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Research into an Electromagnetic Damping Type of Descent Rescue Device

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Abstract: It introduced the structure and working principle of an electromagnetic damping type of high-rise descent rescue device and then it calculated and analyzed the structural strength with finite element analysis based on Patran/Nastran. The analysis results indicate that the location where the structural strength is much weaker is at the tooth root while the strength can meet the requirements which proves the correctness and rationality of the finite element modeling method and lays the foundation for improving the safety and reliability of the descent rescue device.

Key words: Descent rescue device, structure analysis, patran/nastran, finite element analysis, strength check

INTRODUCTION

In today's urban disasters and accidents, the fire is a high frequency of occurrence, involving a wide range of great harm, reacted strongly to sudden disasters. Especially high-rise fires, it often causes people to enormous physical security threats and property losses. Descent rescue device have made people to see the hope of saving high-rise in distress and find popular use life-saving equipment that can adapt to all kinds of people. Therefore, it is human to maximize the ways to protect themselves and reduce social wealth losses. Descent rescue device also can make the fire brigade in the fire, the fire brigade rescue to reduce casualties, to accelerate the fire extinguished can also play an extremely important role (Ding, 2008).The electromagnetic damping type is widely recognized as the most advanced way, it skillfully combines the electromagnetic technology, electronic technology, automatic control technology and machinery and it is bound to become the focus of future research and direction.

In this study, the structure and working principle of a new type of electromagnetic damping type of high-rise descent rescue device will be analyzed and its key parts will be made the finite element analysis.

STRUCTURAL ANALYSES

Structure and working principle: Passive intelligent descent rescue device using a geared transmission structure which is different from common friction escape device relies on reduction gear reducer. Descending in altitude escape process, rope pressed against the rope and drive sheave wheel rotation, After a multi-stage gear drive growth, Kinetic energy is transmitted to the input shaft of the generator, and drive the generator rotor cutting magnetic line motion, which is contribute to generating coil cutting magnetic lines, so the kinetic energy is converted into electrical energy and in the form of heat dissipated (Zhang *et al*., 2010) (Fig. 1).

Without considering the air damping, friction loss and rope slip such circumstances, according to the law of conservation of energy, there is:

$$P_E = P_D + P_H = \frac{1}{2}mv^2 + P_H \quad (1)$$

where, P_E is the human body potential energy in a certain floor height; m is the body mass, P_D is the human body kinetic energy when the body descent from a height, P_D = $mv^2/2$, v is the rate of decline of human when the body descent, P_H is the dissipation of heat through the thermal resistance.

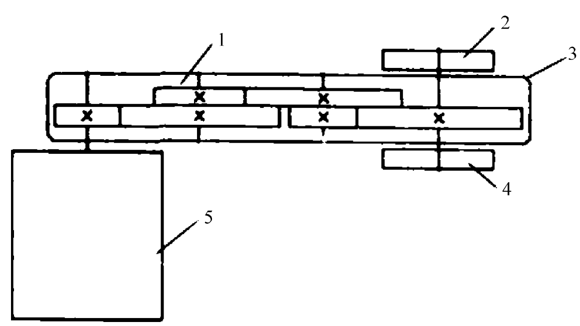

Fig. 1: Structure diagram of descent rescue device (1) Increase gear group, (2) Brake wheel, (3) Shell, (4) Rope wheel and (5) Damping motor

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As can be seen, through a new type of descent rescue device to achieve slow down, the human body potential energy will is converted into the kinetic energy and heat. By controlling the conversion of electrical energy - thermal energy, we can control the rate of decline of the human body. According to the Eq. 1:

$$mgh = \frac{1}{2}mv^2 + I^2 \cdot r \cdot t \tag{2}$$

where, g is the acceleration of gravity; h is the floor height; I is the current through the stator coils; r is the thermal resistance.

If coil resistance is not considered, there is:

$$I = \frac{U}{r} \tag{3}$$

where, U is the output voltage of the damping motor.

According to the characteristics of permanent magnet generator, the current will produce a reverse magnetic field through the stator coil to impeding rotation of the rotor. It is the magnetic damping. And then, the output voltage of the damping motor is proportional to the rotational speed of the rotor and the magnetic damping is proportional to the current through the stator coils. According to the Eq. 2 and 3, by controlling the thermal resistance, we can adjust the size of the motor magnetic damping to control descent speed of the body.

