Recent Development for Metal Forming Simulation

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Abstract

Since 1996, Japan Research Institute Limited (JRI) has been providing a sheet metal forming simulation system called JSTAMP-Works packaged the FEM solvers of LS-DYNA and JOH/NIKE3D, which might be the first multistage system at that time and has been enjoying good reputation among users in Japan. To match the recent needs, "faster, more accurate and easier", of process designers and CAE engineers, a new metal forming simulation system JSTAMP-Works/NV is developed. The JSTAMP-Works/NV packaged the CAD automatic healing function in it and had much more new capabilities such as prediction of 3D trimming lines for flanging or hemming, remote control of solver execution for multi-stage forming processes and shape evaluation between FEM and CAD.

On the other way, a multi-stage multi-purpose inverse FEM solver HYSTAMP is developed and will be soon put into market, which is approved to be very fast, quite accurate and robust.

Lastly, authors will give some application examples of user defined ductile damage subroutine in LS-DYNA for the estimation of material failure and springback in metal forming simulation.

1. Background

Sheet metal forming simulation technology is daily used in the die design and virtual production in the automobile industry and its related industries. The simulation solvers can be mainly classified into three types according to the methodology, which are explicit FEM solver such as LS-DYNA[1], implicit FEM solver and inverse FEM solver, respectively. Generally, explicit solver is much more robust, implicit solver may be more accurate if it converged and inverse solver should be much more fast than others. These three kinds of FEM solvers have been daily applied to various design processes for different purpose simulation according to the advantages of each solver.

As shown in Fig. 1, JRI developed a multi-stage system in 1996 for sheet metal forming simulation called JSTAMP-Works[2-3] using LS-DYNA and JOH/NIKE[4] as solvers, which are widely used in automobile industry, suppliers and steel companies in Japan. To meet the recent needs, "faster, more accurate and easer to use", we developed a new version named JSTAMP-Works/NV[5] in 2004. On the other way, we developed new inverse FEM solver named HYSTAMP[6]. It is available to multi-stage forming processes. It offers many functions for the simulation of formability, springback, process design and interface to LS-DYNA for crash analysis considering forming results, which is here named as multi-purpose simulation.

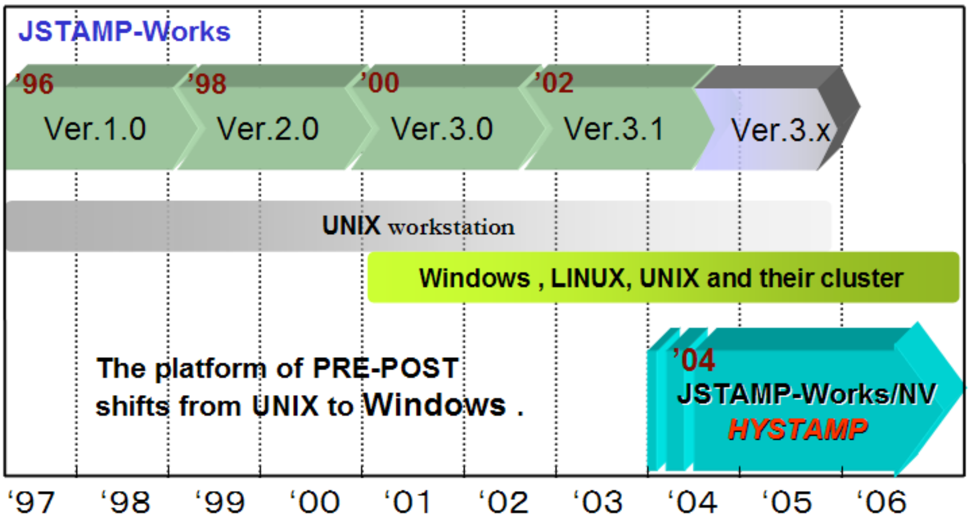
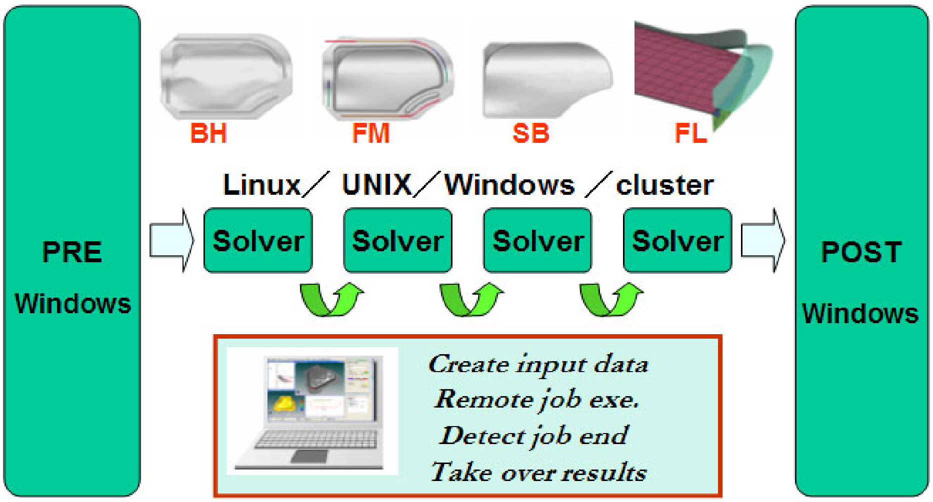


