A Double Deck Beef Cattle Special Trailer with Hydraulic Tailboard

Miao-sen WANG, Hong-mei ZHANG, Yan-yan FAN, and Wan-zhang WANG

College of Mechanical and Electrical Engineering, Henan Agricultural University, Henan Zhengzhou 450002, China

*Corresponding author

Keywords: Beef cattle, Stress syndrome, Trailer, Tailboard.

Abstract. It is the China production pattern that beef cattle bred north and then were transported down south for growing up. With the lack of transport vehicles for beef cattle, they have to suffer much from rugged environments during the long-distance transportation. Jarring and scaring vehicles, shortages of drinking and other such unfavorable factors make cattle in vehicles develop the symptom of physiological stress, so-called transport stress syndrome of beef cattle (TSSBC), and even die, causing huge economic losses to animal husbandry enterprises. This paper raises a goose-neck double-deck enclosed semi-trailer with the length of 13m special for beef cattle based on investigates on animal transportation technologies domestic and abroad. Fans and blinds were set in both sides of the wagon box to air the room, while power-driven scaling tarpaulin on the top functions to protect beef cattle inside from sunshine and rain. And more, innovative design of the vertical lifting and falling hydraulic tailboard make it easy to achieve independently loading and unloading of beef cattle free from more help.

Introduction

The cattle breeding industry has a long history in China. In recent ten years, beef industry has developed rapidly, being a sun-rising industry after the dairy industry. The northeast, northwest and Inner Mongolia areas, have some natural breeding advantages, with rich forage grass resources. Feeder cattle are transported to some areas of the south to breed or slaughter [1]. A great demand for beef and abundant forage resources in south, made the breeding pattern that the cattle transported from north to south, and feed in south. At present, a special cattle transport vehicles is needed during the long-distance transportation. Ordinary van semi-trailer was mostly used in existing transportation with the simple structure and shabby environment. During transportation, especially in long-distance, cattle will appear physiological stress response, even death, namely TSSBC[2], due to the scare, crash, lack of drinking and feeding and some other factors. Drug prophylaxis is not the key solution. According to the data, during the long-distance transportation, morbidity of cattle can be up to 60% and the mortality rate was about 15%, causing huge economic losses. We combined animal transportation technology abroad with national conditions. A double deck special trailer for beef cattle was designed[3].

Double Deck Beef Cattle Special Trailer Design

Double deck beef cattle special trailer uses the goose-neck semi-trailer with the length of 13m. In order to increase the number of beef cattle, the wagon box is divided into two layers by the clapboard. There are inner fences in each layer along the wagon box. Fence gate and feeding door are installed in the inner fence. Water buckets are fixed in the wagon box by the bucket frame, so the cattle can easily drink and feed. There are air fans and shutters on both sides of the fence or on the inner fence for ventilation. There is a wagon gate on the side wall near the inner fence. Between the inner fence and the sidewall are hinged amount of cross fences which are away from the inner fence. Beef cattle are divided into three batches by cross fences, so the stampede and crowding can be avoided. There is a
vertical lifting tailboard at the tail of the wagon box and the power-driven scaling tarpaulin is installed at the top of the wagon box. Power-driven scaling tarpaulin design makes it easy to retract the tarpaulin. It will save a lot of time and effort, and also can protect cattle from sun and rain. The Figure 1 shows the structure of double special trailer for beef cattle.

The overall dimensions is designed into 13000×2500×4000mm, which is based on GB1589 “Off road vehicles-outside dimensions, axle load and quality limit”[4]. The average length of adult cattle is 2.3m while the width of the double special trailer is 2.5m. It can meet the requirements of the design. There is a ladder on the inner fence additionally. The operator can enter the second layer through the ladder. The purpose of the feeding door is that the beef cattle can be watered and fed during the transportation. And it allows people to come in to monitor the transportation situation and the physiological conditions of the beef cattle easily. Therefore, the feeding door is designed two-door structure. Figure 2 is the double deck beef cattle trailer prototype.

**Deck Design**

Deck of the trailer is directly related to the height of beef cattle, an investigation was done for 86 calves, 103 feeder cattle, 120 adult cattle on the height and weight. According to the measurement and record of height and weight, the statistical distribution histograms about three kinds of beef cattle are showed in Figure 3 and Figure 4.
Statistical data show that the average heights of calves, feeder cattle and adult cattle are 80.32cm, 118.76cm and 142.04cm, the average weights are 54.13kg, 202.35kg and 324.09kg.

The beef cattle special trailer can be used to transport calves, feeder cattle and adult cattle. The height of goose-neck type semi-trailer is 4m, the distance between chassis and ground is 1.3m and the interior surplus height of the trailer is about 2.7m. According to the average height, the stories of the trailer can be designed into two schemes. First scheme, both decks can be used for feeder cattle. The average interior height of the trailer is 1.3m. Second scheme, considering the position of the center of gravity of the trailer, the lower deck is used for adult cattle and the upper deck is used for calves, with the lower deck 1.5m and upper deck 1.1m. The partition of the beef cattle special trailer should be designed into a movable partition to be adjusted between two positions.

**Design for Animal Welfare**

In the wagon box, a fan is installed on each deck and fixed to the inner fence with discharge of 180m³/h. The shutters should be designed to shade the light and keep air circulating[5]. The position of shutters should be installed above the cattle with the shutters outside the wagon box tilt up and leaf inside the wagon box tilt up. Beef cattle would crash and climb in the wagon box, and resulting in bruises. In order to reduce or eliminate such hazards, the wagon box can be divided into three columns in length. The inner fence can rotate and remove with the rotation angle of 180 degrees. The water supply system should be installed in front of the under-body to meet the water consumption in the transportation process[6]. The water supply system consists of water tank, pipe, water valve, water bucket and drinking bucket frame. The power comes from the trailer, the air pressure provides power, pressure through the water tank and water valve can release at any time. Rubber carpet with thickness of 2cm can be placed on two decks in the wagon box, for it is non slip, and easy to clean[7].

