Drop Analysis of Waste Transfer Flask

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Abstract

The present paper describes the drop analyses performed on a waste transfer flask using LS-DYNA® finite element software. Radioactive waste generated during retubing of CANDU®6 reactors are placed in waste containers. Waste transfer flasks are used to transfer waste containers from the reactor building to storage structures. The waste transfer flask is a complex mechanical assembly made of double wall steel shells filled with lead.

At the storage area, the waste transfer flask is lifted by a crane to transfer the waste container to the storage structure. During lifting of the waste transfer flask, it is necessary to know the consequence of an unlikely drop event. Analyses have been performed to assess the structural response of the waste transfer flask subjected to impact loads due to various drop events resulting from lifting of the waste transfer flask at the storage area. The waste transfer flask is dropped by considering various orientations viz., dropping on edges, corners and base.

Based on the drop analysis the mode of failure and plastic deformation of various components of the waste transfer flask and the waste container is predicted. Also, an assessment is made regarding the structural integrity of the waste container and its retrievability after various drop events.

Introduction

The operating life of CANDU6 reactors are extended by retubing and refurbishment process. The retubing process involves replacement of pressure tubes, calandria tubes, calandria tube inserts, annulus spacers and end fittings. The radioactive wastes generated during retubing process are filled in waste containers and transported to the waste storage area using waste transfer flasks and then placed inside the storage structures.

The purpose of the waste containers is to confine and to facilitate transfer and storage of the radioactive wastes in the storage structures. The waste containers provide the first confinement barrier for the radioactive waste.

The waste transfer flasks are used to provide shielding and facilitate transfer of the waste containers filled with radioactive waste to the storage area. The waste transfer flask is constructed of double-wall steel shells filled with lead and has the capacity to hold one waste container.

Drop Requirements

At the storage area, the waste transfer flask is lifted by a crane to transfer the waste container to the storage structure. During lifting of the waste transfer flask, it is necessary to know the consequence of an unlikely drop event. The waste transfer flask is expected to absorb impact load due to drop event such that the waste container maintains its structural integrity and can be retrieved after the drop event. The structural integrity is assessed based on the plastic strain induced and the retrievability of waste container is assessed based on the relative permanent deformation between the flask and the waste container. The details of waste transfer flask with waste container inside are shown in Figure 1.

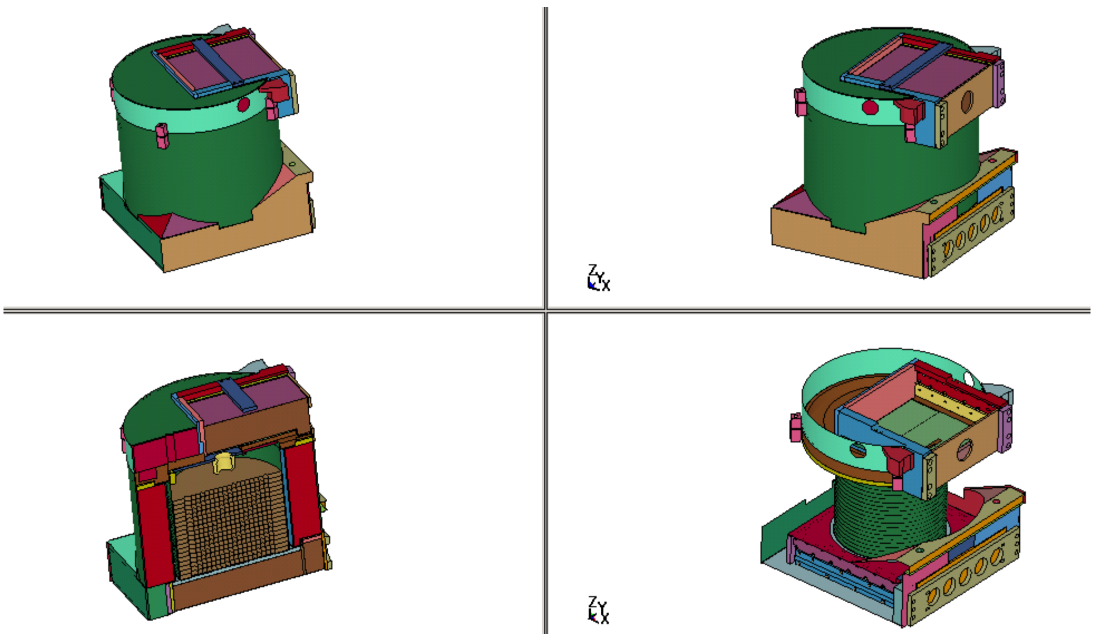

Figure 1: Details of Waste Transfer Flask

Drop Scenarios

Analyses have been performed using LS-DYNA® to assess the structural response of the waste transfer flask subjected to an impact load due to various drop events resulting from lifting of waste transfer flask at the storage area. The waste transfer flask is dropped on an unyielding surface. The unyielding surface causes all of the kinetic energy to be spent deforming the waste transfer flask and also simplifies the analysis by deforming only the waster transfer flask and not the target surface. The use of unyielding surface results in conservative prediction of response of waste transfer flask.

