Rule-based Quality Execution System

The benefits of integrating laboratory testing data into the hot metal forming manufacturing process for the automotive industry. By Michael F Peintinger PhD and Jacqueline Peintinger*

Applying a rule-based quality execution system in the manufacturing process of press hardening steel brings huge benefits through optimisation of the production process while at the same time assuring the highest quality standards. Laboratory testing data is fully integrated into the workflow. This enables quality laboratory engineers to make better and more long-term use of the acquired data, for example, using it for statistical analysis. A better understanding of quality data and their correlation improves process know-how and assures consistent and reproducible product quality. This is a challenge, as steel is transformed from simple geometries like strip or bars into complex components as the result of hot press forming.

Profound process know-how
Hot sheet metal forming has become the state-of-the-art technology when manufacturing components with exorbitant properties for the automotive industry (Karbasian20102103). Providing parts with the highest geometrical complexity and ultra-high strength requires profound process know-how in order to comply with ever increasing customer requirements regarding safety and weight. However, in contrast to non-material-changing manufacturing techniques, the burden of liability is shifted from the steel producer to the part manufacturer. Steel and aluminium producers go to great lengths to assure material properties and product quality by implementing a Quality Execution System (QES) on top of a Manufacturing Execution System (MES) (Fig.1). Data consistency checking and data evaluation as well as product and process grading along the full production chain is mostly automated through the application of rules. However, the application of such systems is not standardised in what is still a young hot stamping industry.

However, continuously evaluating product and process quality data is key to long-term success, especially when targeting the challenging automotive market.

Rule-based quality assurance
Assuring that product and process quality are according to specification is one of the main features of a QES, which is implemented as a set of data-integrating and rule engine-based software modules. Focusing on user-friendliness while still

Fig. 1. MES-QES

Fig. 2. Integrated hot stamping work-flow with QES

* Quinlogic.
implementing advanced features is key for quick adaption and one of the main reasons for the success of QES among steel producers. Such a system allows a multitude of quality criteria to be specified, managed and changed.

Recent quality trends and production performance are displayed on a Live Process Quality Monitor on the press line. The monitor displays all the process and product-relevant quality data (oven temperature, time-from-oven-to-press, total tonnage) of recently produced parts and their type specific, respectively customer specific limits (“data-in-context”).

For reviewing purposes, live production results are also displayed in the quality laboratory where destructive and non-destructive testing is performed, so that samples from specific dies can be requested.

The system creates and stores certificates for each product that are accessible on a web service assisting engineers to resolve customer claims.

Collecting laboratory testing data
Manual laboratory testing executed by experienced technicians verifies if the desired product properties of the hot-stamped part could be successfully achieved. Parameters like mechanical properties, hardness, coating quality and micro-structure are usually tested. However, acquiring testing data is a time-consuming and expensive process that is often carried out manually. Reports are filled in handwritten or on spreadsheets.

In an average manufacturing facility, several thousand samples are analysed every year and as a result gain statistical relevance. This data can be used in rule sets if it is standardised and available within an analysis tool, such as DataDiagnose.

The QuinLogic LabReports module (Fig.2) features an input mask that stores the manually measured data into a database so that it is available throughout the whole QES infrastructure. Standards depending on customer and material can be managed from within the application.

Data from non-destructive testing devices, for example, 3MA from Fraunhofer IZFP (F3MA), which is already stored in a database, can be directly read from the origin database. Reports in PDF file format can be created automatically or on-demand. Having all production and testing data available allows quality engineers to prove product quality if claims need to be settled.

Beyond sample testing
Press-hardening is a knowledge-driven technology \(^3\) (CHS2). Constantly linking production data with the verified material properties of the finished product allows a steep learning curve on the hot metal forming process that goes beyond assuring product quality. A rule set constantly checks if the process parameters are within the specification of the recipe.

However, even if there is no large deviation between process parameter feedback and specification, it does not necessarily mean that the desired material properties were achieved if no sample was taken for testing as verification.

Since all data that is connected to the QES is available within rule sets, the testing data can be used for verification purposes. The LogicDesigner is a rule-creation, -maintenance and -management tool that is used to set up a rule set to verify whether desired product properties were reached. Since there are a significant number of samples per product group available, this can then be extrapolated to the full product group.

By running simulations with differently tightened thresholds, engineers gain insights as to which process parameters are most likely to be responsible for not reaching desired product properties. This leads to faster qualification of new products and helps detecting most common process errors.

Conclusion
Verifying and documenting product quality is key to the long-term success of manufacturers applying hot sheet metal forming technologies. A QES is a major component in the quality assurance process. It does not only provide rule-based product and process grading, but also merges all data sources, automated and manual, into one system allowing statistical analyses. Having one access point to all quality-related data allows quick reaction times to up-building problems.