# Intelligent Hub Shape Correction System

**Jiantao Wu, Yongliang Chen, Jialing Shi**

*School of Art and Design, Yanshan University,*
*Qinhuangdao 066004, Hebei, China*

**Huixue Sun**

*School of Mechanical Engineering, Yanshan University,*
*Qinhuangdao 066004, Hebei, China*

Abstract
It is often difficult for designers to confirm whether their selected design is truly the most appropriate for its manufacture. The aim of this paper is to build a system between intelligent car hub shape design and its constraint conditions. First, based on the ANSYS system, through the three failure testing mode, the basic database can be acquired. And then, according to the principles of engineering, design and aesthetic, it establishes the hub shape database and the constrain database which guide the modified direction and magnitude of the modeling design. It can help designers to complete the shape correction. As a result, combined with the assessment and the interface, it builds an intelligent wheel hub shape correction system with four modules. This method can shorten the time of the previous shape correction according to engineering experience, improve the design efficiency and pass rate, and enhance the collaborative design ability between designers and engineers.
Key words: HUB DESIGN, INTELLIGENT, CONSTRAINT, SHAPE CORRECTION

## 1. Introduction

It's the key factors to improve the competitiveness of products by promoting quality, reducing costs, increasing the life span, diversifying functions and personification customization [1]. As an important element of car modification, the aesthetic appearance and characteristic of the automobile hub, become a new hot spot of consumer perception. For this reason, every wheel manufacture takes hub styling design into consideration to enterprise benefit, especially the product shape design [2].

However, the domestic designers of the modeling of wheel hub mainly depend on the inspiration and subjective feeling at present. To some shape that its far away the technological

requirement, designers must rely on the experience of engineer to rectify [3]. The process of modeling design lacks of design methods and tools of scientific and rational. And most engineering analysis softwares are lack of advises which can help designers to understand and adjustment the reasonable structure. As a hot orientation of today design research based on knowledge including Case Based Design Systems, Design Prototype Based Application System [4], Modeling Based Reusable and Sharing Design System [5]. Goel et al, built an IDEAL and E-KRITIK Systems on Case Based Reasoning, and developed a special design question presentation to Structure-Behavior-Function model [6]. However, it's still a problem to industrial design that's main character consists of images and creative thinking, particularly rare in research of combination modeling design and subsequent manufacturing process.

Therefore, an intelligent modification system is presented in this article, as a main judgment on shape design, in order to establish an intelligent restraint of wheel hub design and its constraint conditions.

**2. Intelligent modification system construction of wheel hub**

We must satisfied the restriction of shape and technology to perfectly manufacture the product form design [7]. This paper based on the research of design constrain that came from one of the most famous wheels hub manufactures about the possibility of product manufacturing process. It builds an efficiency form assistance tool for industrial designer to make up the lack of structure and technology. And it also builds a shape database which accord with the processing conditions, realizing automatic shape recognition, reducing the repeat labor and invalid work and shorten the product developing period.

**2.1. Wheel hub intelligent shape correction system module**

Wheel hub intelligent shape correction system includes four modules, the system framework as shown in Figure 1, a more detailed explanation of each model follows below:

