TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 12, No. 10, October 2014, pp. 7108 ~ 7113
DOI: 10.11591/telkomnika.v12i8.5604

Research on Static Tension Ratio Characteristic of Double-Vessel Friction Hoist System Components

Xie Lirong*, Ge Laifu, Kong Jun, Cheng Jing
Electrical Engineering College of Xinjiang University, Urumqi, 830047, China
*Corresponding author, e-mail: wzywwwxr@163.com

Abstract

Double-vessel multi-rope friction hoist system, of which the lifting, starting, running, and braking must meet the safety conditions in operation. Non-skid safety boundary conditions were originally determined by Euler's formula. In order to avoid the complex task of check and check-again calculation in the friction hoist system design. In this research, static tension ratio c, which was closely bonded with anti-skid design was directly brought into the analysis and research on the system. As a result, characteristic of static tension ratio c of component quality of friction hoist system was found, which offers a simple, sound and reliable theoretical foundation for the anti-skid and optimization of system configuration.

Keywords: *double-vessel friction hoist system, static tension ratio, non-skid safety, dimensionless relative value*

1. Introduction

Multi-rope friction hoist is one of the most important equipment in coal, black metal, non-ferrous metal and chemical mining production. Friction hoist system can be divided into double-vessel friction hoist and single-vessel friction hoist system. Double-vessel friction hoist system, is generally used for single level (layer) lifting only, and a single-vessel friction hoist system can be used for multiple levels (layers) lifting.

Based on principles of frictional force multi-rope friction hoist requires that that the system can brake with non-skid security complying with the given torque of deceleration whether in normal operation or in emergency, and that there is on skid between the hoisting rope and the friction pulley. The problem of slip in friction hoist is of great importance relating the safety of mining production.

Until recently, a lot of research on the problem of slip in friction hoist has been conducted by scholars worldwide. The existing research are mainly focused on actual parameter, combined with the safety regulation in anti-skid checking calculation and anti-skid measures [4-7] without considering establishing the mathematical model of friction hoist component quality using dimensionless relative parameters systematically. As a result, system optimization and research on static tension ratio characteristic of friction hoist have been restricted. Focusing on double-vessel friction hoist system, this paper carried out the research on the relationship between static tension ratio and system component, using dimensionless relative parameters.

Double-vessel multi-rope friction hoist is mainly consist of frictional pulley, hoisting rope, hoisting vessel and balance rope etc., as shown in Figure 1.

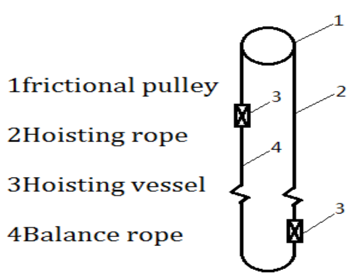

Figure 1. The Mode of Friction Hoist System

Received January 8, 2014; Revised June 20, 2014; Accepted July 15, 2014

2. Symbol Definition

2.1. Actual Parameter Definition

Plenty of parameters are involved in double-vessel friction hoist system. Symbols involved are defined as follows:

(1) Deadweight of vessel Q_z(kg);
Rated load Q_N(kg);
Static tension ratio c.
(2) Hoisting rope parameters
Number of hoisting rope n;
Weight of rope per meter p(kg/m);
Ultimate length of suspension hoisting rope L_o(m);
Height of suspension hoisting rope H_o(m).

2.2. Dimensionless Relative Parameter Definition

A proper value should be selected as the based value first, and then the dimensionless relative parameters are defined as:

Vessel deadweight coefficient $\beta_z = \frac{Q_Z}{Q_N}$

Here, Q_z was selected as the based value.

Weight coefficient of suspension hoisting rope $\beta_H = \frac{npH_0}{Q_N}$.

Height coefficient of suspension hoisting rope $h_0 = \frac{H_0}{L_0}$.

3. System Components and Static Tension Ratio c

Static tension ratio c is the ratio between the maximum tension side and the minimum tension side of the friction wheel, or rather.

$$c = \frac{T_1}{T_2}.$$

T_1 stands for the value of the maximum static tension side, and T_2 stands for the value of the minimum static tension side. While static tension ratio c is equal to or smaller than the boundary maximum value [c] permitted (c≤[c]), the safety regulation of the system is met. Otherwise, the anti-skid safety regulation will not be met, and the system will be at risk.

