

DELAYED IMPACT OF THE CONTENTS OF A TRANSPORT PACKAGE FOR NUCLEAR FUEL

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ABSTRACT

It is a phenomenon that impact load applied onto lid from content with a gap between content and lid could be several times as larger as the one without gap under lid side vertical drop test. As the gap generates a time lag of impact of body and content, the phenomenon is called as “Delayed Impact”.

At the previous PATRAM 2013, we have ever presented the mechanism of the Delayed Impact with FEM analysis results. The analysis has been carried out with initial gap 0mm, individual gap and the maximum initial gap 20mm to show different reaction forces due to different initial gap. It is observed that the reaction forces due to both individual gap and the maximum initial gap 20mm have nearly same value as well as tendency.

In this study, we have carried out some additional analysis with as same condition as previous one and extracted stress of lid bolt and opening of lid to observe the leakage situation. It was observed that some plastic strain and residual opening have occurred.

In order to reduce the delayed impact load, it might be considered to size down the gap or lower the impact load. There is a limit to size down the gap because it is set for absorbing thermal expansion of content. Finally it has been found that installing spring in the gap can be an efficient way to lower the Delayed Impact.

INTRODUCTION

Principle of “Delayed Impact”: when a gap between content and lid exists, after the package hits the rigid floor under lid side vertical drop test, the content hits the lid late, the delayed impact load from content onto lid might be several times as large as the one without the gap.

Reduction of “Delayed Impact”: since the gap between content and lid leads to the delayed Impact, it is considered to reduce the delayed impact by sizing down the gap or lessening the delayed impact load.

Upper gap means the gap between the content and bottom of package, as shown in Figure 1a.

Initial gap means the gap between the content and lid of package, as shown in Figure 1b.

Initial gap 0mm, Initial gap 20mm means that the all contents including fuel assembly and basket are forced to keep touching with the inner face of the lid, having 20mm gap between content and the inner face of the lid respectively, when the packaging hits rigid floor.

Individual gap means that the coexistence initial gaps of contents (including fuel assembly and basket), fuel assembly at different position creates different initial gap during free drop. There are 2 kinds of initial gaps, shown in Figure 2 and Figure 3, “case a” indicates that some fuel assembly does not hit the bottom of the package during free drop, “case b” indicates that some fuel assembly hits the bottom of the package during free drop. The *individual gap* is near real phenomenon.

