Design and Development of Hot Stamping Simulation System and its Applications

Ninshu Ma
JSOL Corporation, Japan
Bonyong Ghoo
JSOL Corporation, Japan
Nobuhiko Sugitomo
JSOL Corporation, Japan
Hidetaka Ito
JSOL Corporation, Japan

Corresponding Author Email: ma.ninshu@jsol.co.jp

ABSTRACT

With the increasing application of hot stamped parts to automobile bodies, simulation has become a basic tool for the formability evaluation in designing parts and tools. The hot stamping process is strongly coupled with multi-physical phenomena of thermal transfer, temperature dependent material properties, material phase transformation in thermal cycles and large mechanical deformation. To answer the strong requests from industries, an easy operational and accurate hot stamping simulation system was designed and developed considering multi-physical characteristics occurred in the hot stamping process. Then, formability was evaluated and hardness was predicted. The thermal cycles due to single shot and multi shots using a test tool with air cooling and with water cooling were simulated and compared with measured ones.

Keywords- Hot stamping, Simulation system, Formability evaluation, Hardness prediction, Thermal cycles.

1. INTRODUCTION

To reduce the weight of automotive bodies and to improve the crashworthiness, convectional stamping parts of advanced high strength steels and hot stamping parts with ultra-high strength up to about 1500MPa have been increasingly employed in automotive bodies. Compared with the conventional sheet metal forming process of high strength steels, the hot stamping process utilizes the good elongation which can improve formability and lower flow stress of steels at high temperature which can reduce forming force.

When the forming process ends, the subsequently fasting cooling process in the closed tools induces a very strong martensite microstructure. As a result, the hot stamping parts have higher strength and also the less springback which was measured by Mori et al [1] and Kusumi et al [2] in their hat bending models.

This advanced forming process stimulated the academic research activities very much which were reviewed by Karbasian and Tekkaya [3]. As a basic research, Merklein and Lechler [4] measured stress-strain relation of a hot stamping steel and its changes with temperature from $500^{O}C$ to $800^{O}C$. Turetta and Bruschi [5] developed an experimental apparatus at high temperature and investigated formability of a hot stamping steel with different austenite volume fraction. Naderi et al [6] measured the Vicker's hardness of the hot stamping steel 22MnB5 at different cooling rate and presented the correlation between cooling curves and hardness with CCT diagram. This work gave us a hint that the Vicker's hardness can be simply estimated for industrial applications if cooling rate was computed by numerical simulation.

This advanced forming process also promoted the research on the simulation technologies and accelerated the development of FEM software for hot stamping simulation. Bergman and Oldenburg [7] investigated thermal-mechanical coupled simulation method, developed a thick shell for thermal simulation and proposed a thermal-mechanical contact algorithm based on the research by Shvets [8]. Akerston et al. [9] developed thermal-mechanical material models for numerical simulation. Shapiro [10] implemented the thick shell thermal element and thermal contact feature into a commercial software for industrial application. Olsson [11] implemented solid phase transformation material model into a commercial software for the coupling simulation among thermal field, mechanical field and microstructure field.

In order to verify the capability of FEM software for practical applications, Oberpriller et al [12] provided an open hot stamping benchmark and necessary data for numerical simulation to industrial engineers and academic researchers. Compared with many participants using various software codes for the cold metal forming benchmark provided by Volk et al [13] and benchmark provided by Roll et al [14], only a few research teams submitted the hot stamping benchmark results. This is because the hot stamping simulation was still difficult for industrial engineers.

The application of hot stamping parts increased the freedom of material selection and the design freedom for automotive bodies. It also accelerated the application of simulation technologies to automobile relating industries. The strong requirements from industries pushed