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Study on the Influence of Ambient Temperature Change on Automobile Quality Consistency

Jun Wang, Jipeng Liang *, Bin Wang

China Automotive Research Institute Automotive Inspection Center (Tianjin) Co., Ltd. Tianjin, China

* Corresponding Author: Jipeng Liang (Email: liangjipeng@catarc.ac.cn)

ABSTRACT

The perceived quality of the whole vehicle is a core issue that car companies are currently focusing on, and dimensional engineering is a key factor affecting its quality. The interior and exterior trims of a car will produce slight deformations due to the influence of ambient temperature, causing changes in the matching dimensions of the interior trims, and placing higher requirements on the consistency of the quality of automobile products. This article analyzes the deformation mechanism of typical parts at different temperatures, combines dimensional engineering technology, reveals the influence of temperature on the gaps of the interior trims of the whole vehicle, and measures the dynamic changes of the gaps and face differences of the test pieces during temperature changes through actual tests, providing a theoretical basis for the dimensional engineering design of automotive interior and exterior trims, while providing practical experience references for product design, development and quality improvement, helping to predict problems in the early stages of design, and creating products with higher quality standards through collaboration in all aspects of production and manufacturing.

KEYWORDS

Vehicle Perceived Quality; Consistency; Temperature Change; Dimensional Chain; Clearance; Dimensional Engineering Technology.

1. INTRODUCTION

In the automotive industry, achieving excellent perceived quality is the goal that car companies are constantly pursuing. The achievement of this goal not only depends on the precise design of the product positioning reference system, but also depends on strict product precision control. Product design is the starting point of precision control. Using the dimension chain analysis method to evaluate the feasibility of product manufacturing in the early stage of design can effectively reduce costs. At present, the dimension chain analysis method has been widely used in the design process of many automobile companies. It can not only be used to calculate cumulative tolerances and conduct feasibility analysis; it can also predict potential dimensional problems in the assembly process in advance, accurately evaluate the impact of each dimensional link on assembly accuracy, and clarify the key to improving accuracy; at the same time, on the premise of ensuring the assembly tolerance requirements, the dimensional tolerance of each link is reasonably allocated; more importantly, when the tolerance exceeds the tolerance in the actual vehicle assembly, the dimension chain analysis can quickly locate the problem link and then implement optimization and improvement. [1,2]

From the design perspective, the dimensional analysis method is an important support for proposing scientific and reasonable design requirements, and its application in R&D design and quality control has become increasingly mature. This article focuses on the dimensional design of components that customers focus on, and combines the consistency inspection issues in the vehicle quality certification process to deeply explore the impact of ambient temperature changes on vehicle dimensional changes.

2. BASIC CONCEPTS

2.1. Dimensional Engineering Technology

Dimensional Technical Specification (DTS) aims to clarify the design requirements for the clearance and flush of the exterior parts of the vehicle. This technology is not only an important yardstick for measuring the quality of automobile manufacturing, but also a direct reflection of the manufacturing level of automobile companies. It also profoundly affects the user's subjective perception of the product. With the continuous innovation and development of the automobile industry, automobile companies are paying more and more attention to the DTS of the whole vehicle. DTS covers key elements such as clearance, flush and tolerance requirements. Among them, the R angle is closely related to the clearance, the alignment affects the flush performance, and the parallelism, symmetry, etc. are directly related to the tolerance requirements. [3,4,5,6].

2.2. Gap Definition

When the vehicle is in a fully assembled state, the gap formed between two parts with an assembly relationship that can be observed visually is the gap. The gap is usually measured using a gap gauge and a feeler gauge. The measurement method is as follows: When two adjacent parts have hemming features, regardless of the size of the hemming radius and the relationship between the two faces, the gap between the two parts is determined by the shortest distance in space. During the gap measurement process, it is necessary to pay attention to identifying the gap features and types to avoid identification errors, which will cause inaccurate measurements.

Clearance is generally divided into design clearance and visual clearance. Design clearance refers to the nominal value of the clearance defined by the design; while visual clearance, in addition to the nominal value of the clearance defined by the design, is also related to the fillet of the components on both sides of the clearance. If the fillet radius R is not designed properly, the visual clearance will be magnified. In dimensional engineering design, this should be given special attention, so that the perceived quality of the product can be effectively improved without increasing costs.

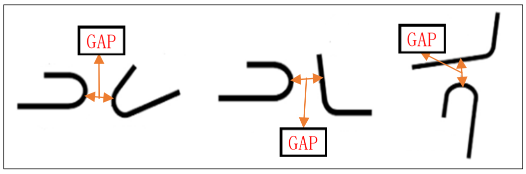

Figure 1. Schematic diagram of gap effects of different features

2.3. Definition of flush

When the vehicle is fully assembled, the height difference between the surfaces of two parts with an assembly relationship that can be seen visually is called the face difference. The measuring device is a face difference ruler. The measurement method is as follows: When the main surface of the reference part (indicated by ▲) is flush with the main surface of the target part, the face difference between the reference part and the target part is zero. When the main plane of the reference part is lower than the main plane of the target part, and the main planes of the two parts are parallel or nearly parallel, the shortest distance between the extension line of the main plane of the reference part and the tangent point of the radius of the main plane of the target part is defined as the face difference.