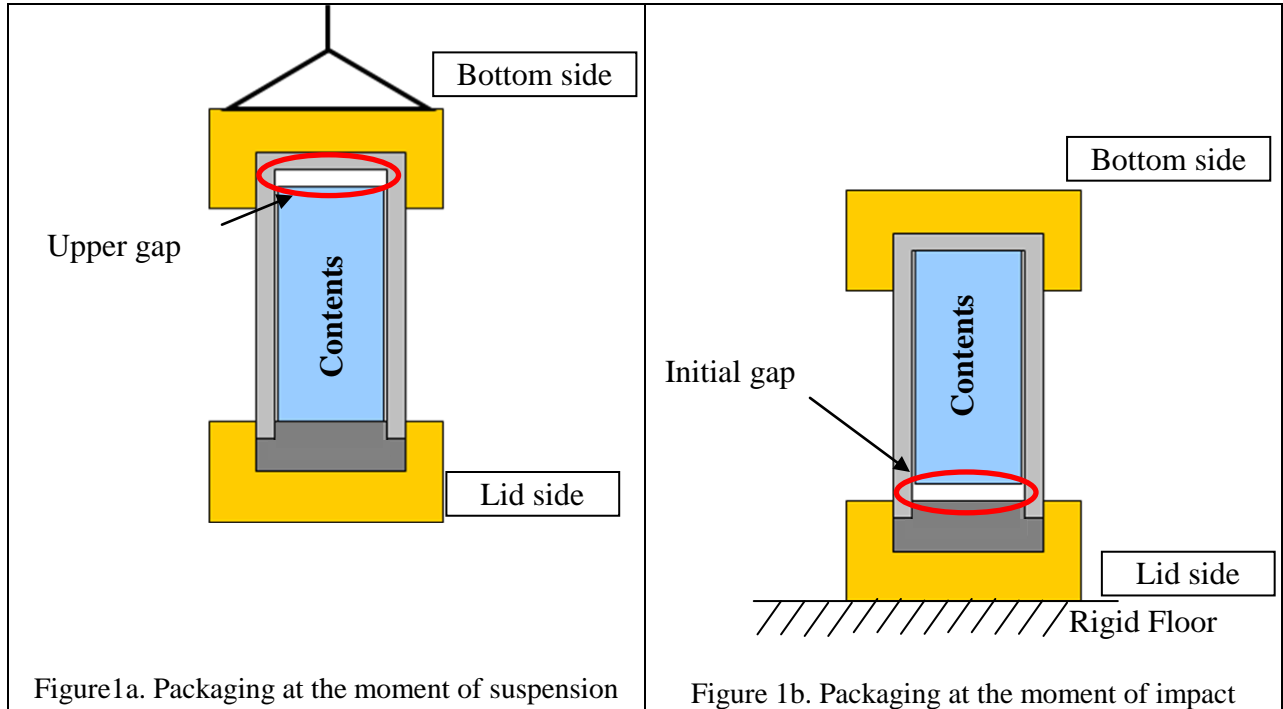


Figure 1. Definition of upper gap and initial gap

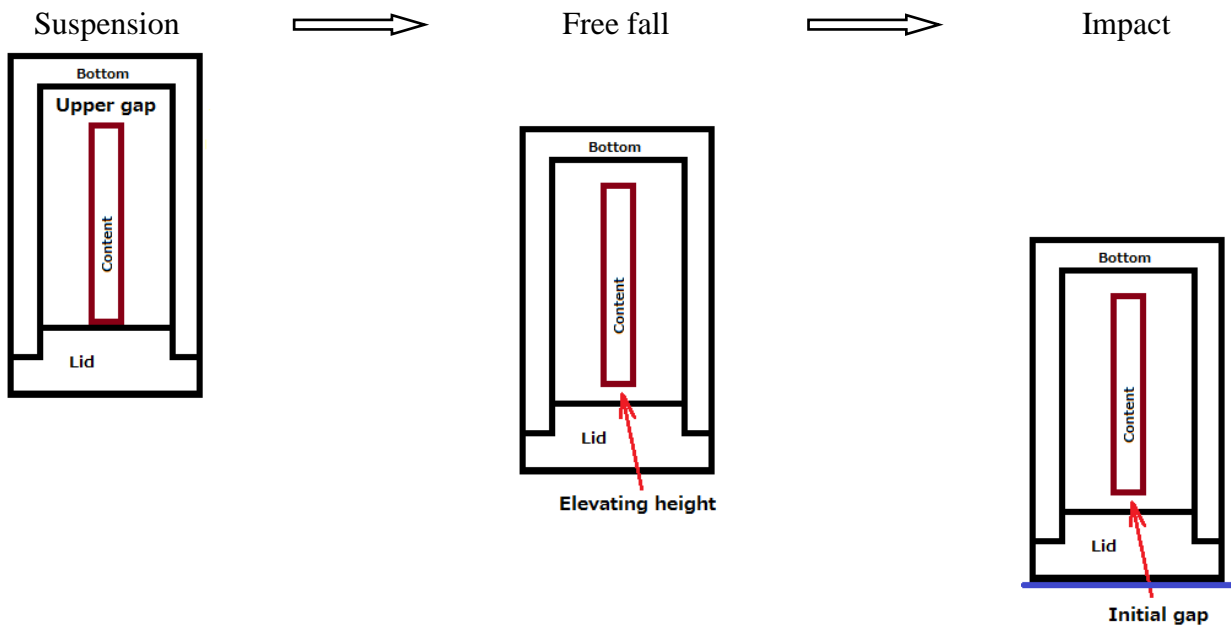


Figure 2. Image of individual gap “case a”

