

OPTIMAL DESIGN SYSTEM FOR V-BELT PULLEY

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ABSTRACT

A V-belt pulley is widely used in automotive industry. More than four pulleys in one automobile are used, such items as crankshaft, water pump, air-con compressor and power steering pump. Although the shape and usage of pulleys are very simple, the design evaluation of a pulley design is difficult because the load conditions and the installation environment are complicated. So, we tried to formulate the design evaluation for the V-belt pulley, which enables the design automation, optimum design and experience accumulation. Since the normal and friction loads upon the contacting surface with a V-belt vary by the position, manual application of the loads is difficult. Equivalent pressure is used to represent tightening torque of bolts. This paper introduces two load factors to accumulate the design experience, which represent the installation and operation conditions.

The optimum design system is expected to contribute in formulating the design evaluation of a pulley. By using this system, an engineer can evaluate a pulley design easily without any painstaking effort, such as consideration of the complicated loads and CAE activities. Also the system helps to accumulate the design experience of a company, which guides the optimum design based on experience.

KEYWORDS

V-belt; Pulley; Design Automation; Optimum Design; CAE

1. Introduction

In designing a pulley for V-belt drive, transmission function can be estimated easily. But pulley strength is difficult to evaluate because the loads and restraints cannot be easily calculated. Even if CAE system is used, the method to apply the loads and restraints should be formulated. A pulley for V-belt drive has two typical loads, one is from V-belt and the other is from the tightening bolts. Restraints for a pulley are applied at two surfaces, where tightening bolts and mating bracket are placed.

In this paper, we formulated the CAE process, in other words, how to apply loads and restraints to evaluate the strength of a pulley. We also developed an optimum design system by following the pre-defined CAE process. By using the developed design system, the strength of a pulley is evaluated accurately, which makes an optimum design is possible. Also engineers are trying to co-relate evaluation from the design system and result of the rig-test, which makes the design system more practical.

The reaction force per length at each contact surface, $R(\alpha)$, is derived as Eq. (4).

$$R(\alpha) = \frac{Q(\alpha)}{N(\sin \frac{\beta}{2} + \mu \cos \frac{\beta}{2})} \quad (4)$$

The frictional force becomes μNR .

3. Formulation of pulley CAE process

There are many methods for evaluating the strength of a pulley with CAE system according to how to model the pulley in pre-processor, apply load conditions and apply restraints. We have tried many methods and determined the following process. We modeled only pulley shape as detail as possible, used solid element, and applied loads and restraints as similar to real status as possible.

