

Quality Variation Control Method and Process

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ABSTRACT

This paper describes the development of a design method and process for quality variation control. Conventional approaches utilizing Taguchi method [6,7,8] can quantify the sensitivities of parts characteristics on a system characteristic from both viewpoints of nominal value and variation. But the interpretation of the sensitivities depends on engineers' judgments. At the new process, function deployment has been introduced as the tool for breaking down hierarchically vehicle performance to the level of parts characteristics. And the relation between vehicle performance and parts characteristics is formulated based on a physical model in order to interpret the sensitivities more technically. The methodology combining the formulated function deployment and Taguchi method is referred to as design response analysis and variation effect analysis. These approaches can facilitate the interpretation of the quantified sensitivities considering the mechanism. This is the distinctive feature against the conventional approaches and makes it possible to determine the design nominal values and important control characteristics more systematically.

1. INTRODUCTION

At Nissan, we are proceeding with a Quality Leadership program aimed at halving the incident rate of Nissan vehicles by 2012. Efforts have been made to strengthen our quality improvement system in order to accomplish this goal. One example in this regard is a type of activity designed to prevent problems in the first place by not creating or passing on any new defects or sources of customer dissatisfaction. Another approach is continuous quality improvement activities aimed at preventing the recurrence of problems by accumulating quality improvement technologies used to address defects and sources of dissatisfaction that surfaced

previously and by applying those technical solutions to improve the quality of new models and ones already in production (Fig 1).

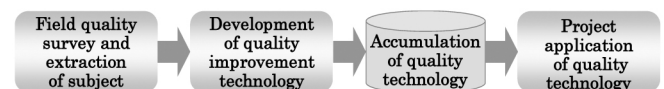


Figure 1. Flow of continuous quality improvement

The most critical issue in these activities is to improve and eliminate defects and sources of dissatisfaction caused by variation in product quality. For the purpose of controlling the quality variation, we have developed a design method that simultaneously considers the mean value and the variation of vehicle performance and system characteristics, and a process has been implemented for applying this method (Fig. 2).

Issues requiring quality variation control have been identified on the basis of analyses of quality reports from the field and the results of the J.D. Power and Associates Initial Quality Study (IQS). Quality improvement technologies have been continuously developed utilizing the quality variation control process. As a result, 34 technical solutions for controlling quality variation were accumulated over a three-year period and applied to the development of new vehicles.

This paper describes the overall quality variation control method and its application process and presents examples of its application and the effects obtained.

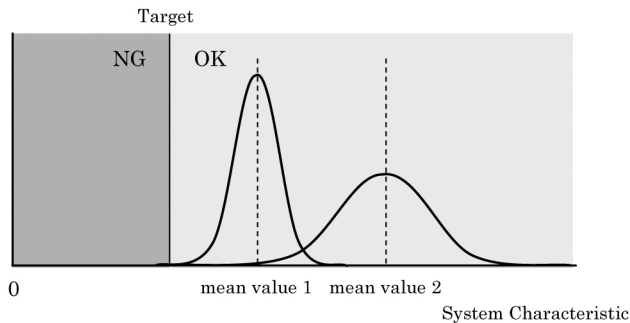


Figure 2. Variation control design

2. IMPLEMENTATION OF DESIGN METHOD AND PROCESS FOR CONTROLLING QUALITY VARIATION

Quality variation is broken down into variation in customer expectations, variation in vehicle performance and functionality, variation in parts characteristics and variation in manufacturing processes. As outlined in Fig. 3, an integrated process and standardized tools have been implemented for controlling quality variation in the quality target setting phase, design phase and production phase.