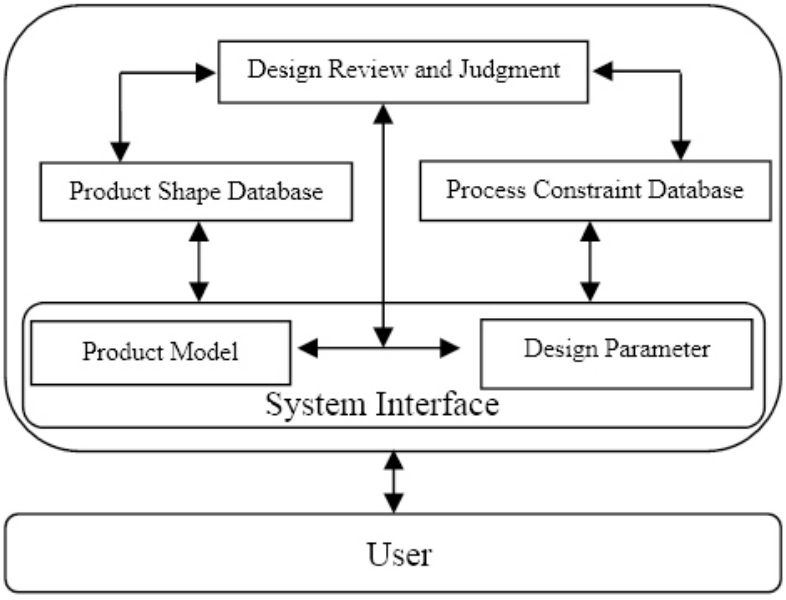


**Figure 1.** Process of product family shape

Product shape database: Summarizing all the company's internal previous products that meet the production standard. By morphological analysis to decompose the product into the independent elements, including size rule and common damaged parts, then product shape database will be built. It can provide designers not only with reference style, but also the functions in selection, combination and transformation.

Process constraint database: First, collecting and arranging the machining technology, it summarized all the part of product shape constrain by analysis. And then under the experience of engineer to modify the shape, building a process constraint database. It can be the guide for new product design process, making the product shape come true smoothly.

Product review and judgment: The main function of this module was to use design thinking to judgment knowledge. It depended on the morphogenesis mode coming from product shape database and the experience rule of engineer modify coming from process constrain database. In the end, it can give designer guidance

suggestions on modeling forms, assessing the results appeared in the system interface in visual form.

System interface: The interface design for connect system with user, including product model and basic parameters.

The system was based on CAID software using the 3D modeling function, combined with the module of knowledge environment in order to make computer intelligent aided design come true.

**2.2. Product shape database creation**

The establish of shape database relied on product deconstruction on morphological analysis. Morphological analysis was established by Zwicky which based on structure and combined with technology to come out more new ideal [8]. The basic viewpoint of morphological analysis was that diverse proposals can be made by restructuring or combination of present design elements to get different design proposals and feasible solutions [9]. Based on the morphological structure under the restriction of engineering, either through analysis product characteristic on the location easily broken under the engineering testing process. Wheel hub product has three test methods in engineering structures: the cornering fatigue test, the radial fatigue test and the impact test. Every test has a corresponding failure mode as shown in table 1.

**Table 1.** The three failure mode

| | Bend fatigue Test | Radial fatigue Test | Impact Test |
|---|---|---|---|
| Failure Mode | The position from PCD of wheel to window | From spoke to draught behind the spoke | Near the center of wheel hub |
| | On the back of the spokes of the wheel on both sides of draught | | In the end of a frame connected J department position |
| | Porous type design of wheel hub and the failure parts produced in hub between PCD hole | | Both side of spoke |
| | A special case of failure modes | | |

According to the broken position in table 1, sorting all the history text material made by company, and by analyzing all the wheel hub products which pass the test, it names these shapes in A, B, C, D, E, F to correspond to different parts of wheel hub and establishes material library into visual form. As shown in figure 2, the table 2 is the instruction of the six positions.

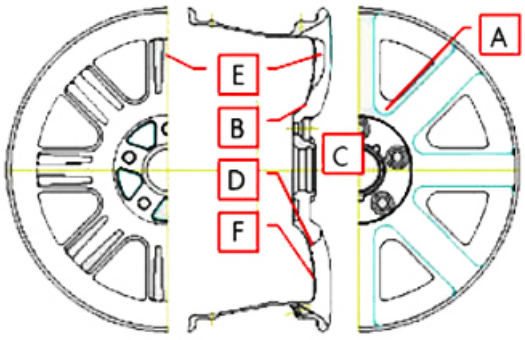


**Figure 2.** The hub rear view, section view and front view

The establishing of shape database was based on the history wheel hub database of the company.

