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Paper No. 1293 **Safety Reviews of Transport Container of Radioactive Sources**

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## Abstract

Some radioactive sources are often used in irradiation industry and radiotherapy, such as co-60, cs-137, i -131 etc. Recently, the amount of radioactive sources transportation is large in china. The safety performance of radioactive material package must meet the requirements of “regulations for the safe transport of radioactive material” (GB11806-2004). According the requirements of GB11806-2004（the requirements of GB11806-2004 are same with the requirements of IAEA SSR6）, containers for radioactive sources transport should be demonstrated to be enough safety by test or simulation calculation methods. In this paper, safety reviews of one type of radioactive sources transport container are presented. Finite element analysis method is used to find the most several damage drop posture. Drop test of one kind of radioactive sources transport package has been conduct, some test results were obtained, such as the stress, acceleration. Both of the simulation results and tests results are used for safety performances reviews of this type of radioactive sources transport container is finally verified meeting the requirements of GB11806-2004. A discussion of how the test and finite element analyses were combined for the safety performance reviews of a type of package is given.

## Introduction

With the development of nuclear technology, more and more radioactive sources are used into the industry and medical. Recently, there are more than 200 large-scale xenon irradiation devices worldwide. In china, the amount of various types of irradiation devices is close to 200 [1]. Co-60 sources are often used as industrial radiation sealed radioactive source [2], and the activity of one single source will exceed 8000 curies. Due to need considering some other factors such as economic, the load activity of one transport container are used to be higher than ten thousand, even hundred thousand. Therefore the safety of radioactive sources transportation should be seriously concerned.

The state council “Regulations for radioactive substances transport safety” and the national standard “Regulations for the safe transport of radioactive material” provide the safety performance requirements for the transport of radioactive materials [3, 4]. The container for Class-I radioactive source transport, must pass the test of normal transportation conditions and transportation accident conditions, and whose safety performances must meet these safety performance requirements.

Drop test is one of the important tests to illustrating the safety performance of a type of package for the transport of radioactive sources meet the requirements of GB11806-2004. The safety performance analysis of package should be under the most several damage conditions according to the requirements of GB11806-2004. Drop test is often destructive, so finite element analysis method is a common method used to find the most several damage drop posture and saves time and cost. Recently, some finite element analysis codes are very mature, such as ABAQUS, ANSYS/LS-DYNA, ALGOR etc. [5-9]

**Container**

The steel-lead-steel structure style is adopt by the container (see Fig.1). The lead shielding layer is encircled by the steel structure material, and both lead and steel provide the shielding function. The container is comprised of the outer container and the inner container. The inner and outer shells of the outer container are made of 0Cr18Ni9 stainless steel, and the wood (damping function) and aluminum silicate fiber blanket (insulation function) are filled into the chamber of the outer container. The inner and outer shells of the inner container are 16MnDr stainless steel, and the chamber of inner container is filled with lead. The dimensions of the container are Φ1300mm×1200mm, and the total weight is about 4700kg.

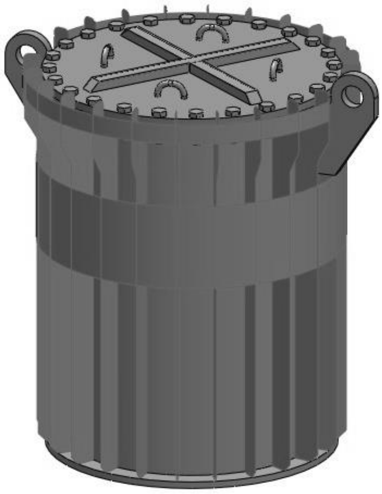

Fig.1 The schematic diagram of the container

**Finite Element Analysis of Drop Test-I**

Initial Input Conditions

Some components was ignored, which are not relevant to the problem under consideration, such as locating pin, the drain pipe, etc.. In order to ensure the accuracy of the calculation results and the computational efficiency, eight-node hexahedral linear solid elements and quadrilateral shell elements are adopt int the container model. Additionally, the ribs, stiffeners, and shock ring use shells elements. The model consists of 198957 nodes, 152402 units. Five drop attitudes, the top, the bottom, the side, the top corner and the bottom corner, are be selected (see Tab.2). The drop speed is 13.28 m/s and the ground is assumed to be rigid. In the calculation, the strain rate effect is considered in the metal materials parameters, inculding 0Cr18Ni9, 16MnDr and lead consider [10, 11], and these materials adopt the C-P model [12]. The mechanical properties of these materials used in the calculation are shown in Table 1.

