STUDY ON STRUCTURE AND THERMAL ANALYSIS OF CSNS R BEAM DUMP

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Abstract

The China Spallation Neutron Source (CSNS) accelerator systems will provide a 1.6 Gev proton beam to a target for neutron production. Beam dump system is an important part of CSNS, and it is used to incept the waste beam. The beam dump system is composed with vacuum part and shielding part. For the design of shielding part, the material is steel at the centre and concrete outside, we must control the temperature of steel and concrete not too high, and it will be a serious problem that the concrete crazes because of the high temperature. So the thermal analyses must be done to ensure safety. Taking CSNS R dump for example, we use software to make model and analyze the thermal, then optimizing the result. According to the result, we control the work time and dimension of the beam to control the temperature of the iron and concrete. This article expatiate the study on the structure design and thermal analyses.

INTRODUCTION

There are four beam dumps in CSNS, the shielding inside the beam dump are steels and concrete outside. The shielding parts of beam dump are built in company with tunnel. Once emplaced completely, those steels will not be taken down and serviced forever. R-dump is the last one of the accelerator, it is designed to incept the scrap H+, the energy of the H+ is 1.6 Gev and the power is 7500 W.

STRUCTURE DESIGN

The shielding materials of the beam dump are steel and concrete, thinking over the manufacture ability and reducing the cumulate error, we adopt many steel plates which thickness are 200 mm to seal together, and the whole volume is 3.6 * 3.6 * 4 = 51.84 m³. Except the screw holes for hoist, those steel plates will not be machined again. Due to the precision of beam hole, we must think over the dimensions of steel plates, at the same time, the sheet steel metals are necessary to adjust the position of each steel plate.

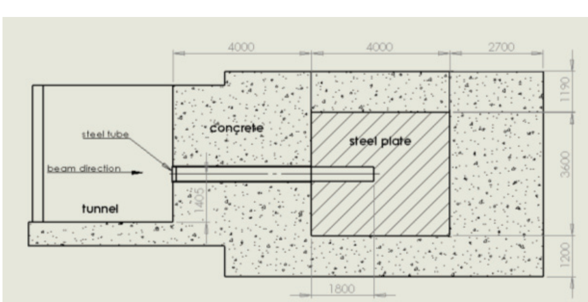

Figure 1: Cutaway view of the shielding part.

It is concrete outside of the beam dump, according to the demand of radiation dose, the concrete thickness is 4 meter at the front of beam and 2.7 meter at the under of beam, else thickness are 1.2 meter. The Fig.1 is the cutaway view of the beam dump.

THERMAL ANALYSIS

The thermal analysis is an important work at the design of beam dump. Because of the gauss distribution of beam, if the diameter of beam is smaller, the temperature at the centre of beam dump will be higher; if the diameter of beam is bigger, the temperature of the concrete will be higher too, so, we must make sure the temperature of concrete do not exceed 333 K, at the same time, it is better that the temperature of steel plates is lower. It is appropriate that the diameter of beam is 0.3 meter. We adopt ANSYS to analyze the thermal distribution of beam dump. Table 1 is the parameters of the materials.

Table 1: Material parameters

Material	Iron	Concrete	Air
Density(kg/m^3)	7800	2500	1.2
Specific heat(J/(kg*K))	460	800	1.4
Conductivity(W/(M*K))	43	1.2	0.03

Calculation about the Beam Energy Distribution

The beam energy is 1.6 Gev, the depth that beam can rip into the steel plates is about 1.08 meter, the energy deposit increases with incidence depth, and the relation is not linear, for easy to calculation, we make the relation of energy deposit and incidence depth to be linear. The two parameters should satisfy the nether equations:

$$\begin{cases} W_1 = k_1 Z_1 + a & 0 \le Z_1 \le 1.066m \\ W_2 = k_2 Z_2 + \mathrm{b} & 1.066 < Z_2 \le 1.08m \end{cases} . \quad (1)$$

In above equations, W1 and W2 are the deposit energy, their units are Watt; Z1 and Z2 are incidence depth, their units are meter. So,

$$\begin{cases} 0 = k_1 \times 0 + a \\ 1.066 \times k_1 + a = 1.066 \times k_2 + \mathrm{b} \\ \int_0^{1.066} (k_1 Z_1 + a) dz = 7030 \\ \int_{1.066}^{1.08} (k_2 Z_2 + b) dz = 470 \end{cases} \quad \begin{cases} a = 0 \\ b = -6589759 \\ k_1 = 12373 \\ k_2 = 393743631 \end{cases} . \quad (2)$$

