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Research on the Optimal Strategy of "Working Together with One Heart" Project

Jing Cong*

Basic Department of Liaoning Institute of Science and Technology, Benxi 117000, Liaoning Province, China

***Corresponding author:** Jing Cong, congjing_2003@163.com

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Abstract: The "Working Together with One Heart" project, also known as the "One Heart Drum" project, is a collaboration skill development project, which assesses the collaboration skills of its team members. In this paper, the method of combining actual problems with physical model analysis is used to determine the influence of different factors in the project operation, and a geometric analysis model is also established. Through MATLAB simulation and assignment operation, the optimal strategy of the project is finally obtained.

Keywords: "Working Together with One Heart" project; Conservation of momentum; Geometric model; Kinetic energy theorem

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1. Introduction

The "Working Together with One Heart" project is a collaboration skill development project, which mainly assesses the team members' collaboration skills, enhances the sense of collective participation, and intensify the cohesion as a team [1]. The weight of the volleyball used is 270 grams. The diameter of the drum head is 40 centimeters, the height of the drum body is 22 centimeters, and the weight of the drum is 3.6 kilograms. The number of players should not be less than 8 people, and the minimum distance between each player should not be less than 60 centimeters. The project begins with the ball falling vertically from 40 centimeters above the drum head. The height at which the ball is pitched should be more than 40 centimeters away from the drum surface. If it is less than 40 centimeters, the project will stop. The goal of this project is to make as many consecutive attempts as possible. The team's optimal collaboration strategy under the ideal situation where everyone can precisely control the direction, timing, and magnitude of the force is first studied to determine the pitching height under this strategy. In reality, the test is carried out under the condition that the number of players is eight and the length of the rope is 1.7 meters. A model is established to represent the relationship between the timing and strength of the players and the inclination angle of the drum head at a certain moment based on the different timing and force data of the nine groups of players recorded in the experiment [2-3].

2. Research principles and methods

In order to obtain the optimal strategy of the project, the method of combining practical problems with physical model analysis [4] is adopted to determine the influence of different factors in the operation of the project. Meanwhile, a geometric analysis model is established, and mathematical verifications are carried out. The concentric drum model is analyzed, and the movement process after the ball falls and hits the drum

head as well as when the team pulls the rope to form a resultant force that makes the ball rise again is also analyzed. Through MATLAB simulation and assignment operation, along with the help of relevant knowledge, such as momentum conservation, kinetic energy theorem, acceleration, and free fall, the optimal strategy is finally obtained.

3. Establishing the optimal strategy of "Working Together with One Heart" project

3.1. Situation 1: Everyone has precise control over the direction, timing, and magnitude of the force

In establishing the optimal strategy of the project [5], it is assumed that the number of people is *n*, the rope length is *l*, the distance of descend is *h*, and the force of each member is denoted as *F*. In an ideal state, the rope is pulled at the same time to establish a force analysis model.

As shown in **Figure 1**, from the free fall formula, the ball is falling 0.4 meters at a speed of V'. From $\mathrm{mg}h' = \frac{1}{2}mV'^2$, $V' = 2\sqrt{2}$ can be obtained. The resultant force in the vertical direction, $F_{\text{resultant}} = nF\sin\theta$. Knowing that $\sin\theta = \frac{h}{l}$, the kinetic energy in the vertical direction is $F_{\text{resultant}}\,\mathrm{h} = \frac{1}{2}MV_{\text{drum}}{}^2$; hence, $V_{\text{drum}} = \sqrt{\frac{nFh}{1.8l}}$ can be calculated. According to the conservation of momentum $\mathrm{M}V_{\text{drum}} - mV' = mV''$, $V'' = 13.3\sqrt{\frac{nFH^2}{1.8l}} - 2\sqrt{2}$ can be obtained. From the kinetic energy theorem, it is known that $mgH = \frac{1}{2}mV''^2$, so $H = \frac{4.9nFh^2}{l} + 0.4 - 2.9\sqrt{\frac{nFh^2}{l}}$.

