ISSN : 0974 - 7435 Volume 10 Issue 4

BioTechnology
An Indian Journal

FULL PAPER

BTAIJ, 10(4), 2014 [719-724]

Baseball best hitting point model research based on momentum medium theorem

Yong Li
Institute of Physical Education, China West Normal University, Nanchong, Sichuan, (CHINA)

ABSTRACT

Every batter knows that there is a best hitting point in the rough part of baseball bat, when ball hits in such point, it can obtain largest energy. This paper applies dynamics knowledge to make respectively force analysis of hitting process baseball and bat, when it occurs to completely non elastic collision, baseball best hitting point in one end of bat. Research shows baseball best hitting point is between bat one end and far from baseball one end S area. When bat is hollowed out, its mass reduces, elastic variable increases, according to Hooke's law $F = kx$ it can get baseball and bat elastic force increase, by momentum theorem $Ft = m(v_2 - v_1)$, it is clear that baseball escape speed increases. When bats textures are different, utilize control variables methods to carry on simulation experiment, it gets when baseball and aluminum bat collide, elastic coefficient is larger than that when baseball and wood bat collide. Apply return energy and total collision energy percentage formula $W_i = k_i^2 z_i + k_0^2(1 - z_i)$, it gets that aluminum bat rigidity is larger than that of wood bat, therefore use metal bat will reduce major league baseball challenge, so that explain the reason of major league baseball prohibiting using metal bat.

KEYWORDS

Medium theorem;
Dynamics force analysis;
Momentum theorem;
Simulation experiment model.

INTRODUCTION

Every batter knows that there is a best hitting point in the rough part of baseball bat, when ball hits in such point, it can obtain largest energy. Deduce by torque simple principle, best hitting point should be the peak of bat, but from the perspective of experience, it is wrong. Why the best hitting point is not in the end? Construct a model to explain the discovery from experience. Many batters believe a good bat can strengthen best hitting point efficiency, and the so-called best bat is a hollowed out and then filled in rubber or cork, which changes wood bat cap. Explain why major league baseball prohibits using the best bat, whether the material is the one can be used to make bat that meets regulation or not? That is to say, the model prediction is through different responses from bat that is made of wood (generally is ash) or metal (generally is aluminum), explaining major league baseball prohibits using metal bat causes.

For baseball best hitting point research and textures problems, many people have made researches,

FULL PAPER

for example Zhang Tong etc. by establishing bat calculation model, according to dynamical theory, and they made research on bat colliding point problem and finally found out best colliding point and predicted wood and aluminum bat efficiency, which defined wood solid bat used in formal game. Tang Lu-Ming etc. looked for baseball best batting point and bat Motel vibration mode, fixed frequency relations by establishing finite element model, if bat model used elastic material, and boundary conditions were two free ends, finally it conformed to practice, in the following the article discussed increasing "best point" effects by baseball "subordination". At last by experiments, it verified model accuracy and rationality. Jiang Quan etc. made deeply analysis of baseball hitting process, they established simple and effective dynamical model. It obtained result: (1)By calculation, it got different initial ball, bat speed and speed when baseball hitting mutual relations;(2) Wood bat hitting speed was far smaller than that of aluminum bat;(3) Though restitution coefficient had no effects on collision central position and hitting area, it had larger influences on bat hitting speed; Besides, the model analysis process was very simple, it was very easily for coaches and players understanding, therefore the model could directly apply in baseball theoretical guiding aspect.

This paper based on previous researches results, by establishing hitting model, it explains baseball hit from best hitting point, hitting speed is maximum speed. To state best hitting point not in the end, then it should solve when baseball at maximum speed, hitting point position. Analyze baseball and bat contact till baseball and bat separate the whole process. Thereupon, we get best hitting point is not in the one end of bat, in real life, baseball best hitting point is between end and far from end S, gripping position D gets further away from mass center, best hitting point would get closer to mass center. When bat is hollowed out, bat mass and elastic variable would change. Major league baseball prohibits using the bat, baseball speed variable increases and so baseball speed increases. Different materials corresponding properties are different, in the subject, it should mainly consider physical property. Bat and baseball collision is between completely elastic collision and completely non-elastic collision, if it permits of professional players use aluminum bat, it can largely increase home run success rate. Perhaps it will break balance attack and defense in this way, let professional baseball enjoyable greatly reduce, so rules require that professional baseball players only use wood bat.