Drop analysis has been carried out by considering various orientations viz., dropping on edges, corners, and base as shown in Figure 2. For edge and corner drop events, the waste transfer flask is oriented such a way that its centre of gravity lies on top of the edge/corner. This results in all of the impact energy to be absorbed at the primary impact region.

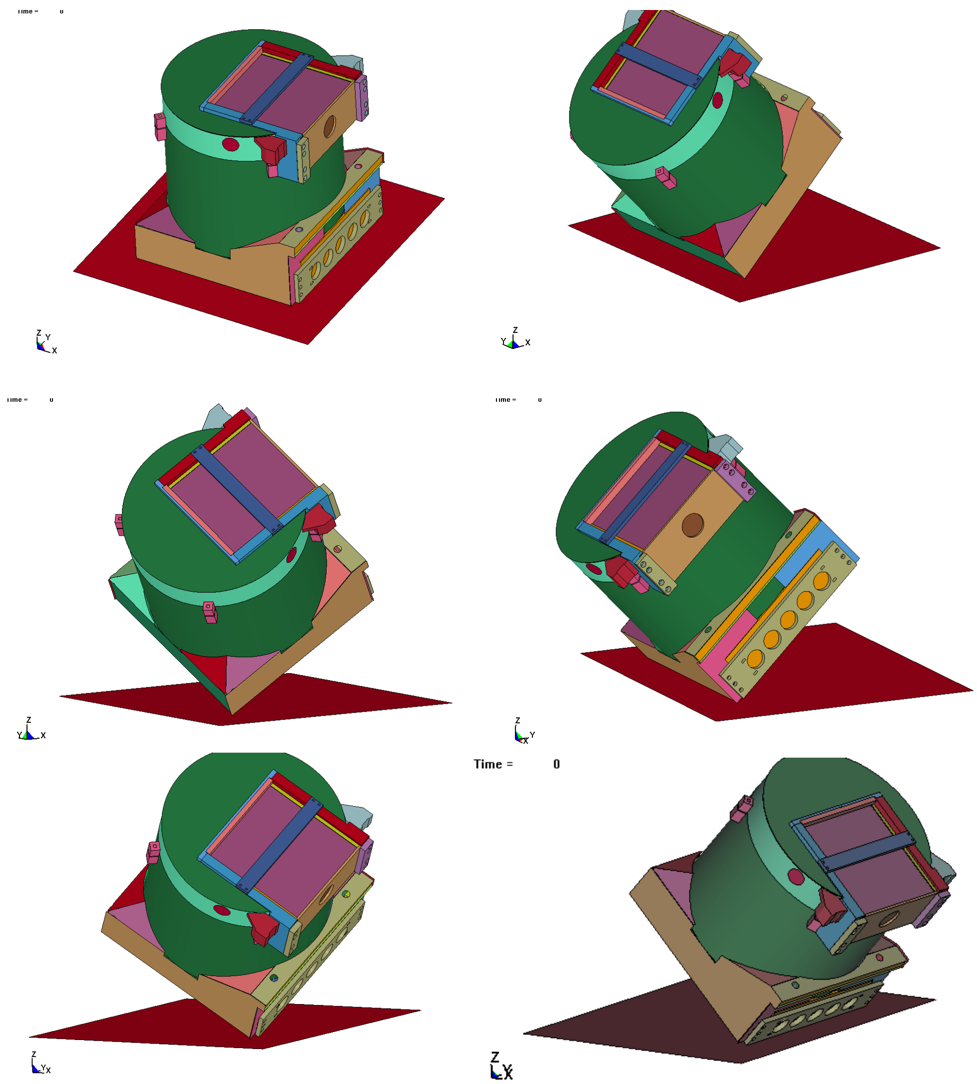

Figure 2: Drop orientations

Finite Element Model

The details of finite element model of waste transfer flask with waste container inside are shown in Figure 3. The model consists of main flask body, lower drawer assembly, upper drawer assembly, cover assembly and waste container filled with waste. The finite element model consists of shell, solid and beam elements. Type 2 Belytschko - Tsay element is used for shells and the solid element is based on Type 1 constant stress element. The bolt connections are modeled using Beam element Type 1 Hughes - Liu with cross section integration. The impact is assumed to be onto a flat rigid surface.

