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Shimojo, Masataka
Faculty of Agriculture, Kyushu University

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Introducing Viewpoints of Mechanics into Basic Growth Analysis – (II) Relative Growth Rate compared with Energy in Wave Function –

Masataka SHIMOJO*

Laboratory of Animal Feed Science, Division of Animal Science, Department of Animal and Marine Bioresource Sciences, Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan

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The present study was conducted to investigate the relative growth rate (RGR) by introducing, into basic growth analysis, the growth jerk that is the derivative of growth acceleration. Relating weight (W), absolute growth rate (AGR), growth acceleration (GA) and growth jerk (GJ) showed that $(\mathrm{GA})^2$ was described using the product of AGR and GJ. GA was obtained by extracting the square root of AGR·GJ, taking both positive (+) and negative (–) values. There was a case where ± sign was given locally to $(\mathrm{RGR})^2$, namely $\pm(\mathrm{RGR})^2$. However, $-\mathrm{RGR}^2$ was contradictory to the principle of differential. In order to resolve this contradiction there was a requirement of complex numbers, $\exp((\pm \boldsymbol{i}\ \mathrm{RGR})\cdot t)$ that was a kind of wave function. This resolved the contradiction by $(\pm \boldsymbol{i}\ \mathrm{RGR})^2 = -\mathrm{RGR}^2$. Comparing $\exp((\pm \boldsymbol{i}\ \mathrm{RGR})\cdot \mathrm{t})$ with the wave function for quantum mechanics showed that there was a lack of wave in space for $\exp((\pm \boldsymbol{i}\ \mathrm{RGR})\cdot t)$. However, there might be a resemblance between RGR in $\exp((\pm \boldsymbol{i}\ \mathrm{RGR})\cdot t)$ and energy in the wave function for quantum mechanics. In conclusion, RGR might look like the energy related to weight changes when placed in the wave function, though there was a logical leap in this procedure.

INTRODUCTION

In the preceding paper (Shimojo *et al.*, 2006) in the same issue, we investigated three aspects of growth mechanics in comparison with Newton's three laws of motion (Kawabe, 2006), using relationships between weight, absolute growth rate and growth acceleration in basic growth analysis. There is a concept of jerk that is the rate of change of acceleration (Jerk, 2006) in mechanics, the derivative of acceleration with respect to time. The use of jerk in basic growth analysis is supported by the existence of an infinite number of derivatives in exponential function with base e.

The present study was designed to investigate growth mechanics by introducing growth jerk into basic growth analysis.

RELATIVE GROWTH RATE COMPARED WITH ENERGY IN WAVE FUNCTION

Weight, relative growth rate, absolute growth rate, growth acceleration and growth jerk in basic growth analysis

In basic growth analysis of an animal or a plant, relative growth rate (RGR) is given by

$$\frac{1}{W}\frac{dW}{dt} = \mathrm{RGR}, \tag{1}$$

where W = weight, t = time.
Equation (1), by its indefinite integral and determination of integration constant, leads to

$$W = W_0 \cdot \exp(\mathrm{RGR} \cdot t), \tag{2}$$

where W_0, = the weight at $t = 0$.

Absolute growth rate (AGR) is given by the derivative of W,

$$\mathrm{AGR} = \frac{dW}{dt} = W_0 \cdot \mathrm{RGR} \cdot \exp(\mathrm{RGR} \cdot t). \tag{3}$$

Growth acceleration (GA) is given by the derivative of AGR,

$$\mathrm{GA} = \frac{d(\mathrm{AGR})}{dt} = W_0 \cdot (\mathrm{RGR})^2 \cdot \exp(\mathrm{RGR} \cdot t). \tag{4}$$

Growth Jerk (GJ) is given by the derivative of GA,

$$\mathrm{GJ} = \frac{d(\mathrm{GA})}{dt} = W_0 \cdot (\mathrm{RGR})^3 \cdot \exp(\mathrm{RGR} \cdot t). \tag{5}$$

Relationships between *W*, AGR, GA and GJ

Equations (2), (3), (4) and (5) are related as follows,

$$\frac{\mathrm{AGR}}{W} = \frac{\mathrm{GA}}{\mathrm{AGR}} = \frac{\mathrm{GJ}}{\mathrm{GA}} = \mathrm{RGR}. \tag{6}$$

RGR is a key to relating terms in equation (6), as shown by Shimojo *et al.* (2002, 2006) who reported the importance of RGR in basic growth analysis. The next section will deal with another aspect derived from equation (6), as compared with the preceding report (Shimojo *et al.*, 2006).

Aspect derived from equation (6)

The aspect that is derived from equation (6) is given by

* Corresponding author (E–mail: mshimojo@agr.kyushu–u.ac.jp)

$$(\mathrm{GA})^2 = \mathrm{AGR} \cdot \mathrm{GJ}. \tag{7}$$

Then, GA is obtained by extracting the square root of AGR・GJ, taking both positive and negative values from the mathematical point of view. Thus,

$$\begin{aligned}\mathrm{GA} &= \pm\sqrt{\mathrm{AGR} \cdot \mathrm{GJ}} \\ &= \pm\sqrt{(W_0 \cdot (\mathrm{RGR}) \cdot \exp(\mathrm{RGR} \cdot t)) \cdot (W_0 \cdot (\mathrm{RGR})^3 \cdot \exp(\mathrm{RGR} \cdot t))} \\ &= \pm\sqrt{(W_0)^2 \cdot (\mathrm{RGR})^4 \cdot (\exp(\mathrm{RGR} \cdot t))^2} \\ &= \pm(W_0) \cdot (\mathrm{RGR})^2 \cdot \exp(\mathrm{RGR} \cdot t),\end{aligned} \tag{8}$$

where ± sign is given to the right–hand side globally.