Fig.1 History of development of stamping simulation system in JRI

2. Development of New Version of Simulation System JSTAMP-Works/NV

JSTAMP-Works/NV consists of CAD interface, pre-post system on Windows, explicit solvers of LS-DYNA and implicit solver of JOH/NIKE with excellent convergence. The solvers are available on any platform of operating systems of LINUX, UNIX, Windows and their cluster as shown in Fig.2.



Fig, 2 Schematic showing of JSTAMP-Works/NV with pre-post and computation servers

2.1 Special Functions of Pre-system [8)]

The pre-system has many functions for stamping simulation. The special functions different from other systems are introduced as follows.

(1) Automatic Healing Function of CAD

As well known, the mesh is necessary for the FEM computation. The newly developed mesh generator has direct interfaces to IGES, JAMA-IS and CATIA V4/V5. To create high quality FEM mesh describing the tool shape, original CAD data of tool surfaces must be checked before meshing. In JSTAMP-Works/NV, the defects of the CAD data of the tool surfaces such as self-intersection, overlap, surface direction mismatch and lack of surfaces can be detected and repaired automatically using healing function of CAD system called spGate[7)], which is based on a check/repair tool of the PDQ* guideline (the Product Data Quality guideline enacted by JAMA and JAPIA). Fig.3 shows an example of die surfaces and good quality FEM mesh generated by JSTAMP-Works/NV.

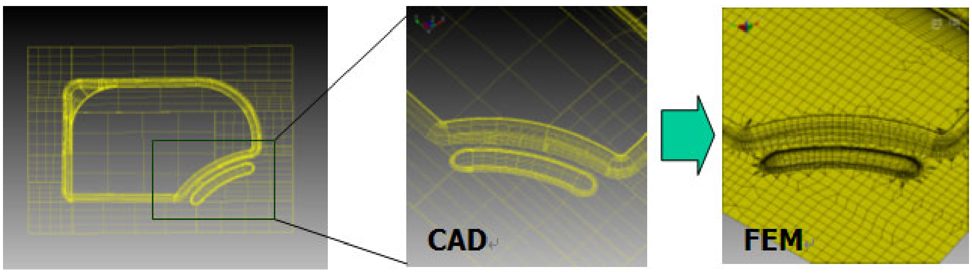


Fig.3 Die surfaces and mesh generated by JSTAMP-Works/NV (NUMISHEET99 BMT model)

(2) Multi-stage job execution with automatically remote control

This pre-system can collectively create the simulation input files for multi-stage processes and turns execution job one bye one into computation server by detecting the termination of previous job automatically. It makes the simulation more efficiently.