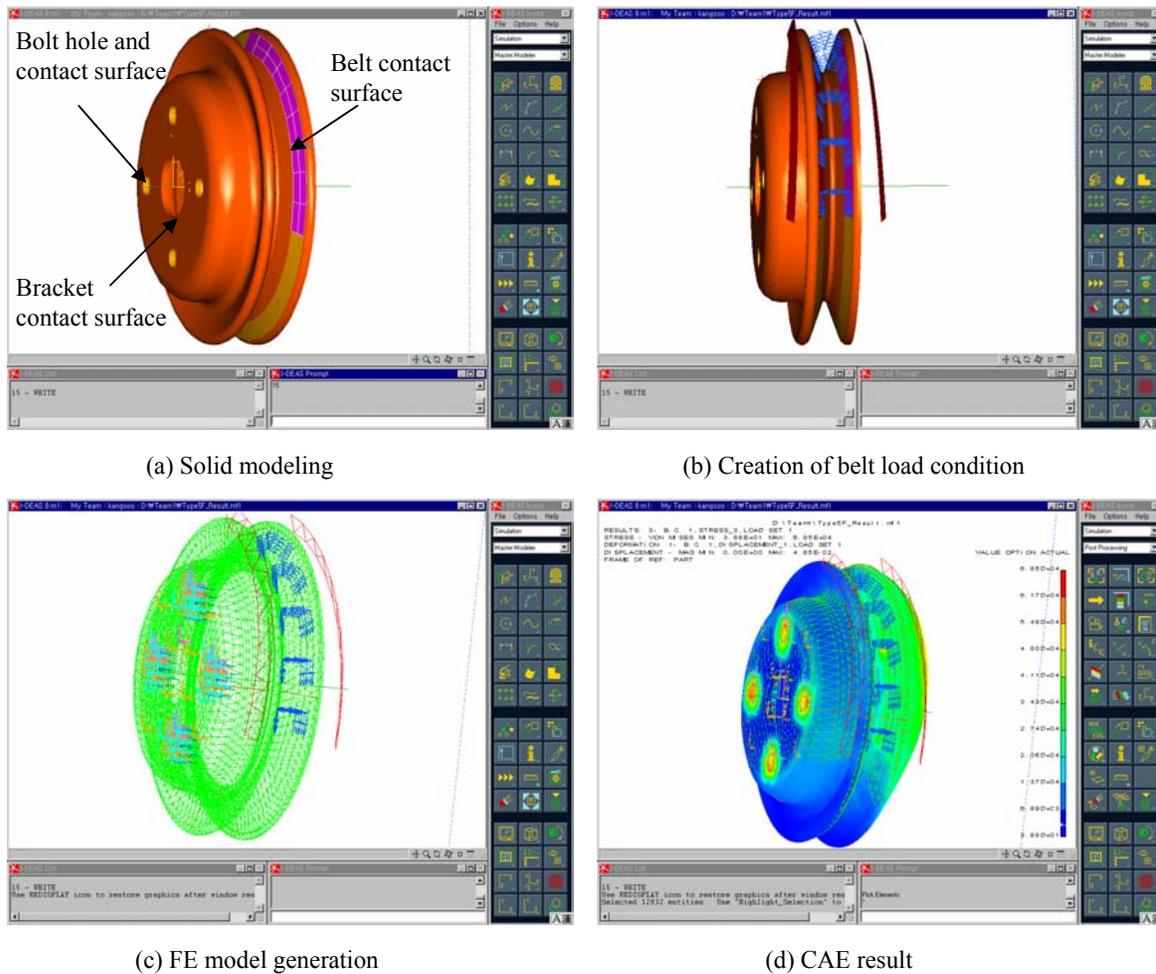


Figure 2. CAE process of a V-belt pulley

3.1 Solid modeling for CAE

In order to evaluate the strength of a pulley, the shape of a pulley should be modeled as shown in figure 2 (a). The contact surfaces with a belt, tightening bolts and a bracket should be represented precisely in order to apply the corresponding loads and restraints. This is the most important step throughout the entire steps to be explained.

3.2 Belt load condition creation

Loads at the contact surfaces with a belt are applied as shown in figure 2 (b). Tension of a V-belt varies according to the position when it carries power. Data surface, which expresses the variant loads in I-DEAS of SDRC, is used to apply the variant tension, $T(\alpha)$. The radial force, $Q(\alpha)$, and the normal force (pressure) at the contacting surface, $R(\alpha)$, are expressed as Eq. (3) and Eq. (4), respectively.

3.3 Creation of tightening bolt loads condition and restraint

The loads and restraints by tightening bolts are applied. The movement along rotational direction is restrained.

3.4 Creation for bracket restraint

The contact surface with a bracket is fully restrained.

3.5 FE model generation

Solid element is used for FEM as shown in figure 2 (c), as it can be used for general purpose without some idealization. In figure 2 (c), all loads and restraints can be shown.

3.6 FE result

Figure 2 (d) shows a stress evaluation from CAE system based on the FE model in figure 2 (c).

4. Pulley design/analysis system

The pulley optimum design system is developed under the following environments.

- O/S: Windows NT Workstation 4.0
- Modeling and analysis: I-DEAS Master Series 8 m1 of SDRC
- Development language: Microsoft Visual C++ 6.0

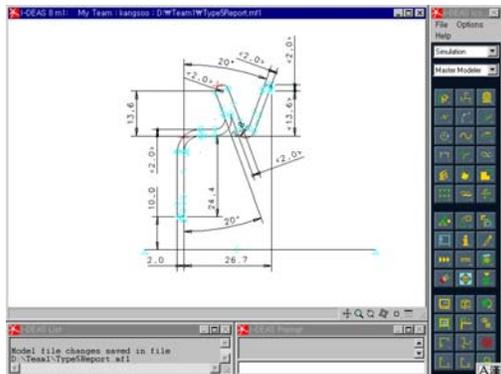
Object methodology to represent a design element, pulley, is used as in Lee's works [4,5]. Interface with I-DEAS, the modeling and analysis system, is implemented by OpenI-DEAS, API of I-DEAS based on CORBA strategy [6,7].

4.1 Modeling in I-DEAS

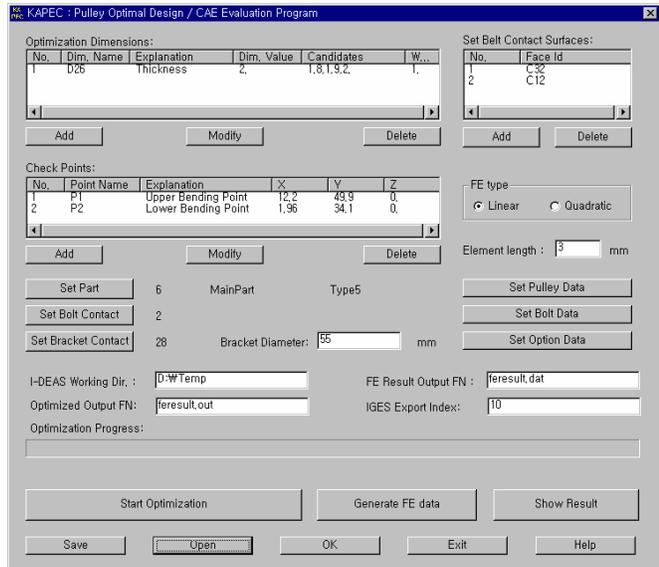
As shown in figure 4 (a), a section profile is modeled in I-DEAS. The following solid shape will be generated based on it. Some independent dimensions to be optimized and some points where stresses will be checked should be set.