3.1. Vessel Deadweight Coefficient and Suspension Hoisting Rope Height Coefficient

The maximum static tension ratio of double vessel friction hoist is the tension ratio between the full load maximum tension side and the load-free minimum tension side of the friction wheel [2, 3, 8]. So:

$$c = \frac{Q_N + Q_z + npH_0}{Q_z + npH_0} = \frac{\beta_z + 1}{\beta_z + h_0} \qquad (1)$$

Equation (1) shows that the value of static tension ratio c is completely determined by the value of vessel deadweight coefficient β_z and height coefficient of suspension hoisting rope h_0, and will decrease as β_z or h_0 increases. The maximum static tension ratio c of double-vessel friction hoist system is equivalent to the summation of 1 and the reciprocal of suspension hoisting rope weight coefficient of load-free side.

$$c = 1 + \frac{1}{\beta_0} \tag{2}$$

It is revealed by equation (2) that the value of c will decrease as the value of β_0 increases. So, only by changing the value of β_0 , the value of c can be adjusted.

2.2. Minimum Permitting Height of Suspend Hoisting Rope

By changing the form of equation (1) the ultimate suspension height coefficient h_0 can be expressed as a function of c and β_z .

$$h_0 = \frac{1 - (c - 1)\beta_z}{c} \tag{3}$$

Equation (3) shows that while c equals to the maximum value permitted considering anti-skid safety, and β_z is constant, h_0 will be the minimum value of suspend hoisting rope height coefficient, and will decrease as β_z increases.

If the suspension hoisting rope height coefficient is smaller than the minimum height coefficient $h_{0\min}$, the value of c will be greater than the maximum value permitted, which violates the anti-skid safety conditions. So the value of h_0 figured out by Equation (3) is the minimum value of suspension hoisting rope height coefficient of double-vessel friction hoist system, namely the minimum value of h_0 permitted within the safety boundary condition.

2.3. Minimum Vessel Deadweight

Vessel deadweight coefficient can be figured out by changing the form of Equation (3).

$$\beta_z = \frac{1 - ch_0}{c - 1} \tag{4}$$

Equation (4) shows that while c equals to the maximum permitting value considering anti-skid safety, and h_0 stands for a certain value, then the value of β_z figured out by Equation (4) is the minimum value of deadweight of vessel and will decrease as h_0 increases.

If the vessel deadweight coefficient is smaller than the minimum value of vessel deadweight coefficient , the value of c will be greater than the maximum permitting value, which violate the anti-skid safety regulation. Therefore, the value of vessel deadweight coefficient figured out by Equation (4) is the minimum one.

3. Dimensionless Relative Value of System Component Parameters and Static Tension Ratio

The dimensionless relative value of system component parameters can be obtained by replacing β_z involved in each equation [9~13] by Equation (4).

Weight coefficient of ultimate height of suspension hoisting rope.

$$\beta_L = \frac{npL_0}{Q_N} = \frac{1 + \beta_z}{1 - h_0} = \frac{c}{c - 1} \tag{5}$$

Weight coefficient per meter of hoisting rope.

$$p^{*} = \frac{p}{Q_N / nL_0} = \frac{1+\beta_z}{1-h_0} = \frac{c}{c-1} \quad (6)$$

Weight coefficient of actual height of suspension hoisting rope.

$$\beta_H = \frac{npH_0}{Q_N} = \frac{1+\beta_z(h_0)}{1-h_0} = \frac{ch_0}{c-1} \quad (7)$$

Weight coefficient of load-free vessel side.

$$\beta_0 = \frac{Q_z + npH_0}{Q_N} = \frac{\beta_z + h_0}{1-h_0} = \frac{1}{c-1} \quad (8)$$

Weight coefficient of full load vessel side.

$$\beta_m = \frac{Q_N + Q_z + npH_0}{Q_N} = \frac{1+\beta_z}{1-h_0} = \frac{c}{c-1} \quad (9)$$

Coefficient of the summated weight of both sides when one side is load-free and another is full load.

$$\beta_{0m} = \frac{Q_N + 2(Q_z + npH_0)}{Q_N} = \frac{c+1}{c-1} \quad (10)$$

Coefficient of the summated weight of both sides when both sides are load-free.

$$\beta_{00} = \frac{2(Q_z + npH_0)}{Q_N} = \frac{2}{c-1} \quad (11)$$

Coefficient of the summated weight of both sides when both sides are full load.

$$\beta_{mm} = \frac{2(Q_N + Q_z + npH_0)}{Q_N} = \frac{2c}{c-1} \quad (12)$$

It is revealed by equation (5)~(12) that each coefficient is inversely proportional to c-1, and the value of β_L, p^{*}, β_H are all equal. In addition, each coefficient is a function of single variable c with an except that β_z and β_H are functions of c and h_0.

