

Understanding MTF Additive Effects on Synchroniser Friction

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ABSTRACT

Specific frictional properties are essential to provide correct and pleasurable shifting in a manual transmission. Synchroniser rings are being manufactured from an increasingly wider range of materials, and so it is important to understand synchroniser-additive interactions in order to develop tailored lubricants that provide the desired frictional performance. This paper describes a study of the interaction of various friction modifier additives with a range of synchroniser materials in order to better understand the potential to develop lubricants that provide optimal frictional performance across a wide range of manual transmission-synchroniser systems. This presentation will outline the results of testing fluids with a range of synchroniser materials and will be followed by a future paper that will describe details of the fluids and analysis of their interactions with the different synchroniser surfaces.

INTRODUCTION

Dedicated manual transmission fluids (MTFs) are vital to delivering the correct balance of performance and longevity to the transmission^{1,2}. One area in which an incorrect lubricant can be directly felt by the driver is synchromesh friction. The wrong friction level may lead to poor gearshift feel through poor synchronisation, along with elevated wear of the transmission. In addition, since manual transmission fluids are long-drain fluids, commonly being fill-for-life

in passenger cars, and having drain intervals of up to 500,000km in commercial vehicles, they must maintain a high level of performance for an extended lifetime with minimal degradation.

In order to provide the best shift feel to the driver and to maximise transmission life, it is desirable to create manual transmission fluids that provide optimal synchroniser friction along with reduced wear. Adding to this challenge is an increasing diversity of synchroniser materials being used in transmissions by original equipment manufacturers (OEMs) globally. This could result in the need to develop different friction modifiers with optimal performance for each friction material or fluids containing friction modifier systems balanced for multiple synchroniser materials.

There are a number of broad classes of synchroniser in use today, which may be grouped by material type; however, some of these can only be grouped to a certain degree, as different variants of a single base material may have very different frictional appetites to each other^{3,4,5}. Developing fluids with this balance of shift quality and wear protection requires a fundamental understanding of the friction characteristics of different systems⁶. In order to provide this fundamental understanding, a study was undertaken to recognise the structure-performance drivers of manual transmission fluids on synchroniser friction.

This paper will outline the design, development, and results of the study to understand the structure performance behaviour of manual transmission fluids on five different synchroniser friction materials. These results will show the importance of understanding synchroniser materials and their interactions with lubricant components when developing an MTF and tailoring performance according to the materials present.

MAIN SECTION

In order to develop new MTF additive systems, a number of different friction modifiers were screened in synchroniser tests using commercially available production hardware from several different OEMs. This testing shows the substantial differences in friction performance that can result from changing synchroniser material or manual transmission fluid.

Synchroniser performance is often classed according to the type of material used, which may allow the lubricant formulator to use their knowledge in developing an appropriate fluid, but may not provide the full story. The material classes are broadly descriptive of the synchroniser according to the alloy or fibre used as the dominant material of construction. Common materials in current use include metallic substrates such as brass, molybdenum and aluminium and non metallic papers or composites such as carbon fibres and phenolics. In the case of materials such as the so-called carbon synchronisers, the classification may not provide sufficient information to allow the correct fluid chemistry to be selected, as this class may include a spectrum of materials with diverse frictional appetites such as woven carbon, carbon fibre containing papers, and graphitic carbon materials.

In order to provide correct synchroniser friction performance, an MTF usually contains a friction modifier system, which provides the desired frictional characteristics with the required synchroniser materials. These friction modifiers may be from a wide range of material types and may include overbased or neutral metal-containing detergents (e.g., calcium sulfonates), organic friction modifiers similar to those used in automatic transmission fluids (e.g., glycerol mono-oleate) or a wide variety of other, multi-functional materials.

In order to evaluate the different appetites of a series of synchroniser surfaces, three manual transmission fluids were selected for testing. The three fluids were selected with different frictional properties, in order to provide a range of responses on the selected frictional materials. The fluids were all low-viscosity fluids designed to meet modern MTF performance

profiles. In this work, the fluids will be referred to as Fluid A, B and C respectively.