Of course, when the principal plane of the reference component is not parallel to the principal plane of the target component or the two components have a matching structural relationship, their surface difference can also be measured. Due to space limitations, this will not be elaborated here.

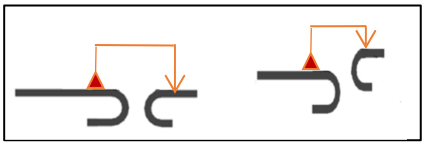

Figure 2. Schematic diagram of the definition of flush with parallel relationship

It should be noted that if the principal plane of the reference component is not parallel to the principal plane of the target component, then the shortest spatial distance between the extension line of the principal plane of the reference component and the tangent point of the radius of the principal plane of the target component is the face difference.

Dimensional engineering technology covers tolerance design, parallelism, symmetry and other requirements. The numerical values corresponding to these requirements have an important impact on the perceived quality of the vehicle and its components, and are the key content of dimensional chain design [7,8,9]. Since this article focuses on the study of clearance and flush, the above content will not be elaborated.

2.4. Vehicle DTS Design

As an important part of dimensional engineering technology, vehicle DTS design is mainly used to define the gaps, flush and relationships between the interior and exterior components of the vehicle. It is a technical standard formulated for the quality of vehicle appearance. Its common expression is: the design nominal value of the gap (or flush) is combined with the tolerance requirement of the gap (or flush). This indicator is not only a key basis for measuring the manufacturing quality of automobile appearance, but also an intuitive reflection of the quality level of vehicle dimensional engineering. In the actual design and production process, each vehicle manufacturer will formulate its own standard value of gap and flush based on its own design concept and process manufacturing level [10].

In terms of the quality requirements for exterior decoration parts, the realization of the vehicle DTS target depends on the coordination of the supplier system. Large exterior decoration parts have a particularly significant impact on the vehicle DTS, among which the front and rear lights, interior and exterior decoration systems play the most prominent role [11,12].

The following is a brief introduction to the appearance quality control and current precision manufacturing level of headlights, rear lights, interior and exterior trim systems.

2.4.1. Front and Rear Lights

Mainstream automobile companies control the precision of headlights and rear lights as follows: the maximum deviation of the primary reference hole diameter is ±0.1mm, and the position accuracy is 0mm; the maximum deviation of the secondary reference hole diameter is ±0.1mm, and the position accuracy is 0mm; the maximum deviation of the mounting hole diameter is ±0.2mm, and the position accuracy is 1.0mm; the contour of the critical matching surface is 1.4mm; the contour of the non-critical matching surface is 2.4mm; and the contour of the non-matching surface is 3.0mm.

2.4.2. Interior and Exterior Decoration

At present, mainstream automobile companies implement the following precision control standards for interior and exterior parts: the limit deviation of the main reference hole diameter is set at ±0.1mm, and the position accuracy is required to be 0mm; the limit deviation of the secondary reference hole diameter is also ±0.1mm, and the position accuracy is also 0mm; the limit deviation of the mounting hole diameter is ±0.2mm, and the position accuracy is required to be 1.0mm; the contour of the critical matching surface is limited to 1.0mm; the contour of the non-critical matching surface is 2.0mm; and the contour of the non-matching surface is 3.0mm.

It can be seen that based on the current manufacturing standards of mainstream OEMs, integrating their own R&D and manufacturing capabilities and their room for improvement, product design and development personnel can formulate a DTS that suits the characteristics of the enterprise, thereby effectively improving the perceived quality level of the body and assembly.

2.4.3. Precision Design in Dimensional Engineering

The commonly used methods in dimensional quality control design are extreme value method and probability method. This paper mainly introduces the probability method and uses the headlamp gap tolerance as an example to illustrate the algorithm.

Probability method is used to calculate the dimensional tolerance . The probability method is also called the root mean square method, which is a type of statistical analysis method. The root mean square method means that the tolerance of the closed loop is the square root of the sum of the squares of the tolerances of the component loops, that is, the tolerance of the target size is obtained. The calculation formula is:

$$T_0 = \sqrt{\sum_{i=1}^{n} T_i^2} \tag{1}$$

In mass production, the probability of parts having opposite limit sizes is very low. According to the principles of probability statistics and the actual situation of machining error distribution, the sizes of parts tend to be normally distributed, so it is more reasonable to use the probability method to solve the dimension chain.

