Quicker Process to Consider Strain Hardening for Crash Analysis Using HYCRASH

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Abstract:

As one of the important issues in correlation of crash analysis, we know that the press-forming effect has large influence for the result of the analysis. Some tries and studies were carried out to assume the forming result to the crash analysis. However these actions haven't spread to the actual product development because of some difficulties.

We mark the Inverse Solver to solve this issue and have developed the new solver HYCRASH, which can calculate the plastic strain and thickness distribution from the final shape of the product.

We would like to represent two things in this study. First, the hardening effect plays an important role in the crash energy absorption. Second, HYCRASH can consider this correlation factor much easier and faster than the usual press simulation technique.

Keywords:

Crash Analysis, Correlation Problem, Stamping Simulation, Hardening Effect, Inverse Solver, Oasys/Primer scripting function, LS-DYNA, JSTAMP/NV, HYCRASH

1   Introduction

To evaluate and design the performance of the vehicle crash, most of the automotive companies use CAE technology. LS-DYNA is one of the most famous solvers for this use.
As a result that CAE has become popular and established technique, the correlation with test is getting more and more important for all of the engineers in this area on these days.
There are a lot of factors which have some influences for the correlation. For instance, mainly in model building technique, mesh size and spot-welding and so on, refers to material, failure and strain-rate effect and variation etc. [1]-[3]
The effect of residual strain distribution and non-uniform thickness due to sheet metal forming – the manufacture process for most of the automotive parts for crash energy absorption - is well known as one of the most affecting factors.[4],[5]
On the other hand, press-forming field also uses CAE technology as crash unit, too.
They take advantage of CAE when they decide the manufacturing process and design the tools. The purpose has widen the field, to predict the crack and wrinkling defect of the blank sheet, to estimate the blank size, springback countermeasure and so on. To achieve this issue, the engineer executes detailed analysis using tool CAD data and forming condition.

Considering these situation, crash and sheet metal forming engineers make some action to collaborate with and solve the correlation problem. However, the movement has not spread so much. As one of its reason, we can find out the data setup difficulty – such as tool CAD and forming condition. Again the press-forming analysis require much finer blank mesh size than crash analysis, so that after getting the press result successfully, we have to map the result to the crash data with taking some effort. Additionally the press analysis requires not a small amount of calculation time.
 Moreover, it is impossible to get the press forming condition as tool geometry, blank holding force, etc. when the body structure is being designed.

2   Recommendation of Inverse Solver – HYCRASH -

From these backgrounds, so many researchers have tried to considering press-forming effect on crash analysis, easier and on demand. [6] That is the Inverse Approach, and here, we present HYCRASH.

The inverse approach is the way to predict the base shape using formed shape. The unknown nodal displacements are calculated by Finite Element Method which performs the strain energy minimization on each formed element.

So the Inverse Solver – HYCRASH – has following advantages, it takes less time to calculate than explicit solver; we can use it only from product shape information.
This HYCRASH attributes can be high advantage in crash field as we mentioned in Introduction.

3   Varification by S-rail problem

In this section, we would like to re-post the effect of plastic strain and thickness distribution by HYCRASH. Moreover the hardening effect, we promote that how useful solver HYCRASH is with the detailed example.
We select the simple S-rail problem because it has the simplified shape of automotive side member. This analysis cases were tested by Society of Automotive Engineers of Japan, Inc [7].

3.1   Analysis condition defined by test

S-rail was compressed by forced displacement as sown in Fig.1 in test. The test measured the reaction force on fixed wall. And the Stress – Strain properties were evaluated by tensile test following JIS.
We executed the CAE analysis according these conditions.
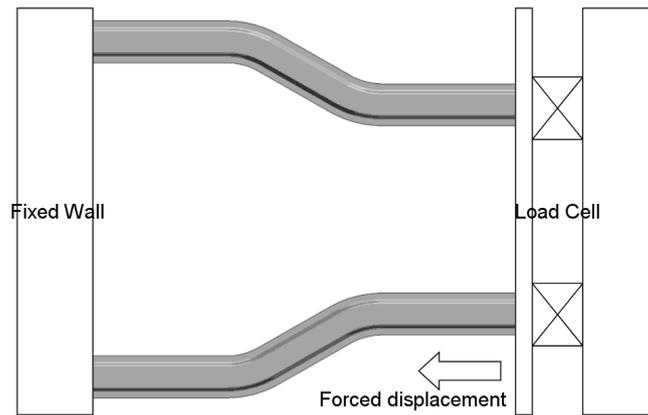There are three types of test piece in Fig 2 and Table 1.