The initial velocity vector of the waste transfer flask is assumed to be perpendicular to the rigid surface. The contact interaction between various components is defined using Automatic_Single_Surface option in LS-DYNA [1]. The friction between all of the interior contact surfaces of the waste transfer flask and the waste container is assumed to be small. Also, the contact between the waste transfer flask and the waste container is assumed to have low friction.

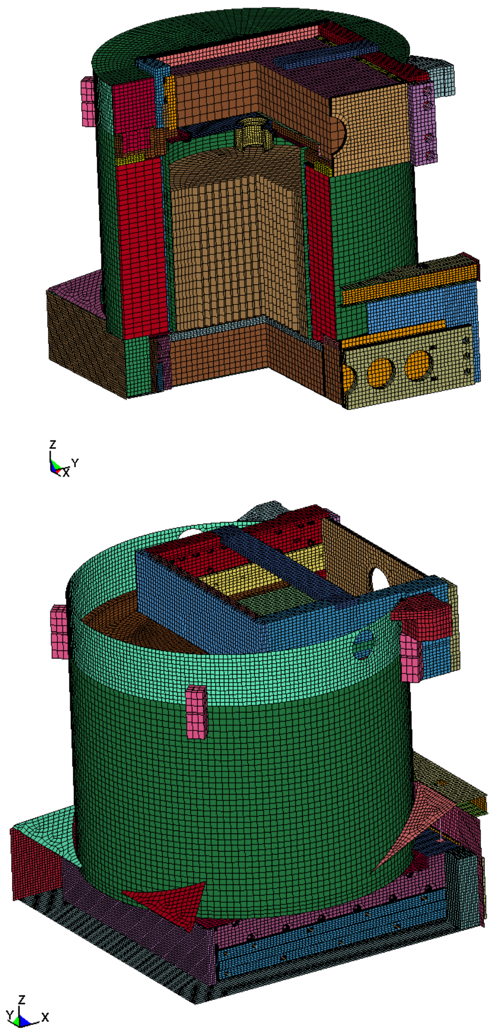

Figure 3: Finite Element Model of Waste Transfer Flask

Results and Discussion

Based on the drop analyses of waste transfer flask, it was found that the drop of waste transfer flask on its base is important for the structural integrity of waste container compared to other drop orientations. The predicted response of the waste transfer flask due to drop on its base is discussed below.

A plot of the kinetic Energy with time is given in Figure 4. As can be seen, the waste transfer flask is an efficient energy absorber.