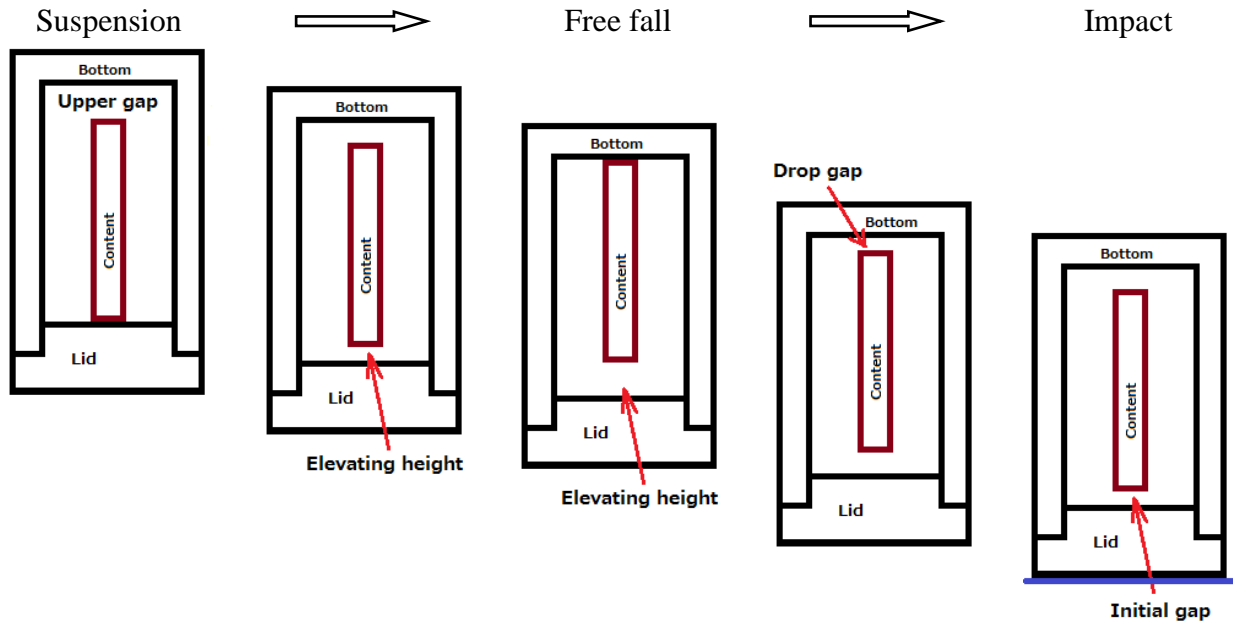


Figure 3. Image of individual gap “case b”

1. LID BOLT STRESS AND OPENING DURING 9M VERTICAL DROP TEST

Figure 4 shows the reaction forces during the 9m lid side vertical drop test, with which we can compare the tendency with corresponding curves of stress of lid bolt and opening of lid.