**Vertical Lifting and Falling Hydraulic Tailboard Design**

In order to realize the beef cattle handling and satisfy the transport demand of the small cattle farm, vertical lifting and falling tailboard was designed on the back of beef cattle trailer[8]. Control unit of hydraulic tailboard was located at the back side of the cab, making it easy to observe the case of beef
cattle handling. Animal electronic scale was set on the tailboard and its accuracy could be achieved Kg level[9]. It can realize the weighing of the beef cattle and collect the beef cattle easily along the way.

The vertical lifting and falling tailboard of double deck beef cattle special trailer mainly consists of a vertical guide rail fixed on the back of the trailer and a lifting column moving along the guide rail which was droved by the hydraulic cylinder. Lifting column was hung to the double-layer tailboard horizontally. Several electronic scale sensors were set on the two layers. Closing hydraulic cylinder driving the tailboard opening and closing was set between the tailboard and the lifting column. Guardrail with rollover fold structure was set on the tailboard, which consisted of left and right guardrail hinged on the tailboard symmetrically. Overturn guardrail were articulated to the ends of the left and right guardrail. Active connection pin was set between adjacent overturn guardrails. Positioning pin was set between each overturn guardrail and tailboard.

Lifting hydraulic cylinder was set on the frame horizontally. Piston rod of hydraulic cylinder connected with a lifting column through the ropes and pulleys[10]. Figure 5 is the structure of vertical lifting and falling tailboard.

![Figure 5. Vertically lifting and falling tailboard structure.](image)

There were four working positions in beef cattle loading and unloading, which was shown in Figure 5. The first position was on the ground A, In the process of loading cattle, people can drive the beef to the tail board. In the process of unloading cattle, beef cattle were unloaded. In the second position B, in the process of loading cattle, people can drive the beef cattle to the first layer of the carriage. In the process of unloading cattle, people can unload the first layer’s cattle. In the process of loading cattle, people can drive the beef cattle to the second layer of the carriage in the third position C. In the process of unloading cattle, people can unload the second layer’s cattle. In the fourth position D, the tail plate was closed and vertical on the tail of the car.

Hydraulic system of vertical lifting and falling tailboard was shown in Figure 6. The working process was as follows. Gear motor drove the hydraulic pump 1 and supplied hydraulic oil. Three position six-way valve 2 and 3 controlled closed hydraulic cylinder 4 and 5 and lift hydraulic cylinder 6. Pressure relief valve 7 ensured that the pressure in the hydraulic circuit was not more than the normal working pressure. A pair of pilot operated check values were used to achieve brake locking of hydraulic cylinder in different positions[11].
In order to calculate beef cattle loading efficiency, the loading ability and the time were necessary. Vertical lifting platform loading time depended on the lifting ability and loading time of hydraulic cylinder. Lifting hydraulic cylinder lifting time \( t \) was as follows.

\[
  t = \frac{H}{v}
\]

where: \( H \) is hoisting height of tail plate.
\( v \) is hoisting velocity of hydraulic cylinder.

Hydraulic cylinder flow \( Q_1 = vA \) was equaled to hydraulic pump flow \( Q_2 = \frac{Q\omega}{60} \).

\[
  v = \frac{Q\omega}{60A}
\]

where: \( A \) is effective area.
\( Q \) is hydraulic pump displacement.
\( \omega \) is hydraulic pump speed.

\[
  t = \frac{60HA}{Q\omega}
\]

where: \( A \) is 78.5cm\(^2\), \( \omega \) is 2500r/min, \( Q \) is 3.3cm\(^3\)/r.

Conclusions were realized from the calculation. The time when lifting hydraulic cylinder lifting to the first layer was 37s. The second layers were 111s or 124s with the same principle. The computational time was equal to the actual time, which met the design requirements. Numbers of once loading formula as follows.

\[
  N = (F_{\text{max}} - Mg)/mg
\]

where: \( F_{\text{max}} \) is the max lifting force of hydraulic cylinder, \( 1.5 \times 10^4 \) N.
\( M \) is the quality of the tail plate, 450Kg.
\( M \) is the quality of calves, feeder cattle and adult cattle, 54.13kg, 202.35kg and 324.09kg.
\( g \) is the acceleration gravity, 9.8m/s\(^2\).

Therefore, about 3 adult cattle, 5 feeder cattle and 19 calves could be lifted in one times.
Conclusion and Discussion

Running tests of the trailer showed that the design solved the economic and convenient for transportation problem, reducing the occurrence of transport stress syndrome of beef cattle and economic losses. The double deck beef cattle trailer has the following features:

1) Fans and blinds can keep ventilation in the wagon box to improve the living environment of beef cattle. Feeding and drinking system can meet the needs of the feeding and drinking of cattle in transportation. Rubber carpet can play the role of nonslip. Cross fence design can avoid damage when beef cattle crash and climb.

2) The auto-scaling tarpaulin protects people from climbing up and down, Avoid the potentially dangerous of manual operation.

3) The tailboard was able to lift 3 adult cattle or 5 feeder cattle or and 19 calves once. It took about 40 seconds for the tailboard to lift to the first layer, about 120 seconds to the second layer. It realized whenever and wherever possible loading and weighing.

References


