

Study on Hydrodynamic Torque Converter Parameter Integrated Optimization Design System Based on Tri-Dimensional Flow Field Theory

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ABSTRACT

Hydrodynamic torque converter parameter integrated optimization design system is established based on tri-dimensional flow field theory. Design segments such as optimization initial values searching by meanline theory, cascade solid modeling, structure mesh of flow passage, CFD(computational fluid dynamics), DOE(design of experiment), RSM(response surface model)and optimization algorithm are integrated in this system and therefore a three dimensional optimization design method for hydrodynamic torque converter is presented and realized. An optimization design instance is accomplished by workstation computer cluster, and its result shows that speed and accuracy of design are improved and design system based on 3D flow field theory is accurate and effective.

INTRODUCTION

Hydrodynamic torque converter is a key part in a vehicle automatic transmission, and is generally composed by centrifugal pump, centripetal turbine and axial stator, in which operating fluid continuously circulates and flows. Its fine low-speed starting performance, infinitely variable speed and acceleration performance greatly improve integral powertrain dynamic and NVH (Noise, Vibration and Harshness) characteristic, while relatively low efficiency and fuel economy are its main shortcomings compared with manual gearbox with clutch.

In recent years demands for vehicle low fuel consumption and high acceleration performance are emphasized by the consideration of energy conservation and environmental protection, in which the transmission characteristic of torque converter play a unique and important role. Moreover the design of torque converter with shorter axial dimension puts forward higher expect, in order to compress cyclical circle to squash shape to layout lockup clutch and damping unit. The tri-dimensional design of vanes and flow passages in a torque converter are required to accomplish the

demands mentioned above. While Current design method is commonly based on one-dimensional Euler meanline theory, empirical or half empirical equations from massive vane surface surveying and mapping, and repetitive process of “design- manufacture- test- mapping- design modification- manufacture- test”, so essentially it is a trial-error method. For the reason of lack of tri-dimensional all-parameter cascade solid modeling design tool and corresponding accurate internal flow field numerical investigation tool, vast time consumption, low efficiency and high final cost are the main defects of the design method, in which calculation, modeling and analysis are disjunctive. Its design optimization is realized by modifying angles of design flow line based on meanline theory^[1], or CFD numerical verification of its optimization results^[2] (Fig.1), so the effect of numerous structure parameters to the transmission performance is difficult to estimate and involved, the main cause is the high cost of vast tri-dimensional numerical analysis and lack of systematic tri-dimensional CFD optimization method.

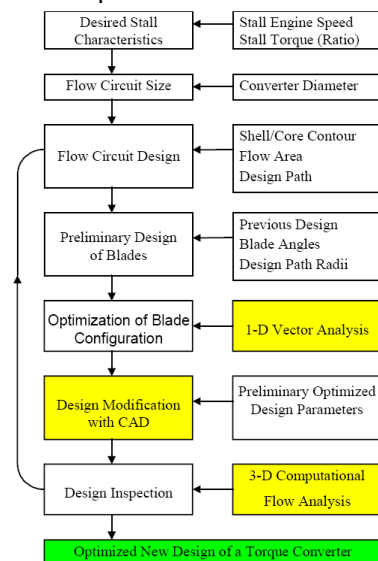


Fig.1 Design process combining 1D and 3D method

Shortening design cycle and enhancing product performance introduce the demand of hydrodynamic torque converter parameter integrated optimization design system based on tri-dimensional flow field theory, integrated frame of which is shown as Fig.2. At first reasonable optimum initial parameters are derived from meanline model, then calculation samples are selected in the entire design space through DOE; for each sample tri-dimensional cascade solid modeling, structure mesh of flow passage and CFD analysis are processed, RSM is constructed by the analysis results; single-object or multi-object optimization solution or solution set and iteration is performed on the response surface, and physical prototype is achieved by fast forming and NC(numeric control) manufacture to verify the design effect; technological process of tri-dimensional optimization design mentioned above is fully engineering accepted^{[3][4]}. Due to the demand of huge computation ability, in this tri-dimensional design system workstation computer cluster includes 9 DELL Precise 370 workstation with Pentium IV 3GHz CPU, DDR266 1G memory and a TP-LINK TL-SF1016 switch.