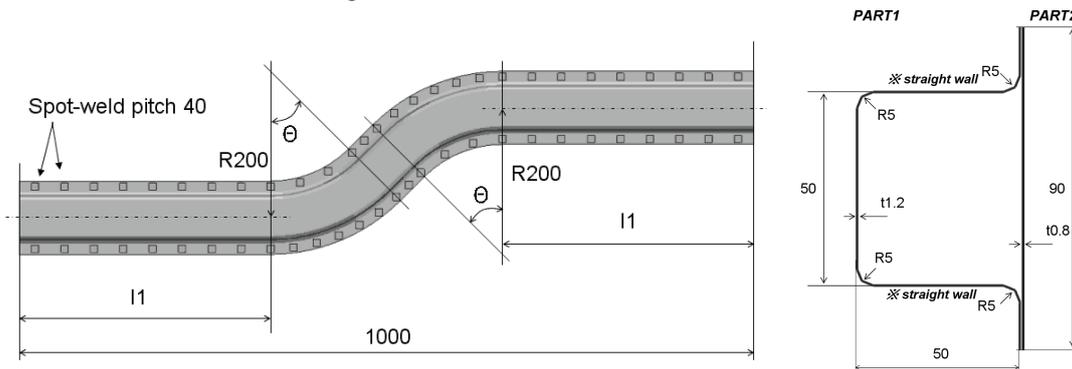*Fig. 1: Illustration of the test condition*

Fig. 2: Shape outline of the test piece and cut-section property

Test piece Name	θ value [degree]	l1 [mm]
Test piece 15°	15°	194
Test piece 30°	30°	316
Test piece 45°	45°	342

Table 1: Parameter for the test piece

3.2   Comparing result1.   Without hardening and Considering Hardening and the test

We would like to re-check the effect of plastic strain and thickness distribution for crash, at first.

3.2.1 To execute HYCRASH

For HYCRASH input, we have to make the extra information without changing crash input as shown in Fig. 3-1. After STAMPED comment, we should describe the LS-DYNA PID for adapting HYCRASH solver and name the crash input file by *INCLUDE. Then we can execute HYCRASH.
Oasys/Primer has very useful function – Scripting – to get this extra data.
This operation flow is described in Fig. 3-2. We have planned to make some demo in the presentation.

```
$STAMPED
$2000385,2000386,2000389,2000390,2000391,2000392,2000397,2000398
$2000399,2000400,2000401,2000402,2000403
*KEYWORD
*INCLUDE
crash_input.key
*END
```

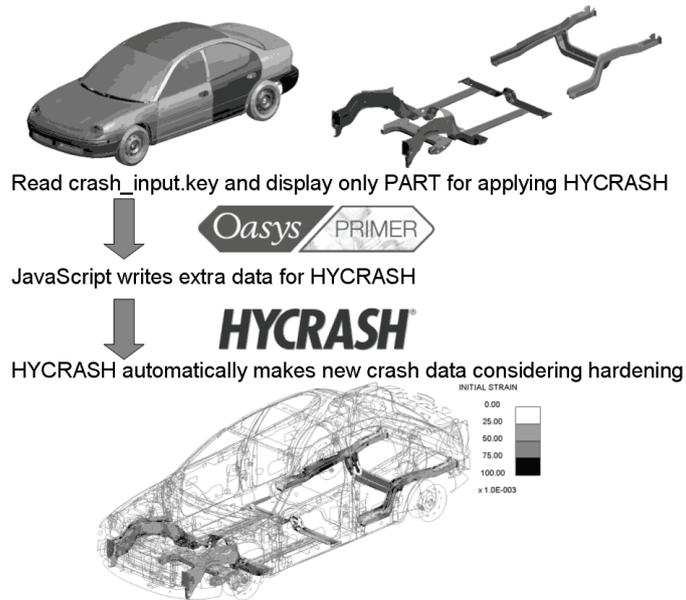*Fig. 3-1: example of extra data for HYCRASH*

Fig. 3-2: Flow image of making crash data considering hardening

In this S-rail example, PART1 in Fig.2 is press-formed part.

3.2.2 Press-forming result by HYCRASH

Fig. 4-1, 2, 3 shows the plastic strain and thickness distribution in each test piece. HYCRASH can represent the strain distribution in R5 region and thickness trend in skewed shape. But it is hard to see the strain in straight wall since HYCRASH cannot consider "bending-back".
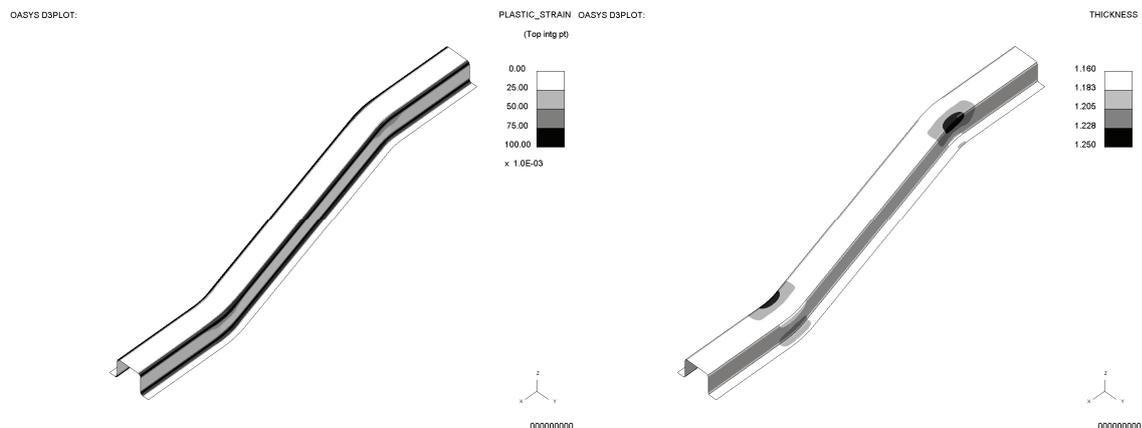

