velocity, time-dependent acceleration, time-dependent kinetic energy and time-dependent mechanical power obtained from the mathematical model, physics model and kinematic parameter of Usain Bolt in the 100 meters sprint. Knowledge of the relative influence of the function of time series on maximal running speed would be a great value to trainers or coaches and provide a composition for developing of Sport science. The scheme of the paper is as follows.

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In section we write the basic Newton's second law in terms of integrate by parts in equation 5. In section, we show result comparison of kinetic performance of Usain Bolt obtain from the experimental data and theoretical of mathematics and physics model. In section contains our conclusions.

Linear Motion Model for the 100 Metres Sprint

We are interested in motion study of a Jamaican sprinter, Usain Bolt, Who is a currently 100 metres world record holder when the applied force is time dependent; that is $\boldsymbol{F} = \boldsymbol{f}(\boldsymbol{t})$. A Jamaican sprinter of mass $\boldsymbol{m}$ starting (run) with an initial velocity $\boldsymbol{v}_0$ is exerted on by the applied force $\boldsymbol{f}(\mathbf{t}) = \boldsymbol{f}_0\, \boldsymbol{t}^2 \boldsymbol{e}^{-\beta t} \big/ \boldsymbol{\beta}$, where $\boldsymbol{t}$ is the time of Usain Bolt in the 100 metres sprint, the initial force of running is $\boldsymbol{f}_0$ and $\boldsymbol{\beta}$ is the positive constants. The applied force of running is given by

$$\boldsymbol{f}(\boldsymbol{t}) = \boldsymbol{f}_0 \boldsymbol{t}^2 \boldsymbol{e}^{-\beta t} \big/ \boldsymbol{\beta} \tag{1}$$

and from Newton's second law[1], we may write

$$\boldsymbol{m}\boldsymbol{a}(\boldsymbol{t}) = \boldsymbol{m}\frac{\boldsymbol{dv}(\mathbf{t})}{\boldsymbol{dt}} = \boldsymbol{f}_0 \boldsymbol{t}^2 \boldsymbol{e}^{-\beta t} \big/ \boldsymbol{\beta} \tag{2}$$

Here $\boldsymbol{a}(\boldsymbol{t})$ is the time-dependent acceleration, $\boldsymbol{v}(\boldsymbol{t})$ is the time-dependent velocity and $\boldsymbol{x}(\boldsymbol{t})$ is the time-dependent displacement of Usain Bolt in the 100 metres sprint. The first task is to determine the indefinite integral:

$$\int_0^{v(t)} \frac{\boldsymbol{dv}(\boldsymbol{t})}{\boldsymbol{dt}}\, \boldsymbol{dt} = \frac{\boldsymbol{f}_0}{\boldsymbol{m}\boldsymbol{\beta}} \int_0^t \boldsymbol{t}^2\, \boldsymbol{e}^{-\beta t} \boldsymbol{dt}\,. \tag{3}$$

Thus

$$\begin{aligned} \boldsymbol{v}(\boldsymbol{t}) &= \frac{\boldsymbol{f}_0}{\boldsymbol{m}\boldsymbol{\beta}} \int_0^t \boldsymbol{t}^2 \boldsymbol{e}^{-\beta t} \boldsymbol{dt} \\ &= \frac{\boldsymbol{f}_0}{\boldsymbol{m}\boldsymbol{\beta}} \left[-\frac{\boldsymbol{t}^2 \boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}} + \frac{\mathbf{2}}{\boldsymbol{\beta}} \int_0^t \boldsymbol{t}\boldsymbol{e}^{-\beta t} \boldsymbol{dt} \right] \end{aligned}$$

We can rewritten the time-dependent velocity of Usain Bolt in the 100 metres sprint as

$$\boldsymbol{v}(\boldsymbol{t}) = \frac{\boldsymbol{f}_0}{\boldsymbol{m}} \left[\frac{\mathbf{2}}{\boldsymbol{\beta}^4} - \frac{\boldsymbol{t}^2 \boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}^2} - \frac{\mathbf{2}\boldsymbol{t}\boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}^3} - \frac{\mathbf{2}\boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}^4} \right]. \tag{4}$$

