Automated Weight Optimization Process for Automotive Wheel Hub Bearing

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***Abstract**: Automotive wheel bearing is an essential component of the vehicle. It transmits engine power into wheels and supports vehicle weight. In recent years, the demand worldwide for weight reduction in automotive part in order to improve fuel efficiency has increased. Despite of it, automakers are requiring that wheel bearing performance in the areas of stiffness, strength, and life be maintained or improved. In this study, weight optimization for automotive wheel bearing was performed. Design variables were the bearing geometry and bearing internal specification. Cost function was bearing weight and constraint conditions were bearing life and stiffness. CATIA was used to model the geometry and Abaqus was used to carry out the stiffness analysis. To construct the optimization formulation, the commercial optimization software, Isight was used. As a result, the optimal model satisfied all of constraint conditions and reduces the weight by comparing with that of the initial geometry. In conclusion, by using the developed weight optimization process, the test and development costs of an automotive wheel bearing can be reduced.*

1. Introduction

Steering characteristic is one of the important performances of the vehicle which it relates comfortable ride during the driving. In response to recently increasing needs for ride comfort and steering feeling, it has been emerged as design requirements from automobile manufacturers. Automaker has to provide the light weight vehicle for satisfying customer's request and government's regulation about the fuel consumption. The weight of wheel hub bearing for the light weight vehicle should be reduced which sustains fatigue life and stiffness of that. The trial and error approach to generate design model and evaluate their fundamental performances individually is very time consuming. It's not easy to generate the optimized design model. In order to develop the light weight wheel hub bearing, the automated weight optimization process should be built for evaluating fatigue life and stiffness as well as various design model creation simultaneously. To verify the reliability and adaptability of the automated weight optimization process onto the real product development process, the various design models were generated and evaluate their performance through that process.

2. Procedure of Weight Optimization

In this research, the automated procedure of weight optimization consists of CAD model creation automation, calculation of fatigue life, FEA(Finite Element Analysis) automation and weight optimization. ILJIN Global Corporation's Bearing Wizard Program and CATIA are used for building up 3D Geometry. The fatigue life was calculated MS Excel based the in-house program. To develop FEA automation, Abaqus for CATIA is adopted for CAE software because it gives the same user interface environment as CATIA so that designer can use easily and run quickly. In the process of weight optimization, Isight controls full process on the 3D Geometry generation, calculation of fatigue life, FEA for stiffness and measurement of weight by batch operation. Because Design or CAE engineer just define the design parameter and maximum allowable job time for the optimization, it very comfortable and intuitive for engineer to generate the weight optimized design model. Design variables were the bearing geometry and bearing internal specification. Objective function was bearing weight and constraint conditions were bearing life and stiffness.

2.1 Automated System for Wheel Bearing Design

Before this research, Design engineer build up wheel hub bearing 3D model manually. Because of the time consuming and the difference of design model generation by design engineers in manual, it's difficult to standardize master drawing. To enhance the conventional design process, the automated design system was setup in this research which can generate various design model based on the vehicle specification and wheel bearing internal specification. The developed automated system will be operated on the MS Windows which consists of the bearing wizard

program (Figure 1) and CATIA program (Figure 2). When users input the vehicle specification and wheel bearing internal specification onto the bearing wizard program, basic bearing part model will be generated based on the CATIA environment automatically. The detail model generation and modification will be available on the CATIA program. Design parameters of generated design model will be automatically linked into the in-house program for the fatigue life and the automated FEA system. For the users convenience, users fill in the necessary information step by step on the automated design system. Also the GUI of this system provides the preview wizard to users.

