

Study on Strength Prediction of 6000 Series Aluminum Alloys Using Machine Learning and its Application to Crash Simulation (Second Report)

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Automobile outer panels such as hoods often utilize 6000-series aluminum which has bake-hardening (BH) property. In the performance development, post-BH yield strength (BHYS) is set up higher than the actual panel property to absorb manufacturing variations. However, the performance development by the aforementioned method is actually becoming inhibiting factors against man-hour increase in defining design specification where the margin is excessive. This inconsistent BHYS is also a challenge in realizing Model-Based Development (MBD). From the above, this study aims to establish BHYS prediction technology and apply this technology to the development, aiming to streamline the design specification finalization processes. In the first report, we selected the BH influencing factors and predicted the aging curve by machine learning. In the second report, we introduce initiatives to enhance the prediction accuracy for the pedestrian protection performances by applying this technology to CAE.

First of all, the initial report to be reviewed. We selected BH influencing factors: "heat treatment time," "heat treatment temperature," "amount of pre-strain," and "application direction of pre-strain". Other influencing factors impacting on BHYS were deemed ignorable since the impact on vehicle development seems minor. Furthermore, the condition ranges for each factor were set in a way of completely encompassing the mass production processes. Machine Learning was utilized for the BHYS prediction. A neural network was employed to create a model which output BHYS prediction values if the four variables were applied as input data. We incorporated 103 cases of learning data sets and modified the algorithm by human knowledge to generate an initial aging curve. We confirmed the prediction accuracy with sixty verification test data sets and figured out that the mean error was $\pm 3\%$ on average and $\pm 12\%$ on maximum.

Next, we introduce the application of this technology to pedestrian protection CAE. Two changes were made to the conventional CAE: the setting of initial strain (=pre-strain) and the setting of BHYS (SS curve) for each initial strain. Initial strain was applied to each area by incorporating the molding analysis results into the collision CAE model. The BHYS values for each initial strain were based on the SS curve for 2% pre-strain (heat treatment conditions: 170°C x 20 min), and the SS curve was shifted to calculate the BHYS value corresponding to the initial strain, thereby setting up SS curves for each initial strain. Ideally, SS curves shall be obtained for each initial strain; however, this method was adopted considering that the impact on CAE validation was minor since this is not a fracture mode. The head impact locations were validated at a total of 33 points in the hood outer perimeter area. This led us to anticipate an improvement in impact locations around the character lines and relatively close to the inside of the vehicle (Y ± 5 , 6th row).

CAE results are illustrated in Fig. 1. The blue cells represent improved performance compared to the base CAE, and the impact point is closer to that of actual unit testing. Overall, we believe that we have achieved desired results. On the other hand, the red cells indicate impact locations underwent worsening from the base CAE and deviated from the results of actual unit tests. These are impact points where structures such as the hood lock, lamp, and hood hinge are located below. As a result of the initial energy absorption (EA) decreases due to the optimization of the hood, the EA was compensated for by a structure harder than the hood, leading to increased drag in the latter half of the collision and a rise in the Head Injury Criterion (HIC). In addition, another contributing factor is that the strength of these components is set higher than that of the actual unit.

In conclusion, we obtained a prospect that adopting this method will improve the accuracy of theoretical estimation for head impact areas where the hood is dominant. Improving estimation accuracy in other areas will require further refinement of the base CAE model, which is a subject for future consideration. From the above, we believe that we have achieved the objectives of this research: establishing BHYS estimation technology and improving the accuracy of MBD. This will enable us enhancing design freedom and improving development efficiency.

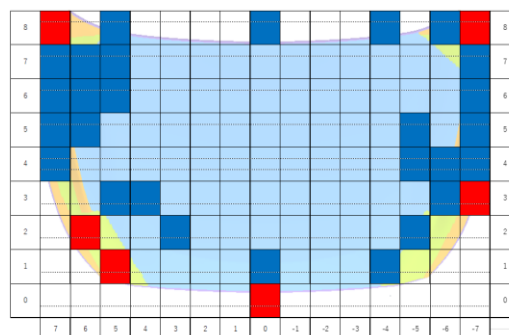


Fig. 1 Result of CAE