Be Substituted by $\boldsymbol{v}(\boldsymbol{t}) = \boldsymbol{d}(\boldsymbol{x}(\boldsymbol{t}))\big/\, \boldsymbol{dt}$ and integration by parts again

$$\boldsymbol{x}(\boldsymbol{t}) = \frac{\boldsymbol{f}_0}{\boldsymbol{m}} \left[\int_0^t \frac{\mathbf{2}}{\boldsymbol{\beta}^4} \boldsymbol{dt} - \int_0^t \frac{\boldsymbol{t}^2 \boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}^2} \boldsymbol{dt} - \int_0^t \frac{\mathbf{2}\boldsymbol{t}\boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}^3} \boldsymbol{dt} - \int_0^t \frac{\mathbf{2}\boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}^4} \boldsymbol{dt} \right] \text{ and}$$

We can rewritten the time-dependent displacement of Usain Bolt in the 100 metres sprint as

$$\boldsymbol{x}(\boldsymbol{t}) = \frac{\boldsymbol{f}_0}{\boldsymbol{m}} \left[\frac{\mathbf{2}\boldsymbol{t}}{\boldsymbol{\beta}^4} + \frac{\boldsymbol{t}^2 \boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}^3} + \frac{\mathbf{4}\boldsymbol{t}\boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}^4} + \frac{\mathbf{6}\boldsymbol{e}^{-\beta t}}{\boldsymbol{\beta}^5} - \frac{\mathbf{6}}{\boldsymbol{\beta}^5} \right] \tag{5}$$

The latter is called the formula of time-dependent displacementof Usain Bolt in the 100 m sprint. Next, we can calculate the time-dependent kinetic energy as

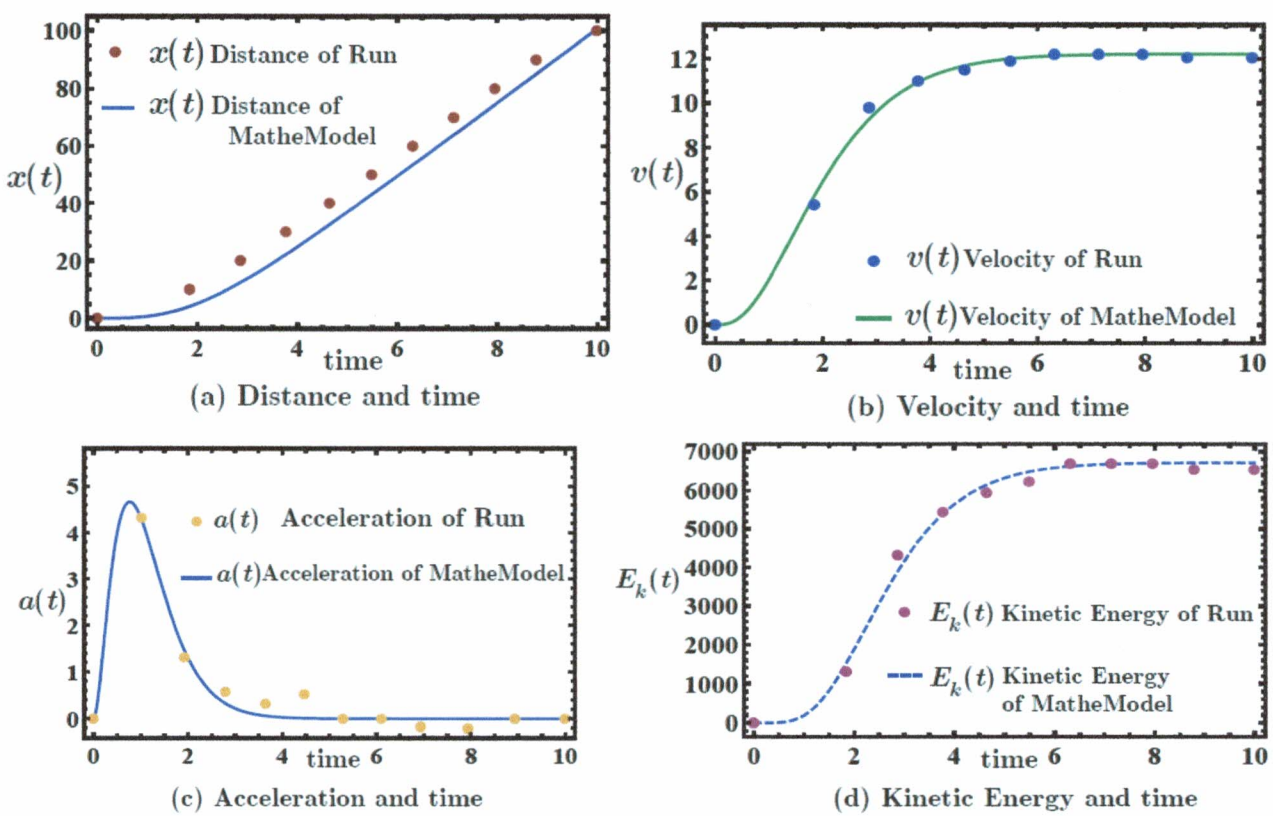
$$E_k(t) = \frac{1}{2}m(v(t))^2 = \frac{f_0}{2m}\left[\frac{2}{\beta^4} - \frac{t^2e^{-\beta t}}{\beta^2} - \frac{2te^{-\beta t}}{\beta^3} - \frac{2e^{-\beta t}}{\beta^4}\right]^2 \tag{6}$$