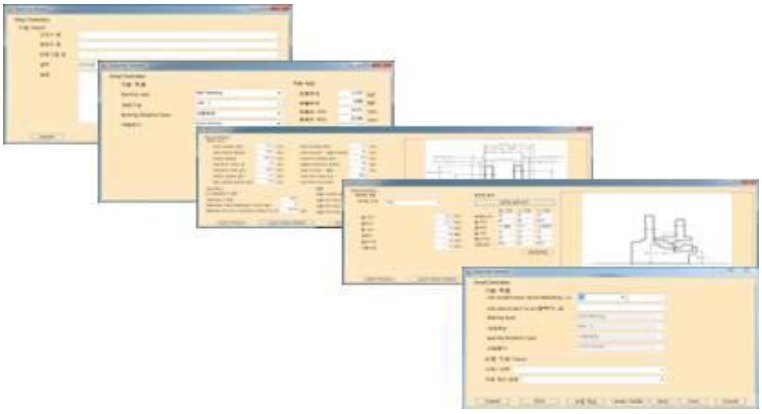

Figure 1. GUI of bearing wizard program

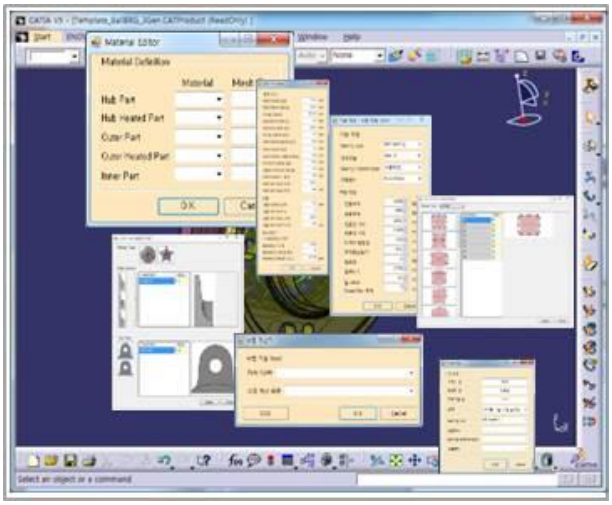

Figure 2. GUI of CATIA program

2.2 Automated FEA System for the Wheel Bearing Stiffness

To develop FEA automation, Abaqus for CATIA is adopted for FEA automation. The design model which was generated from the automated design program will be linked into AFC environment automatically. The FE model, Load and Boundary Conditions were generated and defined automatically without the additional operation. The stiffness analysis based on Abaqus will be ran by batch mode automatically. So design engineer and CAE engineer can easily check the FEA results. Also variety of Automaker's FEA conditions will be reflected on the design model automatically. The minimized FEA running time is necessary to review lot of design cases in limited time. The hexa elements for critical area and tetra elements for the remains of wheel hub bearing will be used to considering the accuracy and minimum run time simultaneously.

2.3 Calculation of Fatigue Life based on the in-house code

There are contact forces between ball and rail of wheel hub bearing during the operation. This contact behavior can cause trouble in indention or lamination at the contact areas. It's a criterion of the fatigue failure of wheel hub bearing. In this process, the fatigue life of wheel hub bearing was calculated by ILJIN Global's in-house program as shown on Figure 3. Because of all of defined design information are available on the in-house program automatically in this process, the in-house program for checking the fatigue life of wheel hub bearing will be ran batch mode automatically. So design or CAE engineer can check the fatigue life of wheel hub bearing without any additional operation.

Figure 3. GUI of life calculation program

2.4 Weight Optimization System

In this research, the weight optimization process which are available on the parametric CAD model creation, calculation of fatigue life, FEA(Finite Element Analysis) automation and weight optimization simultaneously. This process was composed and controlled on the Isight GUI environment as in Figure 5. The importing MS Excel file which was generated by the automated wheel hub bearing design system is just necessary to execute this process full automatically. There are 3 junctions in this weight optimization process to consider various users need. First process for weight optimization can evaluate both stiffness and fatigue life simultaneously. Second one for weight optimization can to generate various design model based on the fatigue life. Last one can take care of only the automated FEA of the generated FE model without weight optimization. So this process will provide the minimized user intervention and automatic operation to users.

