Chapter 14
Automobile Optimal Product Design Model: Application to Study the Bolt–Nut Loosening Mechanism

ABSTRACT

In this chapter, the author establishes an Automobile Optimal Product Design Model (AOPDM) as part of a principle-based research aimed at the innovation of development design processes in the automotive industry. As strategic deployment of Advanced TDS, this model's validity is verified with application to study on loosening mechanism of bolt-nut tightening and others as the auto-manufacturers' bottleneck in the world. To enable the high-quality assurance and simultaneous achievement of QCD to satisfy the requirements of developing automobile product design, it is necessary to initiate the transition from the conventional prototype testing method to predictive evaluation method by the combination of various experiments and CAE.

INTRODUCTION

The technological challenge currently facing Japanese auto-manufactures is to enable the high quality assurance and simultaneous achievement of QCD (quality, cost and delivery) by innovating product design processes, in order for them to prevail in the worldwide quality competition. Therefore, as the strategic deployment of Advanced TDS, it is necessary to undertake principle - based research in design and development (Amasaka, 2012, 2015a, 2019a) (Refer to Chapter 6).

Concretely, the author has conducted actual application case studies and established an Automobile Optimal Product Design Model (AOPDM) by combination of various experiments and numerical simulation (computer aided engineering, CAE) with statistical science based on their findings (Amasaka, 2007, 2008, 2010a, 2012, 2015b, 2019b; Amasaka Ed., 2007a, 2012; Amasaka et al., 2012, 2014).

DOI: 10.4018/978-1-7998-8746-1.ch014

To make the transition from the conventional prototype testing method to predictive evaluation method, this model contains four core models: (i) Total Intelligence CAE Management Model, (ii) Intelligence CAE System Approach Model, (iii) Highly Precise CAE Technology Element Model, and (iv) Highly Reliable CAE Analysis Approach Model. The author has succeeded in helping to overcome the current technological challenge through the unified application and systematic development of these core models for the innovation of product design in automotive industry.

The validity of this creative model was verified with application to study on bolt-nut loosening mechanism and others as the auto-manufacturers' bottleneck in the world automotive industries (Ueno et al., 2009; Takahashi, T, 2010; Yamada and Amasaka, 2011; Kozaki et al., 2012; Onodera and Amasaka, 2012; Amasaka et al., 2014; Hashimoto et al., 2014; Nomura et al., 2015, 2016; Shimura and Sakurai, 2015; Amasaka, 2015a,b, 2019c, 2022).

SIGNIFICANCE OF THE RESEARCH

Automotive Product Design and Production

In response to harsh competition, Japanese automotive enterprises have recently been promoting global production to realize uniform quality worldwide and production at optimal locations (Amasaka, 2007). The mission of the automotive manufacturers in this rapidly changing management technology environment is to be fully prepared for worldwide quality competition so as not to be pushed out of the market, and also to establish a new management technology model that enables them to offer highly reliable products of the latest design that are capable of enhancing value for the customer.

In terms of management technology for development and production processes, it is clear that there has been excessive repetition in prototyping, testing, and evaluation for the purpose of preventing the "scale-up effect" in the transitional stage between design / development and mass production. This has resulted in unstable built-in quality assurance in the product design stage, as well as an increase in development times and cost. Therefore, it is now vital to reform conventional product design processes (Nihon Keizai Shinbun, 2000, 2012). This can be achieved by shifting from so-called "product design through actual product confirmation and improvement" to a process of predictive evaluation–oriented development through the effective use of the latest numerical simulation (CAE) (Amasaka, 2007, 2008, 2010, 2015a).

Figure 1 shows the developments in the automotive product design process in Japan. In the past, model changes required approximately four years from development of product design to production. Once the design process was complete, problem detection and improvements were repeated mainly through the process of prototyping, testing, and evaluation. In some current automotive development processes, vehicle prototypes are not manufactured in the early stage of product design due to the utilization of CAE and simultaneous engineering (SE), resulting in a substantially shorter development periods.

It is now possible to utilize CAE for comparative evaluation, rather than the conventional supplementary "observation" role during prototypes testing. This improvement means that CAE is now utilized to the same extent as prototype testing. The vehicle product design and production processes have been shortened to one year, and there has been a transition to a super short-term concurrent product design process based on the utilization of CAE and Solid CAD, allowing individual processes to progress si-