Fig.4-1:Distribution of the plastic strain and the thickness by HYCRASH   (15°)
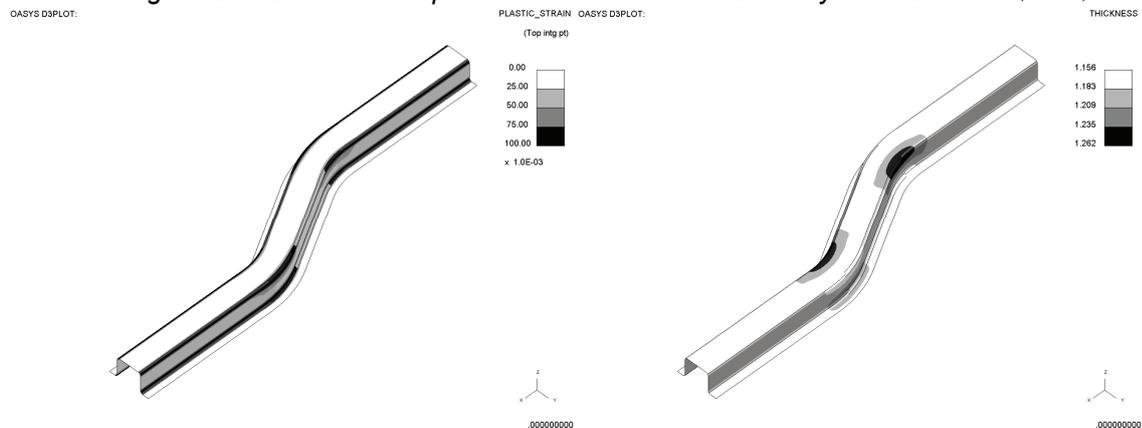

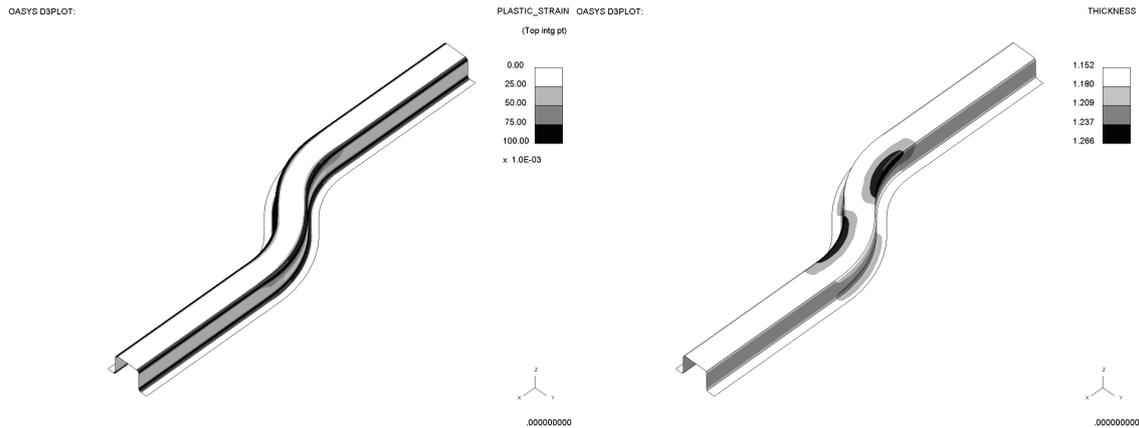*Fig.4-2: Distribution of the plastic strain and the thickness by HYCRASH（30°）*