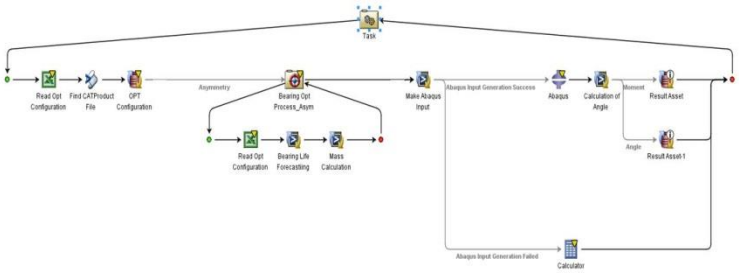

Figure 4. Isight workflow

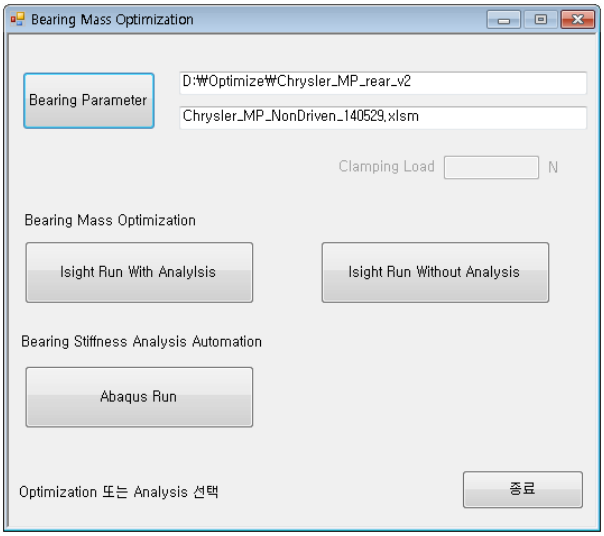

Figure 5. GUI of weight optimization program

3. Adoption of weight optimization Process

To verify the adaptability and robustness of the automated weight optimization program, this process were reviewed with real design model and on the practical wheel hub bearing development process. 9 design variables were reviewed which are related to the stiffness and fatigue life. Objective function was bearing weight and constraint conditions were bearing life and stiffness. As the results of weight optimization process, the Figure 6 shows the reduction of wheel hub bearing by 3.4%. To check the validation of this automated process, it's necessary to take side view of accuracy FEA results in the developed weight optimization process. The stiffness analysis result with FE model which was generated automatically in the weight optimization program was good correlated with the stiffness analysis result with FE model in manual.

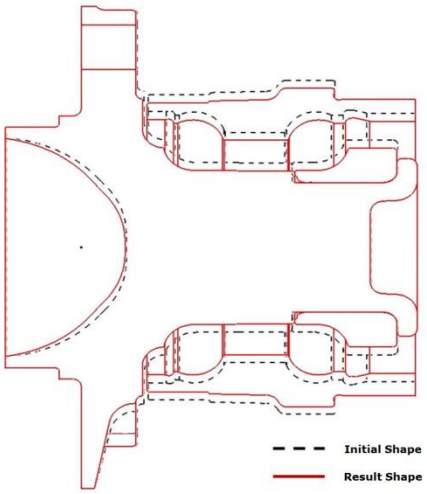

Figure 6. Optimized shape result

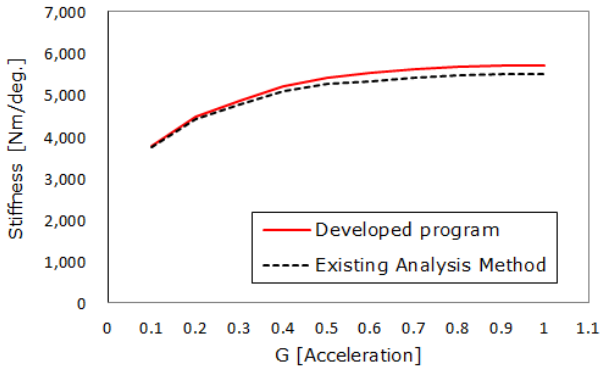

Figure 7. Comparison of analysis result

4. Conclusions

In this research, the automated weight optimization process was developed which is considering weight reduction, fatigue life and stiffness of wheel hub bearing simultaneously. An optimized wheel bearing model was generated through this weight optimization process. Weight reduction rate of the generated weight optimization model is about 3.4%. Design engineer can build-up a light weight wheel hub bearing based on this weight optimization process automatically. It's very useful for reducing development time and cost.

5. Reference

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