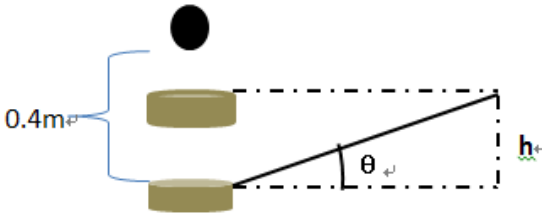

Figure 1. Schematic diagram of the motion system

After MATLAB simulation and assignment operation, the optimal strategy is finally obtained. If the condition of $n = 8$, $l = 1.64$, $h = 0.03$, $F = 80$, and $H = 40.17$ can be satisfied, the height of the ball can be reached. In the assignment operation model, it is required that the height of the ball is not less than 40 centimeters.

$$H = \frac{4.9nFh^2}{l} + 0.4 - 2.9\sqrt{\frac{nFh^2}{l}} \geq 0.4 \tag{1}$$

$\frac{\mathrm{nFh}^2}{\mathrm{l}} \leq 9.9405$ is obtained after arrangement. The number of people and the force of the players are assigned as $n = 8$ and $F = 80$. After calculation, the following can be obtained: $l = 1.64$, $h = 0.03$, and $H = 40.17$ cm.

3.2. Situation 2: Certain errors in the timing and force of the players

The number of players is set to 8, the rope length is 1.7 meters, the drum head is horizontally stationary at the initial moment, and the initial position is 11 centimeters lower than the position when the rope is horizontal. Knowing the length of the rope and the distance of fall from the initial position compared with

the position when the rope is horizontal, the position shown in **Figure 2** can be obtained.

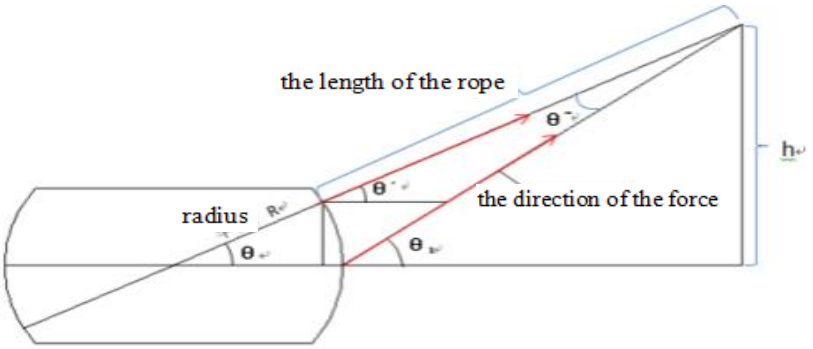

Figure 2. Force analysis model of concentric drum

$$\theta = \arcsin\left(\frac{1.1}{17}\right) \tag{2}$$

From the momentum theorem, the following can be obtained:

$$F_{\text{resultant}} \sin\theta\, t = Mv \tag{3}$$

The conservation of kinetic energy,

$$\triangle E_k = \frac{Mv^2}{2} - \text{Mgh} = 0 \tag{4}$$

In the first case, eight people exert force at the same time; the force of the first person is 90 N, while the force of the other seven people is 80 N. The drum is set to be lifted to h_1, and the time for the drum to work is $t = 0.1$ seconds. Bringing in $F_{1\,\text{resultant}} = 10$ N, the angle between the resultant force and the horizontal plane is $\theta_1 = 3.7^{\circ}$. From formulas (2), (3), and (4), the following can be obtained: $v_1 = \frac{1.1}{61.2}\text{m/s}$ and $h_1 = 1.61 \times 10^{-5}$m. From $\sin^{-1}\left(\frac{2h_1}{D}\right) = \theta_1$, $\theta_1 = 0.0047^{\circ}$ can be obtained.

In the second case, eight people exert force at the same time, but the force of the first and second person is 90 N, while the force of the other six people is 80 N. The drum is set to be lifted to h_2, and the time for the drum to work is $t = 0.1$ seconds. As shown in **Figure 3**, the angle between the two forces is $\frac{\pi}{4}$. The resultant force of the two forces is 18.50 N. The angle with the horizontal plane is $\theta_2 = 4.00^{\circ}$. Bringing in $F_{2\,\text{resultant}} = 18.5$ N, the angle between the resultant force and the horizontal plane is $\theta_2 = 4.00^{\circ}$. From formulas (2), (3), and (4), the following can be obtained: $v_2 = 0.358\text{m/s}$ and $h_2 = 6.41 \times 10^{-5}$m. From $\theta_3 = \arcsin\left(\frac{2h_2}{D}\right)$, $\theta_3 = 1.8361°$ can be obtained.