4.2 Data setting

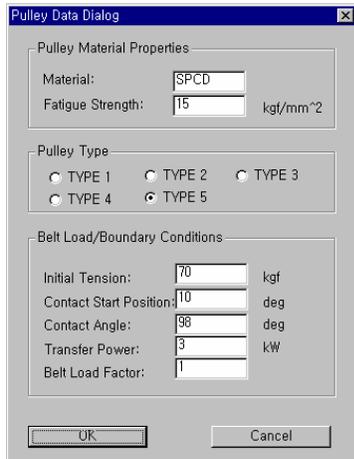
Data that is necessary for optimum design should be set as in figure 4 (b), (c) and (d). Figure 4 (b) is main GUI that manages the whole data and design process. Important data are independent dimensions, stress checkpoints and contact surfaces with a belt, tightening bolts and bracket. In figure 4 (b), if [Set Pulley Data] button is pressed, GUI for setting data related to a pulley is appeared as shown in figure 4 (c). Material and strength of the pulley, type of the pulley and contact conditions with a belt are set in figure 4 (c). Similarly, if [Set Bolt Data] button is pressed, GUI for setting data related to tightening bolts is appeared as shown in figure 4 (d).



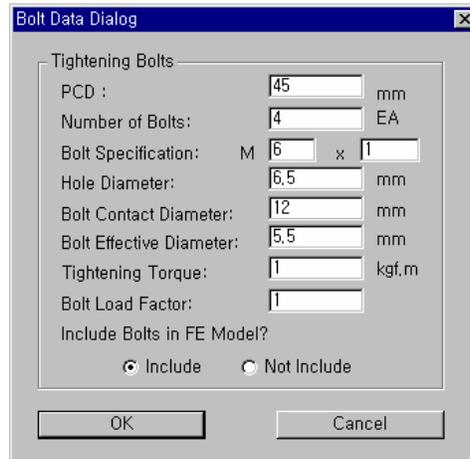
(a) Section profile in I-DEAS



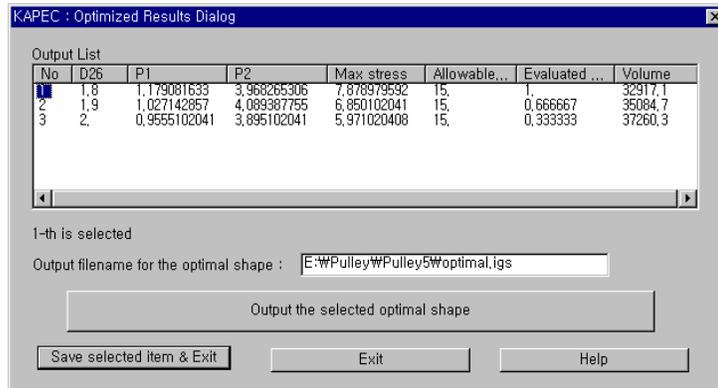
(b) Main GUI for data setting



(c) GUI for setting data for pulley load



(d) GUI for setting data for tightening bolts



(e) GUI for post-processing of optimum design

Figure 4. GUI for data setting

4.3 Optimum design

An optimum design starts based on the data set in figure 4 (b), (c) and (d) when [Start Optimization] button is pressed. Evaluation is repeated as many as the number of the independent dimensions and result is stored for post-processing. Evaluation process consists of solid modeling, FE data modeling, analysis and evaluation as described in chapter 3.

4.4 Post processor of optimum design

After the iteration for optimum design finished, GUI for post-processing appears when [Show Result] button is pressed as shown in figure 4 (e). Stresses at the specified points, maximum stress and volume are shown for every case. User can select the optimum case in figure 4 (e). The selected case is saved and exported as IGES format to be used the following process, spinning simulation process for manufacturing.

5. Conclusion

Some advantages can be achieved by developing an optimum design system for a V-belt pulley as follows.

- A design engineer can perform a precise CAE activity by using the design data of a pulley.
- An optimum design is possible.
- Design experience can be accumulated as an objective evaluation by using the design system.
- Quick response against engineering claims by consumers is possible.

6. Acknowledgements

This work was supported by AnDT, ATES, KAPEC and BK21.

REFERENCES

1. Shigley, J.E. and Mischke, C. R. (1989). Mechanical engineering design, McGraw-Hill
2. Burr, A.H. and Cheatham, J. B. (1995). Mechanical analysis and design, Prentice Hall
3. Distner, M. and Johannesson, T. (2000). Measurements of forces between a synchronous belt and a pulley, Proceedings of DETC2000, ASME 2000 Design Engineering Technical Conferences and Computers and Information in Engineering Conference, DETC2000/PTG-14414
4. Lee, K.S. and Lee, K. (2001). Framework of an evolutionary design system incorporating design information and history, Computers in Industry, 44(3), 205-227
5. Lee, K.S. (1999). Development of integrated design system incorporating design history, information and intent, Ph.D. Thesis, Seoul National University.
6. SDRC. (2000). I-DEAS User's manual
7. SDRC. (2000). I-DEAS Course Guide: OPEN I-DEAS