Study on lifting operation of external heat extractor based on tubular balance beam

Chunying Hu¹,*, Zhuo Wang²

¹College of Engineering, Heilongjiang Bayi Agricultural University, Daqing 163319
²Daqing Oilfield Powerlift Limited Company, Daqing 163312, China

*Corresponding author: huchunying@byau.edu.cn

Abstract. As a kind of petrochemical catalytic cracking unit, the external heat extractor is one of the key factors restricting the production schedule and time limit. In order to realize the load balance of external heat extractor in the lifting process and avoid the adverse effect of impact force on catalytic cracking performance of large equipment, a method of lifting external heat extractor with tubular balance beam was proposed. At the same time, a kind of seamless steel tube balance beam is designed according to the characteristics of the balance beam and the working conditions of hoisting. Through the stress analysis of the external heat extractor and the strength calculation of the balance beam of seamless steel tube, the rope installation point of the balance beam and the section position of the balance beam are determined, which can provide the theoretical basis and reference value for the failure analysis of large-scale lifting operations and the lifting operations of similar external heat extractor.

1. Introduction

External heat extractor is a kind of catalytic cracking unit widely used in petrochemical industry, which can be divided into up-flow external heat extractor, down-flow external heat extractor and gas-controlled external heat extractor according to different gas modes. In this device, multiple groups of tube bundles are connected to the regenerator, and the catalytic particles are vulcanized through the regenerator into the external heat extractor to conduct contact heat exchange with the tube bundles, and then return to the regenerator after the temperature is reduced. The external heat extractor can effectively regulate the catalytic temperature and the heat balance inside the intervention device, so as to realize the ideal ratio of agent to oil in the catalytic process. Once the external heat extractor fails, which seriously reduces the production efficiency and prolongs the manufacturing cycle, the lifting operation must be carried out effectively so as to facilitate the orderly work and process. The structure parameters and mechanical properties of the balance beam in the large lifting process of the type of external heat extractor are analyzed with the size of 2600mm in diameter, 19100mm in length and weight of 83.3t (core and head are 27.3t and shell is 56t).

2. Determination of balance beam

As an important structure of lifting machine, balance beam is used in large lifting. It can not only ensure the balance of the forces of the equipment being lifted, but also reduce the impact of horizontal pressure on the equipment during lifting. Especially in the working condition of multi-machine lifting, the
balance beam is used to reasonably distribute or balance the load action of each lifting point in the device, so as to avoid the impact damage caused by unbalanced force of equipment in lifting. Therefore, the balance beam is the most widely used device in lifting engineering [1].

According to different structural forms, the balance beam can be divided into round wood, square wood, section steel and seamless steel tube, etc. At present, the balance beam used in different hoisting operations has different characteristics. The tubular balance beam is welded with seamless steel tube, lifting lug, reinforcement plate, etc., and is mainly used for hoisting pipe row, steel structural parts and small and medium-sized equipment [2]. Steel plate balance beam is mostly processed on site and made locally. The thickness of steel plate is determined according to the weight of the equipment. It has the characteristics of wide adaptability and strong manufacturing flexibility. Channel steel type balance beam consists of channel steel, lifting ring plate, lifting lug, reinforcing plate and bolt. Its feature is that the lifting point of the partial board can be moved forward and backward, and the lifting point can be selected according to the weight and size of the equipment, which is easy to use, safe and reliable. Truss type balance beam by various steel, hanging ring plate, lifting lug, truss shaft, beam and so on welded. When the extended distance of the lifting point is larger than some numerical range, the truss balance beam is used to increase the stiffness of the operation. During installation and construction, the type of balance beam is usually determined according to the weight, length and special structural requirements of the equipment. After site investigation and actual measurement, the external heat extractor of LR1550 crawler crane was used for removal and installation. Lift and dismantle the tube bundle and shell respectively according to the procedure, then lift and place the shell of the new external heat extractor, set up the catalyst outlet, inlet and flue gas return port, lift and install the new external heat extractor tube bundle after welding. In order to ensure the perpendicularity of the external heat extractor and create convenient conditions for the counterpart, the lifting operation was carried out by using the tubular balance beam in combination with the lifting equipment and field conditions.

The tubular balance beam is composed of seamless steel tube, steel structure and small and medium-sized parts [3]. Among them, the joint use of seamless steel tube balance beam and other lifting equipment is not only conducive to reducing the height of the sling and balancing the lifting equipment, but also can reduce or eliminate the pressure of the sling on the equipment during lifting, which can adopt the form of seamless steel tube balance beam for lifting operations. Its structure is shown in figure 1, which is composed of seamless steel tube, reinforcing plate, lifting lug and so on.

![Fig 1. structural diagram of balanced beam of seamless steel tube](image)

3. Design of tubular balance beam
The balance beam is one of the important tools in hoisting operation. Considering that the processed balance beam will be reused in different large-scale hoisting, proper modification of the weight parameters of the hoisting object can effectively increase the bearing capacity of the tubular balance beam, and at the same time, extend the service life of the tubular balance beam and expand its applicable scope [4-6].
Considering the weight factors of lifting heavy objects, the number of fixed wire rope clasp rings is determined to be four in the design of tubular balance beam. After preliminary calculation, the weight of the clamping ring is 60 tons, and the current 60 tons of clamping ring on the market belongs to the type of uncommon clamping ring, which is also uncommon in the installation and construction unit. Combined with the actual situation, in order to avoid the difficulties in the procurement of accessories and delay the construction period and increase the production cost, the structure of the designed seamless steel tube balance beam was modified, four clamps and lifting lugs were removed and the baffle of the tubular balance beam was changed, as shown in figure 2 is the structural schematic diagram of the seamless steel tube balance beam.