Analyzes the force: The overdrive gear transmission parts are the core of descent rescue device; the size of the intensity directly affects the whole descent rescue device descending safety and reliability. According to the calculation results, the circumferential force and the contact force of level 1 gear transmission are bigger than the others, Therefore, the gear strength of the level 1 only need to check. We consider the pinion in the analysis of the gear failure, whether contact fatigue or bending fatigue failure. Because a pinion which has fewer teeth will turn Z_2/Z_1 circle when big gear wheel turn one circle, namely, pinion work intensity greater than big gear wheel, similarly. In addition, the gear principle determines pinion tooth profile curvature; pinion tooth contact strength is less than big gear wheel. Pinion tooth root slip rate is also the greatest. Thus, we generally considered the strength of the pinion. In summary, the pinion of level 1 gear transmission is strength weaknesses that need to be finite element strength check calculation (Chen *et al*., 2011).

Load calculation: In order to obtain the actual load and to verify the correctness of the results of stress analysis, this study is dynamics analysis to descent rescue device simplified model based on mechanical dynamics simulation software ADAMS. The simplified model is overdrive gear transmission mechanism. After setting up all simulation parameters in ADAMS, start the simulation and measure circumferential force and the contact force, the results shown in Fig. 2 and 3.

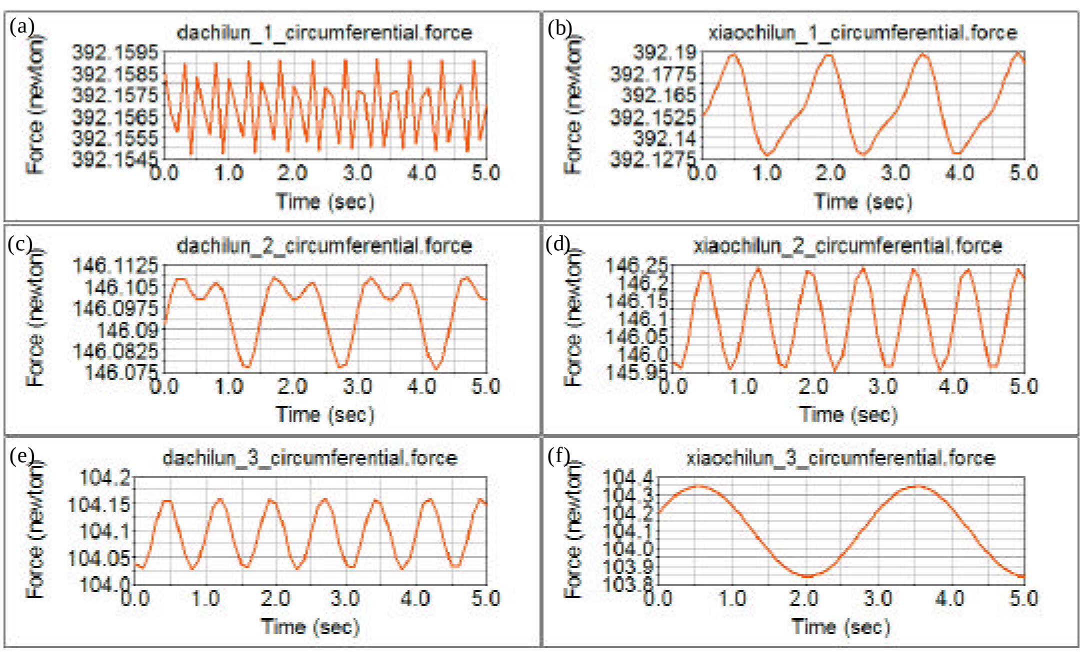

Fig. 2(a-f): Simulation curve of the gear about circumferential force

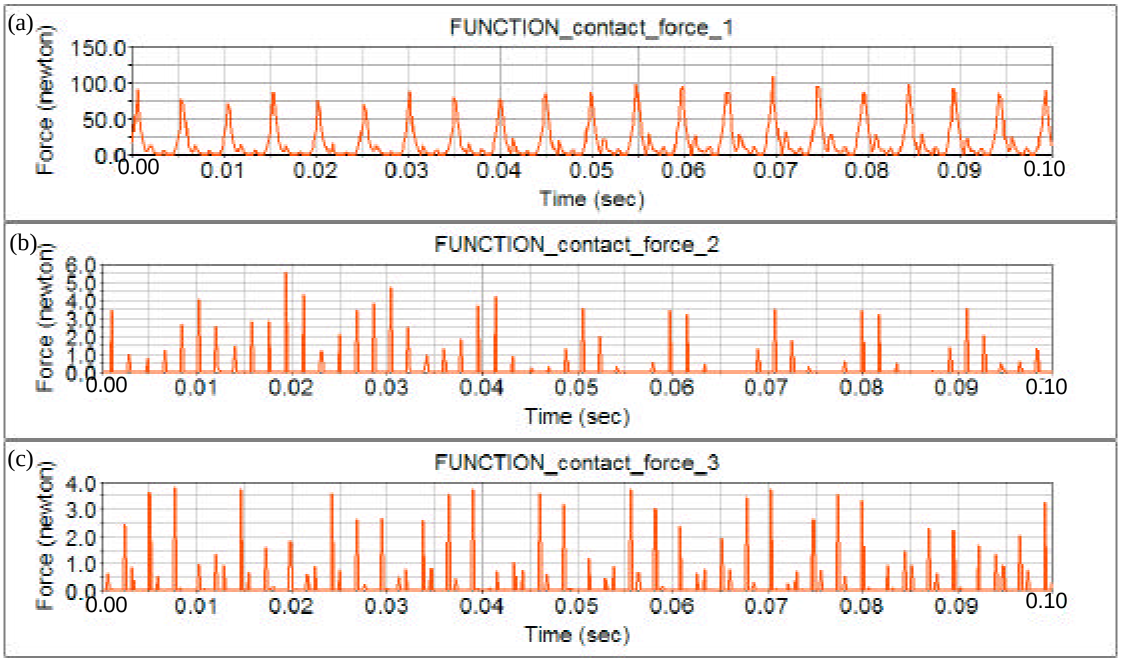

Fig. 3(a-c): Simulation curve of the gear about contact force