MODEL ESTABLISHMENT AND SOLUTION

Symbol description

α baseball entry angle	v_1 speed when baseball returns
F external force when hitting baseball	ω bat movement accelerated speed
a_0 along baseball movement direction accelerated speed	v_0 Baseball its own speed when hit
r ball during returning process trajectory circle radius	k_0 Baseball restitution coefficient
W_1 Wood bat after hitting return energy and total collision energy percentage	W_2 Metal bat after hitting return energy and total collision energy percentage
z_1 Wood bat generates deformation and baseball deformation ratio	z_2 Metal bat generates deformation and baseball deformation ratio
J_C Ball to mass center point rotational inertia	l is hands gripping point D to mass center C distance
x is colliding point E to mass center C distance	α is bat revolving angular accelerated speed

FULL PAPER

I is ball to bat impact force

$\delta(t)$ is function

a_c is mass center C point accelerated speed

F is hand to bat acting force when colliding

b is hands gripping point D to best hitting point E distance

J_E is bat to hands gripping point D rotational inertia

k_1 wood bat restitution coefficient

k_2 metal bat restitution coefficient

Prove best hitting point is not in one end of bat

Baseball and bat collision is between completely elastic collision and completely non-collision. Baseball has maximum speed after hitting from best hitting point. Hitting process is as Figure 1 show.

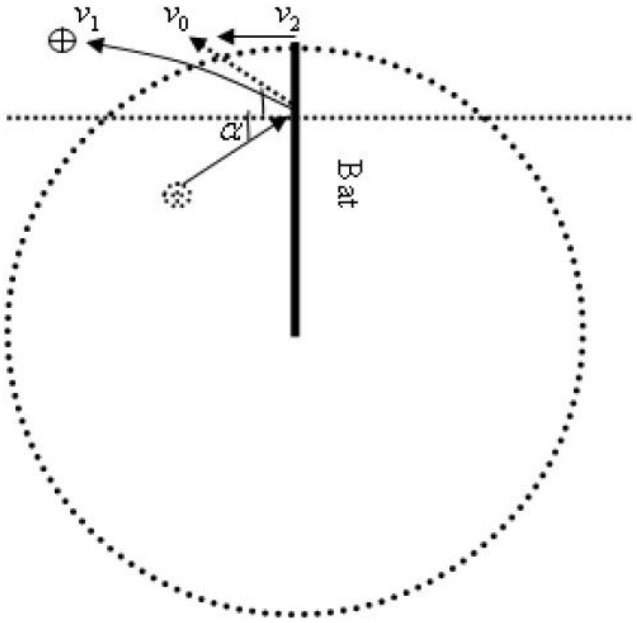

Figure 1: Hitting process figure

If bat and baseball collision is completely non-elastic collision, after bat and baseball colliding, they combine into one entirety that owns common speed. The two have no relative movement. When baseball separates from bat, baseball lies in the top of bat. Therefore, baseball and bat best colliding point is in the one end of bat.

If baseball and bat in completely elastic collision, baseball collides with bat at t entry angle α , no energy loss after colliding.

To define baseball movement trajectory, we make orthogonal decomposition of bat to baseball acting force (along baseball movement direction, vertical to baseball movement direction). As Figure 2 shows.