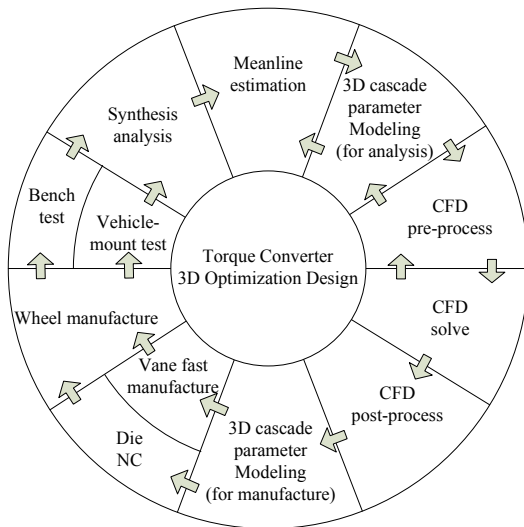


Fig.2 Torque converter 3D design gross architecture

PROCESS OF TRI-DIMENSIONAL OPTIMIZATION DESIGN

DOE table is constructed firstly, in which typical samples are selected from all discrete design space to be analyzed. Commonly independence should be ensured between each sample, which in general theory of statistics means that in DOE table each sample is independent to another^[5]. So by DOE table multiple design variables problem can be solved by relative less analysis experiment times.

Secondly in the workstation cluster dispatching server (1 workstation) sends samples containing design variables from DOE table to computation nodes (8 workstations), and parameterized cascade solid modeling and CFD analysis is performed by computation nodes and result is send back to dispatching server. For

large scale tri-dimensional optimization design with many design variables, significance analysis is needed to ignore variables which have less effect on object function to reduce design difficulty of optimization.

Response surface model is constructed by all of DOE analysis results, and optimum configuration of levels of every factor can be derived by optimization algorithm on approximation model, then verification of optimum solution is applied by tri-dimensional analysis. If verification can not satisfy the convergent criteria, a new RSM will be reconstructed by adding this tri-dimensional analysis until solution is derived. Fig.3 shows the detail of optimization process, where iSIHGT is the optimum platform on which Unigraphics and CFX are called to fulfill the integrated analysis.

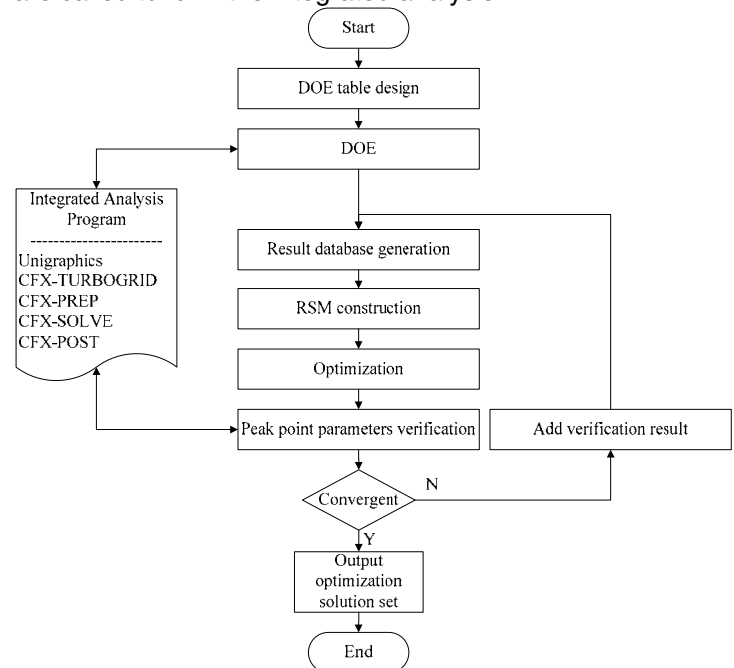


Fig.3 Tri-dimensional design process

In this paper principle and method of key techniques such as tri-dimensional parameterized cascade design, flow field numerical simulation and RSM construction and reconstruction are summarized.

CASCADE PARAMETERIZED SOLID MODELING

In this system meanline optimization calculation is only initial section to provide reasonable initial value for each variable and fasten general convergence speed. Since meanline theory is rather mature during several decades, it is not discussed in detail here, and designers may use their own one-dimensional method to get their own initial values. Optimization model in this paper meanline is based on circulatory flux model^[6].