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Research Article

Design on Buffer Structure of Traction Running with a Constant Speed

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Abstract: This study mainly aims to study buffer structure design on the traction transport system when the traction transport boundary conditions are given. With such conditions as the maximum impact force, traction speed, maximum speed of alluvium, the elasticity coefficient and the mass of buffer structure, a mathematical model was established and the solution of differential equations was solved. At last, a program was compiled with MATLAB language. With this program the elasticity coefficient and the maximum impact force which meet the requirements in impact process can be solved as long as the boundary conditions are input. This provides a quick design basis of buffer structure for most mechanical engineers.

Keywords: Elasticity coefficient, mathematical model, MATLAB, program design

INTRODUCTION

Impact phenomenon is being everywhere in real life and causes lots of trouble and danger to the people's normal life. In order to decrease the damage from impact, buffer structures are usually used to reduce impact. There are a lot of researches about the buffer structures. Many of them used in the electronic testing system can improve the system stability (Xu *et al*., 2004; Hsiao-Tung and Kuo-Ning, 2008). Some people study the energy absorption ability of the single and double thin-walled buffer structures (Scholes and Lewis, 1993; Xiao *et al*., 2009) and multilayer honeycomb sandwich board buffer structures (Yoshiaki, 2000) and scholars have got buffer structures with different performance by changing the circuit parameters (Nagem *et al*., 1997), steel structure shape (Olabi *et al*., 2008) and controlling different AlGaAs layer metal organic evaporation phase growth (Hung-Pin, 2006).

In addition, there are many researches about vibration reducing method and properties of the vibration system itself. Grissom *et al*. (2005) studied a 'reduced eigenvalue method' which used the modal analysis results of the base structure without absorbers, computed just once, to obtain the response of the modified structure. Chtiba *et al*. (2010) studied coupling dynamics problems of the piezoelectric and mechanical buffer structure. Dehghan-Niri *et al*. (2012) studied the performance of a single horizontal conventional Impact Damper (ID) in both wide range frequency and resonance excitations (Papalou and Masri, 1996; Lu *et al*., 2011). The effects of the coefficient of restitution, mass ratio and other parameters on the performance of ID are investigated. All the researches mentioned above provide good methods for buffer-structure design and gain good effects.

Presently, no work has been published about the buffer structures used in traction process with a constant speed which is usual in most situations. So this study is of wide engineering application prospects. And this study is mainly conducted by establishing mathematical model and solving it.

MATERIALS AND METHODS

Description of the problem: Branch of wall materials in a piles plant, the wall-plate mould machines recycle in the whole workshop for chain traction power design. Because the mass of a wall-plate mould machine is over 20000 kg and the speed is about 0.2 m/s, it is powered by a motor-driven chain which drives wall-plate mould machine working. When the wall-plate mould machine and chain speed are inconsistent, it will cause impact on the chain which transfers the impact load to the motor drive shaft. When the shock loads is bigger than the maximum of motor drive load range, the motor will be easily damaged. So installation of an elastic structure between the chain and the wall-plate mould machine aims to protect the motor, so that when it suffers from impact loads, the impact energy can be stored in the elastic structure, thereby reducing the impact force on the motor. If the speed of the motor-driven chain reaches V_0, the wall-plate mould machine running speed reaches V and the motor will withstand the maximum impact force F, then how much is the elasticity coefficient k of designed buffer elastic structure which is used to ensure the maximum impact load of the motor not bigger than F?

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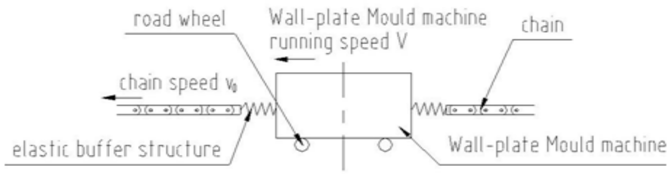

Fig. 1: A wall-plate mould machine transmission and its driving and running diagram

- **The mathematical modeling:** As shown in Fig. 1, the mass of the wall-plate mould machine is M, the chain speed is V_0, the wall-plate mould machine running speed is V, assuming an elastic buffer structure with an elasticity coefficient k is installed between the wall-plate mould machine and chain link.