(3) Automatic modeling for TWB and tools

To reduce the weight and keep the enough strength of the cars, many Tailored Welded Blanks (TWB) have been applied to the car body. The TWB may consist of plates with different thickness or different strength. The design of weld line position, thickness and strength of the TWB, the tool shape close to the weld lines, are very important in order to improve the formability. In the JSTAMP-Works/NV, a special model for TWB was proposed as shown in Fig, 4. The originally weld lines can be easily translated or rotated to new designed position, the TWB mesh and the mesh of tools (die, holder and punch) can be simply changed by referring the weld lines of the TWB.

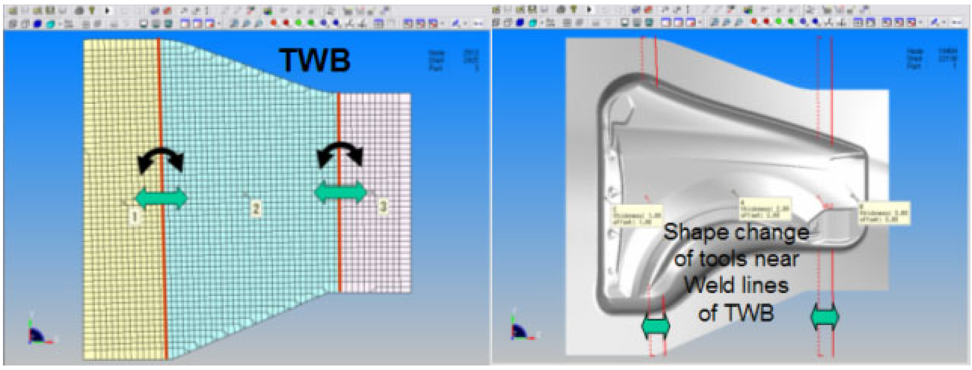


Fig.4 modeling function specialized for TWB simulation (NUMISHEET2002 BMT model)

2.2 Special Functions of Post-system [8)]

(1) Cracking tendency evaluation using FLD, thinning and damage parameters

The cracking tendency can be evaluated by any of thinning, FLD or damage parameters in Post-system. Fig.5 shows an application example of Post-system for cracking prediction based on FLD curve and strain path history of a stamped part during forming.

