Design and mechanical analysis of the loading mechanism of the back-loading garbage truck

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Abstract. In this paper, the loaded garbage truck loading mechanism is the research object. The three-dimensional model of the mechanism is established by software, and the force analysis is carried out under the working condition. Using MATLAB software to draw the curve to show the relationship between compression filling force FL, the pusher stroke x and the installation angle $\alpha_1$, when the optimum installation angle is selected, the maximum compression filling force FL is 188.29 kN.

Key words: Loading mechanism; compression filling force; garbage truck

1. Introduction (Heading 1)
The main features of the rear-loading garbage truck are large compression capacity, good sealing, convenient and fast loading, and high degree of automation. Therefore, it has become the mainstream vehicle for urban garbage collection. Its working equipment is mainly composed of the compartment and the loading box. The composition of the loading mechanism. In this paper, the design and mechanical analysis of the loading mechanism are carried out. The loading mechanism includes the slider, the scraper, the scraper cylinder, the slider cylinder, the loading box, the lift cylinder, etc., as shown in the Fig. 1.

Fig 1. Back-loading Garbage Truck
1 the car body; 2 slider; 3 scraper; 4 scraper cylinder; 5 slider cylinder; 6 loading box; 7 lifting cylinder; 8 the carriage; 9 push plate; 10 push plate cylinder
2. **Working Principle Introduction:**

2.1. **Loading garbage**
When loading garbage, the carriage is fixed on the chassis frame, the loading mechanism is behind the car, and the upper corner hinge is driven by the lifting cylinder to rotate around the hinge axis, and the garbage is loaded into the loading mechanism from the back and compressed by the compression mechanism. The garbage is squeezed forward from loading box into the compartment.

2.2. **Unloading garbage**
The unloading mechanism is driven by the oil cylinder at the front end of the carriage. When the garbage is unloaded, the loading mechanism is first lifted by the lifting cylinder mechanism, the carriage is opened, and the loading mechanism will push out the garbage.

3. **3D modeling of the loading mechanism**
According to the surveying and measuring, the three-dimensional model of the loading mechanism [1] is established shown in Fig.2

![Fig 2. Compressed garbage truck loading mechanism eassembly](image)

4. **Force analysis of the loading mechanism**
The loading mechanism is the most important part of the loading compartment [2], and its working condition directly affects the working performance of the garbage truck. In this paper, the skateboard loading mechanism is taken as an example to analyze the force when loading garbage. As shown in Fig.3

![Fig 3. Force analysis of the slide compression mechanism](image)

When the garbage is loaded, the garbage is moved to the left by compression filling force $F_{f1}$. At this time, the direction of the friction $F_{f1}$ acting on the inner surface of loading box is opposite to the direction of the garbage movement, and the magnitude of the force $F_{f1}$ is:

$$F_{f1} = fpS_1x$$ (1)
Among them:

$S_1$: the circumference of the cross section of the inner surface of the carriage (m);
$f$: The comprehensive friction coefficient of the inner surface and the garbage;
$x$: The displacement of the garbage (m);
$p$: The unit expansion force of garbage ($N/m^2$).

And there is another resistance that hinders the movement of the garbage caused by the gravity of the garbage, recorded as $F_{j2}$, then:

$$F_{j2} = f\rho_j g S_2 x h$$

$S_2$: The approximate width of the carriage (m);
$\rho_j$: The calculated density of garbage ($kg/m^3$);
$h$: Height (m).

The conditions that can push the garbage forward:

$$F_H = F_L \cos \alpha_1 \geq F_{j1} + F_{j2}$$

Simplified

$$F_L \geq \frac{f(pS_1 + \rho_j g S_2 h) x}{\cos \alpha_1}$$

According to the measurement and modeling [3] of the loading mechanism the parameters, $S_1$, $S_2$, $h$, can be determined.

And $f$, $p$, $\rho_j$ vary with the degree of garbage composition and compression, they can be obtained by experiments, recommended [2]

$$f(pS_1 + \rho_j g S_2 h) = 30 kN/m$$

Therefore

$$F_L = \frac{30}{\cos \alpha_1} x \times 10^3$$

Assume $x_{max} = L$

Where $L$ is the pusher stroke (m)

Therefore

$$F_{L_{max}} = \frac{30}{\cos \alpha_1} L \times 10^3$$

Where $\alpha_1$ is the angle between the filling force and the horizontal direction ($^\circ$).

The calculation of $F_{L_{max}}$ can be used as a calculation load for hydraulic system design.

According to the above three-dimensional model of loading mechanism, $S_1=4.7$, $S_1=1.75$, $h=0.6$, $L_{max}=3.6$, all the units of them are (m). Bring these parameters into the above formula, from (1) to (7), and do calculation, $F_L$ will be obtained.

Using MATLAB software [4] to draw the curve to show the relationship [5] between $F_L$, $x$ and $\alpha_1$ as shown in Fig. 4, when the range of the pusher stroke $x$ from 0 to 3.6 m, the installation angle $\alpha_1$ from 45° to 70, $f$ is decided by garbage material.
The source program is as follows:

```matlab
s1=4.7 ,s2 =1.750 ,h =0.6
x=linspace(0,3.6,1000)
a1=linspace((45/180)*pi,(70/180)*pi,1000);
FL=30*x./cos(a1);
plot3(x,a1,FL,'linewidth',2)
title(' relationship between FL, x and a1 ');
xlabel(' pusher stroke x ');
ylabel(' installation angle a1 ');
zlabel(' c ompression filling force FL ');
grid on;
a1=(55/180)*pi
FL=30*x./cos(a1)
max(FL)
```

![Fig 4. compression filling force variation curve](image)

5. Summary
When the installation angle range is changed from 45° to 70°, the maximum compression filling force is \( FL=351.77 \text{kN} \). At this time, the maximum installation installation angle is 70 degrees, but according to the experiment, it is not the optimal angle. According to the optimized design result, \( \alpha_1 \) is 55°, the maximum compression filling force \( FL = 188.29 \text{kN} \).

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References
[1] Heng Sun, mo Zuo Chen ,jie Wen,Ge .Mechanical Principles (Seventh Edition) , Beijing, Higher Education Press, China 2005,pp. 135–147.
[2] W.G. Qiao. Special car structure and design . Beijing:Peking University Press,China 2010, pp. 199–203.
[3] Manoj Khanna, Geeta Bhatt and Pawan Kumar .MATLAB Essentials for problem solving PHI Learning, Delhi: Asoke K.Ghosh,PHI Learning Private Limited, 2016,pp. 90.
[4] Q.R.Xiao M.M.Fan,Vehicle Engineering Simulation and Analysis——Based on MATLAB Implementation,Beijing:Mechanical Industry Press, China 2012 , pp. 185.
[5] Katsuhiko, MATLAB for control engineers,Beijing:,publishing House of Electronics Industry 2013) pp. 38.