Tab.1 The mechanical properties of materials

| Material / Mechanical properties | 16MnDr | wood | 0Cr18Ni9 | lead |
|---|---|---|---|---|
| Density (g/cm$^3$) | 7.85 | 0.62 | 7.85 | 11.37 |
| Yield strength (MPa) | 315 | 235 | 205 | 55 |
| Modulus of elasticity (GPa) | 202 | 1.42 | 199 | 14 |
| Poisson's ratio | 0.30 | 0.99 | 0.27 | 0.42 |

Tab.2 The drop attitudes of the finite element analysis of drop test-I

| No. | Drop Attitude | The States |
|---|---|---|
| 1 | The top corner | The hit position is at the top of the lifting lug, and the angle between the outer container axis and the target surface is 52.4 °, though the gravity center of container. |
| 2 | The Bottom corner | The angle between the outer container axis and the target surface is 53.7 °, though the gravity center of container. |
| 3 | The top surface | The top surface is parallel to the target surface. |
| 4 | The bottom surface | The bottom surface is parallel to the target surface. |
| 5 | The side surface | The side surface is parallel to the target surface. |

## Finite Element Calculation Results

The results of the finite element analysis of drop test-I are shown in Tab.3. and the top corner drop attitude is selected as the drop attitude of drop test-I, because under this drop attitude the container suffer the most severe damage.

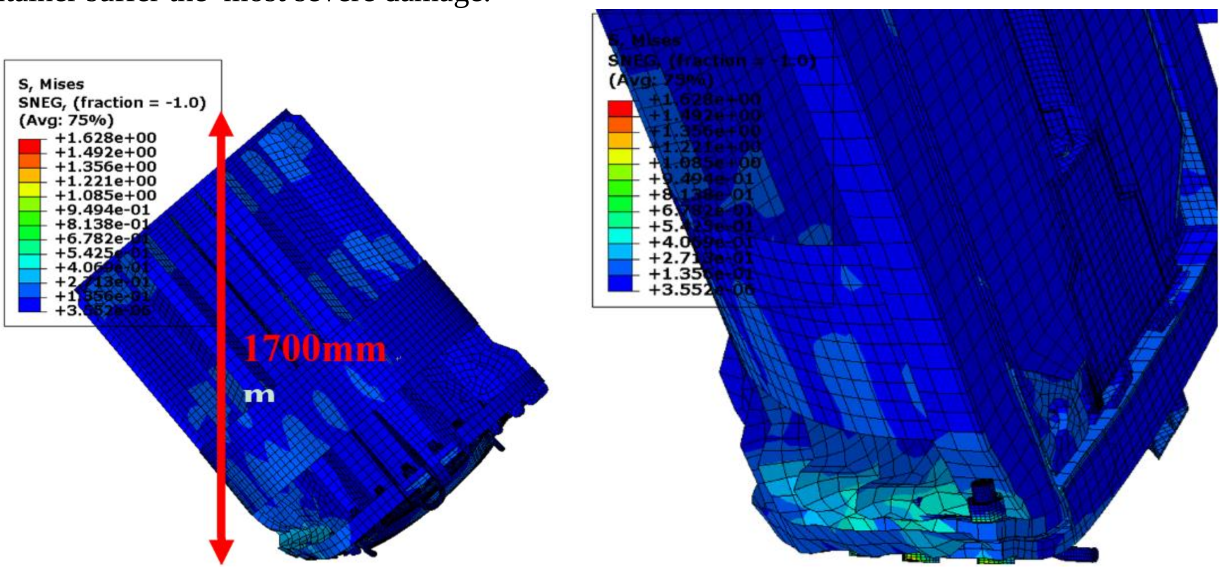


Fig.2 container top angle drop stress diagram

Tab.3 The results of the finite element analysis of drop test-I

| No. | Drop Attitude | The results |
|---|---|---|
| 1 | The top corner | The maximum stress of the inner container is 194 MPa, which occurs at the junction of inner container and the flange. The maximum plastic strain of the inner container occurs at the lifting lug of the outer casing, and the equivalent plastic strain is 0.133. The stress on the inner container bolt does not exceed the yield stress. The maximum acceleration of the inner container is 900g.Six ribs were severely deformed around the impact point, and the nuts of the five connecting bolts of the outer container were severely deformed. The maximum acceleration of the outer container is 450g. |
| 2 | The Bottom corner | The maximum stress of the container is 107.2 Mpa, which occurs at the junction of the inner container and the inner container flange. The maximum plastic strain of the inner container occurs at the impact point of the outer casing cylinder, and the maximum plastic strain is 0.0744. The stress on the inner container bolt does not exceed the yield stress. The maximum acceleration of the inner container is 950g. Severe buckling deformation occurred in the lower part of the reinforcing ring. The maximum acceleration of the outer container is 1000g. |
| 3 | The top | The maximum stress of the inner container is 152 MPa, which occurs at the |

