IMPROVING MANUAL TRANSMISSIONS SHIFT QUALITY IN HIGH PERFORMANCE VEHICLES

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THEME

Motion

SUMMARY

A virtual prototype of a SHIFT CONTROL SYSTEM for a manual transmission was developed in order to reproduce and predict a specific way for gear shifting in high performance vehicles. Based on the current design tests and data, we identified the main causes that produce a high shifting effort and then proceed to reduce it greatly. Each component on the analytical model developed in this study was modelled as a rigid body, to account for compliance and damping between transmission components and the hand ball flexible connectors or bushings were used. The simulation results were then compared with measured data. The changes on Shifting Control System produced a noticeable improvement of shifting quality.

KEYWORDS

Shifting effort, shifting quality, shift patterns, manual transmission,
1. **Introduction.**

Customer demands have increased with time and development of new technologies; the shifting feeling of manual transmission has become a parameter required to qualify and evaluate the shifting quality of a manual transmission. This parameter considers everything that the driver feels during each gear shifting, such as: the number of peak loads, high shifting effort, exact location of shift lever at each gear speed and neutral position, a proper synchronization event, partial or full block out and damping due to high friction coefficient in the Shift Control System.

There are two possible ways to define the shifting quality at different operations conditions:

One of them is based on subjective measurements where the driver drives the vehicle and is able to assign a number from 1 to 10 according to the general shifting feeling during up-shift or down-shift for each gear shifting. A lower number means low quality and a higher number means high quality.

The other one is based on an objective measurement where the measurement equipment is used to get load profiles for each gear shifting.

Furthermore, there are two well known shifting pattern for manual transmission, "H" Shift and "X" Shift pattern, and drivers for high performance vehicle prefer "X" Shift pattern because it is straight line trajectory described by the hand ball instead of the letter "H" trajectory, Fig. 1. This analysis was only focused to 2\textsuperscript{nd} - 3\textsuperscript{rd} up-shift.
This paper deals with the shifting feeling improvement for "X" Shift pattern when using a virtual prototype in MSC.Adams and with the comparison of the mechanical behaviour of the proposed Shift Control System redesign versus test data obtain from the current design.

The criterion used for improving the shifting quality was to minimize the reaction forces that are opposed directly to the axial movement of shift rail according to the specific hand ball trajectory.

II. Simulation model

The multi-body simulation model Fig. 2, was developed to include a shift lever, shift rails, fork and synchronizer assemblies and shift detents, in order to capture the effects of each Shift Control System component during shift engagement and disengagement following a specific hand ball trajectory pre-defined to be as close as possible to the "X" Shift pattern, with the main objective of finding out the main causes of high shifting effort that occur with this specific shifting pattern. Contact forces were defined where required; parts connectivity was defined to satisfy appropriate model degrees of freedom for a normal Shift Control System operation. Every component of simulation model was modelled as a rigid part since the contribution of part flexibility to the
shifting force magnitude and reaction forces was not key part of the study and do not affect the hand ball trajectory results. However it was important to minimize resistance in the direction of the resulting motion of the shift rails that is a direct consequence of the hand ball specific trajectory, to accomplish that compliance/deflection of the hand ball attachment was including by using a bushing as a flexible connector to the shift lever.

III. Results

The specific trajectory defined for "X" Shift pattern as is show in Fig.3, but was necessary to define two specific hand ball trajectories; one of them produced high peak loads (B curve) and the other one did not. Based on the current design, Fig. 3, and this specific trajectory design iterations were done in order to determine the effects they have on improving shifting quality.
Different engagement forces were obtained when using curves A and B on the current Shift Control System, but they showed the same load when involved interlock dimension is manufactured with maximum tolerance and this pushes the shift rail. According to this information it is important to define the involved interlock dimensions as a design critical dimension. The consideration of how feasible is to manufacture the interlock with the proposed dimensions needed to be considered, Fig. 4. Fig. 4 shows the best option for interlock dimension to be lower than 1.5 mm. The prototypes were manufactured and tested in a transmission assembly. During the analysis, with the interlock dimensions kept as the dimensions in the current design, a load peak is shown at time near to 0.51 sec followed by a gradual force increase. When interlock dimension was 1.5 mm a load peak is shown followed by a constant value for a short period of time and followed by an even lower value after that. The best option was obtained when no high load peak was present and load remained relatively constant up to 0.545 sec; after that time all shifting effort curves depend on lateral motion applied to shift lever by driver.
IV. Measurements

According to the SUBJECTIVE measurements on current and proposal Shift Control System design, the shifting quality was substantially improved because partial and full block out were decreased. The OBJECTIVE measurements showed great improvement for up-shift 2nd-3rd gear speed. The current design, Fig. 5, shows high shifting effort for the up-shift 2nd-3rd gear speed, but low shifting effort for the down-shift 3rd-2nd gear speed.
The objective measurements for the proposed design were implemented only for up-shift 2nd-3rd gear speed. Fig. 6 shows two important characteristics:

- The low shifting effort (parameter used to defined shifting quality)
- Location where the low shifting effort happens

The graph shows that the driver will be able to carry out with no problems the up shifting from 2\textsuperscript{nd} to 3\textsuperscript{rd} gear speed, describing a “X” Shift pattern and no block out.

V. Conclusions

1. The detail in the simulation model was enough in order to find the root causes for block outs and define improvements, at the same time it made possible to identify that the block out depends of hand ball trajectory defined by driver, "H" Shift or “X” Shift patterns.

2. It was convenient and feasible to include dimension tolerances to the interlock design as part of the simulation.

3. The proposal changes on interlock design do not affect any other performance of Shift Control System.

REFERENCES

[1] MSC.Adams user´s Help; Rel. 2012.