

A Target Characteristic Setting Method for Tires and Suspensions Using Surrogate Models and FRF-Based Substructuring

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Road noise development is facing increasing constraints due to shortened development schedules and fuel efficiency demands, making early component target setting increasingly important. Conventional full-vehicle finite element models make it difficult to evaluate the coupling effects of individual components independently and require substantial computational resources for evaluating many design specifications. In our previous study, FRF-based substructuring and parametric shape optimization reduced this cost by limiting finite element analyses to the modified subsystem. However, each structural modification still required an analysis, followed by an additional process to convert the resulting structural specifications into target component characteristics.

This study combines subsystem-specific surrogate models with FRF-based substructuring to rapidly determine target component characteristics, such as mass, stiffness, and resonance frequency, while satisfying multiple performance requirements. Surrogate models predicted the uncoupled frequency response functions of the tire/wheel and suspension subsystems. The predicted responses were combined with the transfer functions of the body subsystem to calculate full-vehicle road noise (Fig.1).

A multi-objective optimization process generated 15,000 design candidates based on road noise and handling-stability metrics. Key component characteristics were selected according to their contributions to the performance metrics. The optimization results were classified using a self-organizing map and hierarchical clustering. A cluster whose performance metrics satisfied all targets, including their variations, was defined as the Target Cluster. Cases in the Target Cluster were reclustered using key component characteristics to extract multiple design patterns. One of these design patterns was selected as the Design Pattern for target-range setting (Fig.2).

Target ranges were defined based on the mean values and standard deviations of the Design Pattern. However, new combinations of characteristics within these ranges do not necessarily satisfy the performance targets. Therefore, 1,000 additional cases were generated for each condition to validate the assigned target ranges. When characteristics with contributions of 5% or more were controlled within a range of ± 0.5 standard deviations from the Design Pattern mean, with the manufacturing variation range applied when it was wider, 96% of the generated cases satisfied all performance targets.

The proposed method enables rapid full-vehicle performance evaluation and finite target-range assignment only to the characteristics required for performance control, while retaining design flexibility.

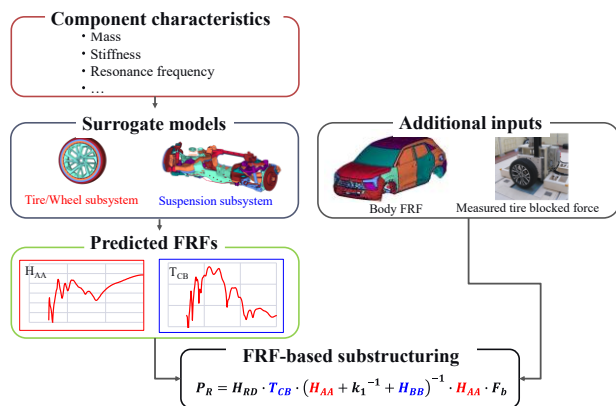


Fig.1 Configuration of component surrogate models

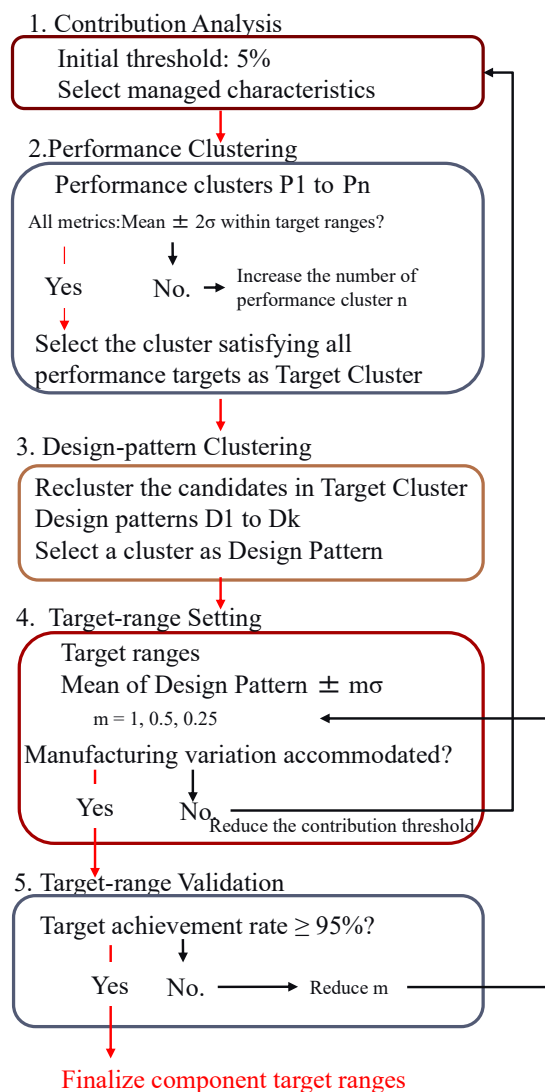


Fig.2 Component target-range setting and validation flow