Estimation of misaligned position in drop test of IP-2 type metallic container

Jongmin Lim*, Yun Young Yang, Ju-chan Lee
Korea Atomic Energy Research Institute, Daedeok-daero989ben-gil 111, Yuseong-gu, Daejeon, Republic of Korea
**Corresponding author: jmlim86@kaeri.re.kr*

1. Introduction

In this study, a misaligned position of an industrial packages Type 2 (IP-2) metal rectangular container in a drop test is estimated. In order to estimate the misalignment of the drop position, an optimization technique with a response surface model is proposed. To construct the response surface model, a computational drop analysis to simulate the drop test is performed.

2. Drop test of the IP-2 metal rectangular container

Figure 1 shows the IP-2 metal rectangular container and strain gauges attached on the test model. The drop test was performed using a test model reduced by a scale ratio of 1/2. The strain gauge is symmetrically attached on each post. A drop height is 0.3 meters corresponding to a normal transport condition of the original scaled IP-2 type container.

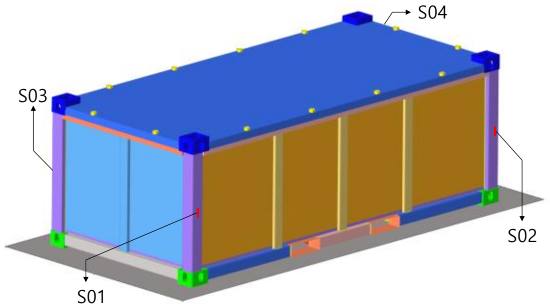

Fig. 1 The IP-2 metal rectangular container

Figure 2 shows strain results of the bottom drop test. Because of the symmetry of the attached strain gauges, the strains of each gauge have to be same in the bottom drop. However, the results show the considerable differences in the strain and the time to reach a peak. The previous study found that these differences are caused by the misalignment of the drop position [1]. In order to evaluate an uncertainty of the drop angle, the optimization technique with the response surface model is introduced in this study.

3. Estimation of the misaligned position in the bottom drop test

In order to estimate the misaligned position of the test model in the bottom drop test, the optimization technique is proposed. The proposed formulation to find the misaligned drop angle is as below

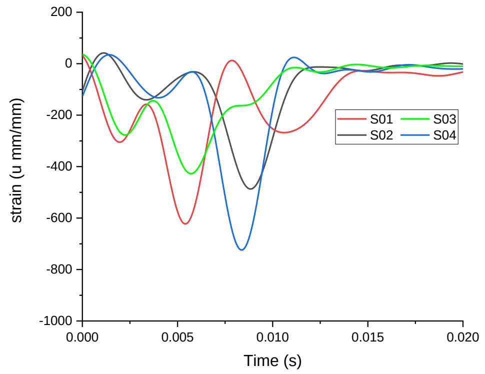

Fig. 2 Strain results of the drop test in the bottom drop (Cut-off frequency 300 Hz)

Find θ_x, θ_y

Minimize $\sqrt{(T_{T1}-T_1)^2+(T_{T2}-T_2)^2}$

Subject to $0.05° \le \theta_x \le 0.3°, 0.2° \le \theta_y \le 0.4°$

$T_{T1} = 0.3 \text{ ms}, \; T_{T2} = 2.96 \text{ ms}$

In the formulation for the optimization, T_1 and T_2 is defined as

$$T_1 = T_{S03}^{max} - T_{S01}^{max}, \; T_2 = T_{S02}^{max} - T_{S01}^{max}$$

where, T_{S0N}^{max} means the time to reach the maximum strain of S0N. T_{Ti} is obtained from the test results, and T_i is obtained from the drop analysis. θ_x and θ_y means the drop angle caused by the misaligned position of the test model.

In order to evaluate an objective function in the formulation, the computational drop analysis is required. Since each optimization step requires the evaluation of objective function and its gradient, the significant number of analyses is required to reach the optimum. For this reason, a response surface model is utilized. The computational drop test is performed at only sampling points which are required to construct the response surface model. After constructing the response surface model, an additional analysis is not required during finding the optimum.

The polynomial basis of the response surface model is as below

$$T_i = c_{i1} + c_{i2}\theta_x + c_{i3}\theta_y + c_{i4}\theta_x\theta_y$$

To construct the response surface model, the coefficient of each polynomials is determined using sampling points. In order to obtain T_i at the sampling points, a computational drop analysis is performed. LS-DYNA was used for the computational analysis, and the finite element model for the drop analysis is shown in Fig. 3. Figure 4 and 5 shows a stress contour of the drop analysis at the first and third impact, respectively.