4. Parameters in Various Forms

Since the static tension ratio c is the ratio of static tension of two sides of friction wheel, functions of c can be converted into functions of T_1 and T_2.

Symbols of dimensionless relative parameters of system components and its relationship with actual parameters, other dimensionless relative parameters, static tension ratio c and static tension T are listed in the table bellow.

Table 1. Parameters and Its Various Forms of Friction Hoist Components

No.	Symbol	Actual parameters	relative parameters	C function	T function
1	β_z	$\frac{Q_Z}{Q_N}$	β_z	$\frac{1-ch_0}{c-1}$	$\frac{T_2-T_1h_0}{T_1-T_2}$
2	β_H	$\frac{npH_0}{Q_N}$	$\frac{(1+\beta_Z)h_0}{1-h_0}$	$\frac{ch_0}{c-1}$	$\frac{T_1h_0}{T_1-T_2}$
3	β_L	$\frac{npL_0}{Q_N}$	$\frac{1+\beta_Z}{1-h_0}$	$\frac{c}{c-1}$	$\frac{T_1}{T_1-T_2}$
4	p^*	$\frac{p}{Q_N/nL_0}$	Ditto	Ditto	Ditto
5	β_m	$\frac{Q_N+Q_Z+npH_0}{Q_N}$	Ditto	Ditto	Ditto
6	β_O	$\frac{Q_Z+npH_0}{Q_N}$	$\frac{\beta_Z+h_0}{1-h_0}$	$\frac{1}{c-1}$	$\frac{T_2}{T_1-T_2}$
7	β_{OO}	$\frac{2(Q_Z+npH_0)}{Q_N}$	$\frac{2(\beta_Z+h_0)}{1-h_0}$	$\frac{2}{c-1}$	$\frac{2T_2}{T_1-T_2}$
8	β_{mm}	$\frac{2(Q_N+Q_Z+npH_0)}{Q_N}$	$\frac{2(1+h_0)}{1-h_0}$	$\frac{2c}{c-1}$	$\frac{2T_1}{T_1-T_2}$
9	β_{Om}	$\frac{Q_N+2(Q_Z+npH_0)}{Q_N}$	$\frac{1+2\beta_Z+h_0}{1-h_0}$	$\frac{c+1}{c-1}$	$\frac{T_1+T_2}{T_1-T_2}$

As is shown in Table 1, each parameter of system components can be expressed in four forms. They are the form of actual value, the form of dimensionless relative value, functions of static tension ratio c and functions of static tension of the hoisting rope. Each of the four has its unique feature and value.

(1) Actual value parameters: Intuitive, easy to understand and master.

(2) Dimensionless relative value: Abstract, it can simplify the calculation; significantly, truths and rules in the problem can easily be revealed and theorized.

(3) The c function: Using static tension ratio c in calculation without the need of anti-skid checking calculation, it can make the optimization and dispatch of the system more valid, sound and reasonable.

(4) The static tension T function: Mainly used in the checking calculation, safety inspection and equipment testing of the hoist system before application.

Once the minimum weight of load-free side is measured, numerous other parameters are determined as well.

5 Conclusion

At present, in friction hoist engineering, system components and its parameters are usually pre-selected and then checked by calculation whether or not the pre-selected components and its parameters comply with the anti-skid safety regulations. If not, the related components and its parameters should be adjusted and checked over again by calculation. Only when all of the anti-skid safety regulations are satisfied can the parameters be finally determined. This is the so-called heuristic algorithm, which can not be avoided in engineering using actual parameters.

(1) In order to avoid the shortcoming and facilitate the design in friction hoist system, static tension ratio c was directly brought into the calculation in dimensionless relative parameters. As a result, parameter value figured out by this means fits the anti-skid safety regulations very well.

(2) Four forms of component parameters are offered in the paper to facilitate the design in engineer. Each has its unique feature and value. They can also be converted into each other, making the design and calculation more convenient.

(3) It is revealed by table I that the quality of system component increases as the height of suspend hoisting rope increases, decreases as static tension ratio increases, and decreases as the tension margin of two sides of friction wheel increases.

Acknowledgements

This research is sponsored by the "National Nature Science Foundation of China" (numbered 51264036, and 61362030).

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