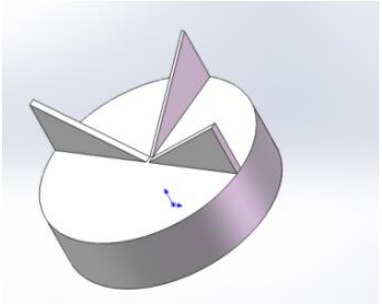

Figure 3. 3D stereo view

In the third case, eight people exert force at the same time, but the force of the first and fourth person is 90 N, while the force of the other six people is 80N. The drum is set to be lifted to h_3, and the time for the drum to work is $t = 0.1$ seconds. The angle between the two forces is $\frac{3\pi}{4}$. The resultant force of the two forces is 7.65 N. The angle with the horizontal plane is $\theta_4 = 9.64^{\circ}$. From the formulas, the following can be obtained: $v_3 = 0.0365\ \mathrm{m/s}$ and $h_3 = 6.33 \times 10^{-5}\mathrm{m}$. From $\sin^{-1}\frac{2h_3}{D} = \theta_5$, $\theta_5 = 0.018°$ can be obtained.

In the fourth case, the first person lifts the drum 0.1 seconds in advance with a force of 80 N, while the other seven people exert force at the same time, in which the force is 80 N. The drum is set to be lifted to h_4, and the time for the drum to work is $t = 0.1$ s. Bringing in $F_{4\ \mathrm{resultant}} = 80\mathrm{N}$, the angle between the resultant force and the horizontal plane is $\theta_1 = 3.7^{\circ}$. From the formulas, the following can be obtained: $v_4 = 0.1434\ \mathrm{m/s}$ and $h_4 = 1.02 \times 10^{-3}$ m. From $\sin^{-1}\frac{2h_4}{D} = \theta_6$, $\theta_6 = 0.295°$ can be obtained.

In the fifth case, the first person and the second person lift the drum 0.1 seconds in advance with a force of 80 N, while the other six people exert force at the same time, in which the force is 80 N. The drum is set to be lifted to h_5, and the time for the drum to work is $t = 0.1$ s. The angle between the two forces is $\frac{\pi}{4}$. Bringing in $F_{5\ \mathrm{resultant}} = 147.82$ N, the angle between the resultant force and the horizontal plane is $\theta_3 = 4.00^{\circ}$. From the formulas, the following can be obtained: $v_5 = 0.286\mathrm{m/s}$ and $h_5 = 4.10 \times 10^{-3}\mathrm{m}$. From $\sin^{-1}\frac{2h_5}{D} = \theta_7$, $\theta_7 = 1.175°$ can be obtained.

In the sixth case, the first person and the fourth person lift the drum 0.1 seconds in advance with a force of 80 N, while the other six people exert force at the same time, in which the force is 80 N. The drum is set to be lifted to h_6, and the time for the drum to work is $t = 0.1$ s. The angle between the two forces is $\frac{3\pi}{4}$, and $F_{6\ \mathrm{resultant}} = 61.23$ N. The angle between the resultant force and the horizontal plane is $\theta_3 = 4.00^{\circ}$. From the formulas, the following can be obtained: $v_6 = 0.119\mathrm{m/s}$ and $h_6 = 7.04 \times 10^{-4}$ m. From $\sin^{-1}\frac{2\mathrm{h}_6}{\mathrm{D}} = \theta_8$, $\theta_8 = 0.202°$ can be obtained.

In the seventh case, the first person lifts the drum 0.1 seconds in advance with a force of 90 N, while the other seven people exert force at the same time, in which the force is 80 N. The drum is set to be lifted to h_7, and the time for the drum to work is $t = 0.1$ s. Bringing in $F_{7\ \mathrm{resultant}} = 90$ N, the angle between the resultant force and the horizontal plane is $\theta_1 = 3.70^{\circ}$. From formulas (2), (3), and (4), the following can be obtained: $v_7 = 0.161\ \mathrm{m/s}$ and $h_7 = 1.30 \times 10^{-3}\mathrm{m}$. From $\sin^{-1}\frac{2\mathrm{h}_7}{\mathrm{D}} = \theta_9$, $\theta_9 = 0.37°$ can be obtained.