When the running speed of the chain and wall-plate mould machine is equal, the wall-plate mould machine is in a normal status without causing impact on the motor, when the speed of them is not same, the wall-plate mould machine will bring additional impact to the chain. The additional impact is equal to the product of elastic structure compression distance by coefficient of elasticity. Because of additional reaction force on the wall-plate mould machine due to compression of the elastic buffer structure, the wall-plate mould machines will slowdown. The elastic structure compression will arrive at its maximum values when the speed reduces to be equal to the chain speed. In the process of compression, the wall-plate mould machines bear the inertia force, the stretch of buffer structure and mass force in the moving direction. Three forces are balanced, thus there is the balance equation:

$$m\ddot{x} + kx = f \tag{1}$$

where,

$$x = \int_0^t (v - v_0)\,dt \tag{2}$$

Indicated the compression process and the motion differential equations of wall-plate mould machine are as follows:

$$m\ddot{x} + \int_0^t k(v - v_0)\,dt = f \tag{3}$$

where,
m : The mass of the wall-plate mould machine
k : Elasticity coefficient of the buffer structure
v : The speed of the wall-plate mould machine
v_0 : Chain speed
f : Mass force

RESULTS AND DISCUSSION

- **Solving the equations:** Calculating the twice time derivative to Eq. (2), we get:

$$\frac{d^2x}{dt^2} = \frac{dv}{dt} \tag{4}$$

Substitute (4) into (3) and get:

$$m\frac{dv}{dt} + \int_0^t k(v - v_0)\,dt = f \tag{5}$$

Calculating time derivative to Eq. (5) and get:

$$m\frac{d^2v}{dt^2} + k(v - v_0)\,dt = 0 \tag{6}$$

The solution of the differential equation can be get substituting the initial conditions t = 0, v = v_1, x = 0 into Eq. (6):

$$v(t) = \frac{f}{m}\sqrt{\frac{m}{k}}\sin\left(\sqrt{\frac{k}{m}}t\right) + (v_1 - v_0)\cos\left(\sqrt{\frac{k}{m}}t\right) + v_0 \tag{7}$$

When the speed of the wall-plate mould machine and chain speed become equal, the impact force between them arrives at the maximum value. The time from the initial time t = 0 to that when the wall-plate mould machine arrives at the maximum impact force is calculated as t_{max}; that is: v (t_{max}) = v_0 helps for the solution of t_{max} and get the maximum impact force in the impact process:

$$\begin{aligned} F &= kx(t_{\max}) \\ &= f + k(v_1 - v_0)\sin\left(\sqrt{\frac{k}{m}}t_{\max}\right) - f\cos\left(\sqrt{\frac{k}{m}}t_{\max}\right) \end{aligned} \tag{8}$$

- **Program design:** In the mechanical design process, the design efficiency is often required so that the shortest time can be used to complete the design. Therefore, a computer program for a complex design to finish the calculation process does not only improve the calculation accuracy, but also improves the study efficiency. Therefore, the MATLAB language is used for program compiling here.

  Basic functions of procedures: In engineering practice, there are often two problems:

- Chain speed v_0 is known, the maximum speed v_1 of the wall-plate mould machine and other impact components during operation is known, the maximum impact load of the drive motor F is also

