The technical trend and future of the simulation of the precision forging in Japan

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1. Introduction
The forging technology supplied various kinds of parts mainly on the auto industry in manufacturing industry of Japan in large quantities. However, economic situation is to have turned worse by Lehman shock of 2008 rapidly, and industrial structure is changing greatly. The assembling industry mainly on the auto industry works on a part and an assembling cost cut by using a Southeastern Asian company. Therefore the forging industry of Japan is moving the production base to the foreign countries because assembling industry requires global supply chain.

The recent forging design utilizes a computer technology of 3D-CAD/CAM and CAE. As a result of having used them well, the forging product of Japan finds high international competitiveness by shortening of the forging process of the forging product of high quality, improvement of the amount of production. In Japan, the development of the new forging technology is necessary. As the means, inflection of the forging simulation becomes more and more important from now on.

From a result of the rapid progress of the computer, the forging simulation became able to analyze a careful phenomenon by carrying out 3D simulation. As a result, it comes to be used a lot now in the spot of forging.

2. Role of the forging simulation
A role of the forging simulation is to predict the phenomenon that occurred by study and development and the trial manufacture of the forging product or a mass production by a calculation (Table 1). It is really important to make a numerical value model based on the theory of the phenomenon to occur to raise predictive precision of the simulation. As for the data necessary for simulation, there are material and the coefficient of friction between the die to become the fixed number and the boundary condition of materials. The result of the simulation is influenced by the measurement precision of these input data.

3. Example of the forging simulations
The forging simulation is carried out at the stage of the design and a stage of the trial manufacture (Fig.1). The simulation of the design stage is used to examine a forging process designed based on demand specifications on a computer. The design of the forging product needs technical information such as estimate of the load to be necessary for production,
deformation process, stress or strain. The simulation of the trial manufacture stage is used to solve the problem that occurred by a result after forging. Based on a simulation result, it is carried out the review of a review and the die design of the process design.

**Table 1 Visualization by forging simulation**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Phenomenon</th>
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<tbody>
<tr>
<td><strong>Forging</strong></td>
<td>Metal flow (filled, dimensional accuracy etc.)</td>
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<td></td>
<td>Defect (crack, permeation etc.)</td>
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<td></td>
<td>Stress, Strain</td>
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<td></td>
<td>Workability (forging load)</td>
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<td>Temperature distribution</td>
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<td></td>
<td>Prediction of material properties</td>
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<tr>
<td><strong>Die</strong></td>
<td>Fracture</td>
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<tr>
<td></td>
<td>Elastic deformation</td>
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<tr>
<td></td>
<td>Stress, Strain</td>
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<td>Seizure</td>
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<td>Wear</td>
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3.1 Simulation of forging process condition

The prediction of the processing condition decides the most suitable condition of forging from metal flow and forging load and stress and strain. The example of the forging simulation is the result that predicted forging load and full enclosed die force of cross join part produced in full enclosed die forging of precision cold forging (Fig. 2). In addition, Fig. 3 is the example that made the parts of toothed of cold forging a net shape utilizing divided flow method.
Fig. 2 Calculated results of load in forging of cross joint.

Fig. 3 Calculated results of deformation and stress in gear part using divided flow method.

3.2 Simulation of the Plate forging part

Fig. 4 is a rotor part for generation such as the hybrid systems of the car. This part is the plate forging technology using the combination of sheet forming and plate forging. Fig. 5 considerably shows distortion distribution and hardness.

3.3 Simulation of the hollow shaft

The hollow shaft of Fig. 6 is a simulation result using the back pressure. Control of the back pressure is important to this forging. When back pressure is small, a break occurs to the sidewall part.
Back Pressure in der Umformtechnik

3.0
1.5
0

(Cross section)

Fig. 4 Actual plate forging part and the position that measured hardness.

Equivalent stress

Fig. 5 Relationship between calculated strain and measured hardness (HRC).

(a) Calculated results of strain using backpressure in backward extrusion.

(b) Actual products

(Most suitable back pressure)

(Small back pressure)

Fig. 6 Calculated results of the hollow shaft.

Measurement point: 1-8
3.4 Materials breaking prediction (Analysis of the ductile fracture in extrusion)

When materials catch the large deformation by the forging processing, and tensile stress occurs partially, ductile fracture may occur. Condition type of Oyane's or Condition type of Cockroft & Latham are suggested to predict these materials breaking.

Fig. 7 is a real damaged forging product. In addition, Fig. 8 is a simulation result provided by a calculation with an expression of Oyane's. It was damage range of these materials, 0.65. A position of the damage is good, and the damaged forging product accords from a calculation result of the simulation.

3.5 Optimization of the die shape

The prediction of damage and the life of the die influences the productivity of the forging product greatly. The prediction of the die life simulates a damaged die and will find out a shape and the structure of the improved die of the stress level. The prediction of the die life simulates a damaged die and will find out a shape and the structure of the improved die of the stress level. As a method to predict die life, Modified Goodman's diagram is used recently.

Fig. 7 Actual product of breaking.

Damage value distribution

Fig. 8 Prediction of crack in rotor part.
4. Conclusion

This introduction example utilized forging simulation in a design and development. The forging simulation becomes the practical use level and is used as one of the tools of the solution to the problem in a design and development. It is wished this software develops in forging as the center of the tool which can create a new process and a method of forming more. Furthermore, an experiment and trial manufacture will be reduced if precision and reliability of the simulation software improve, and how to use improves.

This software expects that it develops of the guarantee of quality system of the forging product, the forging simulation software which integrated an evaluation system, the predictive system of the forging process with a prediction of the die life.

Fig.9 Predictive method of the die life.