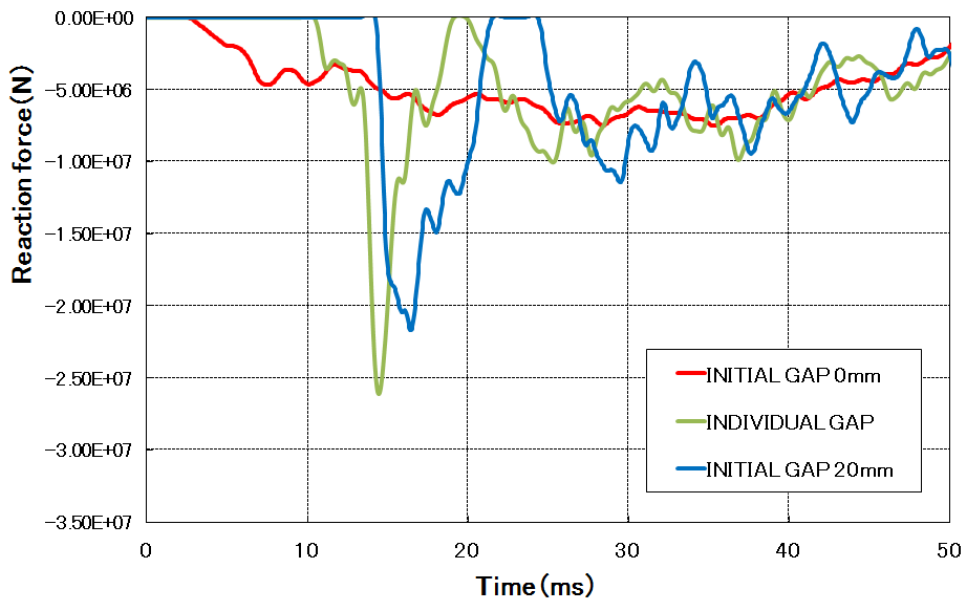


Figure 4. Variation of the reaction forces to the lid

1.1 Lid bolt stress

Figure 5 shows bolt stress histories from analysis results of the upper gap as initial gap 0mm, individual gap and the initial gap 20mm. It is found that maximum stress of the lid bolts has reached the yield strength to create plastic strain. The maximum stress of individual gap and initial gap 20mm were almost same.

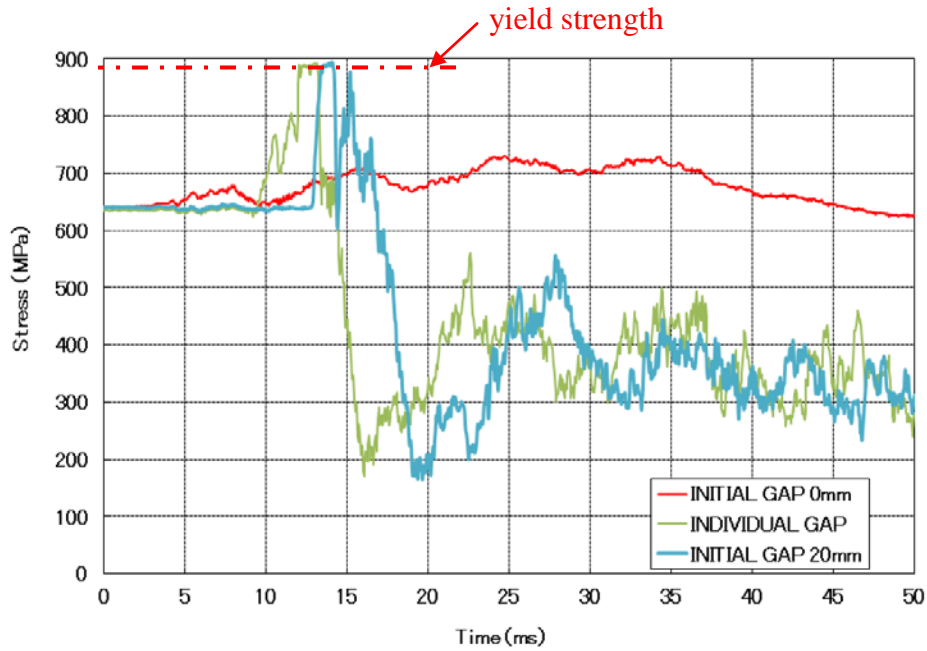


Figure 5. History of bolt stress under 9m lid side vertical drop test

1.2 Lid opening

Figure 6 shows lid opening histories from analysis results of the upper gap as initial gap 0mm, individual gap and the initial gap 20mm. There existed residual opening after the drop because plastic strain occurred. The residual opening just occurred only when the packaging dropped with the individual gap and initial gap 20mm, but did not occur with initial gap 0mm. The value of lid opening due to individual gap is much smaller than the one due to the maximum initial gap 20mm, just different from the tendency of bolt stress.

