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Mechanical Properties Research Based on Snowplow Operation Device

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Abstract. In this paper, combining with the domestic design and application of the snowplow in quality and quantity two aspects, basing on engineering application software ADAMS and CATIA, dynamics for 10t snowplow working device was researched, and the strength of the main stress components was analyzed by finite element method. On the basis of lightweight, strength and structure reasonable design, the snowplow device structure was verified feasibility through the research results. The paper studies could have a certain theoretical reference for the theoretical design and practical application of similar products.

Introduction

In north region of china, snowfall period is up to 3 ~ 5 months each year, some areas even longer, and removing snow for millions of kilometers roads become a realistic problems, and recovering normal traffic condition quickly after snowfall is a common problem for every northern city. Fast and efficient snow-removing machine has become the urgent need in order to improve our country economy development and standard of living[1].

The disadvantages of artificial snow-removing operations and using snowmelt agent could not be overlooked, namely artificial operation efficiency is low, and snowmelt agent would corrode the road surface and vegetation on both sides of the road. The mechanical snow-removing method balances the both aspects of the efficiency and environmental protection, and is more suitable for snow removal now. Snow removal machinery development in China started late, there are some obvious lacks, insufficient core technology, un-complete variety and model, low technical level, single function relatively, un-perfect protection for road, etc. So the foundation theory study of snow removal machine is necessary. In this paper, based on the plough type snow shovel, its dynamic performance would be analyzed[2].

1 Resistance Calculation[3] [4][5]

1.1 Snow removal resistance calculation

As shown in figure 1, the snowplow for plough type, its main composition has snow shovel, racks, lift cylinder and the bearing rod, etc. Some influence factors have close relationships with resistance calculation, such as, snow shovel itself quality, the friction coefficient between shovel body and road

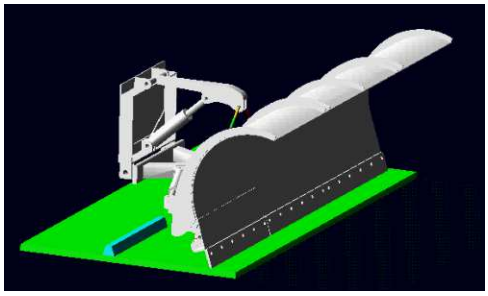

Fig.1 Snow removal machine main structures

surface, the angle of the blade and the road surface, the blade shape, shovel body horizontal pendulum angle, width of snow removal operations, snow removal operation speed, the density of floating snow, floating snow thick.

In the process of snow removing, the main factors influencing the snow removal resistance are the marching angle θ of snow shovel, the angle δ between shovel body with ground, driving speed and density of snow body. To establish a mathematical model, figure 2 is shown the coordinate relationship of snow shovel and driving direction, and the positive direction of X axis is for snow removal way.

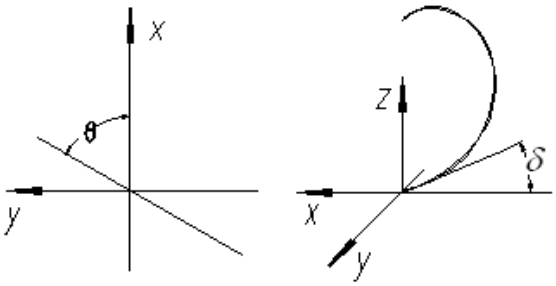

Fig.2 Snow shovel operation coordinate diagram

Usually, there are two different regions scattered by the influences of snow driving velocity and removing-snow resistance, which are 10 ~ 20 km/h speed domain and 20 ~ 40 km/h speed domain, the influence of the different velocity range on the snow resistance coefficient is different. Based on the coordinate relationship of figure 2, the establishment of snow removal resistance to force calculation mathematical model are as follows.

1）Snow removal operation velocity is 10 ~ 20 km/h

$$F_{px} = g \cdot \mu_f \cdot M_p + S \cdot \rho \cdot v^2 (1 + 0.73 sin^2 \vartheta - 0.33 cos^2 \vartheta). \quad (1)$$

$$F_{py} = 1.06 S \cdot \rho \cdot v^2 \cdot sin\vartheta \cdot cos\vartheta$$

$$F_{pz} = g \cdot M_p.$$

2）Snow removal operation velocity is 20～40km/h

$$F_{px} = g \cdot \mu_f \cdot M_p + S \cdot \rho \cdot v^2 (1 + 0.18 sin^2 \vartheta - 0.45 cos^2 \vartheta). \quad (2)$$

$$F_{py} = 0.72 S \cdot \rho \cdot v^2 \cdot sin\vartheta \cdot cos\vartheta$$

$$F_{pz} = g \cdot M_p.$$

Type, F_{px}: x direction resistance component.

F_{py}: y direction resistance component.

F_{pz}: z direction resistance component.

μ_f: the friction coefficient of road surface blade with snow.

M_p: the snow shovel quality.

S: the contact area between floating snow layer and the snow shovel.

v: snowplow driving velocity.

ρ: density of snow.

Snow density usually is 300 ~ 800 kg/m^3, the marching angle for 60 ° to 90 °, take the friction coefficient between shovel blade with snow road surface is 0.2. On the basis of the above formulas, snow removal resistance can be obtained.

1.2 Driving resistance calculation

Snowplow driving resistance experience calculation formula is the following.

$$F_m = g(\mu_\alpha A v^2 + \mu_r M) \quad (3)$$

Type, μ_α: the air drag coefficient.

A: the positive projection area of snow blower.

μ_r: rolling resistance coefficient.