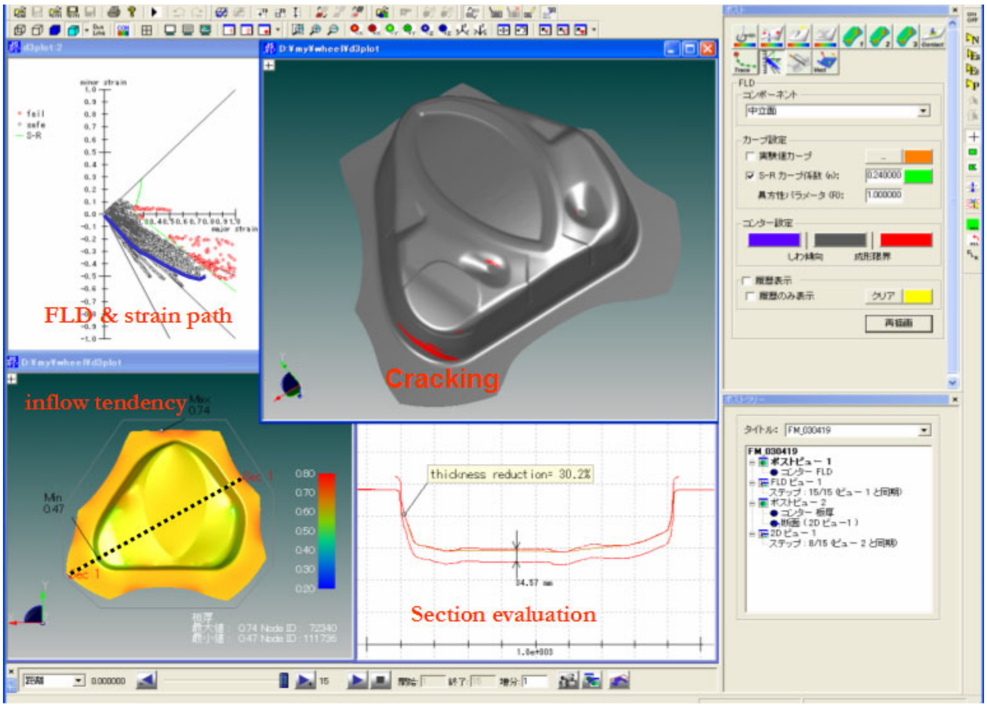


Fig.5 Schematic showing of Post-system

(2) Shape evaluation between CAD and FEM

The deformation of blank computed by FEM can be positioned on the product surface of CAD and the shape error can be measured in the Post-system automatically. This function reduced man-hours and improved evaluation accuracy very much. Fig.6 gives the general application of the function in the tool's design and Fig.7 shows an example how to use this function to evaluate the shape accuracy. The system gives four positioning ways which are so called as global best fitting, local best fitting, three points fitting and manual fitting.

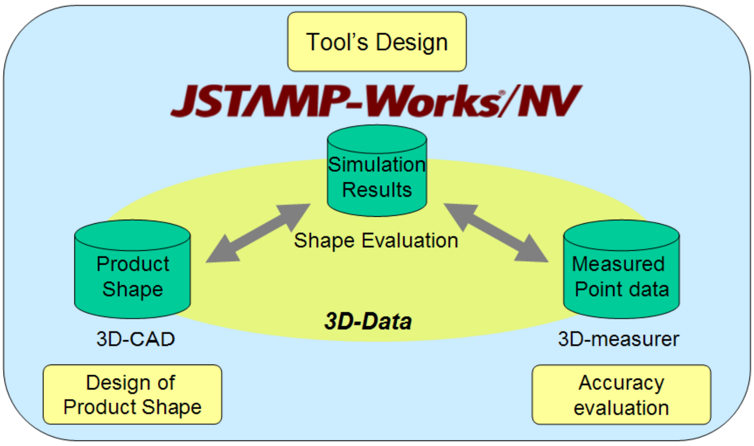


Fig.6 The general application of the shape evaluation function in the tool's design