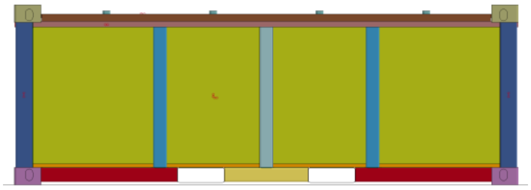

Fig. 3. FE model for the drop analysis of the IP-2 container

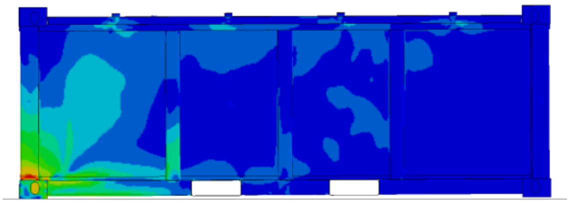

Fig. 4. Stress contour of the drop analysis at the first impact

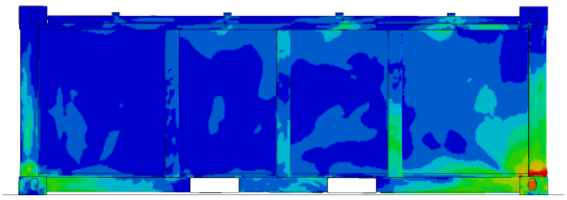

Fig. 5. Stress contour of the drop analysis at the third impact

The sampling points and results of the analysis at the sampling points is shown in Table 1. Using the sampling points in Table 1, the coefficient of the response surface model can be determined.

Table 1. Results of the drop analysis at the sampling points

θ_x (°)	θ_y (°)	T_1 (ms)	T_2 (ms)
0.05	0.2	0.27	2.17
0.05	0.4	0.24	3.55
0.3	0.2	2.49	2.74
0.3	0.4	1.87	4.05

Using the formulation for the optimization, the misaligned drop angle is obtained as shown in Table 2.

Table 2. the misaligned drop angle calculated by the proposed method

θ_x (°)	θ_y (°)	T_1 (ms)	T_2 (ms)
0.111	0.203	0.27	2.98

Figure 6 shows the stain results of the drop test and analysis with the misaligned position obtained by the proposed method.

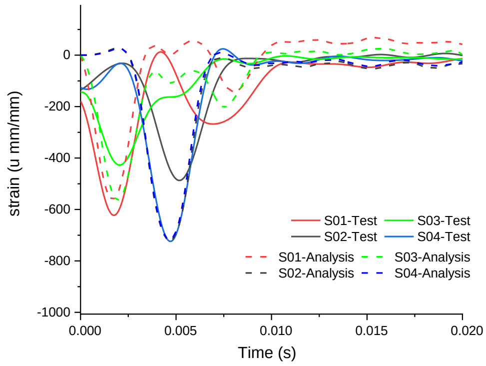

Fig. 6 Strain results of the drop test and analysis with the misaligned position

As shown in Fig. 6, the drop analysis with the misalignment obtained using the proposed method agree reasonably well with the test data with respect to the time difference between the first and third impact. Although the strain S01 of the analysis does not show conservative result, the analysis results in the stain S04 which has maximum strain shows good agreement with the test. The maximum strain of the strain 04 is 720 umm/mm. If the drop analysis is performed with no consideration of the misaligned position, the maximum strain of the strain 04 is 620 umm/mm. When verification between the test and analysis is evaluated, the conservatism of the analysis is one of the most important factor. Because the misalignment causes strong the second impact like an oblique drop, the consideration of the misalignment using the proposed method enables the conservative evaluation for the verification between the test and analysis.

3. Conclusions

In order to evaluate the misaligned position in the bottom drop, the optimization technique with the response surface model was proposed in this study. To construct the response surface model, the computational drop analysis was performed. The misaligned position estimated using the proposed method showed good agreement with the misaligned position of the test.

ACKNOWLEDGMENTS

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REFERENCES

[1] J. Lim, Y.Y. Yang, and J.C. Lee, Sensitivity analysis to evaluate misalignment effect of drop angle in the drop test of IP-2 type metallic container, *Transactions of the Korean Nuclear Society Spring Meeting*, Jeju, Korea, May 21-22, 2020