Topics

Design Technique for Suppressing Vibration in Hydraulic Control System

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Since the hydraulic control system for an automatic transmission consists of a combination of multiple valves (**Fig. 1**), coupled vibration due to mutual interference is likely to arise. The vibration is influenced by many other factors (design specifications), so it is not easy to provide a corrective actions.

This study proposes a generally applicable simulation method with minimum incorporated factors and an optimum design specification method to enable a coupled vibration problem to be solved in a short time. These methods are outlined below.

1) Simulation method

The flow coefficient, bulk modulus, entrained air volume, friction coefficient, viscous resistance and other simulation constants so far handled as incorporated constants have been both experimentally and theoretically derived. Especially, the viscous resistance and frictional force so far unknown have been determined by measuring the response of the spool valve using a non-contact displacement sensor. A theoretical flow formula added with the displacement and eccentricity of the spool valve was also introduced to formulate the flow rate coefficient in a spool valve for an automatic transmission. As a result, the applicability of the simulation has been improved for the easy reproduction and forecasting of hydraulic vibration. Hydraulic element data are stored as a library using Dymola, a simulation tool having an excellent user interface, to allow easy modeling of the hydraulic control systems by designers.

2) Optimum design method

With the foregoing simulation as the base, the sensitivity of each design factor to hydraulic vibration is analyzed according to the Taguchi method [1]. The number of iterations for simulation is minimized by using the orthogonal array shown in **Table 1**.

The sensitivity is analyzed by using the ratio of the expected evaluation value to dispersion (SN ratio) using the maximum amplitude and vibration frequency as evaluating functions. The analytical result is shown in **Fig. 2**. The vibration damping effect of each factor is clearly indicated as an SN ratio for easy judgment in order to optimize the design specifications.

Fig. 3 shows the test result of the design

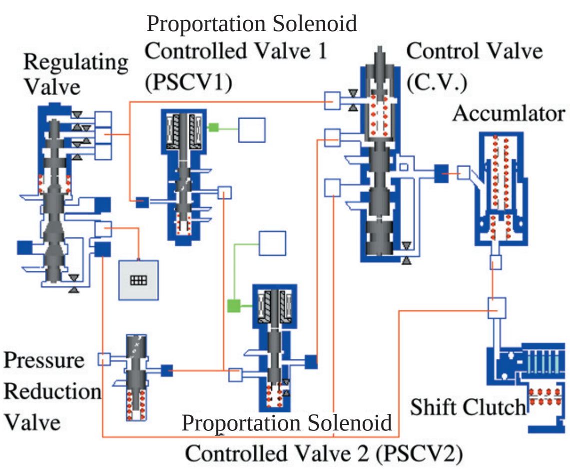

Fig. 1 Simulation model of hydraulic control system.

Table 1 Factors and these level.

			Level 1	Level 2	Level 3
Controlled Factor	A	Lap Length of C.V.	Small	Middle	Big
	B	Clearance of C.V.	Small	Middle	Big
	C	Spring Constant of C.V.	Small	Middle	Big
	D	N[illegible] Angle of C[illegible]	Sm[illegible]	Middle	[illegible]
	K	Lap Length of PSCV2	Small	Middle	Big
	L	Spring Constant of PSCV2	Small	Middle	Big
	M	Notch Angle of PSCV2	Small	Middle	Big
Signal F.	N	Duty Rate	Small	Big	-
Error F.	O	Eccentricity Rate	Small	Big	-
	P	Air Rate in Oil	Small	Big	-
	Q	Duty Change Speed	Small	Big	-

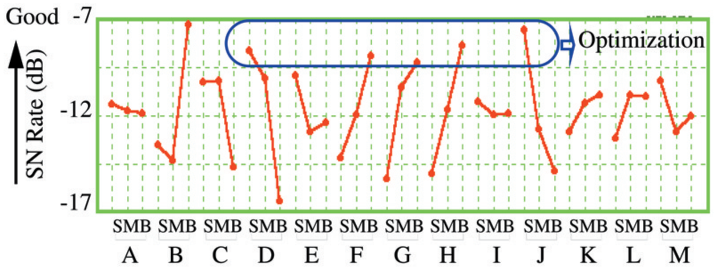

Fig. 2 Signal to noise ratio.

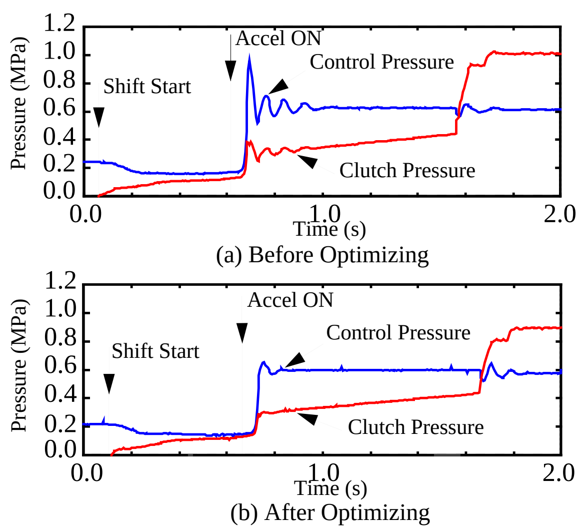

Fig. 3 Experimental results of optimizing.

optimization through experiments. This figure indicates a significant reduction in the vibration by optimization of the design specifications.

Techniques 1) and 2) above have made systematic vibration suppression by departing from the conventional trial-and-error type actions.

This study was jointly conducted by Toyota Motor Corporation and Aisin AW Co., Ltd., and has been applied to hydraulic control system development in both companies.

Reference

1) Taguchi, G. and Yano, H., Quality Engineering for Technology Development, 1994, Japanese Standards Association

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