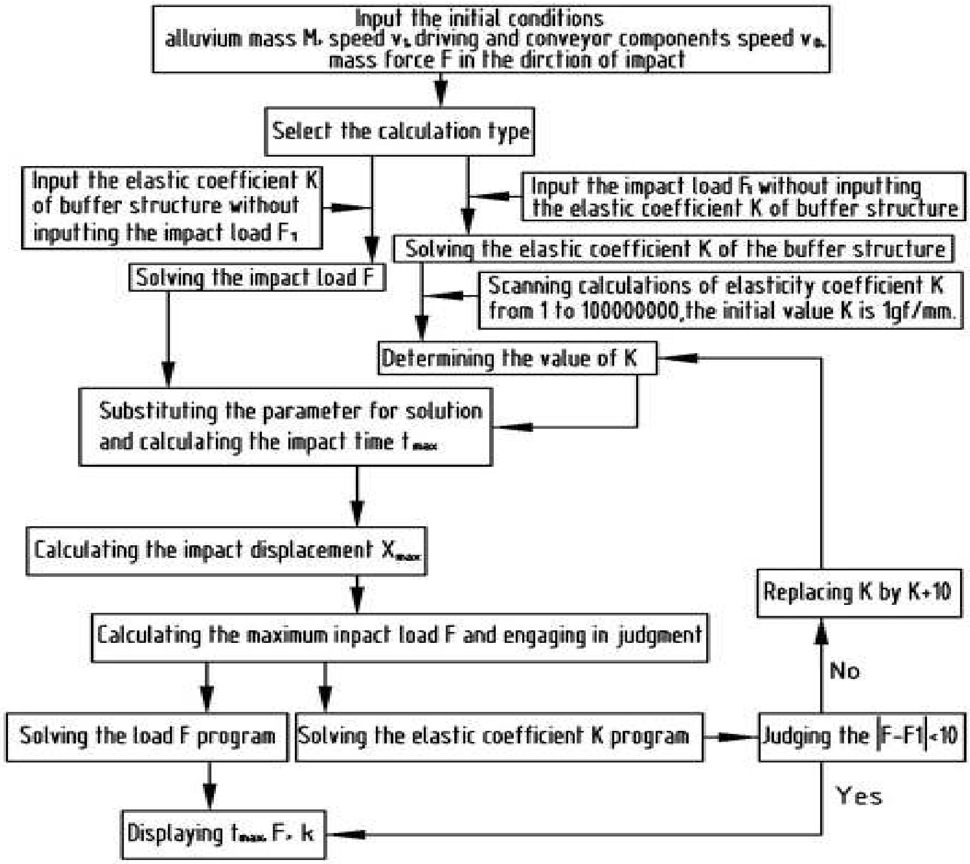

Fig. 2: The program flow graph

known, then it is necessary to solve the elasticity coefficient k of the elastic structure.

- Chain speed $v_0$is known, the maximum speed v_1 of the wall-plate mould machine and other impact components during operation is known, the spring constant k of the elastic structure is also known and then it is necessary to solve the selected driving force of the motor. The program design mainly aims to the two cases above.

The programming flow: For a known elasticity coefficient k of an elastic buffer structure, this program resorts to the above analysis for solving process directly to display. For unknown elasticity coefficient k, the program uses segmented iterative calculation by selecting k from 1-1000000000 and compares the calculated structure impact and the known, when the compared difference is less than 10 g/mm, the program iterative calculation will stop and display the results. The process is shown as Fig. 2.

Program code: Define the program name as dzh/m. Input dzh in MATLAB window and input the known parameters and unknown parameters in terms of screen prompts and then go on entering directly for solution. The program codes are as follows: function dzh () % this program can be used to the calculation of relative moving impact load with a constant velocity v and a constant force (mass force) in an impacted direction. It can also be used for shock absorption design calculations.

```
m =  Input ('Please enter the mass of impacting object: (t)') * 1000
v  = Input ('Please enter the speed of the impact object: (m/s)')
v0 = Input ('Please enter the speed of other impacted object with a constant speed v: (m/s)')
k =  input ('Please enter the elasticity coefficient of buffer structure: (t/mm), for solution, input enter ') * 9.8 *1000000
F  = Input ('Enter the allowable maximum impact load: (t), for solution, input enter') * 1000 * 9.8
f =  Input ('Please enter the constant force of the impact direction (mass force): (t)') * 1000 * 9.8
jieguo = 1;
g = 9.8;
if isempty(k)
i = 0;
    for t = 1:1000:100000000
     a = sqrt (t/m)
    c = sqrt (f^2/m/t+(v-v0)^2)
    bd = asin ((v-v0)/c);
```

```
tmax = sqrt (m/t)*(pi-bd);
Fc = f+t*(v-v0)/a*sin (a*tmax)-f*cos (a*tmax);
      if abs (F-Fc)<10
disp ('elasticity coefficient of the buffer structure is: (t/mm)')
      k = t/9.8/1000000
      x = F/t+v0*tmax;
break;
      else
      end
             i=i+1;
end
if i> = 100000
   disp ('The calculation has gone beyond the programmed range, pleas adjust the scope of the elasticity coefficient to recalculate);
   jieguo = 0;
  else
  end
else
      a = sqrt(k/m);
      c = sqrt (f^2/m/k+(v-v0)^2);
      bd = asin ((v-v0)/c);
tmax = sqrt (m/k)*(pi-bd);
x=f/k+(v-v0)/a*sin(a*tmax)-f/k*cos
(a*tmax)+v0*tmax;
F=f+k*(v-v0)/a*sin (a*tmax)-f*cos (a*tmax);
disp (:impact loading of this structure in the conditions is (t) ');
F = F/9.8/1000
end
if jieguo = =1
disp ('impact time of the structure (s): ');
tmax
disp ('impact displacement of the structure(mm):');
x = x*1000
else
end
```

CONCLUSION

With the further acceleration of the industrial automation, such transmission structure is indispensable of the most important components in the automated production line. Therefore, this study will help mechanical engineers and provide a theoretical basis for buffer structural design. Meanwhile, it can also provide design and calculation procedures and greatly reduce the engineers' design time and improve the design efficiency which will play significance on the process of industrialization.

Highlight:

- The mathematical model is established to buffer structure of traction running with a constant speed.
- The process to solve the dynamic equation has been programmed with MATLAB-language.

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