In the eighth case, the second person and the fifth person lift the drum 0.1 seconds in advance with a force of 80 N, while the first person and the fourth person lift the drum with a force of 90 N at the same time as the remaining four people who use a force of 80 N to lift the drum. The drum is set to be lifted to h_8, and the time for the drum to work is $t = 0.1$ seconds. Bringing in $F_{8\ \mathrm{resultant}} = 66.859$ N, the angle between the two resultant forces and the horizontal plane is $\theta_4 = 4.00^{\circ}$. From formulas (2), (3), and (4), the following can be obtained: $v_8 = 0.467\ \mathrm{m/s}$ and $h_8 = 1.09 \times 10^{-3}$ m. From $\sin^{-1}\frac{2\mathrm{h}_8}{\mathrm{D}} = \theta_{10}$, $\theta_{10} = 3.12°$ can be obtained.

In the ninth case, the fifth person and the eighth person lift the drum 0.1 seconds in advance with a force of 80N, the first person and fourth person use a force of 90 N to lift the drum at the same time as the remaining four people who use a force of 80 N to lift the drum. The drum is set to be lifted to h_9, and the time for the drum to work is $t = 0.1$ s. Bringing in $F_{9\ \mathrm{resultant\ 1}} = 61.229$ N and $F_{9\ \mathrm{resultant\ 2}} = 7.65$ N, the angle between the two resultant forces and the horizontal plane is $\theta_4 = 9.64^{\circ}$. From formulas (2), (3), and (4), the following can be obtained: $v_9 = \frac{0.289\mathrm{m}}{\mathrm{s}}$, $h_9 = 4.05 \times 10^{-3}\mathrm{m}$, $v_{10} = 0.036\mathrm{m/s}$, and $h_{10} =$

1.27×10^{-3}m. From $\sin^{-1}\frac{2h_9}{D} = \theta_{11}$ and $\sin^{-1}\frac{2h_{10}}{D} = \theta_{12}$, $\theta_{11} = 1.16°$ and $\theta_{12} = 0.363°$ can be obtained. The angle of inclination is $\theta_{13} = \theta_{11} - \theta_{12} = 0.797°$.
All data for the above nine cases are shown in **Table 1**.

Table 1. Nine sets of data and the resulting drum head inclination

Order	Force parameter	1	2	3	4	5	6	7	8	Drum head inclination (degrees)
1	Time of using force	0	0	0	0	0	0	0	0	0.0047°
	Magnitude of the force	**90**	**0**	80	80	80	80	80	80	
2	Time of using force	0	0	0	0	0	0	0	0	1.836°
	Magnitude of the force	**90**	**90**	80	80	80	80	80	80	
3	Time of using force	0	0	0	0	0	0	0	0	0.018°
	Magnitude of the force	**90**	80	80	**90**	80	80	80	80	
4	Time of using force	**-0.1**	0	0	0	0	0	0	0	0.295°
	Magnitude of the force	80	80	80	80	80	80	80	80	
5	Time of using force	**-0.1**	**-0.1**	0	0	0	0	0	0	1.175°
	Magnitude of the force	80	80	80	80	80	80	80	80	
6	Time of using force	**-0.1**	0	0	**-0.1**	0	0	0	0	0.202°
	Magnitude of the force	80	80	80	80	80	80	80	80	
7	Time of using force	**-0.1**	0	0	0	0	0	0	0	0.369°
	Magnitude of the force	**90**	80	80	80	80	80	80	80	
8	Time of using force	0	**-0.1**	0	0	**-0.1**	0	0	0	3.120°
	Magnitude of the force	**90**	80	80	**90**	80	80	80	80	
9	Time of using force	0	0	0	0	**-0.1**	0	0	**-0.1**	0.797°
	Magnitude of the force	**90**	80	80	**90**	80	80	80	80	

4. Conclusion

A model is established to determine the relationship between the timing and strength of the players and the inclination angle of the drum head at a certain moment, in order to obtain the optimal strategy of "Working Together with One Heart" project.

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Disclosure statement

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