M: quality of snowplow.

According to the above formulas and the corresponding amount ,the driving resistance can be obtained.

2 Main Component Mechanical Analysis

Using dynamic analysis software ADAMS and static strength analysis software CATIA, the dynamics and intensity analysis for snowplow were carried out on the typical stress components.

2.1 Strength analysis in the lifting condition of working device

In the lifting condition of working device, the force role in the bearing rod shoved by the lift cylinder directly is larger, and it is necessary for strength check.

Through the snow removal resistance and driving resistance calculating, and the dynamic operation in ADAMS, the tension values of the bearing rod can be measured and calculated[6]. The time-domain force curve is shown in figure 3.

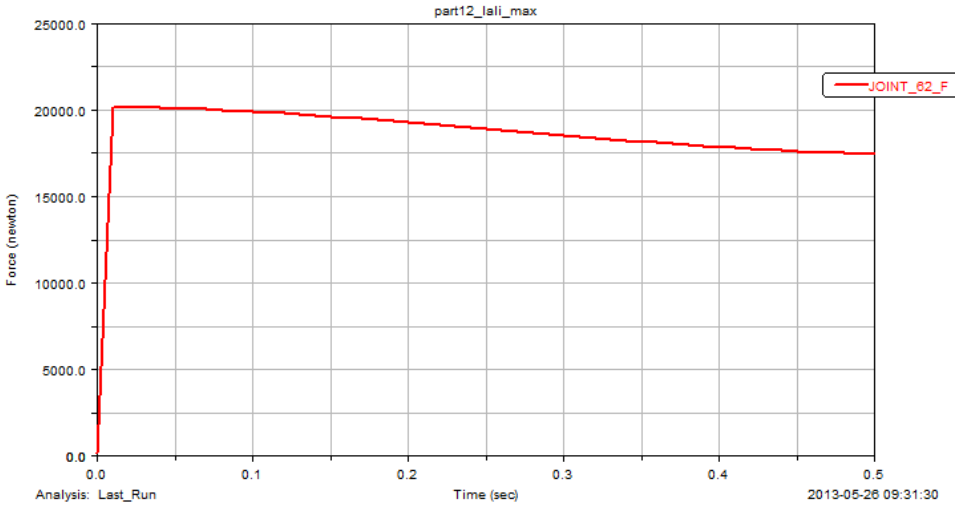

Fig.3 Time-domain force curve of bearing rod during snow shovel lifting

The figure 3 shows that the largest value of the bearing rod force occurs in the initial lifting of snow shovel, the maximum is 20153N, then the force decreases later.

Through improving the model into CATIA software, and setting the boundary conditions according to the connecting relationship of the bearing rod mechanism, the stress can be analyzed. The stress size and distribution of bearing rod are shown in figure 4.

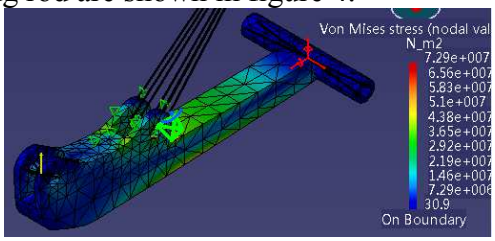

Fig.4 Stress distribution diagram of the bearing rod during lifting operation

By the stress distribution, we can see that, the stress maximum 72.9 MP, which is satisfy the requirement of the steel yield limit, that is, the strength of the bearing rod can select general steel. By Fig4, the stress distribution in the middle layer of the bearing rod stress is larger, specially, in the joint

of hydraulic cylinder and bearing rod, as shown in figure 5,which is due to the complex shape parts, so there is stress concentration phenomenon in this position. Further, the stress value on both sides of the central bearing rod up and down are larger, and the middle layer is smaller.

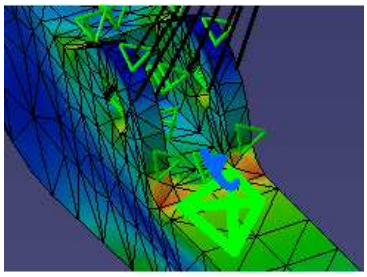

Fig.5 Bearing rod stress distribution of partial enlargement

2.2 Deflection analysis in the lifting condition of working device

Figure 6 is the bearing rod deflection distribution, it is not hard to see the maximum deflection is 0.876 mm, the maximum points is the contact parts between the wire rope with bearing rod.

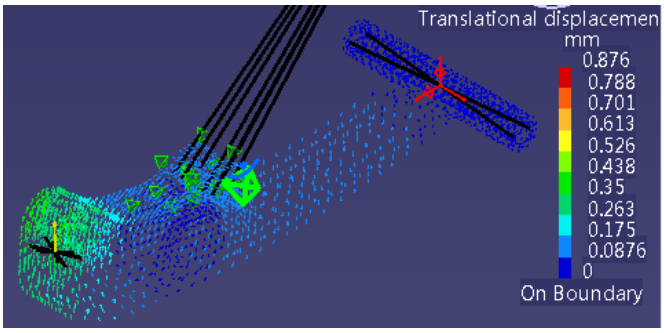

Fig.6 Bearing rod deflection distribution during lifting operation

3 Conclusions

1) By the integrated application design method using numerical calculation and engineering analysis software, dynamics and strength characteristics of snowplow device can be effectively analyzed. The research method could help to the similar dynamic system design.

2) Through analysis and calculation, the paper analysis verifies the practicality of one of the main carrying part of the snowplow, the bearing rod, that is, its material and structure are feasible, and can meet the use of the snow removal equipment.

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