3. EXPERIMENTAL VERIFICATION

Aiming at the problem of vehicle quality inspection consistency, this paper selects a high-end model of a well-known brand car company as the test object, studies the gap surface difference between the left headlamp and the counterpart under different temperature environments, and measures the gap surface difference between the headlamp and the surrounding fender at temperatures of 23 °C , 50 °C , 60 °C, 70 °C, and 80 °C. The measuring points are shown in Figure 3. The maximum deviation of the main reference hole of the headlamp of this model is ±0.1mm, and the position accuracy is 0mm; the maximum deviation of the secondary reference hole is ±0.1mm, and the position accuracy is 0mm; the maximum deviation of the mounting hole is ±0.2mm, and the position accuracy is 0.5mm; the tolerance of the headlamp locating hole and the fender locating hole is ±0.5mm, and the maximum deviation of the fender locating hole is ±0.5mm.

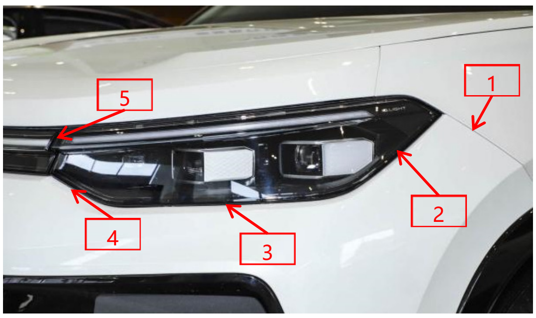

Figure 3. Schematic diagram of gap and flush measurement points

According to the probability calculation formula, the gap tolerance here is

$$T_0 = \sqrt{0.1^2 + 0.1^2 + 0.2^2 + 0.5^2} = 0.75$$

This article selects the standard of a certain enterprise as the standard value for this research and verification. The standard value is shown in Table 1 below.

Table 1. Example of standard values for vehicle clearance

project	Reference parts	Opponent	C-Class Standard
1	Fender	headlamp	1±0.75
2	Front bumper	headlamp	2.5±1.2
3	headlamp	Front grille	3.5±0.75

Table 2. Correspondence between horizontal axis numbers and ambient temperature

Serial number	1	2	3	4	5	6	7	8	9	10
Temperature/℃	23	50	60	70	80	50	60	70	80	23

Figure 4 below, the gap surface difference measurement results between the headlamp and the fender at different temperatures. The corresponding relationship between the horizontal axis numbers and the ambient temperature is shown in Table 2.

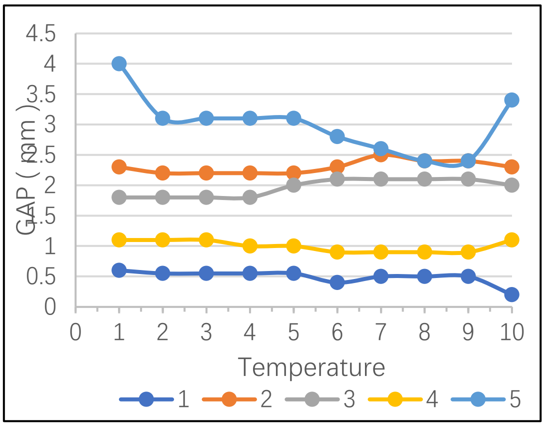

Figure 4. Gap changes under alternating temperature environment

Two points can be seen from the figure: 1) In the alternating temperature environment, the gap between the headlight and the opponent is basically within the design value range, and the amplitude of the change is not large. Only the intersection with the bumper at position 2 does not meet the design value requirements. 2) In the temperature alternating environment, there is a certain change in the gap between the headlight and the opponent, especially when the temperature rises, the gap with the front bumper and fender near the installation point decreases to varying degrees, while the gap away from the installation point increases. It can be seen that temperature changes will have a certain impact on the vehicle installation dimension chain, and have a greater impact on the consistency inspection during the vehicle quality certification process.

4. SUMMARY

1) Since the temperature alternation environment will affect the installation size of the vehicle, the effect of temperature alternation must be fully considered during the parts selection and dimensional engineering design stage.

2) In the quality monitoring work of vehicle quality certification, environmental factors such as temperature that affect vehicle consistency need to be taken into consideration, so as to achieve the

scientific nature of the vehicle quality inspection process and avoid errors caused by environmental factors.

3) The change of gap under the use conditions will not only reduce the perceived quality of the product, but also significantly shorten the service life. Therefore, in the product design process, it is necessary to quantify the change of product gap and formulate corresponding constraint standards to ensure product consistency. At the same time, by constraining the change of gap, the product service life can be effectively extended, the product value retention rate can be improved, and the product market competitiveness can be enhanced.

4) From the perspective of "raising the bar" for voluntary product certification, corresponding inspection items can be added to the type test plan or factory inspection product consistency inspection link, and key inspections can be carried out on typical assembly locations to help improve product quality.

5. SUMMARY

1) This study has limitations and has not yet explored the effects of interior and exterior trims in low temperature environments.

2) Subsequent research can broaden the scope of data collection, conduct in-depth analysis of the effect of sample shape on dimensional engineering, and use 3DCS software to specifically solve dimensional design problems such as plane or space gap flush.

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