By enrichment of information, the data material will be more and more abundant and complement. It will be helpful to designers in subsequent design. At the same time, it's essential to import the parameterized editing concept, so every part of wheel hub in shape database is required to pass through parametric setting. In this way it can be in accordance with the quantitative data manipulation of the morphological characteristics of libraries and ensure the accuracy of shape analysis.

**Table 2.** Shape position

| | |
|---|---|
| A:The front spoke and window | B:X-factor |
| C:The front disk and PCD | D:Draft Angle |
| E:The back spoke draught | F:The thickness of the spoke |

**2.3. Parametric technology constraint database**

Parametric is also called dimension driven, essentially on the constrain of model description[10]. Parametric design takes the

method of parametric reservation to establish a graphic geometric constraint set. Assigned a set of size as a parameter associated, it makes all relations into application program. Modifying the parameter size in the method of human-computer interaction, it achieves the result of design changes by parameter driving [11, 12].

In the period of modeling and elaboration phases of wheel hub design, a designer fulfills the final modification task in the cooperation of engineer's craft experience. However the both side difficulty reach the consensus opinion in design principle and aesthetic formation. It will bring enormous difficulty to the subsequent development work. It must build the parametric technology constraint database according to the past engineering modify experience, principle collections and sorting [13]. Parameterized matching the technology constraint database and shape database, it reduced the risk of realization process.

**Table 3**. Modify rules Commonly

| | |
|---|---|
| A: output the window | E: Modify the back of spoke loss draught weight |
| A1:pay out 2mm | E1:Depth to shallow 2mm |
| A2:pay out 4mm | E2:depth to shallow 4mm |
| B: reduce X distance | E3:narrow the one-side widths 2mm |
| B1:reduce 2mm | E4:deepen the depth 2mm |
| C: positive decline | E5:deepen the depth 4mm |
| C1:decline 2mm | F: Spoke car cut thin |
| D: modify draft angle | F1:Cut car thin 2mm |
| D1:Modify 9°to 12° | F2:Cut car thin 4mm |

According to the match of engineering modify experience and the shape database, there are six parametric modify rules been set up and the modifier tent to be moderate [14]. Generally, the thickness of the spokes of the wheel hub is around 15-25mm, the modifier tent to be 2mm, or at most 4mm, the modifier of Draft Angle around 3 to 6. According to the table 2, A, B, C, D, E develop the strategy of A1 - F2 separately, see table 3.

**2.4. The estimation and judgment of design**

This module combines the shape database and technology constraint database, and both of them can be applied Excel VBA as a bridge, while external users have to use Visual Basic to build the interface. As a result, the estimation and judgment of design are in the form of Excel VBA and Visual Basic which confirm the relation between the two databases. The results can be a feedback to interface as a guidance to designer [15].

**3. Wheel hub intelligent correction system application form**

**3.1. Systematic work flow**

This system uses ANSYS system as platform. The specific design process as shown in figure 3: (1) Establishing 3d design platform model through UG. (2) Importing the ANSYS engineering analysis system. (3) Choosing shape design system plug-in and get shape feedback by aided design tools. (4) Determing parameters on customer demand. (5) Designing review feedback through the UG 3d design platform model established.