![Diagram of balance beam](image)

**Fig 2. balance beam of seamless steel tube**

The preliminary determination of the structural parameters of the tubular balance beam facilitates the mechanical analysis of the hoisting process. The tension and durability of the steel wire rope determine the lifting effect and service life of the seamless steel tube balance beam. The lifting weight is 120 tons, which makes the scope of application of the balance beam expand. The wire rope adopts active connection, which can replace the wire rope specifications according to the weight of the hoisting object, increase the design flexibility, and enhance the versatility and permanence of the balance beam in the hoisting operation. According to the weight of condole outfit, if use single steel wire rope to serve as condole rope, criterion steel wire rope can be too thick, increase job difficulty, use 2 steel wire rope so both ends, bend to wrap 4 to use clip loop connection, convenient job, can avoid at the same time condole outfit is lifted because of steel wire rope is stuck happening when landing accident.

4. Mechanical analysis of tubular balance beam

The external heat extractor of the tubular balance beam is installed in a double-branch way. In particular, the weight of the external heat extractor is Q=120t, and the stress analysis of the balance beam is carried out according to the external heat extractor and the double-branch hoisting rope, as shown in figure 3. The strength of the balance beam and the diameter of the wire rope of the balance beam rope are calculated according to the production requirements, and the section position of the balance beam is determined.
Fig 3. stress analysis of balance beam

The Angle between the branch tension $P_1$ and the balance beam is 60 degrees, and the lifting weight is 120 tons. The branch tension of the sling can be calculated by formula (1), i.e

$$P_1 = \frac{Q}{n} \times \frac{1}{\sin \beta} = 69.3 \text{ t}$$  \hspace{1cm} (1)

The safety factor of sling $K=6$, The breaking tension of the sling can be calculated according to the safety factor, namely

$$P = P_1 \times K = 415.8 \text{ t}$$  \hspace{1cm} (2)

The steel wire rope of $6 \times 37+1$, whose tensile strength is $170 \text{ kg/mm}^2$, diameter $d=47.5 \text{ mm}$, is made into sling with the steel wire rope of this specification, the steel wire rope on both sides is bent into 4 strands, and the joint is connected with 20t clamps.

According to the Angle between AB and BC, the horizontal component of the bifurcation tension $P_1$ is obtained as

$$P_2 = P_1 \times \sin 30^\circ = 34.65 \text{ t}$$  \hspace{1cm} (3)

Known to use the balance beam $\Phi 220 \times 9$ seamless steel pipe, steel tube geometric properties of the look-up table $F=59.695 \text{ cm}^2$, $i=7.46 \text{ cm}$, $L=320 \text{ cm}$

Calculate the length $L_1$ according to formula (4)

$$L_1 = u \times L$$  \hspace{1cm} (4)

Since the two ends of the balance beam are rotatable, take $u=1$, Therefore, $L_1 = u \times L = 320$

Slenderness ratio for

$$\lambda = \frac{L_1}{i} = 42.9$$  \hspace{1cm} (5)

Look-up table to $\psi = 0.89$
Consider the inequality coefficient \( k = 1.2 \), Calculated load \( P \) is

\[
P = K \times P_2 = 42 \text{ t}
\]  
(6)

Plug type

\[
\sigma = P / \psi F = 0.791 \text{ kg/cm}
\]  
(7)

\([\sigma] < 2\), Meet safe production conditions.

| Slenderness ratio \( \lambda \) | No. 2, 3, 4 steel | 16 Manganese steel | Cast iron | wood |
|--------------------------|-----------------|-------------------|---------|-----|
| 0                        | 1.00            | 1.00              | 1.00    | 1.00|
| 10                       | 0.99            | 0.98              | 0.97    | 0.99|
| 20                       | 0.97            | 0.95              | 0.91    | 0.97|
| 30                       | 0.95            | 0.92              | 0.81    | 0.93|
| 40                       | 0.92            | 0.89              | 0.69    | 0.87|
| 50                       | 0.89            | 0.84              | 0.57    | 0.80|
| 60                       | 0.86            | 0.78              | 0.44    | 0.71|
| 70                       | 0.81            | 0.71              | 0.34    | 0.60|
| 80                       | 0.75            | 0.63              | 0.26    | 0.48|
| 90                       | 0.69            | 0.54              | 0.20    | 0.38|
| 100                      | 0.60            | 0.46              | 0.16    | 0.31|
| 110                      | 0.52            | 0.39              | -       | 0.25|

5. Conclusion

Due to the use of the balance beam in the field hoisting of the external heat extractor, the clamping phenomenon between the wire rope and the equipment can be effectively avoided, and an effective construction condition is provided for the hand-over. Therefore, the lifting operation of large-scale external heat extractor device with tubular balance beam provides a theoretical basis for achieving good lifting effect, reducing the accident rate in the lifting process, realizing safe production, and also provides an application value for shortening the maintenance period and improving production efficiency in the process of production and maintenance.

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