辽宁工程技术大学
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# ENERGY CONVERSION AND TRANSFER IN BLOCK ROCK MEDIA IN THE PROPAGATION PROCESS OF DYNAMIC STRESS

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2019.6.23

# Report Outline

Ⅰ、Research background

Ⅱ、Analysis of energy propagation in block rock mass

Ⅲ、Conclusion

# Ⅰ、Research background

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(4)

Fig. 1 Rock burst in coal mine

# Ⅰ、Research background

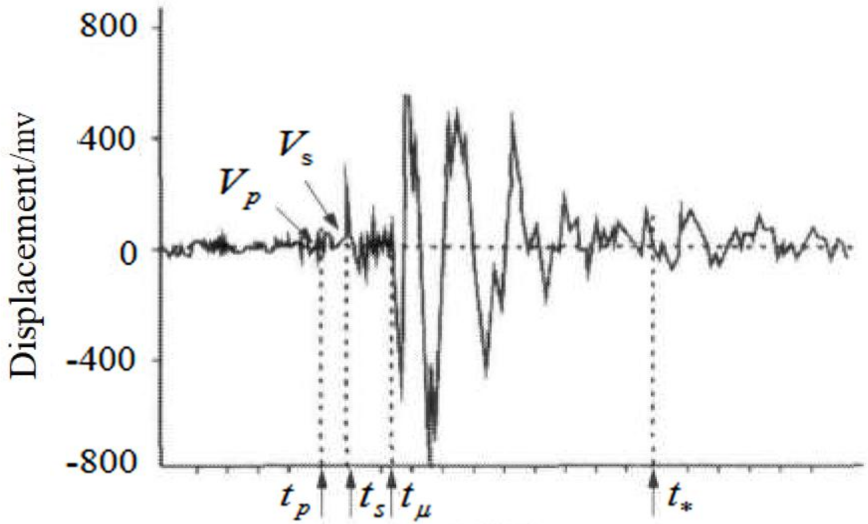


Fig.2 Waveform in deep underground explosion(Kurlenya M.V.)

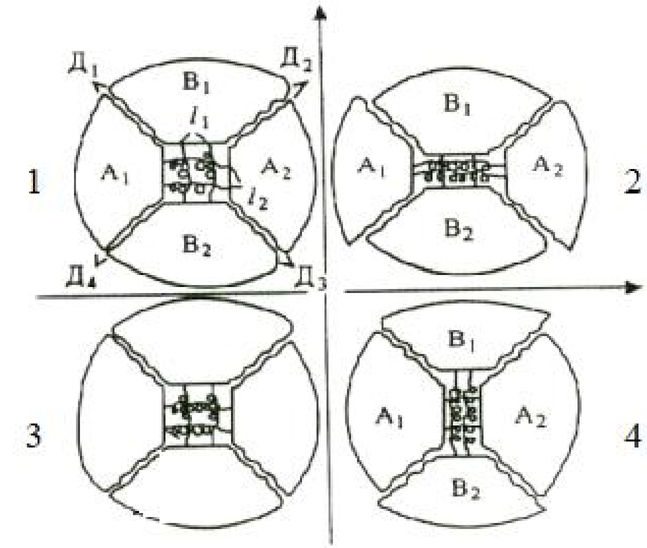


Fig. 3 Model of block rock mass compression(Oparin V.N.)

# Ⅱ、Analysis of energy propagation in block rock mass

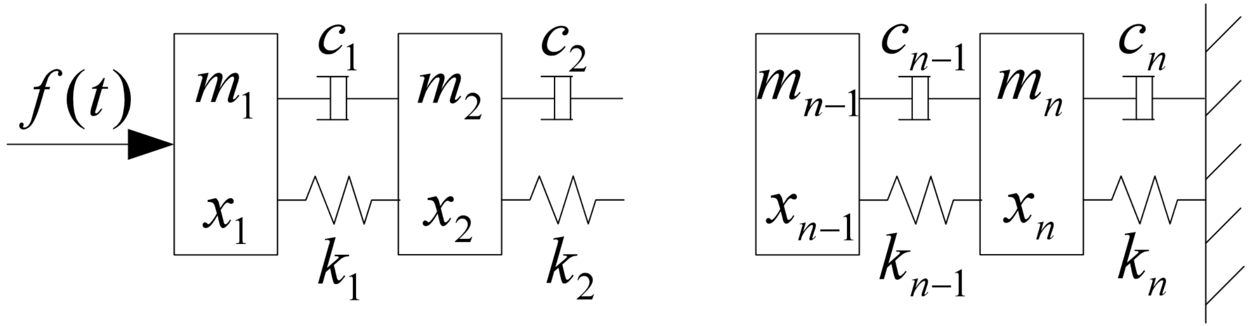


Fig.4 One-dimensional model of block rock mass on dynamic stress

$$M \times \ddot{x}(t) + C \times \dot{x}(t) + K \times x(t) = F(t)$$

Where, $M = diag[m_1, m_2, \cdots, m_n]$ $\quad x = [x_1, \cdots, x_n]^T$ $\quad F(t) = [f(t), 0, \cdots, 0]$