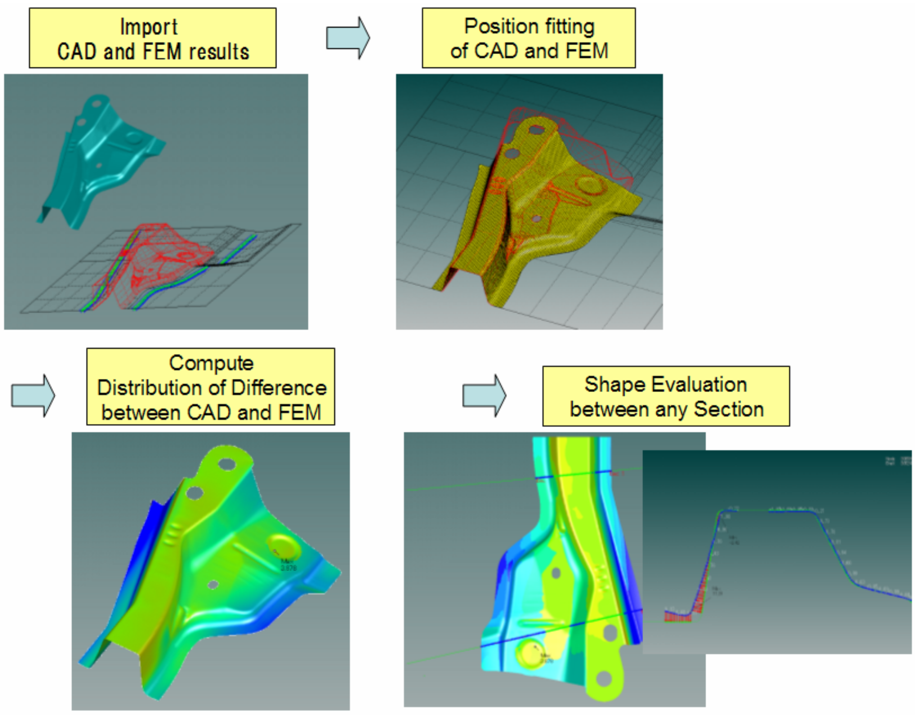


Fig.7 The flow of the use of the shape evaluation function (NUMISHEET2005 BMT model)

(3) Prediction of 3D trimming lines [9]

Up to now, the 3D trimming lines after drawing are mainly determined by experience and trial errors. This function can give much high accuracy of 3D trimming lines by using the multi-stage simulation results effectively. Fig.8 shows the flow how to predict the 3D trimming lines before flanging.

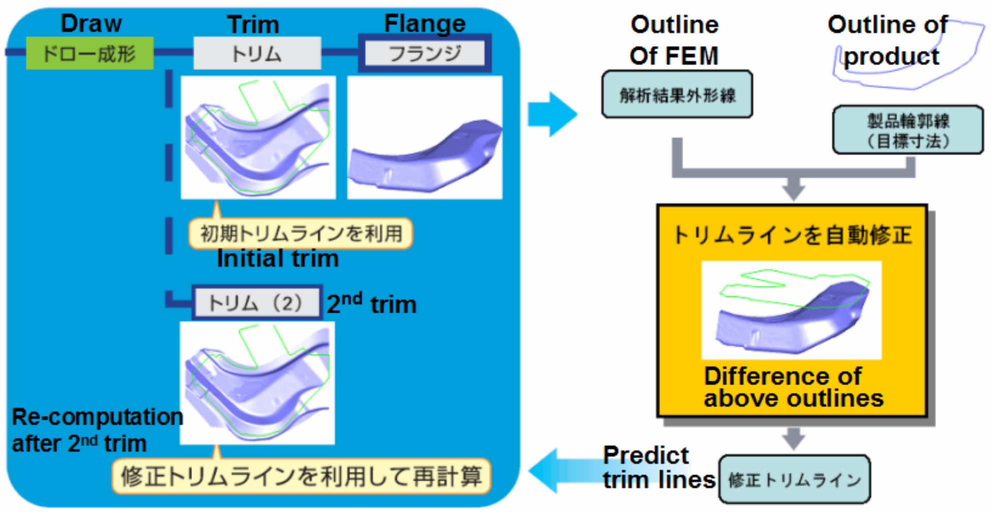


Fig.8 Prediction functions of 3D trimming curves (model from Takao Kinzoku Kogyo Co.[14])

2.3 FEM solvers

JSTAMP-Works/NV used LS-DYNA in forming simulation and implicit JOH/NIKE3D in the prediction of gravity deflection and springback, respectively. JOH/NIKE3D is customized according to user's requests in the convergence and accuracy.

As well known, LS-DYNA has SMP version and MPP version. PC-cluster will be much cheaper than UNIX. Therefore, many companies prefer to use PC-cluster with OS of LINUX and MPP version of LS-DYNA. Recently, user-defined subroutines are also developed for more accurate prediction of springback and cracking.

3. Development of Mutistage Multipurpose Inverse FEM Software HYSTAMP

Generally, inverse method is only used for single stage forming and blank size prediction. The HYSTAMP proposed a new methodology. It can be used for multi-stage and multi-purpose forming simulation. The main features are introduced in following sections.

