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A RAPID PRELIMINARY DISK DESIGN METHOD FOR TWO-DIMENSIONAL AEROENGINE SCHEME DESIGN

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This paper attempts to establish a rapid preliminary disk design method for two-dimensional aeroengine scheme design, including disks of high-pressure compressors and turbines. Rapid disk preliminary design methods could be used for initial engine weight estimation, shaft geometry and vibration calculations, multiple discipline optimization, and the elimination of unreasonable engine designs. Based on the Kriging interpolation method, PSO optimization, and the equal-thickness ring method, the program can achieve the preliminary design of disks within several seconds after creating the two-dimensional flow-path. The program is implemented according to the following procedure:

1. A nine-parameter model describing the geometry of the disk was developed. The parametric model is based on NASA's web disk model;
2. Obtain the geometry data of the disk and find linear relationships between parameters based on over 30 engine drawings;
3. Rapid calculation of strength and safety factors for disks based on the equal-thickness ring method, which is faster than FEM calculation;
4. According to the statistical model, pick three parameters out of nine that need to be optimized. Using the Kriging fitting method, the initial values of three optimized parameters are fitted based on flow-path geometry parameters, including radius of shroud, hub, width of blade, and number of stages;
5. The initial generated disk is optimized with a minimum mass objective based on the particle swarm optimization algorithm. After 50 steps of optimization, disks of components will be generated within several seconds.

Compared with the disk geometry of the V2500 engine, the method was found to meet the accuracy requirements of the preliminary 2D engine design and could be used for the 2D scheme design of the whole engine.

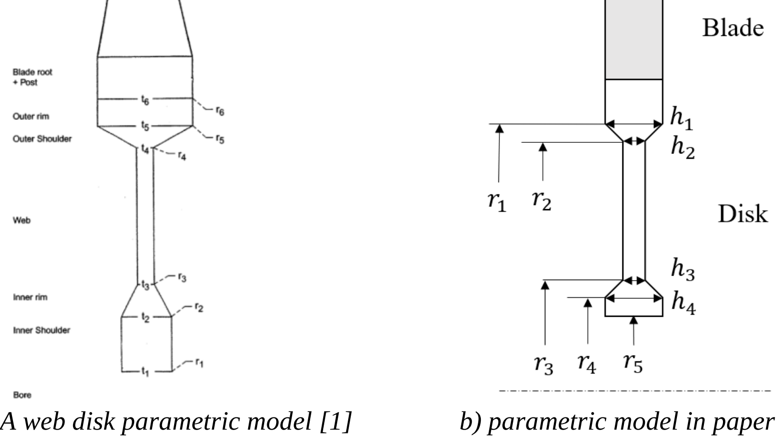

Fig. 1 – a) NASA web disk parametric model [1] b) parametric model in paper

From the figure 1， the disk geometry of the engine can be simplified by using 12 parameters to describe. According to this article [2], this parametric model can be simplified to 9 parameters based on some assumptions, including $t_6 = t_5$, $t_1 = t_2$, $r_6 = r_{hub}$. Finally, get the parametric model used in this paper (fig. 1-b).

According to this article [2], the web disk parameters have some inner relationships. To figure out relationships between parameters and reduce optimization parameters, measurements have been made on the disks of over 30 engines. And finally, find out the linear relationships between parameters. For example, in high pressure compressor statistics, first normalize all the parameters by being divided by radius of the shroud. And find out the linear relationships between normalized values.

In fig. 2, the normalized values $\bar{r_1}$ and $\bar{r_2}$ have a high degree of linear correlation with a coefficient of determination over 0.8. Similarly, it can be found that in high pressure compressor disks, between $\bar{r}_{hub}$, $\bar{r_1}$ and $\bar{r_2}$, between $\bar{r_3}$, $\bar{r_4}$ and $\bar{r_5}$, between $\bar{h}_2$ and $\bar{h}_3$ there are linear relationships. As a result, the parametric model of HPC disk can be simplified to 3 variables, including $\bar{h}_2$, $\bar{h}_4$ and $\bar{r}_3$.

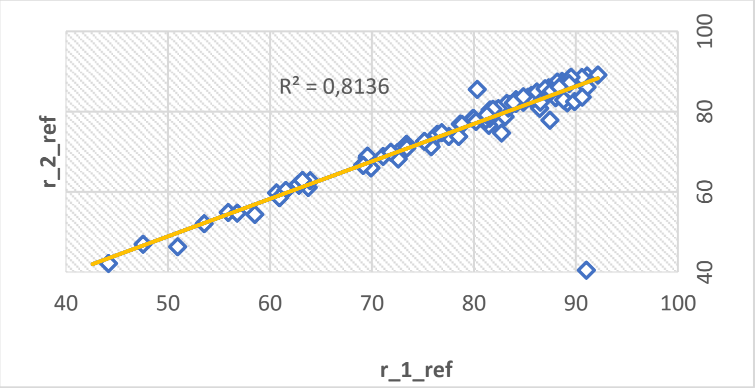

Fig. 2 – The relationship between $\bar{r_1}$ and $\bar{r_2}$

After picking up 3 variables, the Kriging fitting model of these variables can be established. As a result, generate the initial values of the disk used for optimization.

The optimization method is the particle swarm optimization algorithm. The target function is the weight of the disk, and constraints include the safety factor of the disk and the breaking speed of the disk. To calculate the safety factor, the semi-thickness ring method has been applied, which is faster and more concise than the FEM method, and can be composed with an optimization program without specialist business software like Ansys.

In fig. 3, it's the comparison between V2500 HPC disks and generated disks. For preliminary design, precision meets requirements. By accessing more suitable materials and more accurate blade tensile stress, the accuracy of disk generation could be further improved. Similar methods could be applied in generating high-pressure turbine and low-pressure turbine disks.

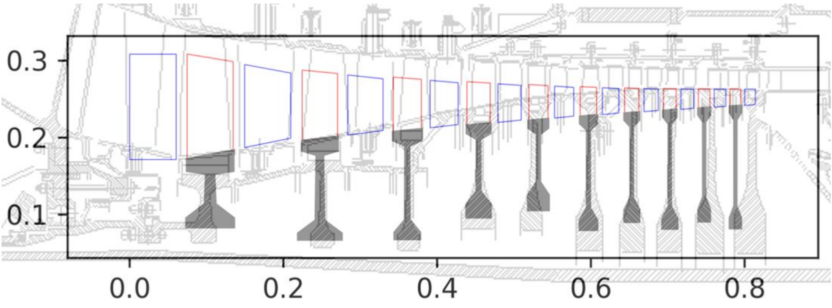

Fig. 3 – The comparison between V2500 real engine and generated disks

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