

Shudder Durability of a Wet Launch Clutch

Part II – Durability Study

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ABSTRACT

Under the initiative of the United States Council for Automotive Research LLC (USCAR[§]) Transmission Working Group, a collaborative effort was made with LuK USA LLC to study the influence of the friction interface parameters on the shudder durability of a wet launch clutch. Clutch configurations with different combinations of four friction materials (A, B, C and D), three groove patterns (waffle, radial and waffle-parallel) and two separator plate conditions (nitrided and non-nitrided) were considered. Durability testing consisted of a test profile, with 110 kJ energy per test cycle, developed earlier in this project. Materials A, B and C with nitrided separator plates reached the end of test criteria for the torque gradient and showed shudder. Materials B and C were more wear resistant as compared to materials A and D. The loss of friction coefficient (μ) was lower for materials B, C and D as

compared to material A. Material D showed good friction properties but failed via material break-out. The radial groove pattern showed lower wear and μ loss but higher pore plugging than the waffle and the waffle-parallel pattern. Materials C and D showed lowest pore plugging. The durability life of the waffle-parallel pattern was lower than the waffle and the radial groove pattern. The non-nitrided separator plates showed high μ loss and high wear although they did not show shudder. Reducing the friction contact area by 50% showed significant μ loss, wear, pore plugging and black spotting due to heat on the separator plates.

INTRODUCTION

In recent times, launch devices in automotive transmissions often include a wet clutch system. Considerable amount of effort is being dedicated toward development of the wet launch clutch [1,8]. The launching device should fulfill the requirements of providing a smooth launch, good NVH behavior and durability. Essentially, the wet launch clutch is a multi-friction-plate system immersed in an oil bath. Therefore, the performance requirements of a friction clutch including, but not limited to, high friction coefficient (μ), positive friction gradient (i.e. positive μ -v relationship, where v is the sliding velocity), low wear, stable μ over

[†] : USCAR Transmission Working Group member

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life and durability are essential for desirable performance of the wet launch clutch. Shudder, or friction induced vibrations, is a commonly known undesirable phenomenon in friction clutches [2,4,9]. An initiative was made by the United States Council for Automotive Research LLC (USCAR[®]) Transmission Working Group to study the influence of friction interface parameters on the shudder durability of a wet launch clutch, in collaboration with LuK USA LLC. A shudder test bench was developed for this study. Clutch configurations with different combinations of four friction materials (A, B, C and D), three groove patterns (waffle, radial and waffle-parallel) and two separator plate conditions (nitrided and non-nitrided) were considered.

In an earlier stage of this project, a durability test profile with 110 kJ energy per engagement was developed for this study [3]. The test clutch is a mechanically actuated DCT clutch with four friction plates. In the subsequent sections the durability test profile is described. The durability results and friction properties measurements have been presented. The different materials, groove patterns and separator plates have been compared on the basis of loss of friction coefficient (μ), number of test cycles to failure, occurrence of shudder, pore plugging, wear and post test separator plate conditions.

EXPERIMENTAL SET - UP

A shudder test bench used in this study, the end of test criteria of -0.075 Nms/rad torque gradient limit and a durability test profile with 110 kJ energy per engagement have been developed during an earlier stage of this project [3].

NOMENCLATURE OF CLUTCH CONFIGURATIONS

Friction materials from four different industry suppliers were tested in this study. These materials are referred to as material A, B, C and D. Two different separator plate conditions were considered, nitrided and non-nitrided. Three different groove patterns are referred to as W for waffle, R for radial and X for a waffle-parallel pattern which was a combination of waffle and parallel grooves. Groove pattern X had 14 % less groove area than the groove patterns W and R.

The clutch configurations were named with two or three letters. The first letter representing the material type and the second representing the groove type. As an example, AW represents friction material A with waffle grooves. A third letter was added in certain cases, P for the non-nitrided separator plate condition or Q when the friction material area was reduced by 50%.