$$C = \begin{bmatrix} c_1 & -c_1 & & & & \\ -c_1 & (c_1+c_2) & -c_2 & & & \\ & \ddots & \ddots & \ddots & & \\ & & -c_{i-1} & (c_{i-1}+c_i) & -c_i & \\ & & & \ddots & \ddots & \ddots \\ & & & & -c_{n-1} & (c_{n-1}+c_n) \end{bmatrix}$$

$$K = \begin{bmatrix} k_1 & -k_1 & & & & \\ -k_1 & (k_1+k_2) & -k_2 & & & \\ & \ddots & \ddots & \ddots & & \\ & & -k_{i-1} & (k_{i-1}+k_i) & -k_i & \\ & & & \ddots & \ddots & \ddots \\ & & & & -k_{n-1} & (k_{n-1}+k_n) \end{bmatrix}$$

# Ⅱ、Analysis of energy propagation in block rock mass

$$y(t)=\left[x_1(t),\cdots,x_n,\dot{x}(t),\cdots,\dot{x}_n(t)\right]^T=\Phi d q_0$$ [1]

[1] Wang K.X.,Pan Y.S.,Dou L.M.Energy transfer in block-rock mass during propagation of pendulum-type waves[J]Chinese Journal of Geotechnical Engineering,2016,38(12):2309-2314.

where, matrix $\Phi$ comprised of eigenvector $\varphi_i$ ($i=1,\cdots,2n$) of $B^{-1}A\varphi=\varphi/\lambda$. $d=diag(e^{\lambda_1 t},e^{\lambda_2 t}\cdots,e^{\lambda_{2n} t})$

and $\lambda_i$ is eigenvalue corresponding with generalized eigenvector $\varphi_i$, $q_0=a^{-1}\Phi^T Ay(0)$ and,

$a=\Phi^T A\Phi=diag(a_1,a_2,\cdots,a_{2n})$, $y(0)$ is initial conditionon on transient impact $f(t)$: $x_i(0)=0$,

$i=1\cdots n$, $\dot{x}_1(0)=v$, $\dot{x}_i(0)=0$, $i=2\cdots,n$.

Kinetic energy of each block

$$E_i(t)=\frac{1}{2}m_i\dot{x}_i^2(t)$$

Kinetic energy of the block system

$$T=\frac{1}{2}\sum_{i=1}^{n}m_i[\sum_{r=1}^{n}(\lambda_r\varphi_{ir}e^{\lambda_r t}+\overline{\lambda}_r\overline{\varphi}_{ir}e^{\overline{\lambda}_r t})]^2$$

# Ⅱ、Analysis of energy propagation in block rock mass

Potential energy of weaker medium in block partings

$$U_i(t) = \int_0^{\Delta x_i} f_i(t) d(\Delta x_i) = \frac{1}{2} k_i \cdot \Delta x_i^2$$

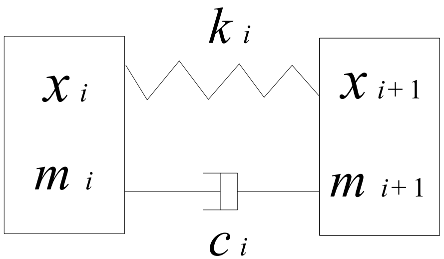


Fig.5 Model of adjacent block rock

Potential energy of block system

$$U = \frac{1}{2} \sum_{i=1}^{n-1} k_i [\sum_{r=1}^{n} (\varphi_{ir} e^{\lambda_r t} + \overline{\varphi}_{ir} e^{\overline{\lambda}_r t}) - \sum_{r=1}^{n} (\varphi_{i+1,r} e^{\lambda_r t} + \overline{\varphi}_{i+1,r} e^{\overline{\lambda}_r t})]^2$$