(1) Fast solver available to large scale of models

The simulation models become larger and larger in order to conduct details analysis of large size parts. The computation time will become very long with the increasing of the FEM freedom. A new algorism is developed in HYSTAMP and the computation time can be much shorter. As an example shown in Fig.9, to compute a model with 280000 elements for formability evaluation, only 19min CPU time is necessary on Pentium4(2.0GHz).

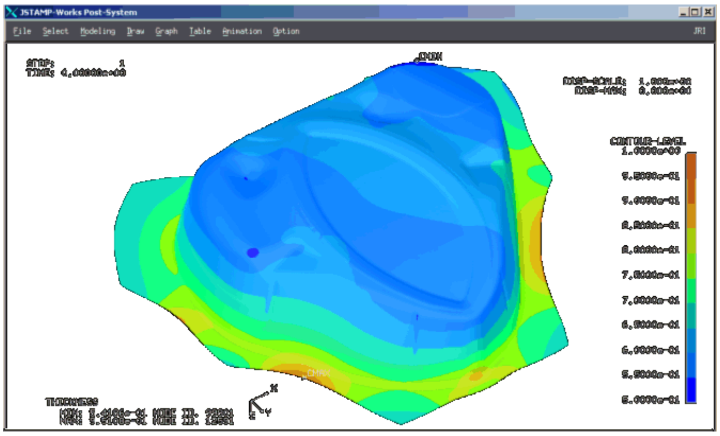


Fig.9 A model with 280000 elements and CPU time=19min on Windows

(2) Springback considering history of stress and strain

Because the history of the stress/strain for the material flowed into die cavity along the radius of the die shoulder is considered in HYSTAMP, the prediction of the springback becomes possible. Fig.10 shows an example for springback prediction when three materials with different yield and tensile strengths are used. Good agreement is obtained compared with experimental report[10).

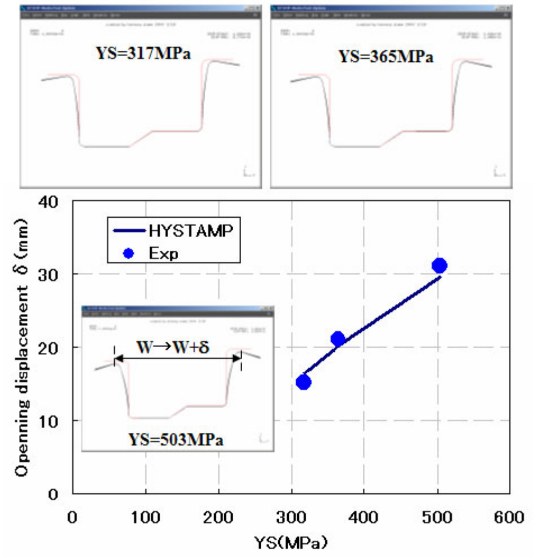


Fig.10 The springback predicted by HYSTAMP and measured by experiments[10)]

(3) Multi-stage simulation capability

A multi-stage example consisting of drawing (stage1), trimming (trim stage) and re-drawing (stag2) is shown in Fig.11. The simulated results are reasonable compared with those computed by LS-DYNA.