The different configurations tested were AW, AR, AX, BX, CW, DW, AWP and AWQ. Two replicates of each configuration were tested for durability, each replicate being labeled as 1 or 2. Only one replicate of the configuration DW and AWQ were tested.

110 kJ DURABILITY TEST PROFILE

The durability test begins with a break-in procedure developed earlier to provide good conformance of the friction material before the first high energy engagements and to avoid localized burning [3].

The friction characteristics were measured at constant torque values of 25 Nm, 90 Nm and 175 Nm during the development of the 110 kJ test profile [3]. However, this would result in a change in facing pressure when the facing area changes. Thus, the friction characteristics conditions were changed to be measured at facing pressures of 100 kPa, 250 kPa and 500 kPa. These facing pressure values corresponded to the 25 Nm, 90 Nm and 175 Nm torque values of the baseline friction material AW. The oil inlet temperature was maintained at 90°C. The friction characteristic measurements were conducted after break-in, after 2500 and 5000 durability cycles and subsequently after every 4000 durability cycles.

The 110 kJ durability tests were conducted at 130°C inlet temperature. The end of test criteria was established at -0.075 Nms/rad torque gradient limit at 250 kPa friction characteristic measurement. If this criteria was met, a shudder probe test was run at 250 kPa facing pressure. The oil inlet temperature during the shudder probe was varied from 30-90°C to see the influence of temperature on shudder. The durability test procedure is tabulated in Table 1.

Event	Description	Oil inlet temperature
Break-in	Developed and described in an earlier stage of this project [3]	
Durability	110 kJ energy per test cycle [3]	130°C
Friction characteristics	100, 250 and 500 kPa facing pressure. Intervals After break-in, after 2500 and 5000 durability cycles, subsequently after every 4000 durability cycles	90°C
Shudder probe	Run after -0.075 Nms/rad torque gradient limit in the 250 kPa characteristic measurement	30-90°C

Table 1: Durability Test Procedure

TEST CLUTCH

A mechanically actuated DCT clutch with four friction plates was used for the purpose of this study. DCT oil was used as the operating fluid. Figure 1 shows the numbering of the separator and friction plates for durability testing. The separator plates are odd numbered starting at 1 farthest from the actuator. The friction plates are even numbered starting at 2 farthest from the actuator.

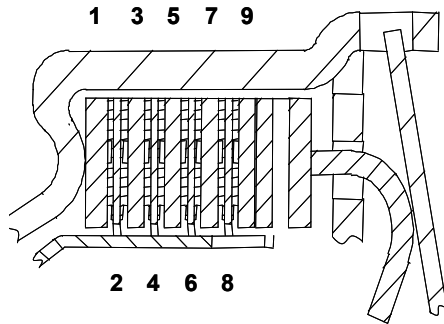


Figure 1: Mechanically actuated DCT clutch

DURABILITY TESTING

The durability tests were conducted as described in Table 1. The configurations tested were AW1, AW2, AR1, AR2, AX1, AX2, BX1, BX2, CW1, CW2, DW1, AWP1, AWP2 and AWQ1.

TORQUE AND FRICTION CHARACTERISTICS

Typical durability cycles at the start and end of the durability test are shown in Figs. 2 and 3. These plots are for configuration BX1.