All the energy of the block rock system

$$W(t) = T + U$$

# Ⅱ、Analysis of energy propagation in block rock mass

## Numerical Example

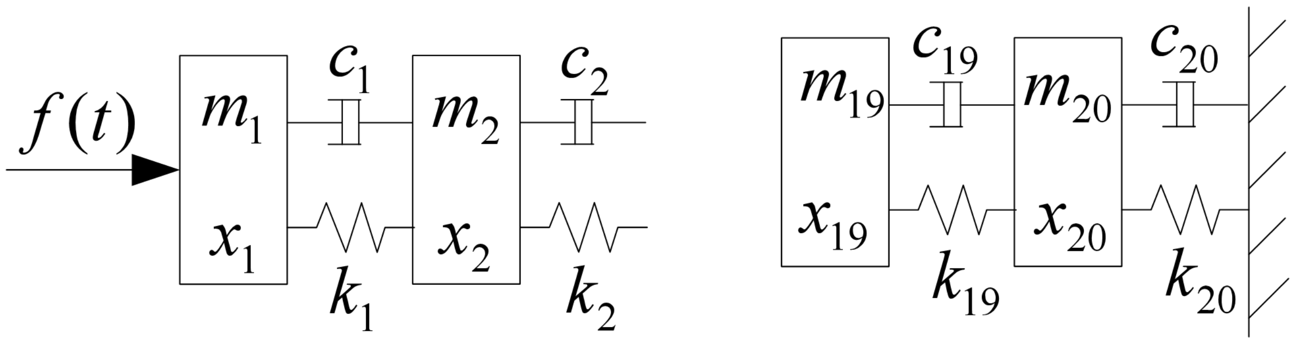


Fig.6 Block rock mass which composed by 20 blocks

Calculation parameters: $c_i = 35kg/s$ , $k_i = 6\times10^5 kg/s^2$ , $m_i = 10kg$ , $i = 1,\cdots,20$ .Initial impact energy 500J,therefore $\dot{x}_1(0) = 10m/s$ .