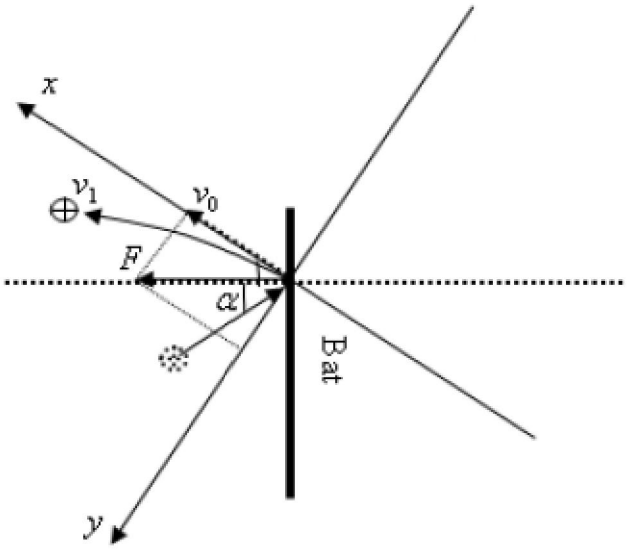

Figure 2 : Make orthogonal decomposition of bat to baseball acting force

Along baseball movement direction:

$$\mathbf{F\cos\alpha = m_0 a_0} \quad \textbf{(1)}$$

Vertical to baseball movement direction:

$$\mathbf{F\sin\alpha = m_0 \frac{v_1^2}{r}} \quad \textbf{(2)}$$

Now, baseball speed is composed of two parts, one part is its own speed, another part is speed generated by bat acting. To define baseball and bat relative position, we make orthogonal decomposition of baseball itself speed (along bat direction, vertical to bat direction). As Figure 3 shows.

Along bat direction:

$$\mathbf{v_0'' = v_1 \sin\alpha} \quad \textbf{(3)}$$

Vertical to bat direction:

$$\mathbf{v_0'' = v_1 \cos\alpha} \quad \textbf{(4)}$$

Above statements show baseball and bat before separating, they exist relative displacement S . When

FULL PAPER

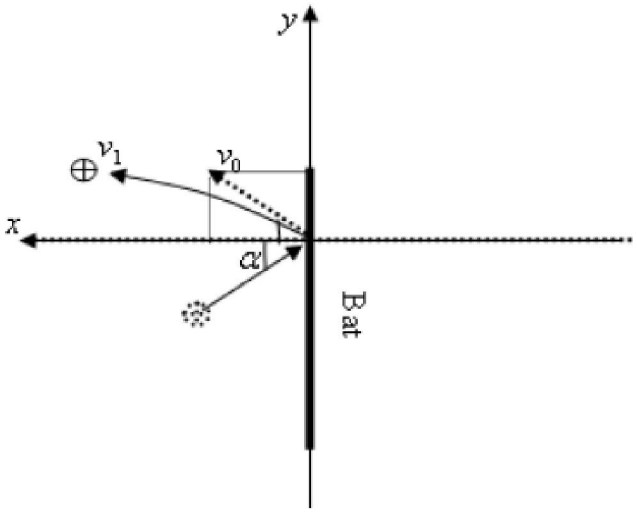

Figure 3 : Baseball itself speed orthogonal decomposition figure

baseball and bat separates, the position lies in one end of bat, so, in this case, baseball and bat best colliding point lies in S area far from endpoint.

Above statements show baseball and bat before separating, they exist relative displacement S . When baseball and bat separates, the position lies in one end of bat, so, in this case, baseball and bat best colliding point lies in S area far from endpoint.

Conclusion: Due to in real life, baseball and bat collision process is between completely elastic collision and completely non-collision, in real life, baseball best hitting point is between endpoint and S far from endpoint.

Define baseball best hitting point

To more simplify problems, set: baseball as rigid even material thin rod, E is colliding point, D is gripping point, and ball collision direction is vertical to bat, as Figure 4.

According to Figure 4 and combine with moment of momentum theorem[4], it has:

$$(J_C + ml^2)\ \alpha = (1+x)\ I\delta(t) \quad (5)$$

$$\alpha = \frac{(1+x)I\delta(t)}{J_C + ml^2} \quad (6)$$

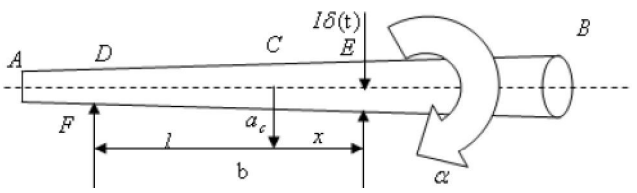

Figure 4: Bat setting model

According to mass center motion law[3]:

$$I\delta(t) - F = ma_c \quad (7)$$

$$I\delta(t) - F = \frac{m(1+x)I\delta(t)l}{J_C + ml^2} \quad (8)$$

$$F = I(\delta)t - \frac{m(1+x)I\delta(t)l}{J_C + ml^2} = \frac{J_C - mxl}{J_C + ml^2} I(\delta)t \quad (9)$$