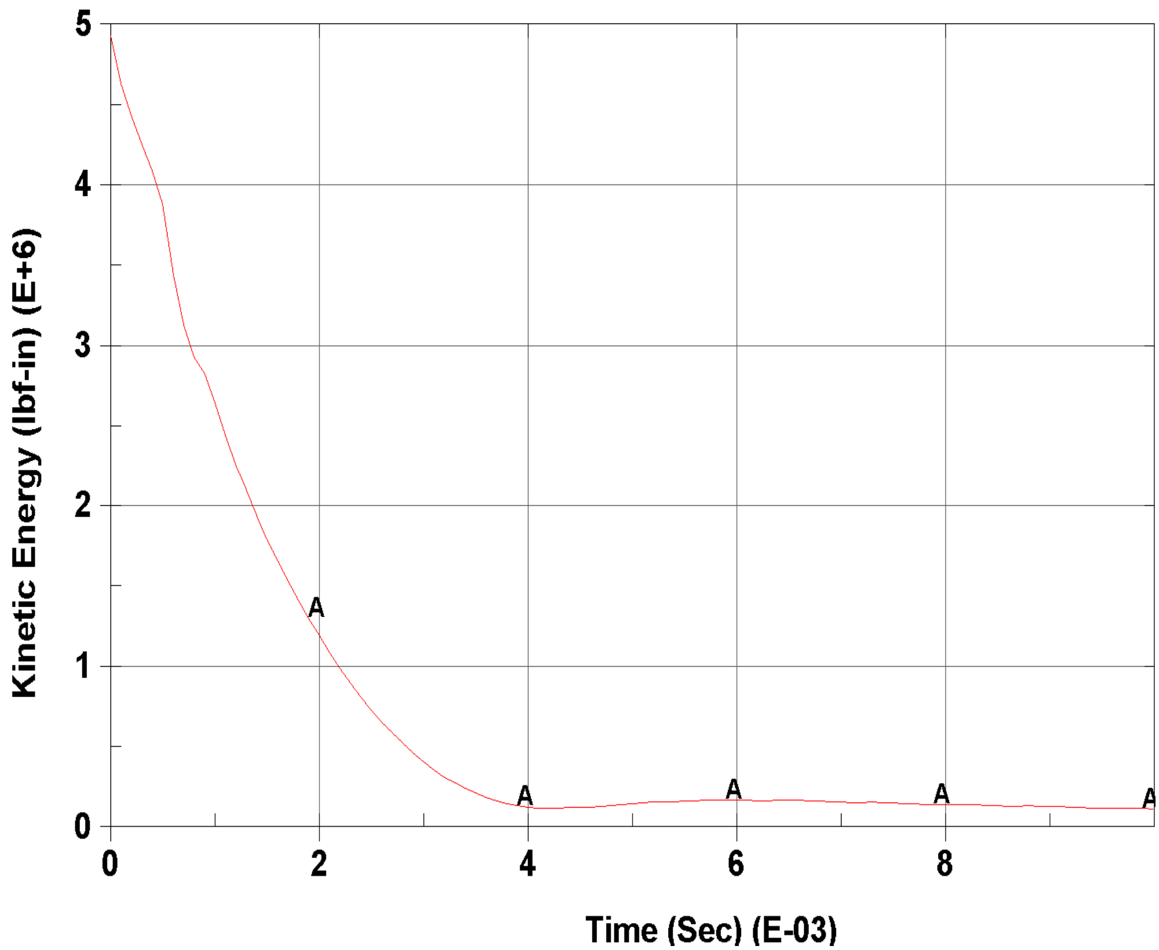

Figure 4: Kinetic Energy Distribution

Figure 5 shows the deformed shape of the waste transfer flask. As can be seen, most of the permanent deformation is concentrated in the bottom parts of the waste transfer flask. The permanent deformation of the middle and top regions of the waste transfer flask is small.

The permanent deformation of the waste container is shown in Figure 6. As can be seen, most of the permanent deformation of the waste container is concentrated in the top cover area. The permanent deformation of the sidewall and bottom plate is negligible. The relative permanent deformation between the body of the waste transfer flask and the waste container is very small and hence the waste container can be retrieved after the drop event.