Fig. 4-3: Distribution of the plastic strain and the thickness by HYCRASH （45°）

### 3.2.3 Result of crash analysis and discussion

Fig.5-1, 2, 3 shows the principle stress distribution in each test case when the reaction forces are almost peak value. The figures of Without Hardening and Considering Hardening are arranged by left and right hand side. At the same time and stroke, the force arise the higher stress in HYCRASH result.
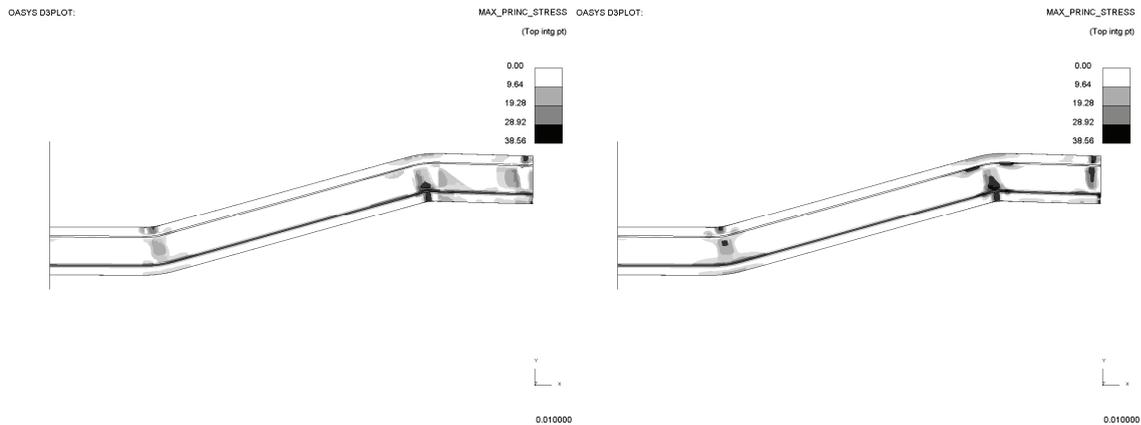
(Without hardening)   (Considering hardening)
Fig. 5-1: Comparison of principal stress distribution   （Test piece 15°）
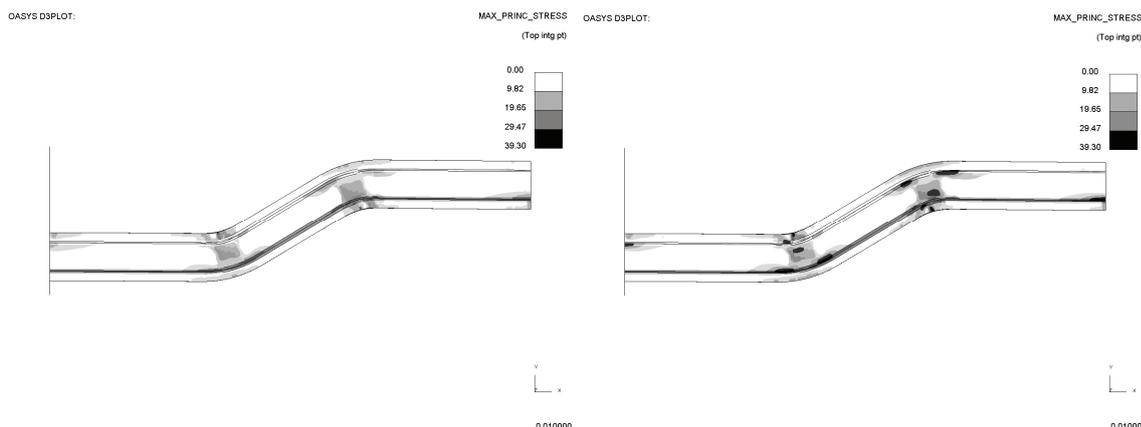
(Without hardening)   (Considering hardening)
Fig. 5-2: Comparison of principal stress distribution   （Test piece 30°）
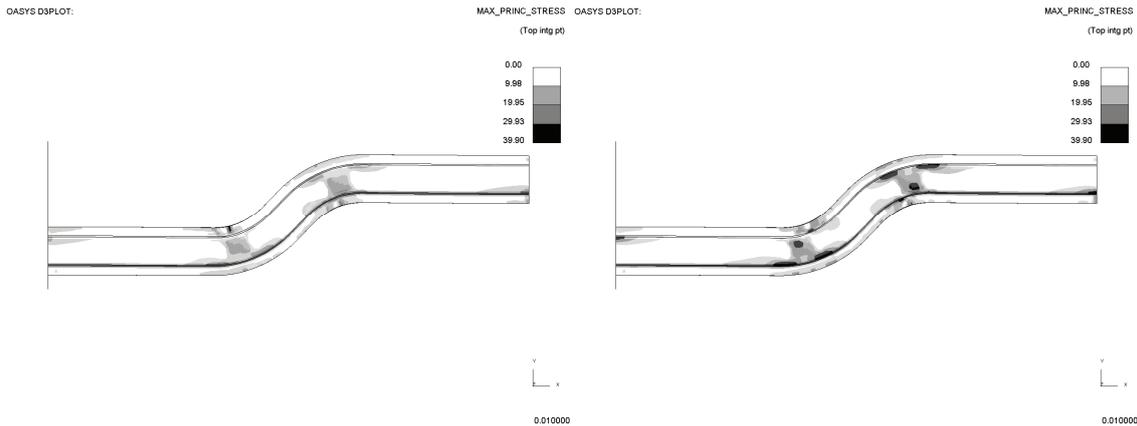
(Without hardening)   (Considering hardening)
Fig.5-3 :Comparison of principal stress distribution (Test piece 45°)

As the evaluation of energy absorbing property, we checked the force-stroke and energy-stroke curve in Fig.6-1, 2, 3 and Fig.7.

Fig.6-1, 2, 3 consists of three items – Test, Without Hardening and Considering Hardening. The enhanced view of 40mm stroke was set on the right hand side to check the detail of the difference.

These results show that the peak value of reaction force rise 15%-20% compared to without hardening and the effect of hardening approximates the test result.

