The Structure Optimization of Diesel Injection Pump Based on DOE

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Abstract—**The fuel supply quantity of high-pressure pump and the fuel supply quality from constant pressure valve to high pressure vitta was very important to capacity of the diesel engine. In this paper, the model of the fuel injection system is established by Hydism and the model is integrated with Isight in DOE research. According to the DOE results, two optimization interdigitations were used to optimize the fuel injection system to improve the cubage efficiency of high-pressure pump and the flow capacity of delivery valve. The optimization results showed that the united use with system model and DOE in optimization design of the fuel injection system is effectively and the cubage efficiency of pump could be promoted 5.97 % and the flow capacity of delivery valve could be promoted 24.65%.**

Keywords-Fuel injection system, System model, DOE, Cubage efficiency, Flow capacity, Optimization design

I. INTRODUCTION

In the fuel injection system, the fuel supply quantity lies on the cubage efficiency of high-pressure pump and the fuel supply quality from constant pressure valve to high pressure vitta lies on the flow area of ball valve. It is very important that how to choose appropriate structural parameters and characteristic parameters of system to get the best cubage efficiency of high-pressure pump and flow capacity of delivery valve[[1-2].

It is very complex and inefficiency with manual programming to study influencing factors of the system. So the paper build the fuel-injection model with Hydism and carries out sensitivity analysis of structural parameters and characteristic parameters to the cubage efficiency and flow capacity with DOE(design of experiment) of Isight software. The ANOVA (Analysis of Variance), main effect and interaction effect were analyzed from DOE results. After that two optimization interdigitations were used to optimize the main factors of system[3].

II. MODEL OF FUEL INJECTION SYSTEM

Because autobody panels emphasis curved surface whole artistic effects, measurement accuracy is not the first problem considered in the course of the measuring car body, but trying to make the development time shorter [4].

According to the characteristics of the diesel engine, the model of the fuel injection system is established by dividing it into components including high pressure pump, constant pressure valve, high pressure vitta and injector, all of which are represented by elements such as volume, hydraulic valve, piston, orifice, pipeline, and cam. The system is illustrated in Fig.1.
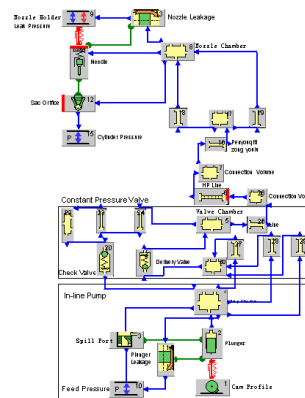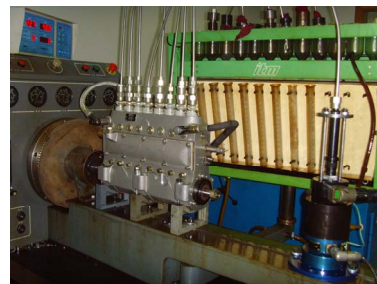

Figure 1.   Fuel injection system model

Figure 2.   High-pressure pump test-bed

To verify the veracity of models, the fuel pressures at the outlet of delivery valve of high-pressure pump has been measured in high-pressure pump test-bed (Fig.2) with cam speed being 1000r/min and the fuel supply quantity in one cycle being 450mm3.

As illustrated in Fig.3, the difference between the maximal fuel pressure of simulation results and that of test results is 1.8%. The simulation model is validated.
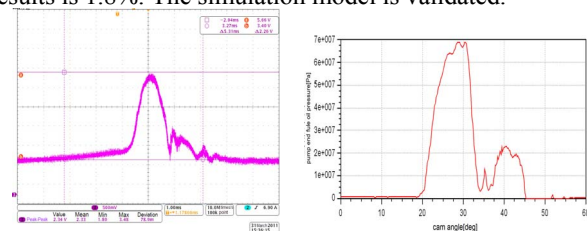