# Ⅱ、Analysis of energy propagation in block rock mass

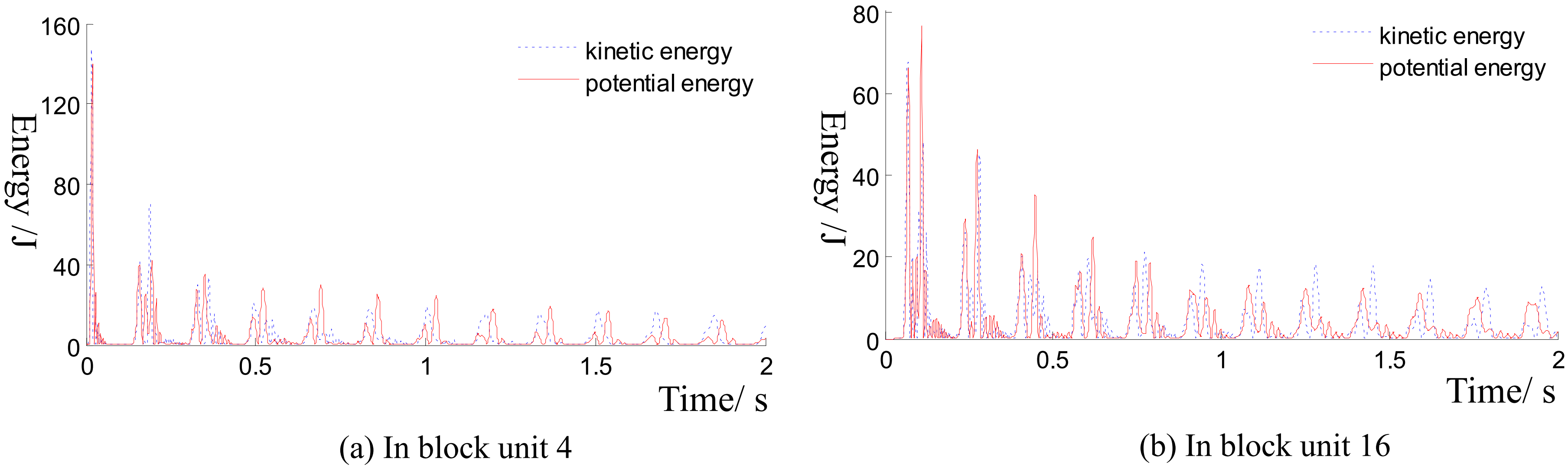


Fig.7 Kinetic energy and potential energy in block unit 4 and unit 16

# Ⅱ、Analysis of energy propagation in block rock mass

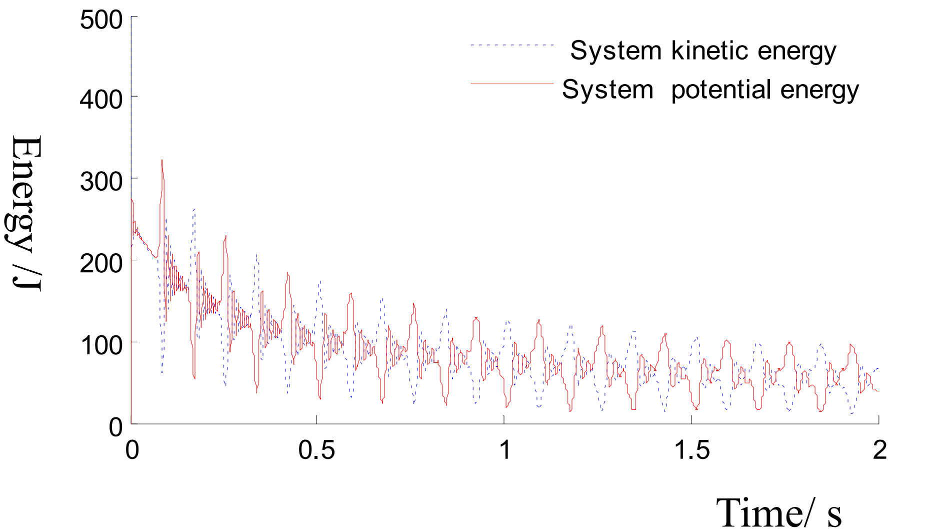


Fig.8 System kinetic energy and potential energy

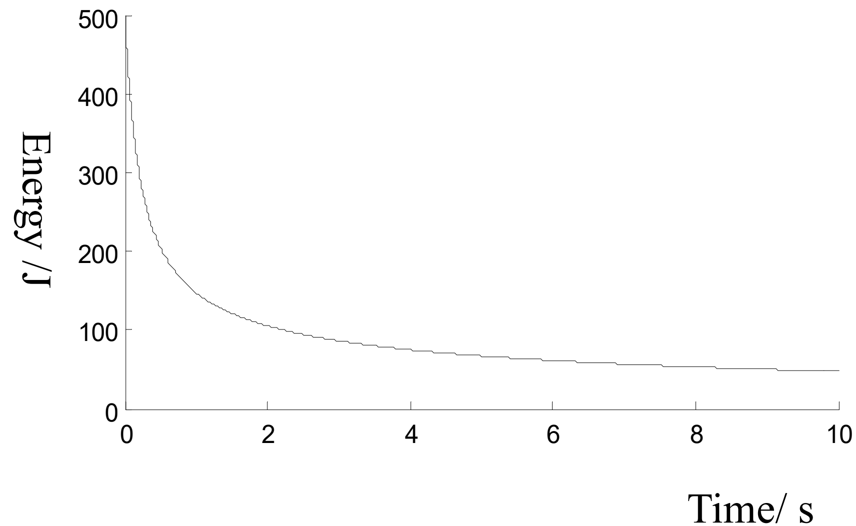


Fig.9 System energy dissipation

# Ⅱ、Analysis of energy propagation in block rock mass

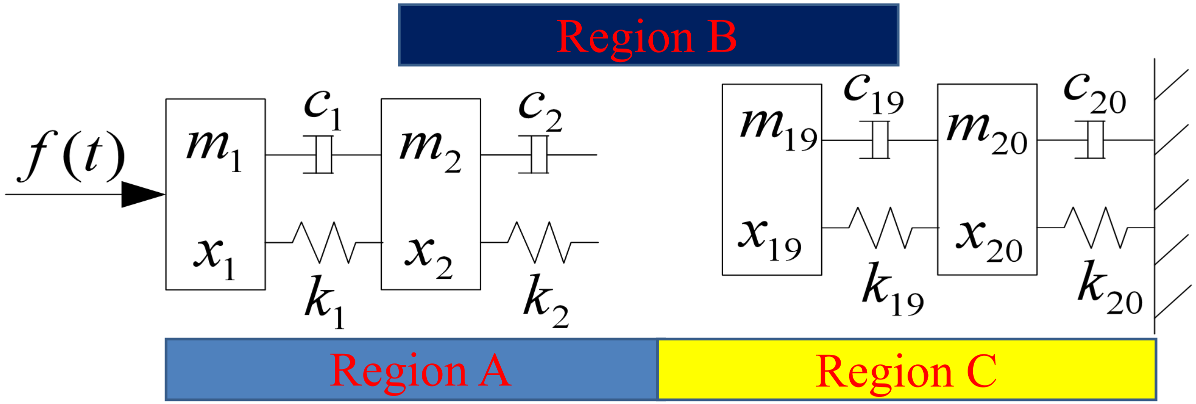


Fig.10 Region division of block rock mass

Region A is the first half of the block medium which composed by block $m_i$ ($i = 1 \cdots, 10$) and partings.

Region B is the intermediate of the block medium which composed by block $m_i$ ($i = 6 \cdots, 15$) and partings.

Region C is the second half of the block medium which composed by block $m_i$ ($i = 11 \cdots, 20$) and partings.