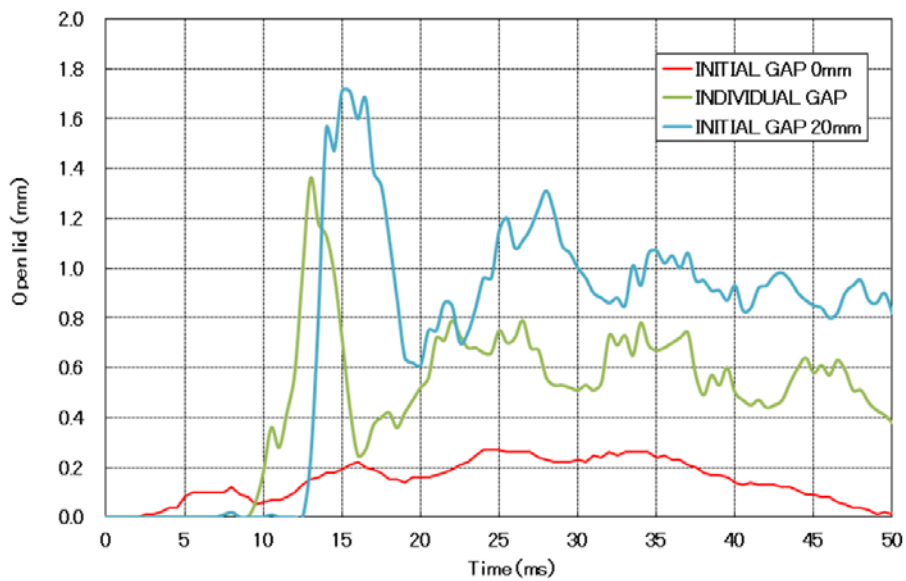


Figure 6. History of Lid Opening under 9m lid side vertical drop test

1.3 Observation

Existence of gap generated large stress in lid bolt under 9m lid side vertical drop test. The maximum stress in lid bolts ever reached yield strength and residual opening occurred in lid during the drop. It indicates that plastic strain had occurred in lid bolts due to the Delayed Impact.

2. METHOD OF REDUCING THE DELAYED IMPACT LOAD

Having observed the analysis results mentioned above, it is found that the reaction force depends on the gap between content and lid. Therefore dealing with the gap might be a key to reduce the “Delayed Impact”.

2.1 Background

The gap between content and lid can not be eliminated because the gap is for absorbing thermal expansion of content. So we have to find a method to reduce the delayed impact load with the gap.

When the package is being hanged reversely with lid side downward, the lid supports the content and deflects. As soon as the package starts drop, the lid moves down and leaves off the content to be unloaded status instantaneously. While the lid’s deflection turns into straight plane during unloading, the lid springs back and raises the content upward to create the initial gap, which leads to the Delayed Impact.

When the lid creates larger deflection, the content will be raised higher and larger initial gap will be created, it implies that the content located near the center of lid creates larger initial gap, see Figure 7. Lowering the initial gap can be an efficient way to reduce delayed impact load.

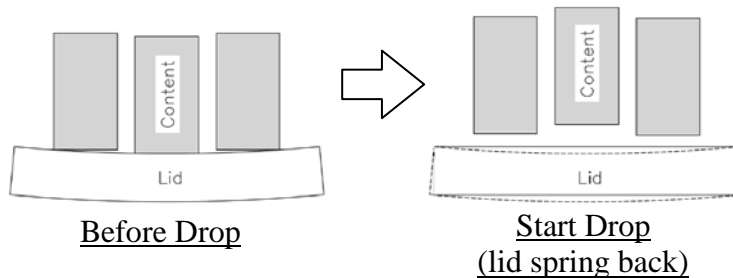


Figure 7. Image of lid spring back

2.2 Strategy

Considering the two merits as shown below, we are willing to install some springs into the gap to reduce the Delayed Impact load.

- 1) The spring may not be a barrier to thermal expansion of contents, but may soften the impact load from content onto lid.
- 2) The spring can make content keep touching with lid during lid side vertical drop to hold the lid spring back.

Since it is difficult to deal with the thermal expansion about many kinds of fuel assemblies, we have just dealt with the gap between the basket and lid.

2.3 Analysis model

The current analysis model has been used and some springs have been installed into the upper gap. The free length of spring is selected as longer than the maximum upper gap 20mm, the spring will be compressed and shortened until 20mm by basket’s self-weight, the spring will not push back against the inner face of lid to add any extra load to lid bolt after basket is loaded. When the package is turned reversely as well as during 9m lid side vertical drop test, the spring

will tend to stretch and push back to make the basket keep touching the inner face of lid, see Figure 8.