As shown by Shimojo *et al.* (2006), there will occur mathematical contradictions if globally giving is changed into locally giving where ± sign is given to one of the three terms. However, resolving these contradictions might be expected to derive new aspects from growth mechanics.

Locally giving ± sign to the right–hand side of equation (8)

There are two cases according to the preceding report (Shimojo *et al.*, 2006).

(A) Giving ± sign to W_0 or to exp(RGR・t)

This is given by

$$\mathrm{GA} = (\pm W_0) \cdot (\mathrm{RGR})^2 \cdot \exp(\mathrm{RGR} \cdot t), \tag{9}$$

or

$$\mathrm{GA} = (W_0) \cdot (\mathrm{RGR})^2 \cdot (\pm\exp(\mathrm{RGR} \cdot t)). \tag{10}$$

Equations (9) and (10) show the same phenomenon, because W_0 and exp(RGR・t) are related by the product form as shown in equation (2) that describes W. Therefore, equation (9) only is taken up.

However, equation (9) is contradictory to equation (2) because of including $-W_0$. Resolving this contradiction requires a modification of equation (2) as follows,

$$W = (\pm W_0) \cdot \exp(\mathrm{RGR} \cdot t). \tag{11}$$

This modification has already been shown in the preceding report (Shimojo *et al.*, 2006).

(B) Giving ± sign to $(\mathrm{RGR})^2$

This is given by

$$\mathrm{GA} = (W_0) \cdot (\pm(\mathrm{RGR})^2) \cdot \exp(\mathrm{RGR} \cdot t). \tag{12}$$

There occurs a problem for $-\mathrm{RGR}^2$, because this is contradictory to the principle of differential and RGR square always takes positive values in growth function. There is no problem in the case of $+\mathrm{RGR}^2$.

However, if $-\mathrm{RGR}^2$ is accepted, then we have to take up complex numbers. Therefore, equation (2) for W is replaced by

$$W = (W_0) \cdot \exp((\pm \boldsymbol{i}\ \mathrm{RGR}) \cdot t), \tag{13}$$

where $\boldsymbol{i}$ = imaginary unit.

The second derivative of equation (13) gives

$$\begin{aligned}\frac{d^2W}{dt^2} &= \mathrm{GA} \\ &= (-\mathrm{RGR}^2) \cdot W_0 \cdot \exp((\pm \boldsymbol{i}\ \mathrm{RGR}) \cdot t).\end{aligned} \tag{14}$$

Equations (13) and (14) may resolve the contradiction that is caused by $-\mathrm{RGR}^2$ in equation (12), though there is a gap in the process of resolution.

What is derived from equation (13)

Equation (13) belongs to the world of complex numbers, a leap from the world of real numbers. Equation (13), which is transformed into

$$\begin{aligned}W &= (W_0) \cdot \exp((\pm \boldsymbol{i}\ \mathrm{RGR}) \cdot t) \\ &= W_0 (\cos(\mathrm{RGR} \cdot t) \pm \boldsymbol{i} \sin(\mathrm{RGR} \cdot t)).\end{aligned} \tag{15}$$

has a characteristic of wave.

Therefore, I would like to take up the following equation that is known as wave function for quantum mechanics, as shown, for example, by French and Taylor (1978). Thus,

$$\Psi = A \cdot \exp\left(\boldsymbol{i} \frac{p}{\hbar} x - \boldsymbol{i} \frac{E}{\hbar} t\right), \tag{16}$$

where Ψ = wave function, $\boldsymbol{i}$ = imaginary unit, $\hbar = h/2\pi$ (h: Planck's constant, π: circular constant), p = momentum, E = energy.

Equation (13) might show a resemblance to equation (16).

Then, I would like to compare equation (13) with the following equation (17) that is obtained by transforming equation (16). Thus,

$$W = W_0 \cdot \exp((\pm \boldsymbol{i}\ \mathrm{RGR}) \cdot t), \tag{13}$$

$$\Psi = A \cdot \exp\left(\boldsymbol{i} \frac{p}{\hbar} x\right) \cdot \exp\left(-\boldsymbol{i} \frac{E}{\hbar} t\right). \tag{17}$$

When compared with equation (17), there is a lack of term related to wave in space in equation (13).

However, in the right–hand side of both equations, the second term in equation (13) will be compared with the third term in equation (17). Thus,

$$\exp((\pm \boldsymbol{i}\ \mathrm{RGR}) \cdot t), \tag{18}$$

$$\exp\left(-\boldsymbol{i} \frac{E}{\hbar} t\right). \tag{19}$$

There might be a resemblance between equations (18) and (19), a comparison between RGR and $E/\hbar$. E is, which is placed in the wave function (19), the energy that a particle has. Roughly speaking at the risk of making a logical leap, RGR might look like the energy related to weight changes when placed in the wave function (18).

Conclusions

Introducing growth jerk into basic growth analysis gives a wave function in which RGR is placed. RGR might look like the energy related to weight changes when compared with the energy in the wave function for quantum mechanics.

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