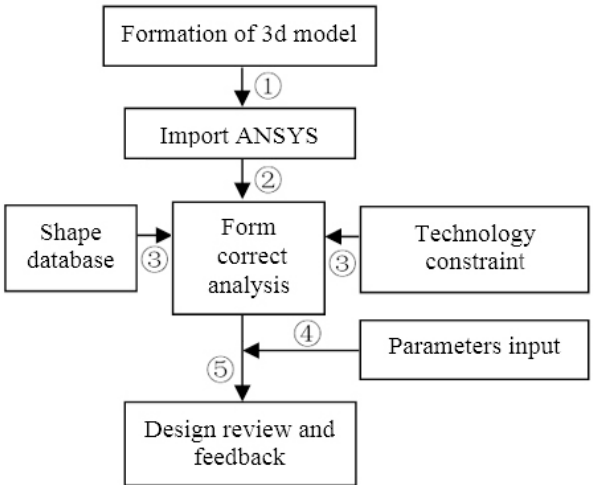


**Figure 3.** The system flow

**2.2 System operation**

This system runs on ANSYS system. When a user clicks bending fatigue test system, a basic parameter input dialog was shown in figure 4. The background analysis of feedback is given as shown in figure 5.

Through the evaluation and feedback, designers can modify the previous form. The pass rate of revised model will increase substantially and Subsequent project development can run smoothly.


**Figure 4.** The dialog of parameter input

### 2.3 System verification

The table 4 is the data and test results of Wheel hub for bending simulation analysis. The wheel hub has 2 analyses and trial runs. The first analysis of average stress, and amplitude stress and failure probability is 55.4MPa、42.36MPa and 70.52%. According to the test result, after the modify of the feedback and evaluation of shape design system, it continues the second analysis. The average stress, and amplitude stress and failure probability have been reduced to 35.57MPa、22.61MPa and 24.35%.

Bending test failure has decreased from 70% to just 24.35%, hugely enhancing the test qualification rate of product. When using the system on the radial test and impact test, the Radial failure has decreased from 100% to 29.36% and the impact failure has decreased from 81.1% to 26.66%. As a result of this comparison on simulation test failure, it verifies the correctness of this paper's new solution, and it provides the references to predict whether the new products through the test and analysis.

**Table 4.** Data analysis and simulation of bending test

| Factors | First analysis | Second analysis |
|---|---|---|
| Average stress | 55.4MPa | 35.57MPa |
| Stress amplitude | 42.36MPa | 22.61MPa |
| Failure probability | 70.52% | 24.53% |
| Test result | NG | OK |
| Modify advice | outside the window put 2 mm, positive decline 2 mm | |

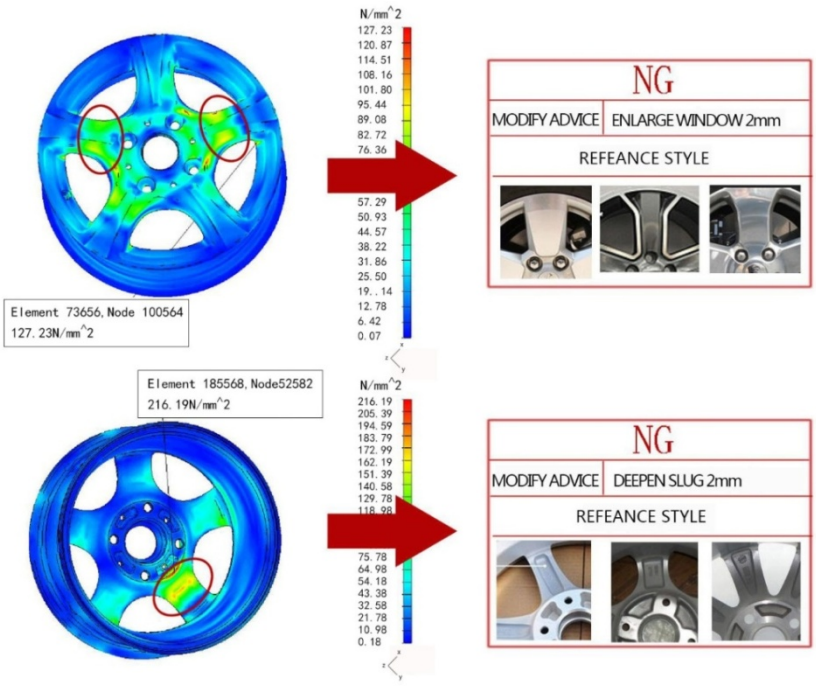


**Figure 5.** Evaluation and feedback

### 3. System evaluation

The testers' advice and efficiency of system were applied for statistics, including 6 designers and 4 engineers, testing 10 people on usage scenarios.