The last half of test piece 15 degree remains large difference between tests and analysis. But we can ignore the error in this report because there are same tendency in both without hardening and considering hardening cases.
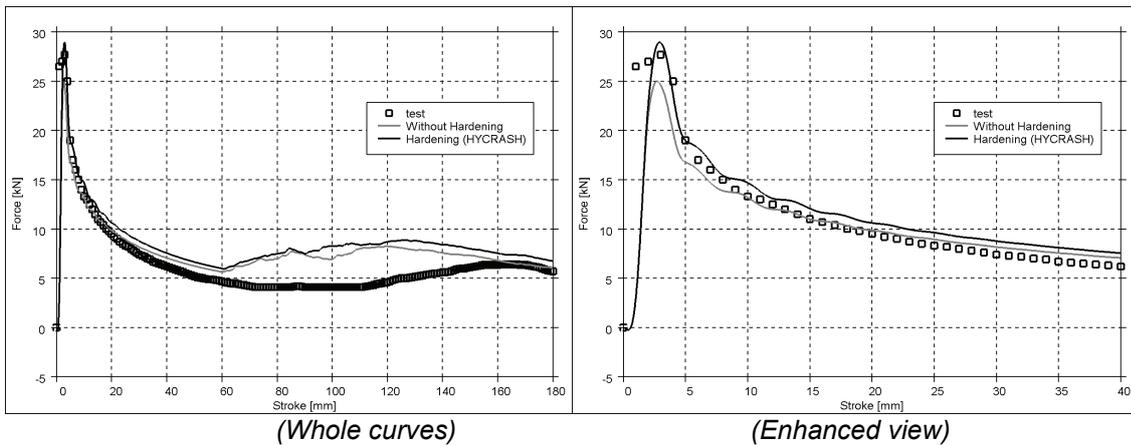
(Whole curves)   (Enhanced view)
Fig. 6-1: Comparison of force-stroke curve   (Test piece 15°)
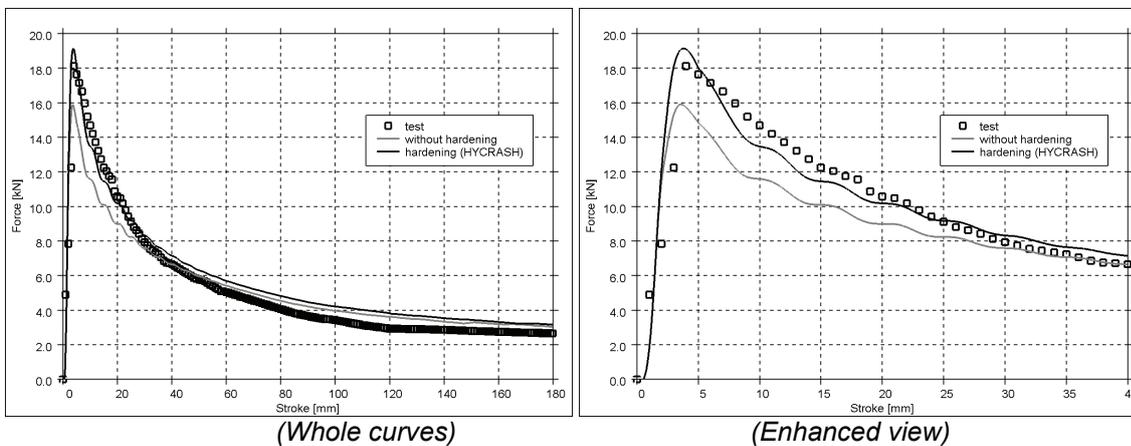
(Whole curves)   (Enhanced view)
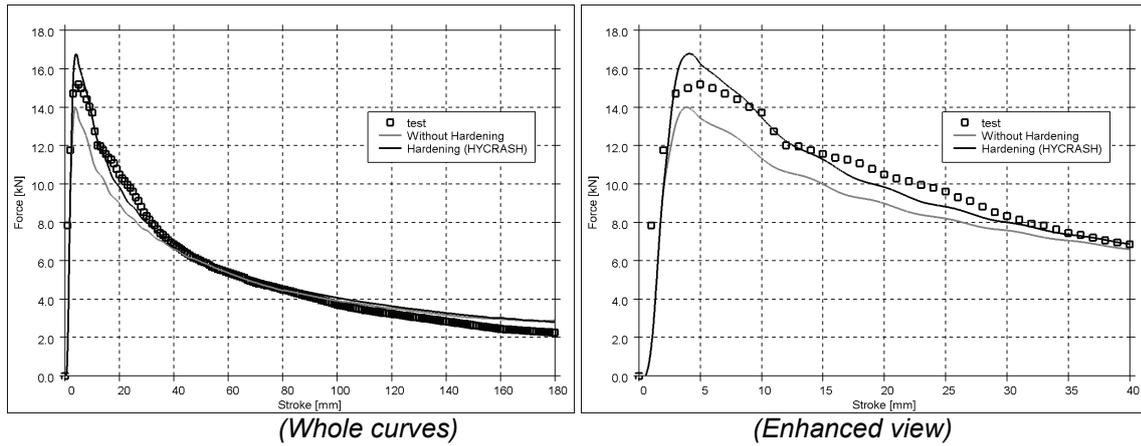*Fig.6-2: Comparison of force-stroke curve   (Test piece 30°)*

(Whole curves)   *(Enhanced view)*

Fig.6-3: Comparison of force-stroke curve   （Test piece 45°）

The energy absorbing property in each case is shown in Fig.7 energy-stroke curve. In the initial rising phase, the analysis results approximate the test result by considering hardening. Although the test piece 15 and 30 degree have large difference between test and considering hardening in the final stroke, the test and considering hardening in 45 degree matches well in the global.