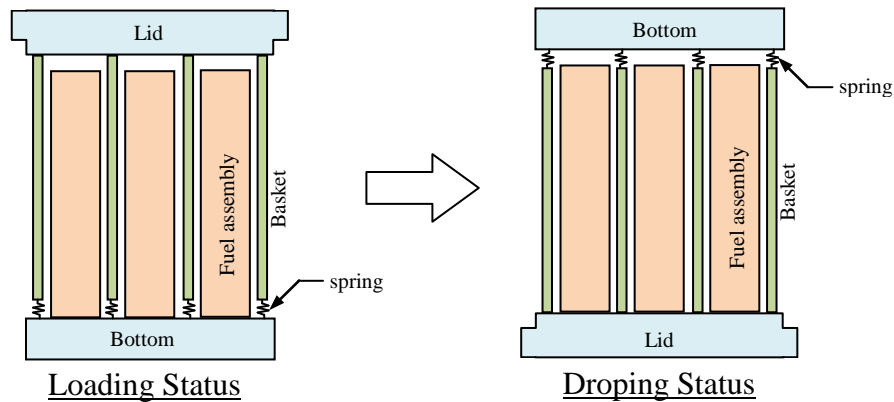


Figure 8. Image of installing spring into the upper gap in analysis model

However, basket almost does not deflect in its axial direction and does not match with lid's deflection curve, only outer circumference of the basket can touch the inner face of lid under lid side down status, the touching point seems like adding a couple of supports between lid bolts to shorten the lid spring back span, see Figure 9. The mass proportion of fuel assembly to basket is about 7 to 1. The constant of spring depends on the weight of the basket. It is presumed that the effect of holding the lid spring back must be small.

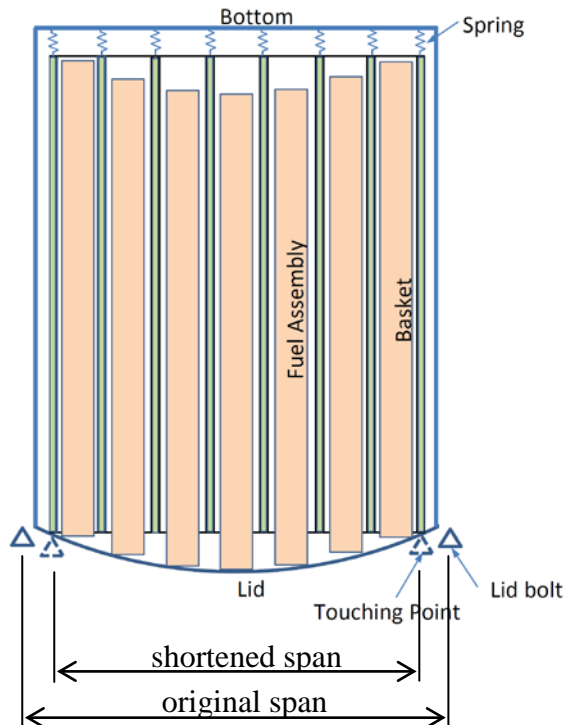


Figure 9. Image of touching points in the inner face of the lid

2.4 Analysis condition

The current analysis conditions have been used, such as initial gap 0mm, individual gap and initial gap 20mm. The fuel assembly's condition is as same as the current one completely, but only basket's condition has been changed as mentioned above.

2.5 Analysis results

Figure 10a and Figure 10b show the comparison of the reaction forces history of lid side vertical drop test between with spring and without spring in the upper gap. Both of them have similar shapes. 3 main impacts waves are shown in each graph, the peak value of the first impact wave with spring is smaller than the one without spring, but the second and third ones are larger than the ones without spring conversely.

On the other hand, some additional vibrations occurred before the first impact wave in cases of individual gap and initial gap 20mm with spring installation, which may indicates the effect that the spring keeps touching with the lid during the free drop.