System Utility:10 testers all agreed that traditional testing method which use intelligence shape correction system can do purposeful aimed at modification, especially do good in subsequent processing. Through the modified system analysis, the pass rate of wheel hub can be significantly improved.

System operation steps: as everyone has his own using habit, the actual sequence of steps was not the same. But all the testers all considered that the system forming by shape database and technology constrain database had significantly increase the easiness of operation. It would be a mature system, in case that having more control system and detail design.

User advise: Testers believed that the bottom of system can be more easy using, the weakness in operation would be resolve in optimizing the operation interface.

### 4. Conclusions

This system relies on shape database and technology constraint database to make product evaluation and feedback. It will extent the material database and technology constraint constantly and will improve accuracy of outcomes. Keeping improvement the shape of intelligential and parameterization modifying of feedback, it will be a great advantage to product integrated development. In addition, this research is only focus on intelligent modify. The all system will be more perfect on extending the area of color and material in future.

### Acknowledgements

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### References

1. Wensheng Dai (2005) *Stress Distribution in Aluminum Wheel Rim Improvement and Optimization Design.* Taiwan: Dayeh University.
2. Jiang-hong Zhao (2008) Design and Design Method for Forty Years. *Decoration*, No.9, p.p.44-47.
3. Youbo Xie (1996) Modern Design and Knowledge Acquisition. *China Mechanical Engineering*, 7(6), p.p.36-41.
4. Rosenman M A, Gero J S. (1993) Creativity in design using a design prototype approach. *Modeling Creativity and Knowledge-Based Creative Design*, p.p.11-138.
5. Van Heijst G, Schreiber A T, Wielinga B J.(1997) Using explicit ontologies in KBS development. *International Journal of Human-Computer Studies*, 46(2-3), p.p.183-292.
6. Dzbor M. (2001) Towards a framework for Acquisition of Design Knowledge. *27th ASME DETC Design Automation Conference*. Pittsburgh, America, p.p.3-10.
7. Sun Liqing, Lin Yi, Sun Fengchun (1999) Simulation of Restraint System Performance upon the Occupant's Response during Impact. *Journal of Beijing Institute of Technology*, 78(19), p.p.207-213.
8. F, Zwicky (1967) New Methods of Thought and Procedure. *Pasadena: Springer Berlin Heidelberg*, Berlin, Germany, p.p.316-317.
9. N, Cross (1994) *Engineering Design Method: strategies for product design.* Chichester: John Wiley & Sons Ltd.
10. Xiangxu Meng, Yanning Xu (2002) Parametric design studies. *Journal of Computer-aided Design and Graphics*,14(11), p.p.1086-1090.
11. Wei Ding (1999) Electrical Appliances Product 3 d Modeling Design Method Research. *Mechanical Development*, 113(1), p.p.37-40.
12. Fei Zheng (2006) *The Research and Development of Standard Parts Library Based on Pro/E of the Network System.* Wuhan Huazhong University of Science and Technology: Wuhan.
13. E. Poirson, J.F. Petiot, F. Richard (2010) A method for perceptual evaluation of products by naïve subjects: application to car engine sounds. *International Journal of Industrial Ergonomics*, Vol.40, p.p.504-516.
14. H.B. Yan, V.N. Huynh, T. Murai, Y. Nakamori (2008) Kansei evaluation based on prioritized multi-attribute fuzzy target-oriented decision analysis. *Information Sciences*, 178, p.p.4080-4093.
15. D. McDonagha, A. Brusebergb, C. Haslamc (2002) Visual product evaluation: exploring users' emotional relationships with products. *Applied Ergonomics*, 33, p.p.231-240.