# Ⅱ、Analysis of energy propagation in block rock mass

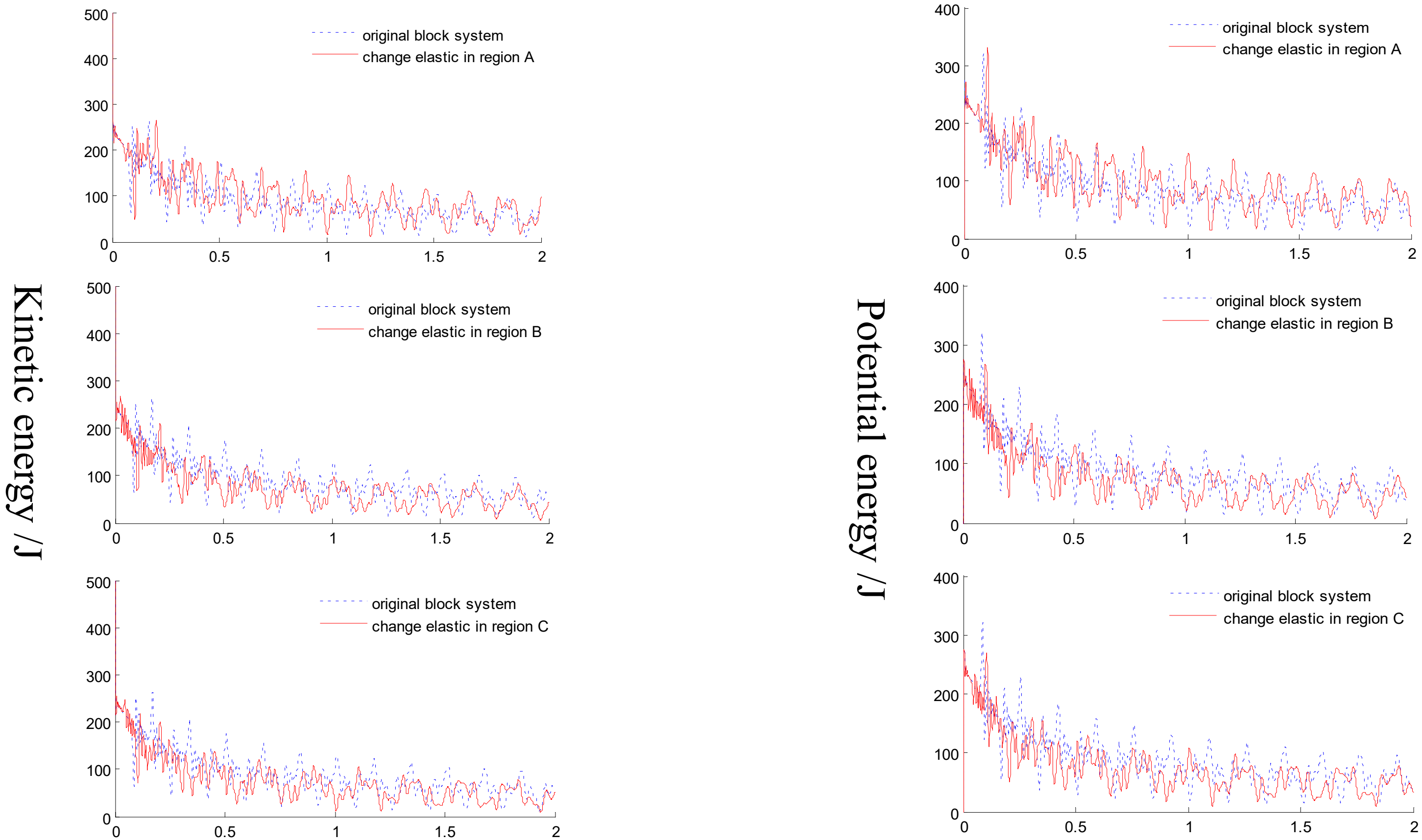


Fig. 11 Energy variation on elastic coefficients reduced to half value ($k_i$=3105 kg/s$^2$) in different regions