We can construct the mechanical time-dependent power of Usain Bolt in the 100 m sprint as

$$P(t) = f(t)v(t) = \left(f_0t^2e^{-\beta t}/\beta\right)\left(\frac{2}{\beta^4} - \frac{t^2e^{-\beta t}}{\beta^2} - \frac{2te^{-\beta t}}{\beta^3} - \frac{2e^{-\beta t}}{\beta^4}\right) \tag{7}$$

The time-dependent displacement, time-dependent velocity, time-dependent acceleration, time-dependent kinetic energy and time-dependent mechanical power are shown in Figure 1 and table 1 of Usain Bolt in the 100 m sprint.

Numerical and Result



(a) Distance and time

(b) Velocity and time

(c) Acceleration and time

(d) Kinetic Energy and time

Fig. 1 Comparison of the displacement, the velocity, the acceleration, the kinetic energy obtaine from the experimental data(see table 1 and 2) and theoretical mathematical model and physics model of Usain Bolt in the 100 metres sprint at the Beijing olympic games.

Table 1 Representation time and velocity and Velocity of model parameter of running of Usain Bolt in the 100 m sprint: Beijing 2008.

time	velocity	Velocity of model	%difference
1.85	5.40	5.80620	7.24956
2.87	9.80	9.29850	5.25172
3.78	10.99	10.94282	0.43023
4.65	11.49	11.68049	1.64425
5.50	11.76	11.99701	2.00020
6.32	12.19	12.12763	0.51296
7.14	12.19	12.18163	0.06868
7.96	12.19	12.20339	0.10905
8.79	12.19	12.21201	1.34605
9.69	11.11	12.21545	9.46093
Correlation of Model			0.993142

Table 2 Illustration time and acceleration parameter of running for Usain Bolt in the 100 m sprint: Beijing 2008, Berlin 2009 and London 2012.

time	Acceleration of model
1.02	4.314
1.93	1.308
2.80	0.575
3.65	0.318
4.47	0.524
5.29	0.000
6.11	0.000

Form table 1, the velocity of linear modeling the velocity time-dependent via the applied force time-dependent model has look like a linear modeling the velocity time-dependent via the applied force time-dependent oscillation model 1 and model 2 of Aunchana C. et al[6]. We can calculation of the correlation coefficient by program mathematica so that

$$\text{Model1} = \text{Correlation}[\{5.4,9.8,10.99,11.49,11.76,12.19,12.19,12.19,12.19,11.95\},\ \{5.806,9.298,10.943,11.68,11.997,12.128,12.181,12.203,12.212,12.215\}]$$

It can concluded from the correlation coefficient this is 0.993142 in the Beijing Olympic Games 2008.

Conclusion

In conclusion, we represent the method used by obtaining integration by parts to solve the one-dimensional Newton's second law perturbed from a set of the external force in equation (1). In our calculation, we can obtain the displacement, the velocity, the acceleration, the kinetic energy function of time which correspond with the data of Usain Bolt in the 100 metres sprint at Beijing olympic games 2008. The f_0 / β is the force of ground field act to the runner between force and weight (gravitation force) of the runner that press to the ground field. If the performance parameter β is small the speed endurance of runner (β^{-1}) will be large and the parameter β large the speed endurance of runner will be small.

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