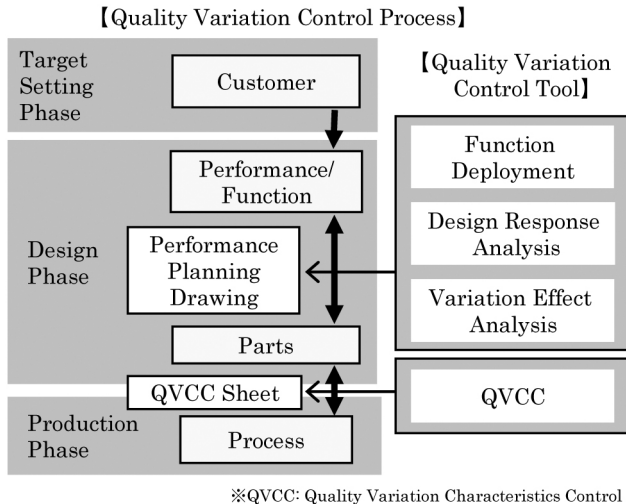


Figure 3. Quality variation control process

2.1. ASCERTAINING VARIATION IN CUSTOMER EXPECTATIONS

Customer expectations regarding the functionality and performance of operations they perform, such as door opening/closing effort and vehicle pull on freeways, vary depending on their driving experience, physique and personal preferences. Ascertaining this variation in customer expectations is regarded as being the first step toward the

development of technologies for controlling quality variation. Quality targets are set by taking into account such variation in expectations, based on the results of interviews with customers, observations made while riding with them, motion analyses and other methods.

2.2. TOOLS FOR CONTROLLING QUALITY VARIATION

(1) Function deployment

We have standardized a method, called “function deployment,” for breaking down vehicle performance or system characteristics hierarchically and in a mutually exclusive and collectively exhaustive (MECE) manner to the level of parts characteristics. Three patterns have been standardized in this method: the balance of force or energy, vibration transmission characteristics and the accumulation of positional and dimensional tolerances. These three patterns can cover most of the quality variation issues. Function deployment in a MECE manner makes it possible to avoid missing any variation elements that affect system characteristics. Based on function deployment, a physical model is applied to a phenomenon of interest, and the relationships between the system characteristics and parts characteristics are formulated. In cases where the phenomenon does not fit the physical model, a simulation model or an experimental equation is also used. This formularization approach is the biggest difference from quality function deployment (QFD), and it facilitates the combination of function deployment with the quality engineering methods that will be described later.

Figure 4 outlines the application of function deployment to the door glass elevating speed. In the first step of function deployment, the force balance is expressed, and the second step extends the analysis to the parts characteristics composing the forces involved. In the case of this example, the relationship between the door glass elevating speed and parts characteristics is formulated in terms of the torque and speed characteristics of the drive motor based on the force balance.

(2) Design response analysis and variation effect analysis

Combining formulated function deployment with the parameter design method of quality engineering [3] makes it possible to execute a design that simultaneously takes into account the mean value and variation of system characteristics. We refer to this approach as design response analysis and variation effect analysis.

