An Optimal Missile Autopilot Design Model

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ABSTRACT

This article describes how one optimal design method is given to the design of missile autopilots. This method profits from an exhaustive method. By this method, the design process of a missile autopilot is simplified, and the design efficiency is improved. In the design process of this method, the performance indexes of autopilot are translated into constraint conditions, and the response speed is translated to an objective function. Thus, the optimal design of missile autopilot is translated into the optimal design of a nonlinear system with multiple constraints. The optimization algorithm is found to be out of controller parameter combinations which can satisfy constrained conditions. Firstly, calculations of the corresponding objective function values. Second, by the extract the optimal combination which has the minimal objective function value.

KEYWORDS

Autopilot, Exhaustive Method, Nonlinear System Optimal, Optimal Design

1. INTRODUCTION

Autopilot is an important part of missile guidance and control system, and it has great influence to the stability and controllability of missile (Meng, 2003). The classical control theory is used for the design of traditional missile autopilot mostly, and the control parameters, which can satisfy the performance indexes, are obtained by empirical equations and cut-and-try. These methods have high requests in experience, and the optimization period is long. Many novel missile autopilots based on modern control theory have been put forward in recent years, such as robust control autopilot, neural networks control autopilot, dynamic inversion control autopilot (Godbole et al. 2011; Talole et al. 2011; Sadr and Momeni, 2011; Tomazic and Matko, 2011; Robert et al. 2013). The performances have been improved by these novel control methods. But the deficiencies of these methods are difficult to design, and have not been adopted widely. In this paper, the traditional missile autopilot has been studied, and one optimization method based on time-domain analysis has been put forward, in order to improve the optimization design efficiency of control parameters.

2. PRINCIPLE OF OPTIMAL DESIGN

The preconditions of autopilot optimization are that the rise time, overshoot, transient time and steady state error should satisfy the performance indexes (Wang, 2007; Wang, 2006; Shen, 2007). Therefore, we should ascertain the ranges of overshoot and steady state error by empirical values firstly. The

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optimization objective is minimizing the rise time. And then the optimization design could be regard as solve the optimization problem with multiple constraints and single target.

Suppose overshoot is a percent of steady state value, steady state error is $\pm b$ percent of steady state value, transient time is t_1, simulation time is T, simulation step size is h, and steady state value is g. Then the sketch of system response with constraint conditions could be shown as Figure 1.

Constraints have been set in every simulation node of system response curve. As shown in Figure 1, there is one constraint in every simulation node from 0s to t_1s, and the simulation value should lesser than the constraint value; there are two constraints in every simulation node from t_1s to Ts, and the simulation value should between the constraint values. Therefore, the number of constraints is $t_1/h+2(T- t_1)/h$.

The simulation time, when the simulation value is rise to 80 percent of steady state value firstly, is defined as the rise time. This rise time is the optimization objective. Then we should find out the control parameters which have the minimum rise time and satisfy the constraint conditions. Thus, the optimal design of missile autopilot is translated to the optimal design of nonlinear system with multiple constraints.

3. REALIZATION OF OPTIMAL DESIGN

There are many optimum design methods in modern control theory, such as LOG reaction control system optimum design method, H_∞ & μ synthetic optimum design method. But these methods are difficulty to calculate and realize. So the idea of exhaustion method in classical control theory has been considered in this paper, and one optimization method has been put forward for the design of missile autopilot.

The mathematical simulation flow diagram of one missile attitude autopilot is shown in Figure 2. And this attitude autopilot is the object of following study

Where, φ_C is the control signal of pitch attitude angle, $\dot{\varphi}$ is the pitch attitude rate, φ is the output signal of pitch attitude angle, a_0^φ and a_1^φ are static gain and dynamic gain which need to be

Figure 1. Sketch of system response and constraints