We can be sure that the hardening effect such as plastic strain and thickness distribution plays an important role in the crash capability.
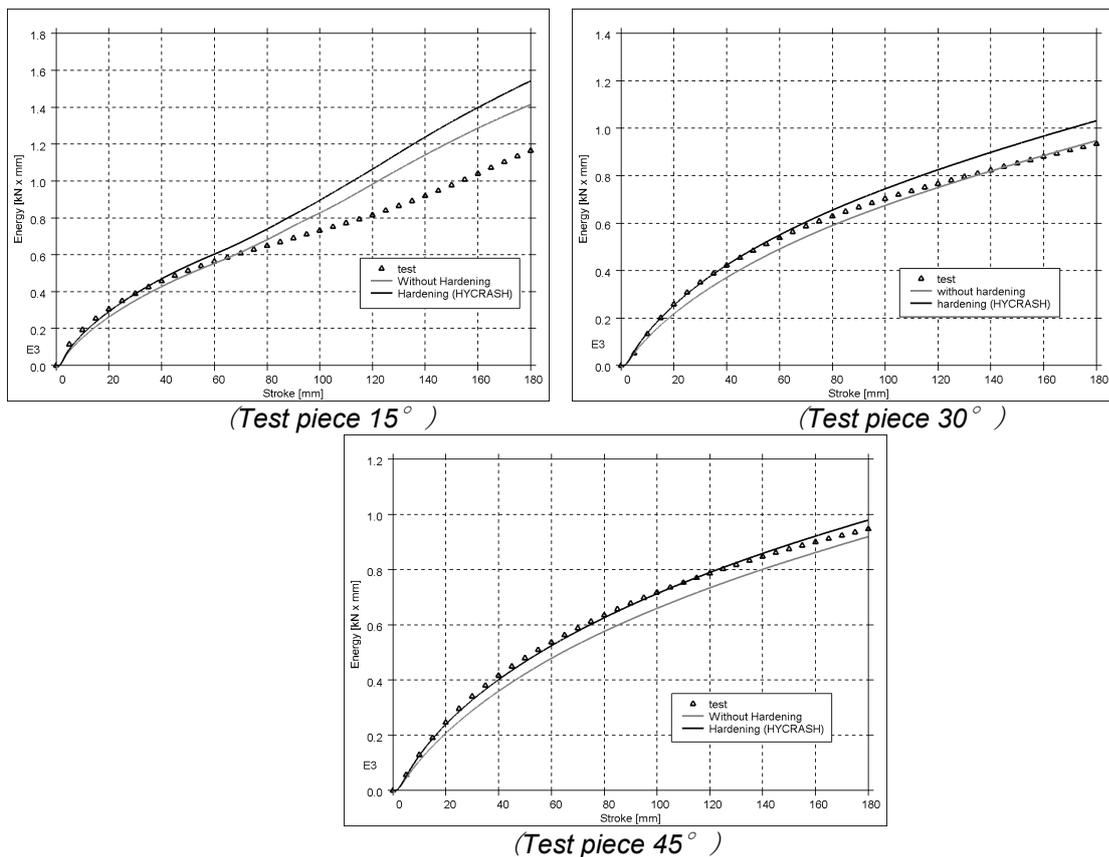

(Test piece 15°）   *(Test piece 30°）*

(Test piece 45°）

Fig.7:Comparison of energy-stroke curve

3.3   Comparing result２．Inverse Solver and explicit solution technique

In the section 3.2, we introduced that HYCRASH can improve the crash analysis result. We would like to present the specific advantage of HYCRASH through the comparison of explicit solution.

As the representative explicit solver, we select LS-DYNA and set up the standard press-forming analysis using JSTAMP/NV which we have developed as an integrated forming simulation system.

We used the test piece 30 degree in section3.2 for examination.