According to Fig. 2 and 3, the circumferential force and contact force of the level 1 gear transmission are bigger than the others and the circumferential force is about 392.2 N, the contact force is about 107.85 N. The stress analysis results, the calculation results and the simulation results are consistent.

FINITE ELEMENT ANALYSES

Establish finite element model: In order to quickly establish the finite element model and reduce the calculated amount of computation model, according to the principle of without affecting calculation results, a drive pinion of the three-dimensional model can be simplified to three teeth for analysis based on the symmetry of the gear (Zhang *et al.*, 2012).

To calculation of finite element analysis, the quality of the mesh directly affects the accuracy of the calculation time and result, therefore, this study choose hexahedral mesh establish finite element model. The geometry model is created by SolidWorks and imported into Patran. When meshing using a 10-node tetrahedral element, although the calculation time increases, the result is very close to the actual situation (Xu *et al.*, 2008). Finite element model has a total of 5,733 units, 8,914 nodes; the finite element model is shown in Fig. 4.

The materials used steel 40 Cr, the elastic modulus M = 2.06×10^{11} N mm^{-2}, Poisson's ratio μ = 0.29, the density $\rho = 7.85\times10^3$ kg m^{-3}. The above parameter input material properties. In the division of the finite element mesh, involves only the topological properties of the elements, physical characteristics is not involved, therefore, we must define the physical properties of the elements in Properties, assign the physical properties to the mesh elements (Xie *et al.*, 2004).

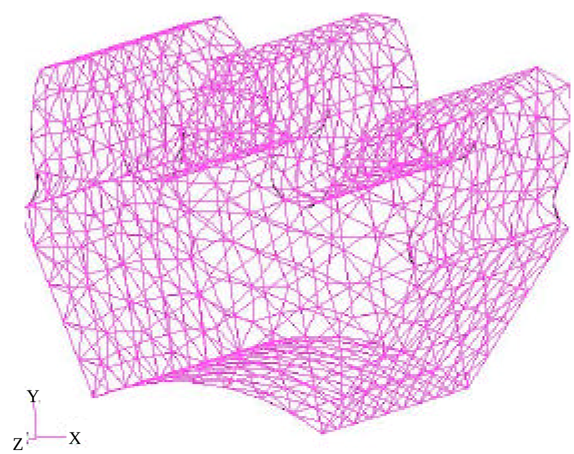

Fig. 4: Finite element mesh model of the pinion

The boundary condition is reasonable or not, it will directly affect the results accuracy of the finite element analysis and different constraints may cause results to vary greatly (Asi, 2006; Hinton, 2007; Geveci *et al.*, 2005).