# Ⅱ、Analysis of energy propagation in block rock mass

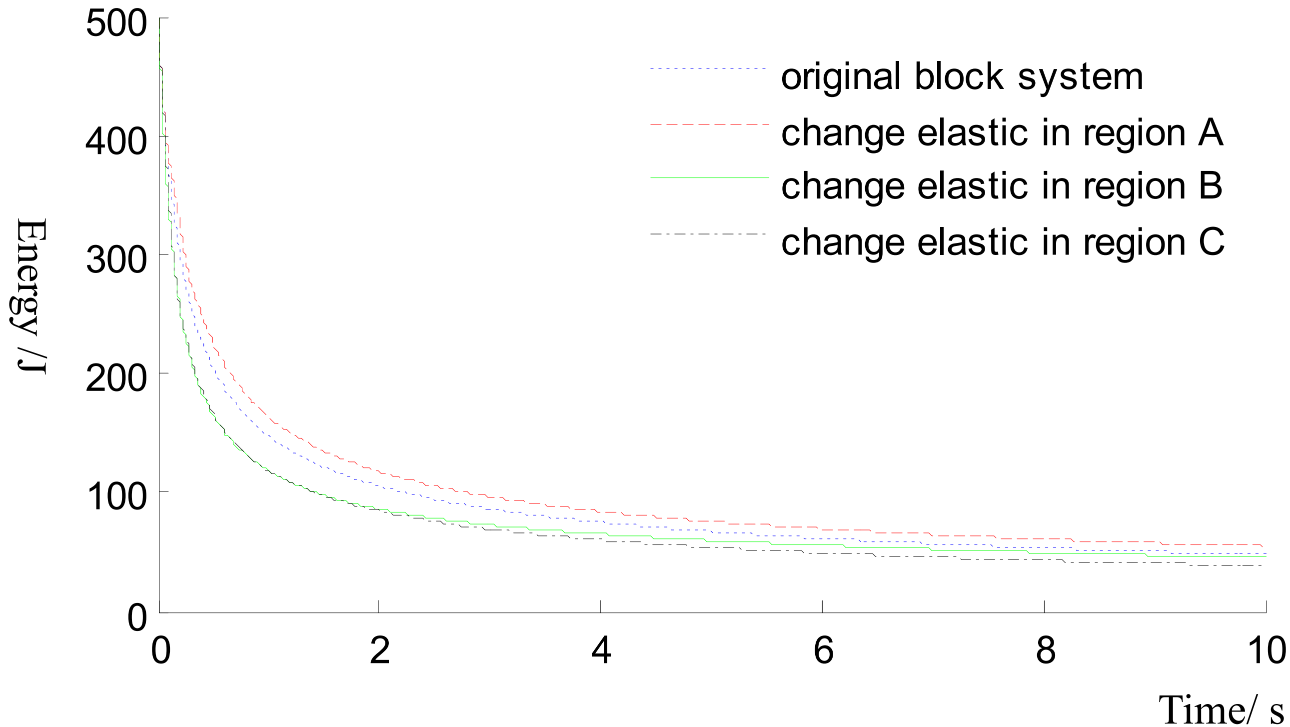


Fig. 12 Block rock medium system energy dissipation

# Ⅱ、Analysis of energy propagation in block rock mass

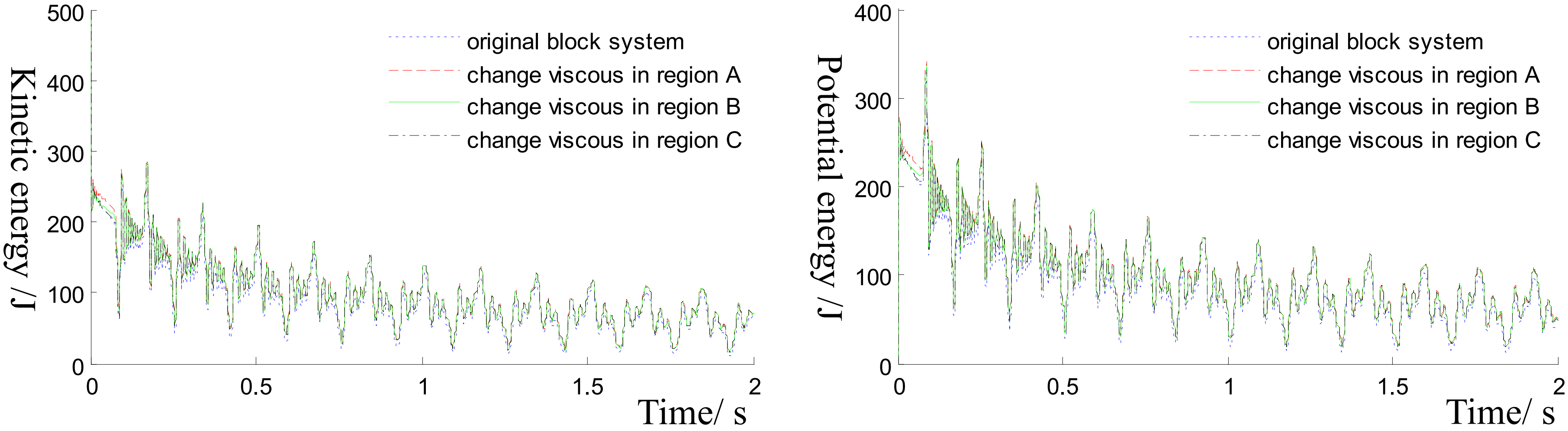


Fig. 13 Energy variation on viscous coefficients reduced to half value ($c_i$=17.5kg/s) in different regions