| | | |
|---|---|---|
| | surface | junction of the inner container inner casing and the inner container flange. The maximum plastic strain of the inner container occurs at the lifting lug of the outer casing, and the maximum plastic strain is 0.0823. The stress on the inner container bolt does not exceed the yield stress. The inner containert has a maximum acceleration of 950g. The stress on the inner container bolt does not exceed the yield stress. The maximum acceleration of the inner container is 770g.The outer container impact area produces a large plastic deformation, and the three rib plates and the upper and lower reinforcing rings in the impact area are crushed and severely deformed. The maximum acceleration of the outer container is 1300g. |
| 4 | The bottom surface | The maximum stress of the inner container is 201.7 MPa, which occurs at the junction of the inner container and the inner container flange. The maximum plastic strain of the inner vessel occurs in the triangular region at the bottom end of the inner casing of the vessel, and the maximum plastic strain is 0.0767. The stress on the inner container bolt does not exceed the yield stress. The maximum acceleration of the inner container is 780g.The outer container impact area produces a large plastic deformation. The maximum acceleration of the outer container is 900g. |
| 5 | The side surface | The maximum stress of the inner container is 178 MPa, which occurs at the junction of the inner container inner casing and the inner container flange. The maximum plastic strain of the inner container occurs at the impact point of the outer casing cylinder, and the maximum plastic strain is 0.107. The stress on the inner container bolt does not exceed the yield stress. The maximum acceleration of the inner container is 1300g.The impact region is severely plastically deformed, and the top end of the rib plate contacts the ground and undergoes severe buckling deformation. The maximum acceleration of the outer container is 1700g. |

**Free Fall Test I Test**

The free fall test I test was carried out by using of drop test device of the China Radiation Protection Research Institute (CIRP). The device consists of the test target, the acceleration and strain measurement system and the deformation measurement system (see Fig.3). The total mass of the mechanical test target is about 130 tons, with the volume 3800mm ×3550mm ×3500mm.

The acceleration measurement positions are located on the surface of the outer container and the inner container(see Tab.4).

Fig.3 The drop test device of the China Radiation Protection Research Institute (CIRP)

Tab.4 The Acceleration point arrangement

| No. | Point Arrangement |
|---|---|
| 1 | outer container 0 °, 710mm from the bottom |
| 2 | The top surface of the outer container is 180 °, 250mm from the side |
| 3 | The upper edge of the cylinder of the inner container 0 °~270 °, 120mm from 0 °line |
| 4 | The upper edge of the cylinder of the inner 90 °~180 °, 130mm from 180 °line |

The results of the visual inspection and geometric measurement showed that only some paints of the inner container are removed from the bottom surface, and the range was less than 2 $cm^2$. The structure integrity and the shield integrity of the inner container are remained after the free fall test.

The flange is bent downward along the circumferential chord is about 60 cm lengt, and the maximum bending is about 6 cm, which is almost coincidence with the finite element calculation results. In addition, the five ribs of the outer container are distorted, and the middle three pieces are more severely deformed. The two upper sides are bent and buckled on the upper cover, which is almost coincidence with the finite element calculation results.

Four bolts were broken the outer container at the impact point, and the fracture surface was located under the nut. The nuts of the five connecting bolts of the outer container were severely deformed, which is almost coincidence with the finite element calculation results (see Fig. 4).

Fig.4 The state of the package after the test

The external radiation level of the container are detected after the test, and the results show that the outer radiation level of the package meets the relevant requirements of GB11806 (see Tab.5), indicating that the package remains intact after the free fall test.

Tab.5 The measurement results of the outer radiation level (μSv/h)

| Site / Results | 1m from the surface of container | | |
|---|---|---|---|
| | Side | Top | Down |
| The measurement results | 33.90 | 1.18 | 0.31 |
| The calculation results | 24.6 | 2.3 | 1 |
| The limit value of GB11806 | 10000 | | |

## Conclusion

In this paper, one type of radioacitve sources tansport container is review using the finite element analysis and the free fall test. The finite element analysis were carried out to determine the maximum damage drop posture for the package free fall test. The simulating results under different different drop postures show that the package can still maintain structural and shielding performance. Through free fall test and measurement, it is further proved that the structure and shielding performance of the package meet the standard requirements. At the same time, by analyzing the damage of the container, it can be seen that the test results and the calculation results are in good agreement. In this paper, the rationality and reliability of the finite element analysis mothed is verified, which can be used to guide the test and measurement work, saving the test cost and shortening the cycle of container safety review. One reference is expected for the development of radioactive material transport container safety review.

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