Figure 3.   Comparison of fuel pressure of test results and simulation results

III. DOE RESEARCH

A. DOE process integration

The fuel injection model is integrated with Isight in DOE research. The data is exchanged between Hydism and Isight. Firstly, the simulation results of Hydism model is transmitted to Isight and the results is stored in Isight. Then the design parameters of Hydism model are changed by Isight according to test schemes and the new simulation results could be gotten. The integrated process is illustrated in Fig.4[5].
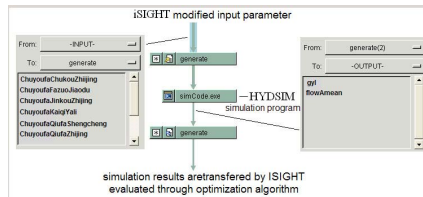

Figure 4. Data flow of HYDSIM and Isight

Figure 5. Configure parameters

B. Design parameters

According to the structural characteristics of high pressure pump, the design parameters are determined which are illustrated in Fig. 5.The maximal fuel quantity at outlet of delivery valve and the mean value of flow area at channel restriction of ball valve are determined respectively as objectives of cubage efficiency and flow capacity.

C. Test schemes

Six kinds of scheme are determined basing on the test method, the test times and the level values. The paper chooses Orthogonal Arrays and Latin Hypercube.

TABLE I. THE TEST SCHEMES OF DOE

scheme	1	2	3	4	5	6
Test method	OA	OA	OA	OA	LH	LH
Number of level	3	3	3	3	-	-
Range of level	±5%	±7%	±8%	±9%	±8%	±9%
Test times	243	243	243	243	520	910

④DOE results

Due to limitations on space, the paper only gives the cubage efficiency results of scheme 1.

The Pareto result (Fig.6) showed that the cubage efficiency was most sensitive to the hydraulic diameter and

the length of high pressure vitta, the maximum lift and the opening pressure of delivery valve ball, the preload of plunger spring.
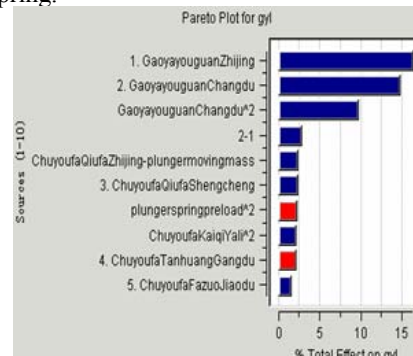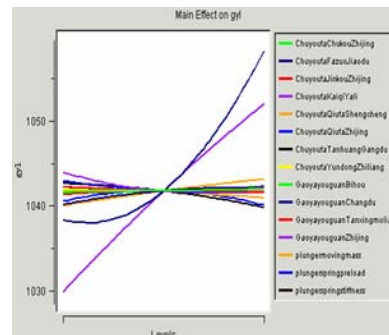

Figure 6. Pareto of scheme 1

Figure 7. Main effect of scheme 1

The main effect result (Fig.7) showed that the slope of titration curve which is bigger means the parameter has more important effect on the cubage efficiency.

As illustrated in Tab.2 and Tab.3, the paper gives the important design parameters of cubage efficiency and flow capacity of all schemes.

The cubage efficiency was most sensitive to the hydraulic diameter and the length of high pressure vitta, the maximun lift and the opening pressure of delivery valve ball, the plunger equivalent moving mass.

The flow capacity of delivery valve was most sensitive to the plunger equivalent moving mass, the half-angle of delivery valve seat, the delivery valve equivalent moving mass, the diameter of delivery valve ball and the hydraulic diameter of high pressure vitta

TABLE II. IMPORTANT DESIGN PARAMETERS OF CUBAGE EFFICIENCY

Scheme 1	L D	L L	L B	P S P	O P B
Scheme 2	L D	L L	L B	O P B	P M
Scheme 3	L D	L L	L B	O P B	P M
Scheme 4	L D	L L	L B	O P B	P M
Scheme 5	L L	L D	V S A	B D	P M
Scheme 6	L D	L L	L B	B D	P M