# Ⅱ、Analysis of energy propagation in block rock mass

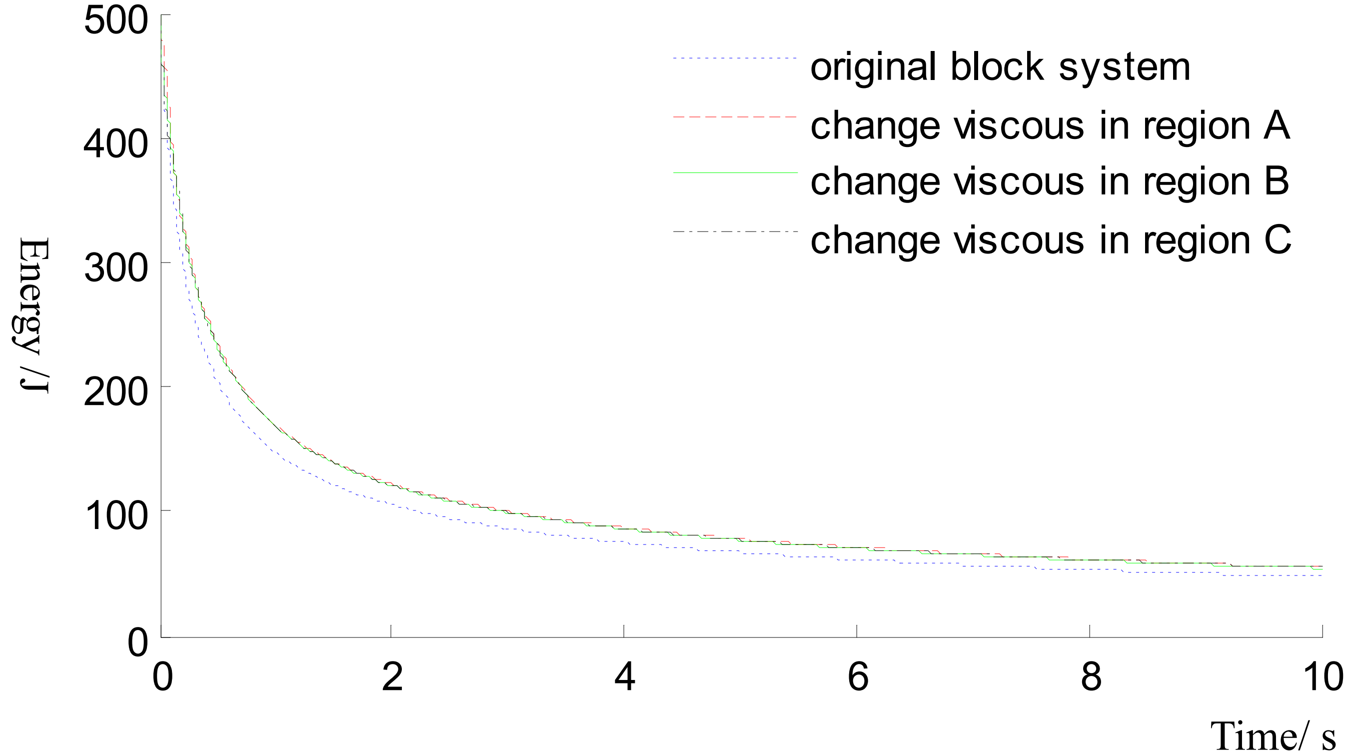


Fig. 14 Block rock medium system energy dissipation

# Ⅱ、Analysis of energy propagation in block rock mass

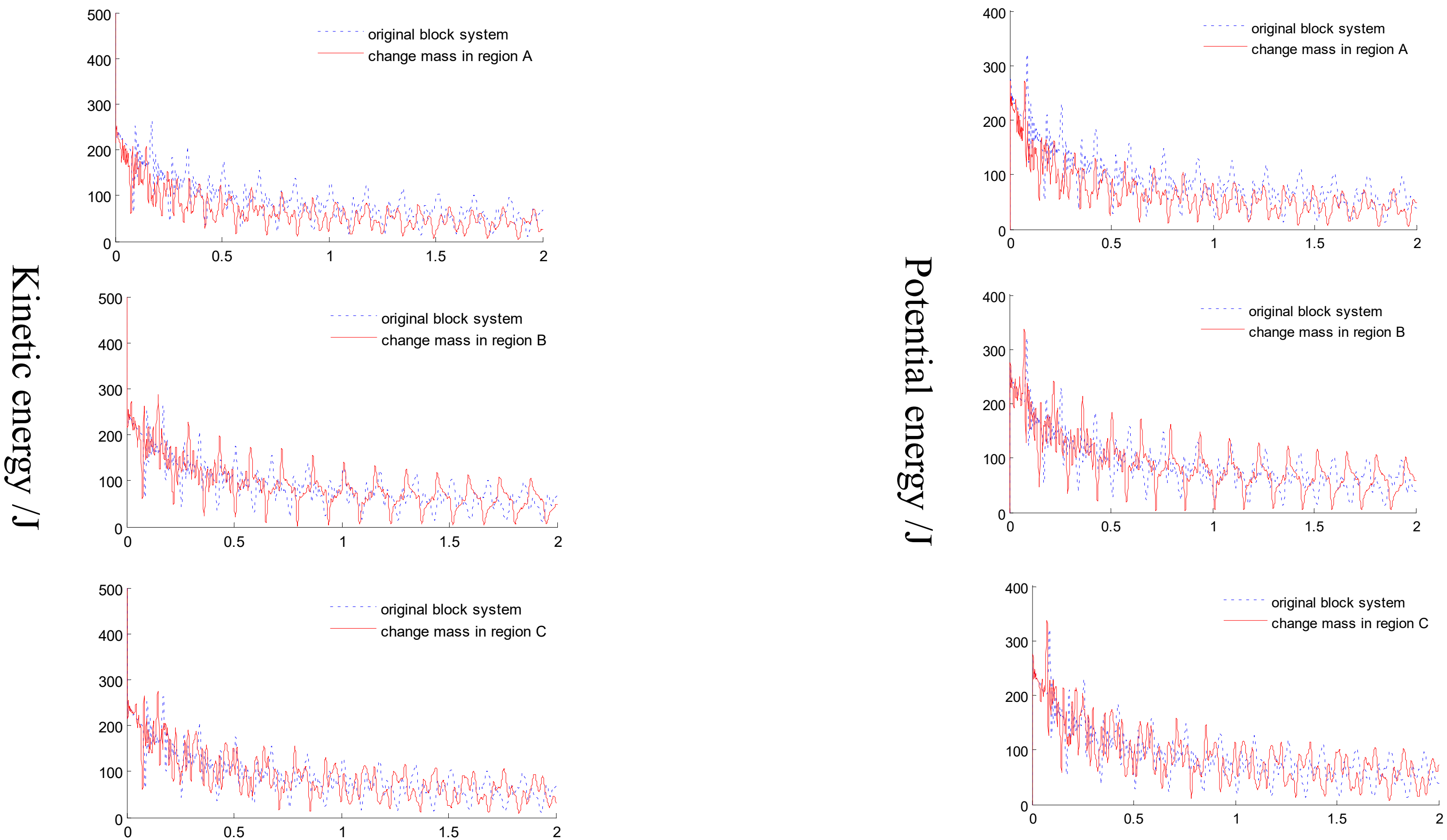


Fig. 15 Energy variation on mass of block reduced to half value ($m_i$=5kg) in different regions

# Ⅱ、Analysis of energy propagation in block rock mass

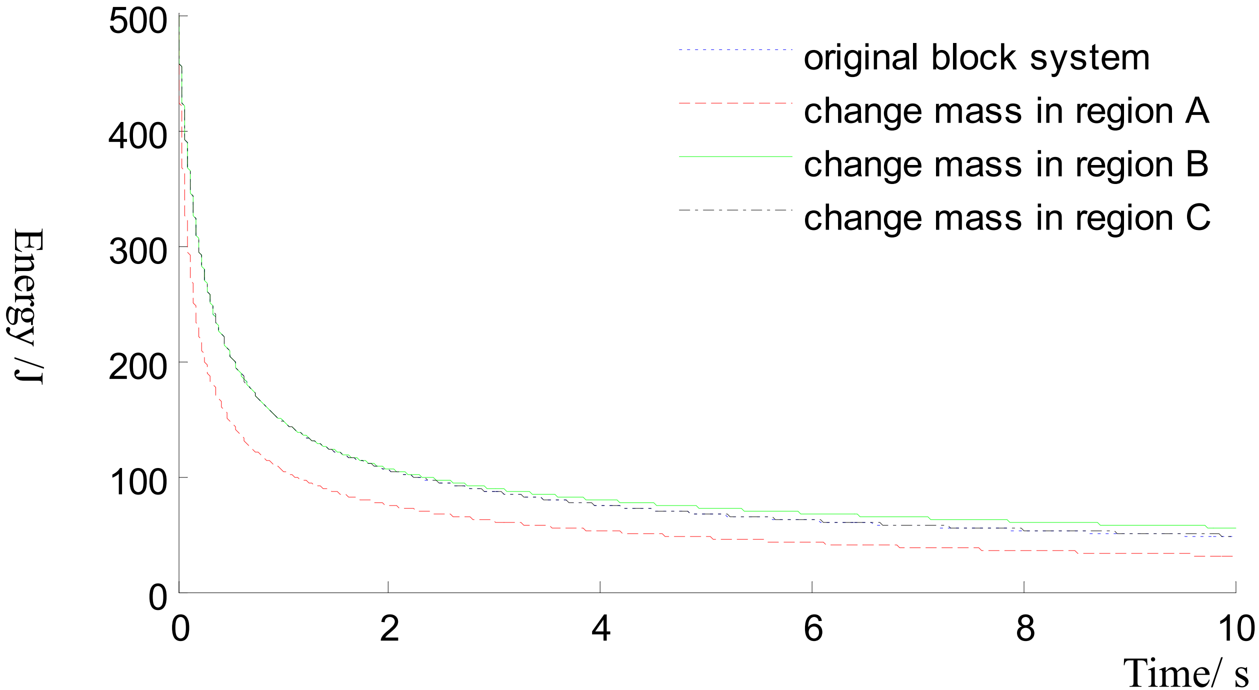


Fig. 16 Block rock medium system energy dissipation

# Ⅲ Conclusion

- Kinetic energy and potential energy are coexist in block medium and conversion to each other.

- Energy dissipation of block rock system depends on parameters variation regions.When dissipation is rapidly it occurrence in elastic decreased in the second half region and mass of blocks decreased in the first half region.But,viscous variation in different regions have no obvious difference to energy dissipation.

# Thanks For Attention

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