The diameter of the beam is 0.3m; we can get the functions about energy distribution:

$$\begin{cases} G_1 = 788089 * z * \exp[-(x^2 + y^2)/0.005] \\ G_2 = (393743631 * z - 419729873) * \exp[-(x^2 + y^2)/0.005] \end{cases} \quad .(3)$$

$$\begin{matrix} 0 \le z \le 1.066m \\ 1.066 < z \le 1.08m \end{matrix} \quad . \qquad (4)$$

Thermal Analysis

We adopt ANSYS to analyze the temperature distribution of beam dump. We do the steady-state analysis firstly, after inputting the material parameters; we get the result showed in Fig.2. From the result we can see that the highest temperature is about 620.4 K, Fig.3 shows the temperature distribution of concrete, and the highest temperature is about 511.5 K, exceeding 333 K which we hope.

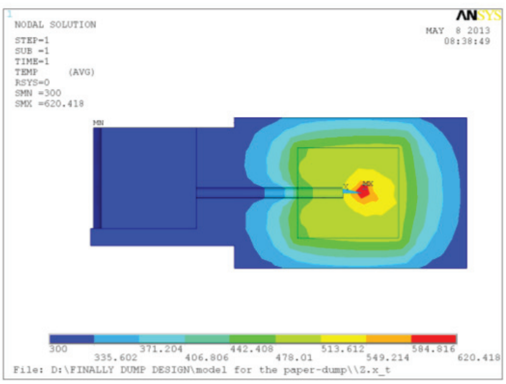

Figure 2: Result of steady-state analysis.

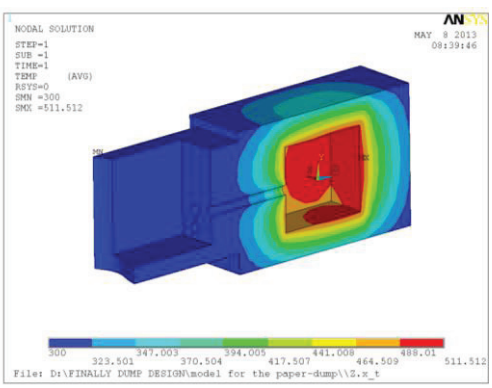

Figure 3: Temperature distribution of concrete.

Because of the concrete temperature too high, so, we do the transient analysis, the time is three days which we need; Fig.4 and Fig.5 show the results. From the results, we can see that the highest temperature of the beam dump is about 442 K, it is not high enough to thaw the steel plates; the highest temperature of the concrete is about 332 K, it just fulfils our request that below 333 K.

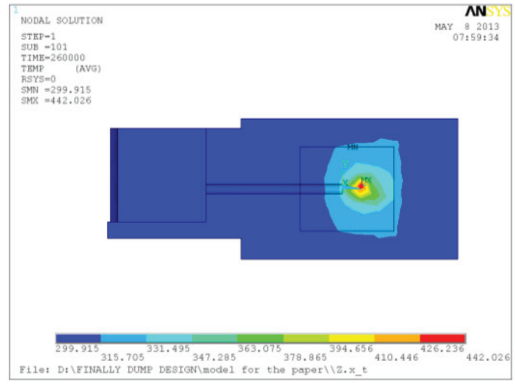

Figure 4: Result of transient analysis.

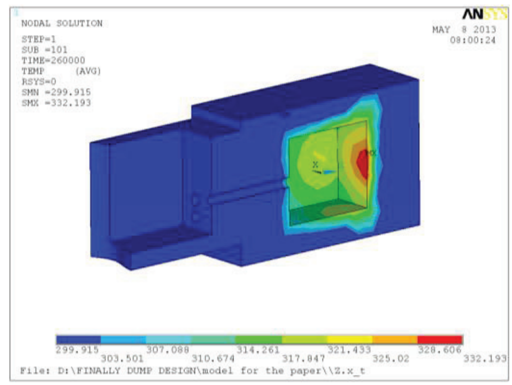

Figure 5: Temperature distribution of concrete.

CONCLUSION

This article studies the structure and thermal analysis of CSNS R beam dump. The beam energy is 1.6 Gev and the diameter is 0.3 meter, under the condition that continuing use time is not more than three days, the analysis results satisfy our request. According to the study, we know that lesser beam diameter also satisfy our request, we can adopt the same way to study.

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