TABLE III.   IMPORTANT DESIGN PARAMETERS OF FLOW CAPACITY

Scheme 1	P M	V S A	B D	B M	L D
Scheme 2	P M	V S A	B M	B D	L D
Scheme 3	P M	V S A	B M	B D	L D
Scheme 4	P M	V S A	B M	L D	L D
Scheme 5	P M	V S A	B M	B D	B D
Scheme 6	P M	V S A	B M	B D	L D

IV.   OPTIMIZATION DESIGN

In order to improve the cubage efficiency of high-pressure pump and the flow capacity of delivery valve, the Isight was used to optimize the structural parameters and characteristic parameters of pump and high pressure vitta.

①Optimization schemes

Two optimization interdigitations were used to optimize the system with consideration on the optimal strategy of Isight.

Scheme 1: Directed Heuristic Search with NLPQL
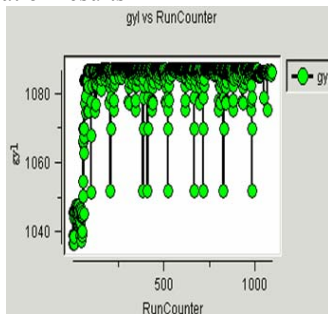Scheme 2: MMFD

②Optimization results

Figure 8.   Optimization process of scheme of cubage efficiency of pump
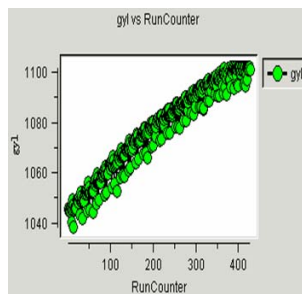

Figure 9.   Optimization process of scheme of cubage efficiency of pump
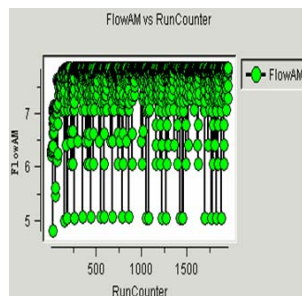

Figure 10. Optimization process of scheme of flow capacity of delivery valve
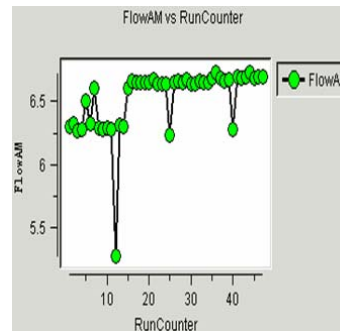

Figure 11. Optimization process of scheme of flow capacity of delivery valve

As illustrated in Fig.8 and Fig.9, the cubage efficiency of pump could be respectively promoted 4.4% and 5.97 % in scheme 1 and scheme 2. The flow capacity of delivery valve could be respectively promoted 24.65% and 6.82 % in scheme 1 and scheme 2, as illustrated in Fig.10 and Fig.11. The cubage efficiency and the flow capacity of delivery valve all tended to rise, but the former at a modest rate and the latter increased by a wide margin .

V.   CONCLUSION

The cubage efficiency was most sensitive to the hydraulic diameter and the length of high pressure vitta, the maximun lift and the opening pressure of delivery valve ball, the plunger equivalent moving mass.

The flow capacity of delivery valve was most sensitive to the plunger equivalent moving mass, the half-angle of delivery valve seat, the delivery valve equivalent moving mass, the diameter of delivery valve ball and the hydraulic diameter of high pressure vitta.

The cubage efficiency of pump could be promoted 5.97% and the flow capacity of delivery valve could be promoted 24.65%. The cubage efficiency and the flow capacity of delivery valve all tended to rise, but the former at a modest rate and the latter increased by a wide margin .

The united use with system model and DOE in optimization design of the fuel injection system is effective in promoting the cubage efficiency of high pressure pump and the flow capacity of delivery valve.

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