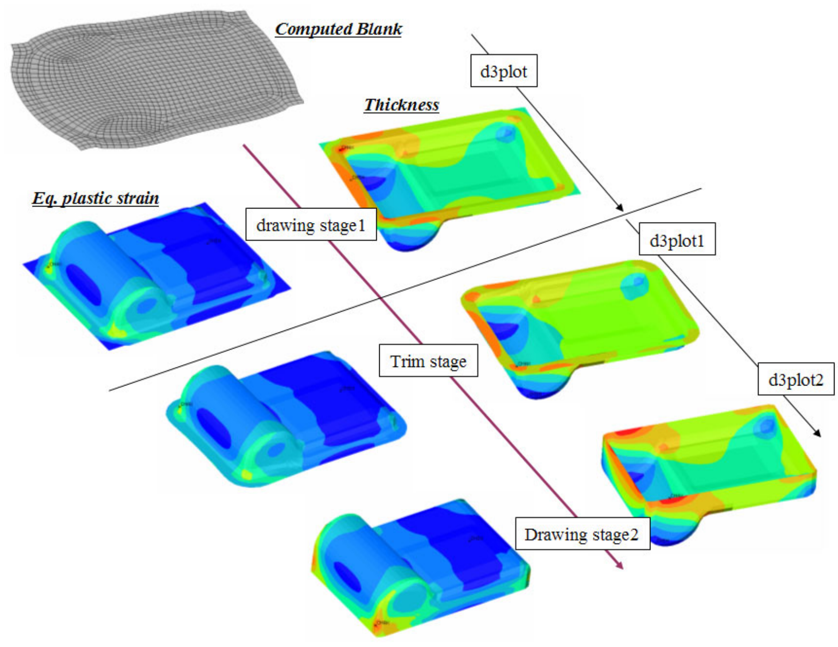


Fig.11 A multi-stage forming example and the results

(4) Interface to LS-DYNA for crash analysis

Recently, various analysis of stamped part such as crash strength and deformation due to heat treatment are observed. The distribution of thickness, stress and strain produced in stamped parts may have obvious effect on the followed simulations. However, the stamping results can not be prepared by exact solvers in very short time. HYSTAMP has interface to LS-DYNA for crash analysis. Any stamped part of car body as shown in Fig, 12 can be specified simply and stamping results can be automatically created for crash analysis within several minutes.