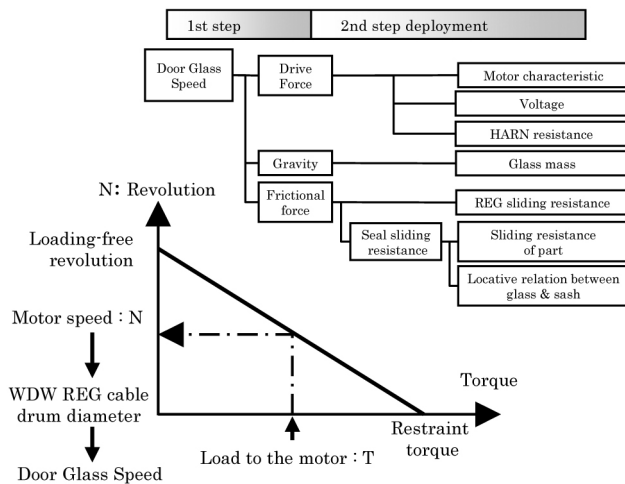


Figure 4. Function deployment on door glass elevating speed

In a design response analysis, the sensitivity of parts characteristics to the mean value and variation of the system characteristics is quantified. Parts characteristics are assigned to a three-level orthogonal array [3], consisting of upper limit, median and lower limit values, within the allowable degrees of design freedom. Two further levels are specified for each of the three levels within the range of manufacturing variation so as to create a two-level orthogonal array. These two orthogonal arrays are combined to calculate the system characteristics. This makes it possible to quantify simultaneously the sensitivity of the parts characteristics to mean value and variation of the system characteristics. Additionally, the use of orthogonal arrays allows the sensitivity of all parts characteristics to be quantified in a vastly fewer number of calculations compared with full factorial calculations. For example, in the case of six parts characteristics, by combining the three-level orthogonal array of L_{18} and the two-level orthogonal array of L_8 , the number of calculations can be reduced by 1/324 compared with full factorial calculations.

In general, the sensitivity of the parts characteristics to the system characteristics varies depending on the levels of the other parts characteristics. However, calculating the sensitivity according to the arrays of the orthogonal tables results in averaged sensitivities in relation to the equal changes occurring in the levels of the other parts characteristics.

Figure 5 shows an example of the application of a design response analysis to the door glass elevating speed in order to quantify the sensitivity of each part characteristic. The results indicate that motor characteristic B is effective in improving the mean value of the system characteristic (i.e., door glass speed). It is also seen that motor characteristic A, seal friction, harness resistance are effective in improving the

variation. The signal-to-noise (S/N) ratio given in the figure is the measure used in quality engineering to evaluate variation of the system characteristics. It corresponds to the magnitude of the ratio between the mean value and the standard deviation of the characteristic.

Using the results of the design response analysis, the values of the parts characteristics are determined from the dual perspectives of the improvement in the mean value and variation of the system characteristics.

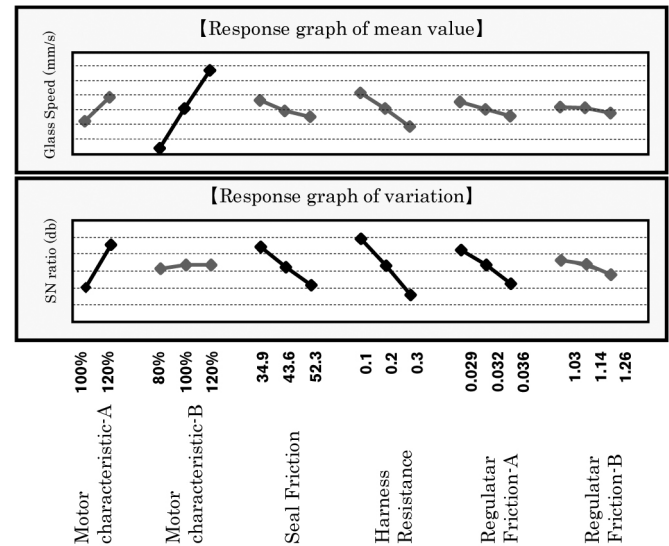


Figure 5. Response graph of the mean value and variation for door glass elevating speed

A variation effect analysis is then conducted to identify the important characteristics to be controlled. This is done by analyzing how the variation in parts characteristics affects the variation in system characteristics. In this analysis, the system characteristics are calculated by specifying two levels of parts characteristics around the design values determined in a design response analysis and within the range of manufacturing variation or design tolerances. The variation effects are found by using orthogonal arrays in the same way as in the design response analysis. In the case where six parts characteristics are selected and assigned to an L_8 orthogonal array, the number of calculations can be reduced by 1/8 compared with full factorial calculations.

Figure 6 is a Pareto chart of the variation effects for the example of the door glass elevating speed. Variation effects can be quantified with contribution ratio normally used in design of experiment (DOE). The chart shows that approximately 80% of the variation in the door glass elevating speed can be attributed to the variation in the drive motor characteristics. Determining the variation effects quantitatively makes it possible to identify exactly the important characteristics that should be controlled in the manufacturing processes. In this way, we succeeded in