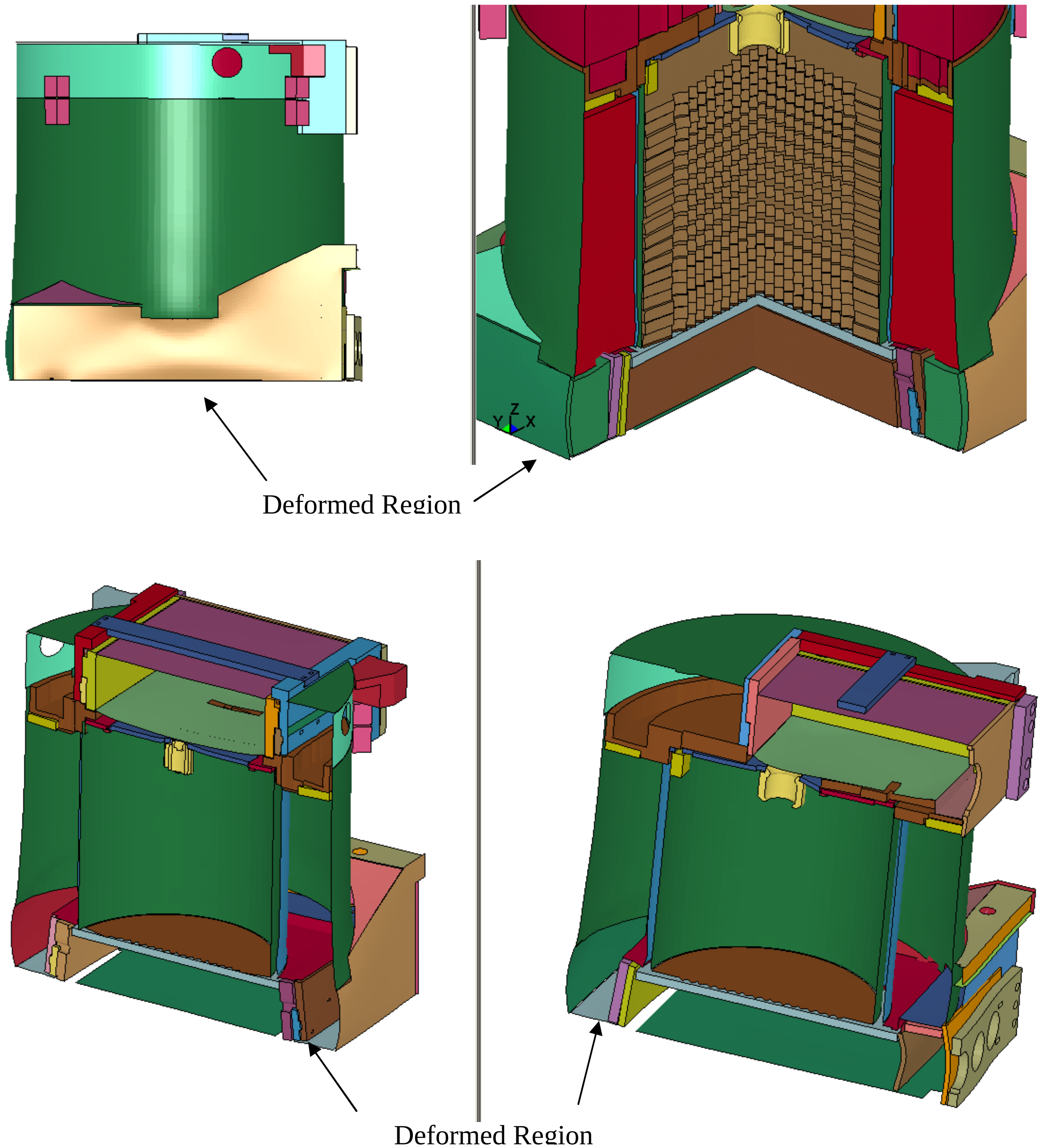

Figure 5: Deformed Shape of Waste Transfer Flask

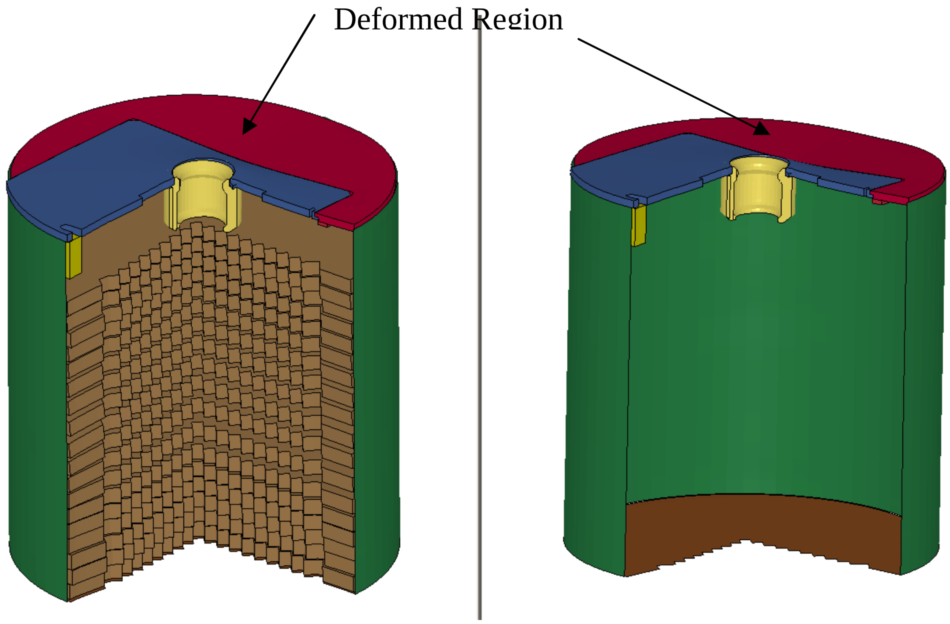

Figure 6: Figure 4: Deformed Shape of Waste Container

Summary

Drop analysis using LS-DYNA showed that the waste transfer flask acts as an efficient energy absorber and protects the waste container placed inside. For all the drop events analyzed, the waste container maintained its structural integrity and its capability to retain the waste inside. It was also shown that the container could be retrieved after the drop events.

References

1. LS-DYNA®, Livermore Software Technology Corporation, Livermore, California.