In formula(9): When F=0, it is the best colliding position, when colliding, hands to bat acting force is minimum as 0, at this time, hands will not feel impulse force. When F=0, by formula (9), it gets:

$$x = \frac{J_C}{ml} \quad (10)$$

$$b = l + x = \frac{J_D}{ml} \quad (11)$$

According to relative theory, it gets:

$$J_D = J_C + ml^2 \quad (12)$$

So it meets formula(12)point E is colliding point central position[6], E is best colliding point. Because baseball surface is rotative surface, space as circle is best colliding point. From formula (11), it is clear that when x gets smaller, l will get bigger, so when gets closer to A point, hands gripping position D distance gets further away from mass center, best hitting point will get closer to mass center.

Explain major league baseball all prohibit "corking"

After bat is hollowed out (or fill with rubber or cork), bat mass reduces, elastic variable increases. (As Figure 5 show) according to Hooke's law:

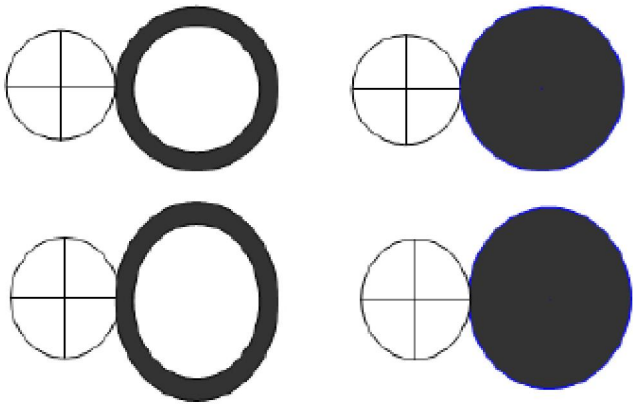

Figure 5 : After hollowing out hitting process deformation degree, without hollowing out bat hitting process deformation degree

$$\mathbf{F = kx} \quad (13)$$

When elastic variable gets bigger, bat and baseball elastic force increases. Meanwhile, bat and baseball contact time increases. According to momentum theorem:

$$\mathbf{Ft = m(v_2 - v_1)} \quad (14)$$

It is clear baseball speed variable increases, so baseball speed increases.

Major league baseball prohibits using metal bat causes

After baseball bat textures change, bat mass, elastic coefficient all would change. Different textures generated collision responses are different, to get the conclusion, we make collision experiment (As Figure 6 show).

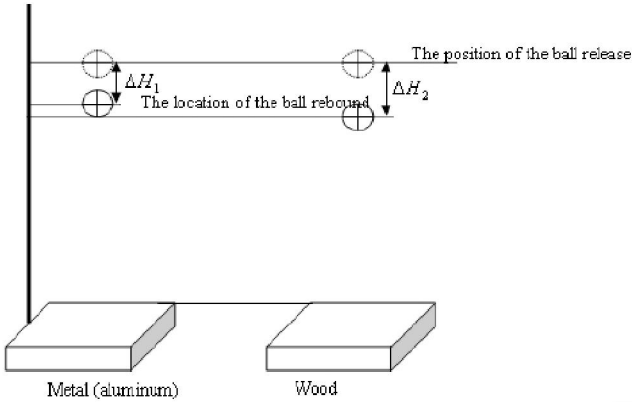

Figure 6 : Different textures collision reaction experiment schematic figure

This experiment is to different textures colliding baseballs possessed elastic potential energy. Put same size wood block and metal block in the same horizontal plane, release same baseball from same height at zero initial speed. According $mg\Delta H = E_D$

Compare two balls bounce heights, if wood block colliding and bouncing baseball height is higher that metal block colliding and bouncing baseball one, then it shows baseball and wood elastic potential energy is larger than baseball and metal elastic potential energy. On the contrary, it indicates that metal contacted elastic potential energy is larger.

