

Simulation and Analysis of a Resolver for HEV Electric Drive Application

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ABSTRACT

Resolvers as position and speed sensors are widely used in many areas including the automotive industry, especially in the application of an electric drive for a hybrid electric vehicle. One of the disadvantages of using resolvers is that their complexity usually leads to quality issues during development that requires engineering resources and time to solve, which could be better served in solving the complex system issues of improving the hybrid system functionality. This paper describes the creation of a full resolver system simulation that can be used to prevent development issues, improve the hybrid system DFMEA, and act as a catalyst for solving development issues when they do happen. The system simulation model utilizes an integrated systematic approach using co-simulation between several commercial simulation tools to simulate the resolver's electromagnetic characteristics using a transient solver of finite element method, the excitation and termination circuits using an electric/electronic circuit simulator, and the behavior model of a Type II tracking closed loop algorithm to simulate the dynamics of the R/D IC using MATLAB SIMULINK™. The simulation model is verified with test results and then used to predict the behavior during failure modes.

INTRODUCTION

Resolvers as position and speed sensors are widely used in many areas including the automotive industry, especially in the application of an electric drive for a hybrid electric vehicle. Compared with optical encoder or contact types of position sensor, its advantages include

high speed and resolution, capability of severe operation conditions and long distance output transmission [1], etc. However, many vehicle quality issues are also related to the problems caused by resolver failures. Typically, simplified equation models of the resolver characteristic are used to understand its behavior. But in many cases, the simplified ideal behavior models are not capable of representing the distorted signals commonly observed in field application. Therefore, an accurate resolver model with consideration of the resolver's electromagnetic coupling effect would be helpful to analyze the performance and failure modes. This paper uses an example from the resolver for mild hybrid electric vehicle application, and proposes an integrated systematic approach using co-simulation between several commercial simulation tools to simulate the resolver's electromagnetic characteristics using a transient solver of finite element method, the excitation and termination circuits using electric/electronic circuit simulator, and the behavior model of a Type II tracking closed loop algorithm to simulate the dynamics of the R/D IC using MATLAB SIMULINK™. All these components are finally integrated into a systematic solution by co-simulation of these software tools.

RESOLVER SIMULATION MODEL

DESCRIPTION

A typical resolver is normally comprised of a wound stator including a plurality of stator magnetic poles, a steel rotor with a plurality of rotor magnetic poles, and a shaft extending axially through the rotor. There are many configurations of windings applied to the resolver.

Typically, an excitation circuit generates a sinusoidal signal with a carrier frequency of 10kHz, 12kHz, 15kHz or others, which activates the excitation winding of the resolver motor, typically part of stator winding. When the rotor moves, the changing air gap between the rotor and the stator varies the coupling between the excitation winding and the output sinusoidal and cosine signals. These output signals are detected by the resolver-to-digital IC to acquire the angular position information of the rotational motion. A structural diagram is shown in Figure 1.

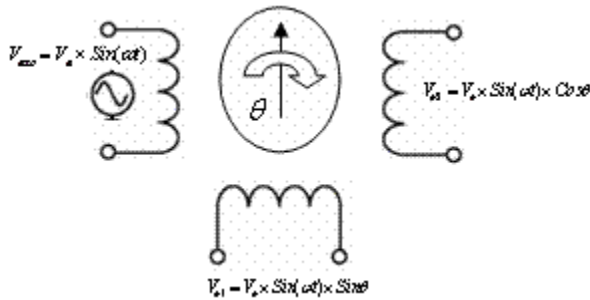


Figure 1 Diagram of resolver windings

This paper uses a resolver with 10 slots stator and 1 pole pair rotor as an example to introduce the simulation approach. The rotor does not have any winding coil but only oval-shaped laminated steel sheets. The slots of stator are filled with the winding for sinusoidal, cosine and also excitation signal. For the sinusoidal and cosine outputs, the number of turns of each winding is altered at each pole to make the current in each winding follow the pattern of sinusoidal and cosine mathematical relationship.

DESCRIPTION

A finite element analysis model is set up to simulate the electromagnetic behavior of this resolver. The model is created with the approximate 2D geometry; therefore, the end turn effects are estimated here. The windings are defined by strand type conductors with certain number of turns, which follows the winding patterns of excitation, SIN and COS. The rotor and stator are all modeled as laminated sheets with the defined thickness. The transient solver with ideal sin/cos external circuit for excitation and termination is used to verify the simulation initially. However, due to the complexity of the actual excitation and the termination circuit, another system circuit simulator is adopted to drive and terminate the transient simulation model in order to achieve better fidelity.

Figure 2 shows the magnetic flux density of the resolver at the initial position, which gives a brief view of the electromagnetic simulation result.

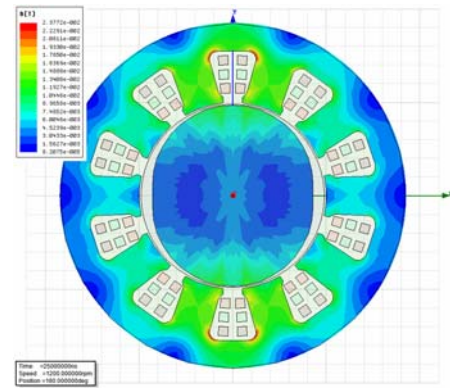


Figure 2 Magnetic flux density at the initial position

RESOLVER ELECTRONICS MODEL

EXCITATION CIRCUIT MODEL

An excitation circuit is used to drive the excitation winding of the resolver to provide the time-variant magnetic field while the rotor is rotating. It amplifies the excitation signal with carrier frequency generated from the R/D IC chip, and converts it into a differential signal to apply to the excitation winding. There are many configurations of excitation circuit based on different requirements. Figure 3 shows an example of a generic driving circuit of the excitation signal used to drive this resolver subsystem from a sub-sheet in Simplorer™ environment. More complicated excitation circuits are also simulated in this study to make better correlations with experiments.

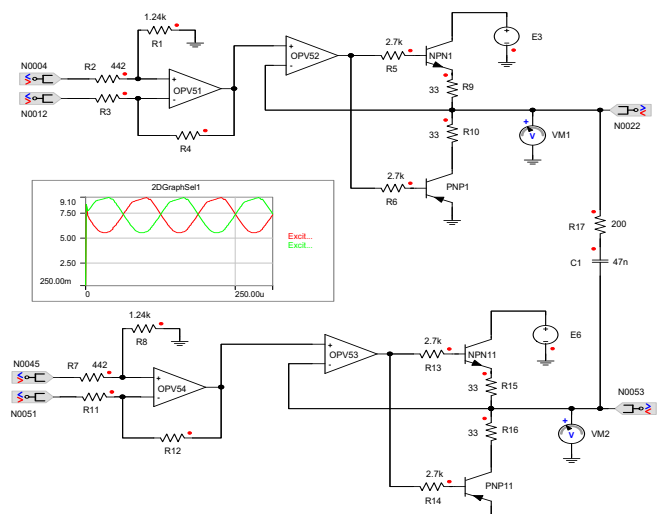


Figure 3 Generic example of excitation circuit model

In the excitation circuit, the reference carrier frequency signal is simulated using an ideal sinusoidal signal generator, which represents the typical 10kHz to 15kHz reference signal from the R/D converter hardware. For the next step, the resolver excitation winding will be connected to the external connectors respectively, and linked with the finite element model through co-simulation interface with transient solver.