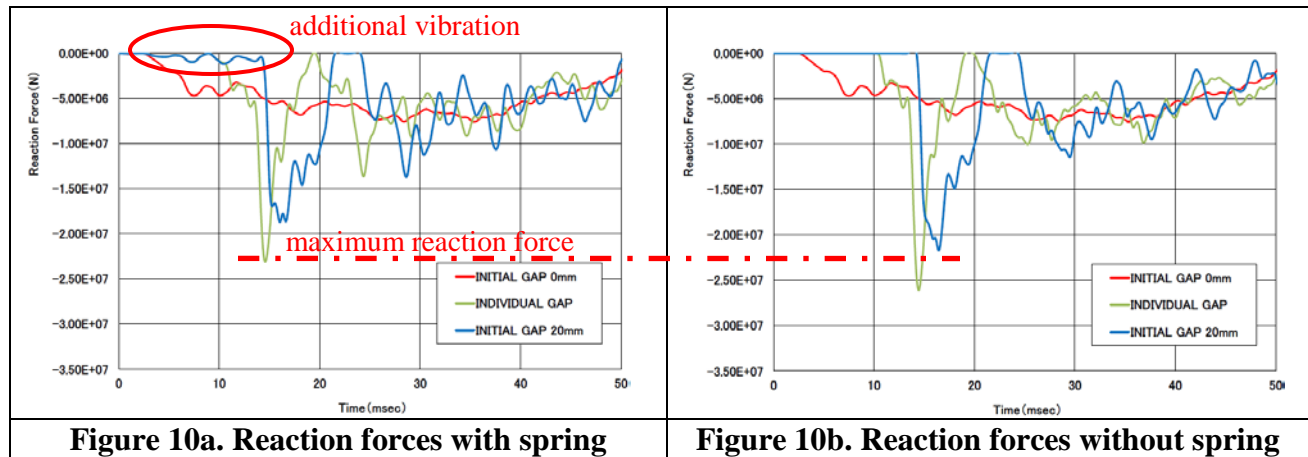


Figure 10. Comparison the reaction force during lid side vertical drop test with and without spring at the upper gap

Figure 11a and Figure 11b show the comparison of the lid bolt stress history of lid side vertical drop test between with spring and without spring in the upper gap. The maximum stress of them still reaches yield strength, but the remained initial tightening stress with spring is larger than without spring, it indicates that the loss of initial tightening stress gets smaller because of spring installation.

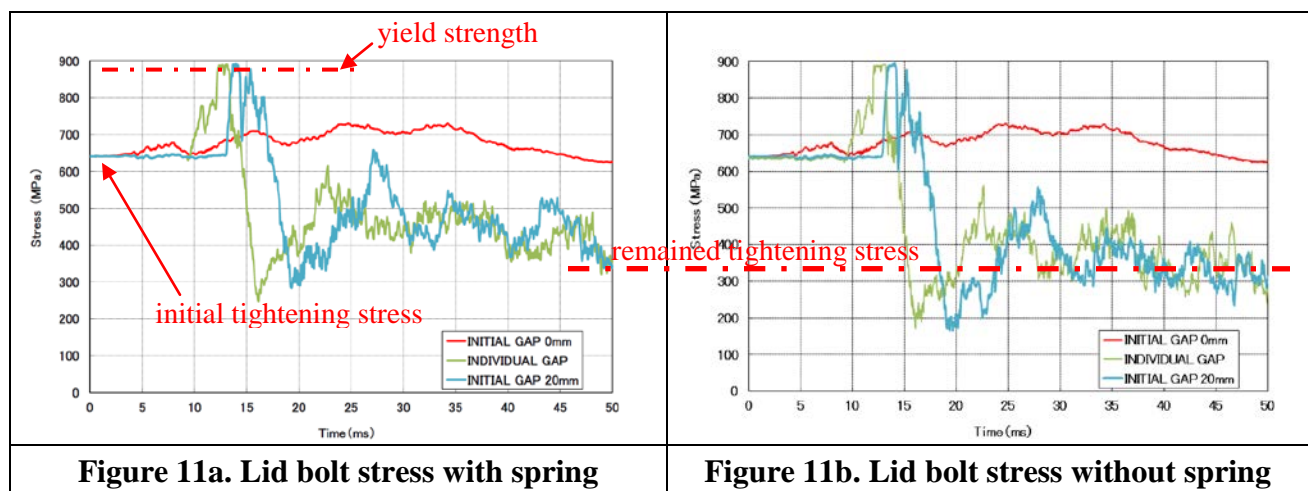


Figure 11. Comparison lid bolt stress during lid side vertical drop test with and without spring at the upper gap