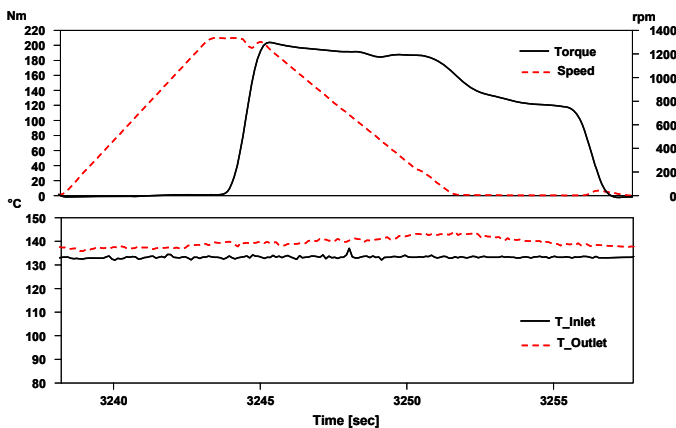


Figure 2: Durability cycle at the start of test for BX1

Figure 2 shows a downward sloping torque shape during the engagement implying a positive torque gradient or friction gradient. As the test progresses, the gradient gradually worsens and the torque shape tends to slope upwards. Figure 3 shows BX1 after nearly 40000 durability cycles. In most cases, a sharp torque increase or rooster tail was also seen towards the end of of

engagement. The rooster tail is a characteristic of bad or negative low speed friction gradient.

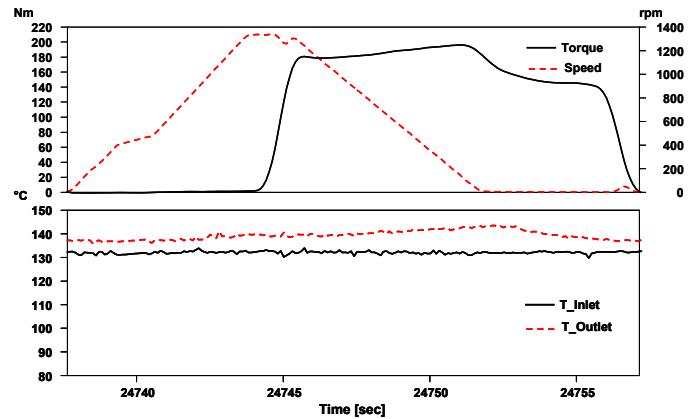


Figure 3: Durability cycle at the end of test for BX1

The friction characteristics, shown in Figs. 4, 5 and 6 for CW2, demonstrated similar trends for almost all the materials. The μ values typically increased for the first 5000 cycles and then started decreasing. It is known that the friction coefficient (μ) value drops with increase in apply pressure [5]. The μ values were highest for 100 kPa engagements followed by the μ values for 250 kPa and 500 KPa engagements, as expected.

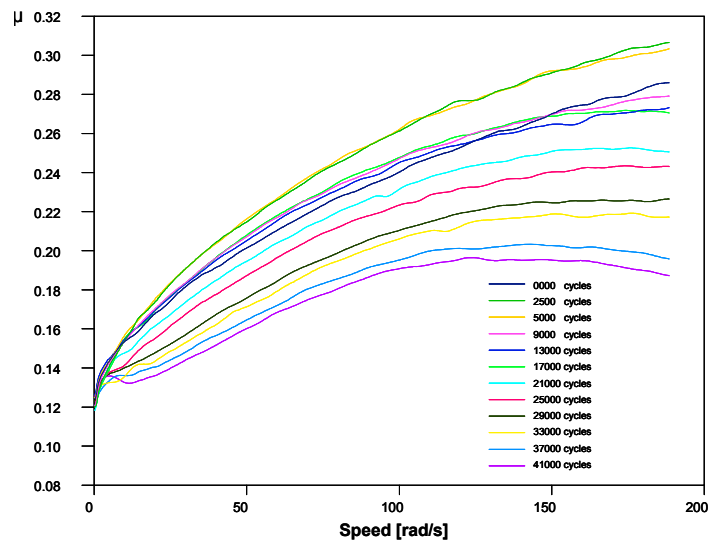


Figure 4: 100 kPa friction characteristics for CW2

As seen in each of Figs. 4, 5 and 6, the high speed and low speed friction gradients were positive at the start of the test. The friction curves became flatter as the test progressed. Eventually both the high speed and low speed gradients became negative in the 100 kPa measurements. For the 250 kPa and 500 kPa measurements, the high speed gradients were positive until the end of the test in most cases.