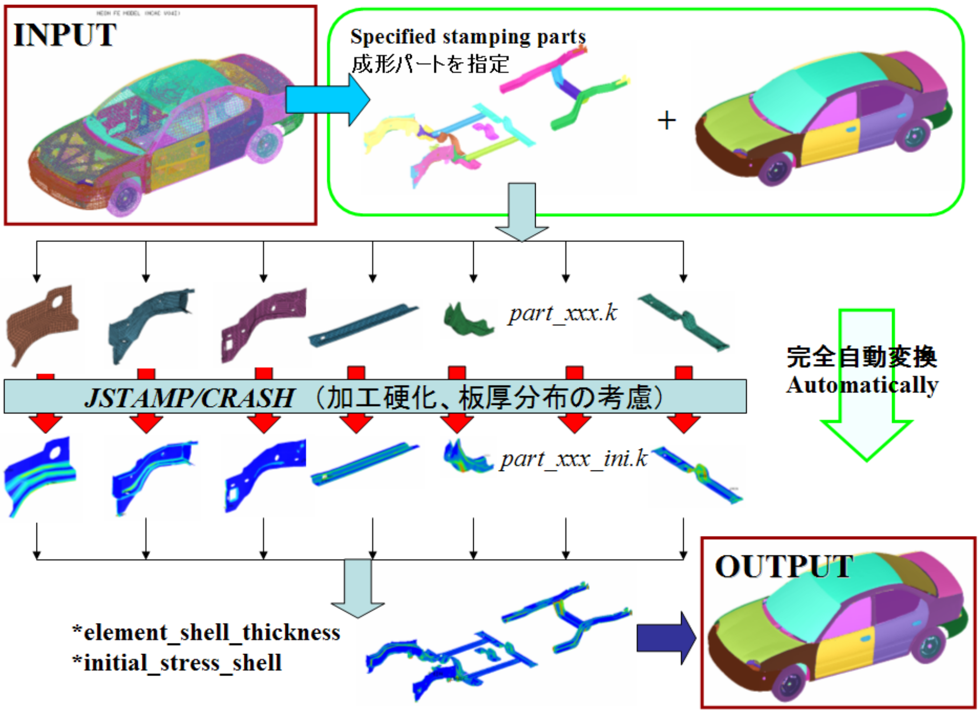


Fig.12 The flow on the crash analysis with stamping results using LS-DYNA

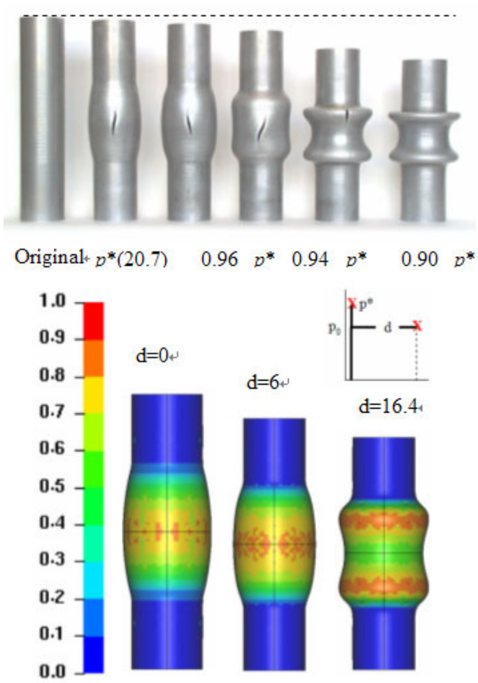
4. Development of Accurate Material Models for Stamping Simulations

(1) Damage parameters for material failure

The material failure due to metal forming is often evaluated by principle strains on FLD and thinning of plates or tubes. LS-DYNA user subroutine of ductile damage parameters is developed and used in the prediction of cracking produced in stamping and tube hydro forming. Fig.13 shows the distributions of ductile damage parameter of tube hydro forming. Good agreement is obtained between experiment[11)] and computation[12)].

(2) Kinematic hardening material models

As well known, the accuracy for springback prediction is affected by material model, the deflection of tools and application technology of software. We are now investigating various material models with kinematic hardening. Fig.14 shows a basic history of total stress and back stress using Yoshida-Uemori kinematic harderning model [13)]. The development of LS-DYNA user subroutine of kinematic hardening models will be soon finished and used in the simulation.



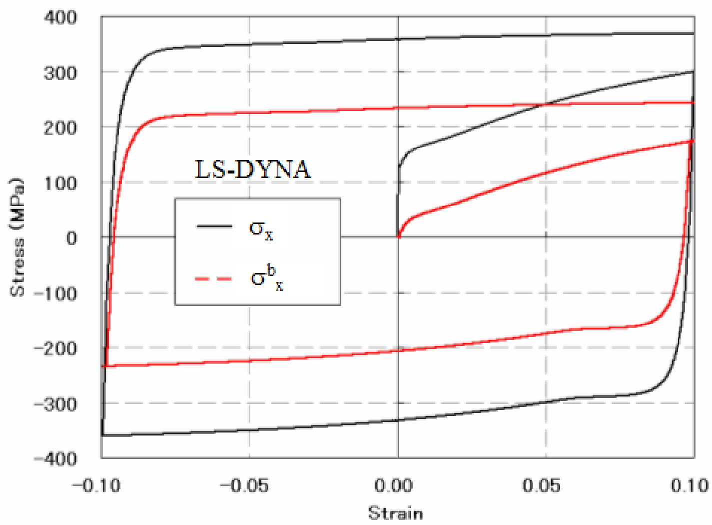


Fig.13 Prediction of forming limit computed using ductile damage parameter [11-12)]

Fig.14 The history of stresses by Yoshida-Emory kinematic hardening model

5. Conclusions

The metal forming simulation system JSTAMP-Works/NV, inverse FEM solver HYSTAMP and LS-DYNA user subroutines for the more accurate computations are developed. We will continue to supply the high quality services to the customers and to give a contribution to CAE.

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