Figure 12a and Figure 12b show the comparison of the first lid opening history of lid side vertical drop test between with spring and without spring in the upper gap. Both of them have

similar shapes and tendency. Unfortunately, even though the maximum value has got smaller, the residual opening has still existed.

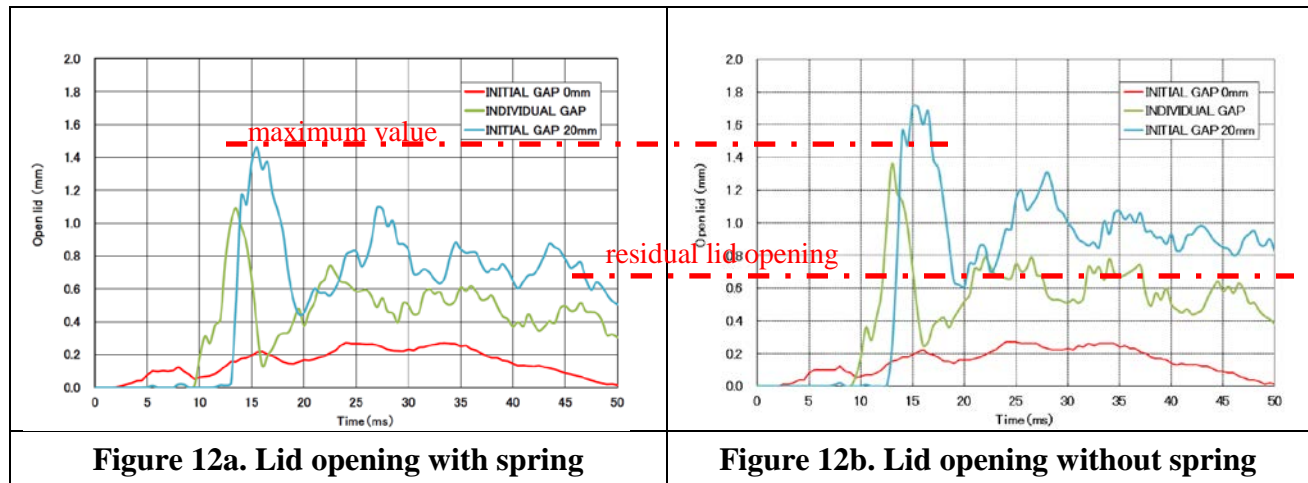


Figure 12. Comparison lid opening during lid side vertical drop test with and without spring at the upper gap

2.6 Observation

The maximum impact load with the spring is smaller than the one without the spring in the gap. Therefore we can say that it is efficient to install spring into the upper gap of basket for reducing the reaction force due to the Delayed Impact as expected.

CONCLUSIONS

Bolt stress and opening of lid due to the Delayed Impact

- The maximum stress reached the yield strength when the Delayed Impact occurred.
- The maximum stress does not depend on the size of the upper gap except the upper gap 0mm.
- The magnitude of residual lid opening depends on the status of the initial gap.

Effect of spring installation against the Delayed Impact

- Shorten the equivalent span of lid to reduce spring back and lower reaction force.
- Reduce the maximum reaction forces.
- Does not affect the tendency of reaction forces, but only lower the maximum value.

There may exist some other method to reduce the Delayed Impact load, which will be our next subject in future.

REFERENCE

- [1] LS-DYNA THEORY MANUAL, John O. Hallquist, March 2006
- [2] THE behavior of contents of a spent fuel package during a 9m vertical drop test with lid side downwards, Fumito Shigeyoshi, August 2013