3.3.1 Set up of LS-DYNA data

We explained the preliminary arrangement and special instruction to exhibit the explicit analysis.
We make tool CAD data for tool mesh from S-rail shape. We assumed that the die face was flat and there's no-bead line. It takes half or one hour to complete the CAD. We decided the die stroke and holder pressure from our experience.
We could handle tool CAD and press condition by force because the test piece has simple shape. However, in the real development, it is too difficult to complete it without the press-field collaboration, indeed.
We settle the LS-DYNA forming model in Fig.8.
To assure the forming quality and accuracy, we selected the 2mm blank mesh size which was smaller than that of crash analysis of this study.
We provided the springback analysis after the forming process then we map the plastic strain and thickness distribution for crash mesh using Oasys/Primer forming function.
Fig.9 shows the plastic strain and thickness distribution calculated by LS-DYNA. It is quite obvious that the plastic strain distribution has large difference between LS-DYNA and HYCRASH. But the global trend of the plastic strain and thickness distribution are almost the same.
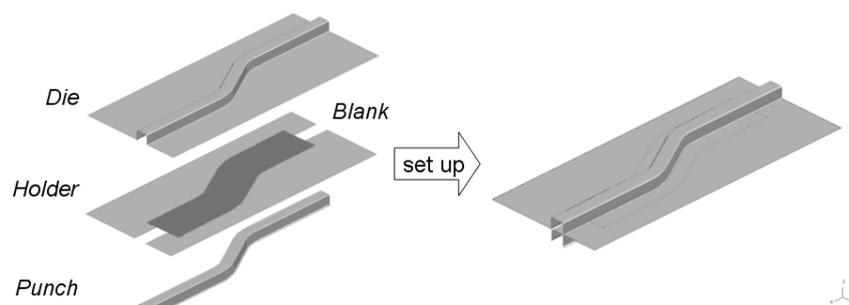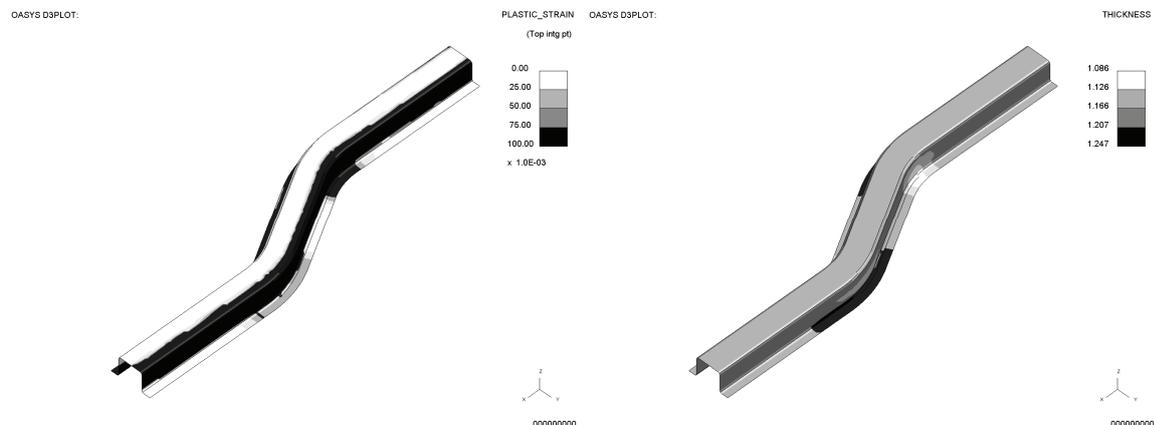

Fig.8: LS-DYNA forming model

Fig.9 : Plastic strain and thickness distribution calculated by LS-DYNA （test piece 30°）

3.3.2 Result of crash analysis and discussion

We compared the crash result taken over HYCRASH and LS-DYNA by the three contents – principal stress distribution at peak reaction force in Fig. 10, the force-stroke curve in Fig.11and the energy absorbing property in Fig.12 same as section 3.2.
The stress distribution seems to be almost the same except for the local segment on the skew flange.
On the other hand, the force-stroke and energy property of last half don't approximate the test result. We determine that there is the other correlation problem both HYCRASH and LS-DYNA and estimate the initial peak using enhanced view of Fig.11 and 12 right hand side. LS-DYNA always tends to reflect a little bit higher reaction force than HYCRASH and the peak force value is 2 % higher than HYCRASH, and the energy absorbing property also has this trend. We can consider this higher reaction force and energy absorbing are caused by the plastic strain distribution on the straight wall in Fig.9. However, these differences are negligible in designing the crash parts. We conclude that HYCRASH can plenty represent hardening effect in crash analysis.
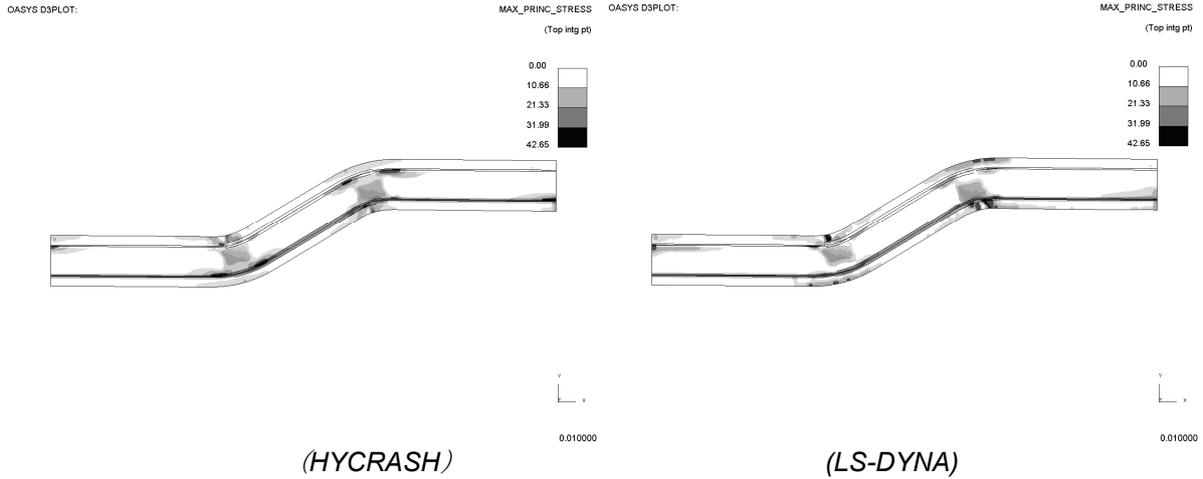
(HYCRASH)　　　　　　　　　　　　　*(LS-DYNA)*
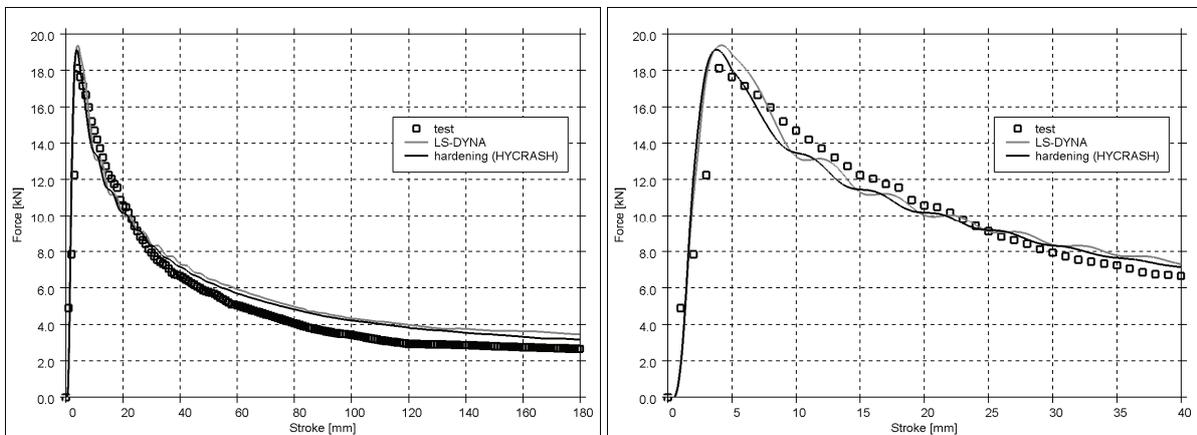*Fig.10: Comparison of principal stress distribution*