Conclusion: By experiment comparing, it can get metal elastic potential energy is larger. Due to metal bat mass is light, when athletes use same size force swing bat, bat possesses speed is larger. While due to metal bat elastic potential energy is larger, speed that baseball leaves bat will get larger. Therefore, use metal bat has less difficulty than using wood bat, it will reduce game challenge and enjoyable.

For bat rigidity, wood bat and higher speed bat restitution coefficient is nearly the same, it records as k_1, and aluminum bat restitution coefficient is recorded as k_2. In collision process, wood bat generated deformation and baseball deformation ratio is recorded as z_1. Aluminum bat generated deformation and baseball deformation ratio is recorded as z_2. Thereupon, it can calculate after hitting return energy and total collision energy percentage, formula is as following:

$$W_1 = k_1^2 z_1 + k_0^2(1 - z_1)$$

$$W_2 = k_2^2 z_2 + k_0^2(1 - z_2)$$

By consulting relative documents[1], $k_1 = k_0 = 0.45$, $k_2 = 0.9$, $z_1 = 2\%$, $z_2 = 10\%$, input above formula, it gets $W_1 = 20\%$, $W_2 = 26\%$. Therefore, in case other conditions not change, ball hit by aluminum bat, its initial speed is larger. Therefore, ball hit by it will be further; we have reasons to believe that if permit professional players to use aluminum bat, it can largely increase home run success rate. Perhaps it will break balance attack and defense in this way, let professional baseball enjoyable greatly reduce, so rules require that professional baseball players only use wood bat.

CONCLUSIONS

The model reasonable illustrates baseball best hitting point is not in one end of bat, meanwhile it explains different textures bats effect on hitting baseball, we verifies wood bat is more suitable to game by simulation experiment model. In the process, we still have shortcomings, ignoring air resistance influences, but the problem hasn't generated more influences on conclusions. The model obtained conclusions can be applied into China baseball players' training process, which plays positive roles in improving our country baseball players' performance. The subject involved model can also apply into table tennis, badminton and other ball type sports best hitting point problem by revising relative coefficients.

REFERENCES

[1] Zhang Tong, Jia Zhi-Xi, Wang Zan-Peng, Jiang Zhi-Bin; Study on best shot point of baseball bat and material selection[J]. Journal of University of Science and Technology Liaoning, **34(2)**, 163-167 **(2011)**.

[2] Tang Luming Shui Xiaoping Shen Zhenxing; Dynamics of baseball bat[J]. Mechanics and Engineering, **33(5)**, 57-60 **(2011)**.

[3] Jiang Quan, Xu Wei, Gong Jiang Yong, Dai Hai Feng, Tang Wei; Dynamic analysis on impacting during baseball batting[J]. Journal of Medical Biomechanics, **25(5)**, 375-379 **(2010)**.

[4] Sun Boqing et al; The Determination of the Batting Pionts and Distances[J]. Journal of Xi'an Institute of Physical Education, **2**, 57-60 **(1994)**.

[5] Jiang Quan, Xu Wei, Gong Jiang Yong, Dai Hai Feng, Tang Wei; Dynamic analysis on impacting during baseball batting[J]. Journal of Medical Biomechanics, **25(5)**, 375-379 **(2010)**.

[6] Wang Fusheng, Liang Roughai, Zhou Zaiming, Fu Zhong; Study on the preparation technique of tungsten alloy balls[J]. Journal of Central South University:Science and Technology, **6**, **(1996)**.

[7] Ren Xiping; A study of mechanical mechanism in tennis serve effect[J]. Journal of Zhejiang Normal University Natural Sciences, **35(2)**, 226-230 **(2012)**.

[8] Ai Zhen-Guo; Study on characteristics of inference ability of chinese outstanding baseball athletes[J]. Journal of Daqing Normal University, **29(6)**, 121-123 **(2009)**.