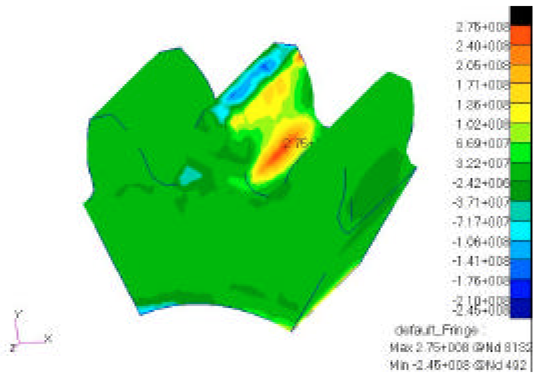

Fig. 5: Bending stress chart of pinion

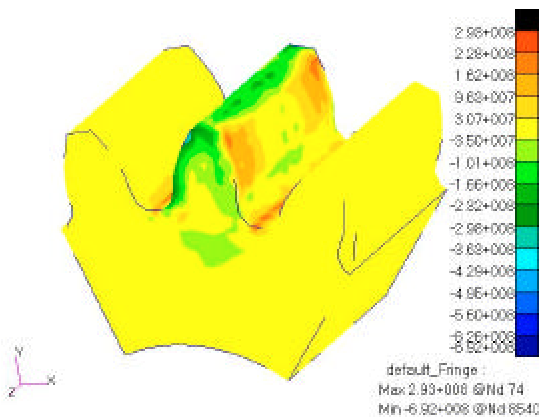

Fig. 6: Contact stress chart of pinion

To make boundary conditions of the descent rescue device completely realistic is impossible, we can only simplify the actual boundary conditions. This work select surface of the pinion inner hole as constraints boundary and the top edge of the pinion applied load. Load calculation has been described in before.

Analyses about finite element results: Finite element results are shown in Fig. 5 and 6. By the stress chart shows following:

Minimum principal bending stress	=	-2.45E+08 N m^{-2}
Maximum principal bending stress	=	2.75E+08 N m^{-2}
Minimum principal contact stress	=	-6.92E+08 N m^{-2}
Maximum principal contact stress	=	2.93E+08 N m^{-2}

They are basically consistent with the results of mechanical design empirical formula, and then the pinion contact fatigue strength σ_H = 550 Mpa and contact fatigue strength σ_H = 293 Mpa.

Pinion material is steel 40 Cr, according to consult relevant information, Pinion bending fatigue strength limit σ_F = 500 Mpa and contact fatigue strength limit σ_H = 550 Mpa. Take the material safety factor s = 1.4, Fatigue life factor K_{FN} = 0.95, K_{EN} = 0.95, respectively, by bending fatigue allowable stress formula $[\sigma_F] = K_{FN}\sigma_F/S$ and contact fatigue allowable stress equation $[\sigma_H] = K_{HN}\sigma_H/S$, we can obtain: the pinion bending fatigue allowable stress $[\sigma_F]$ = 339.3 Mpa: The pinion contact fatigue allowable stress $[\sigma_H]$ = 373.2 Mpa. So:

$$[\sigma_F] = 339.3\ \text{Mpa} > 275\ \text{Mpa} = \sigma_F$$

$$[\sigma_H] = 373.2\ \text{Mpa} > 293\ \text{Mpa} = \sigma_H$$

The pinions strength of the level 1 gear transmission meet the requirements (Yao *et al*., 2010).

CONCLUSION

This study introduce the structure and working principle of an electromagnetic damping type of high-rise descent rescue device and then it analyze the mechanical properties, the result show that the location where the structural strength is much weaker is at the tooth root. By establishing the finite element model of the key parts, it obtains the stress characteristics. By comparing the results of finite element calculated and allowable stress, both are basically consistent, the result show that the stress characteristics of the key parts consistent with the actual situation, the strength can meet the requirements and the finite element modeling method is correct and reasonable.

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REFERENCES

Asi, O., 2006. Failure analysis of a crankshaft made from ductile cast iron. Eng. Failure Anal., 13: 1260-1267.

Chen, H., R. Zhang, G. Xiong, F. Liang and L. Liu, 2011. Intelligent control method research on the high-rise buildings rescue apparatus. Proceedings of the 9th World Congress on Intelligent Control and Automation, June 21-25, 2011, Taipei, Taiwan, pp: 744-748.

Ding, Y.F., 2008. Buildings should be equipped with descent rescue device. Orient Fire Protection, 12: 38-39.

Geveci, M., A.W. Osburn and M.A. Franchek, 2005. An investigation of crankshaft oscillations for cylinder health diagnostics. Mechan. Syst. Signal Process., 19: 1107-1134.

Hinton, R.W., 2007. Failure analyses of six cylinder aircraft engine crankshafts. J. Failure Anal. Prev., 7: 407-413.

Xie, H.D., Z.Y. Zhou and W. Xia, 2004. The precise modeling and finite element mode analysis of helical gear. Modern Manuf. Eng., 11: 55-56.

Xu, Z.M., X.J. Mu and X.Y. Peng, 2008. Engine crankshaft static strength analysis based on the finite element method. J. Chongqing Univ., 31: 977-981.

Yao, X.J., L.D. Yang and G.K. Shan, 2010. Finite element analysis of wind turbine hub based on MSC. Patran J. Shenyang Univ. Technol., 32: 620-624.

Zhang, R., H. Chen and S. Liu, 2010. Research on a high-rise buildings rescue apparatus. Yadian Yu Shengguang, 32: 1002-1004.

Zhang, X.Z., Q.H. Jiang, K. Wu and Y. Sun, 2012. Finite element analysis and experimental verifications of press frame. J. Mach. Des., 29: 11-14.