Fig.11: Comparison of force-stroke curve　　*(Test vs. HYCRASH vs. LS-DYNA)*
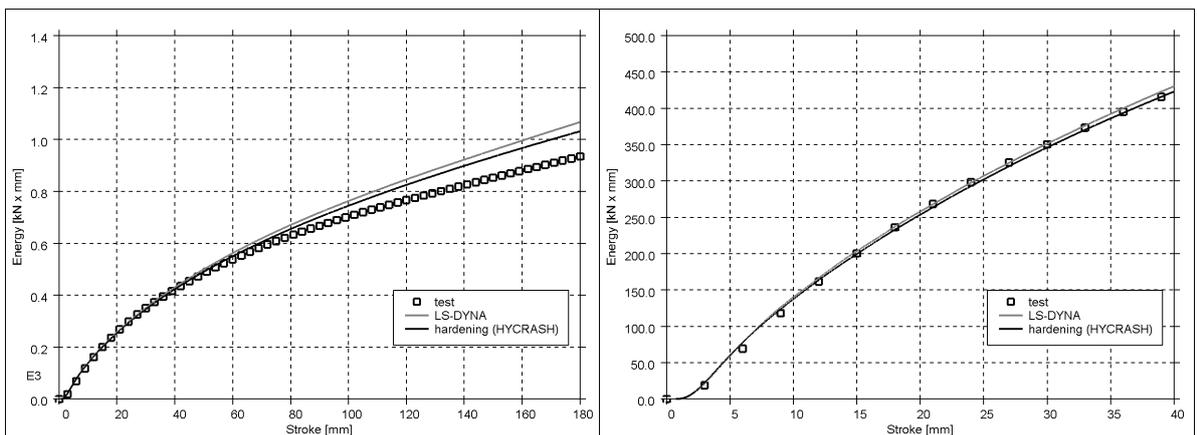

Fig.12: Comparison of energy-stroke curve (Test vs. HYCRASH vs. LS-DYNA)

3.3.3 Information of necessary time and data

At the end of this section, we would like to summarize the costs involved in table 2.

This table and preceding results show that HYCRASH is not much accurate but calculates and reflect the enough result in easy way and fast turn around time.

Items	LS-DYNA	HYCRASH
Data for the analysis	Tool CAD, forming condition, blank line information etc. All of the information to form the object	Shape of the object
Limitation	There is no limitation as shown in HYCRASH.	Difficult to represent the local detail. Initial blank has to be flat.
Time consuming phase	Data collection and set up the analysis.	Nothing
CPU time for this example #1	3 hours	0.2 minutes

#1 Intel Core2Duo 2.66GHz, 2GB memory, Number of deformable element 8000

Table2. : The summary of the difference between LS-DYNA and HYCRASH

4   Summary

We have presented the inverse solver HYCRASH to consider the sheet metal forming effect on the crash analysis.

HYCRASH can contain the plastic strain and non-uniform thickness much easier than usual press-forming analysis technique.

We apply HYCRASH for the S-rail model – simplified automotive side member – and compare the difference between without hardening, considering hardening and the test. By considering hardening, the reaction force was improved and the energy absorbing capability approximate test result.

And HYCRASH can reduce the data preparing and the analysis cost compared by the explicit analysis. In terms of accuracy we found that HYCRASH is accurate enough to predict the forming effect for the crash analysis even though it incorporates simple calculation method.

We are looking forward to show you the other application example – full vehicle case - at the conference.

5   Literature

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