The three test fluids were formulated to low viscosity, and are all ca. 5.5cSt at 100°C. They all use the same EP/anti-wear additives but vary in the friction modifier systems used, which were chosen as they are expected to give different synchroniser friction appetites. The fluids all use the same synthetic (poly alpha-olefin) base oils to provide a consistent baseline for comparison. The performance of these three manual transmission fluids was assessed using an Automax® synchroniser test rig. The same procedure was used for each of the friction materials in order to provide a direct comparison between the synchronisers and fluids.

The Automax® rig does not simulate a full engagement and only measures the friction between the synchroniser and the cone. The rig comprises a test rig bath where the components are assembled. The synchroniser is attached to the test rig key on one side of the chamber and the cone assembled onto a test rig jig on the other side (Figure 1). The test conditions used are shown in Table 1. The fluids were maintained at 80 °C with the synchroniser spinning at 1000 rpm. The contact time was 0.2 seconds with a load of 981 N and the off time 5 seconds.

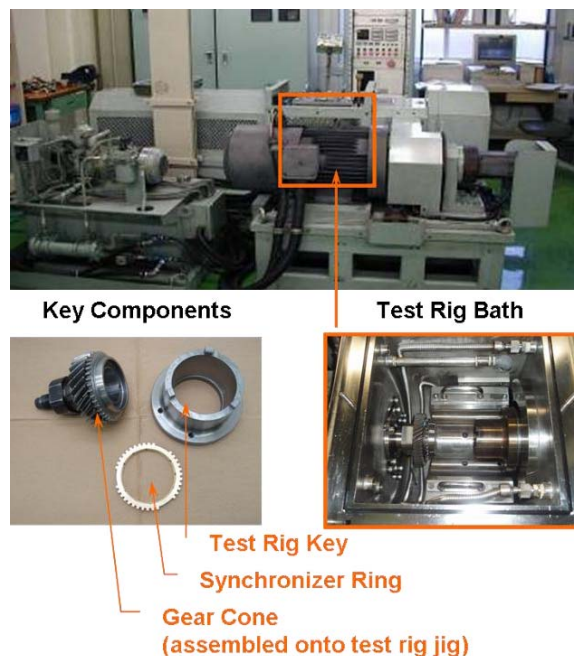


Figure 1 – Test rig and components

Oil Temp	(°C)	80
REV	(rpm)	1000
LOAD	(Kg)	100
	(N)	980.6
On Time	(sec)	0.2
Off Time	(sec)	5.0
Inertia	(Kg cm sec ²)	0.75
Calculated Torque	(Nm)	41

Table 1 – Synchroniser test conditions

The test procedure is segmented into five stages, as follows:

- Break in phase (100 cycles)
- Initial performance phase, whereby a number of frictional measurements are taken at defined speeds (between 1000 and 25 rpm).
- Durability phase, whereby the dynamic friction is recorded (10,000 cycles)
- After durability performance phase, whereby a number of frictional measurements are taken at defined speeds (between 1000 and 25 rpm).
- Finally a static friction measurement is taken.

This procedure is also summarised in Figure 2 below

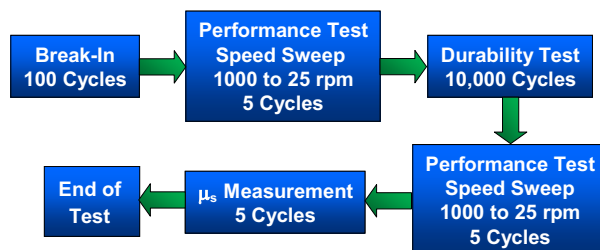


Figure 2 Schematic of Automax synchroniser test procedure

The data from the test provides several key parameters that allow a comparison of the friction and wear performance of the candidates. Comparisons of the relative durability and shift quality of the different candidates are made based upon the following parameters:

- Friction levels assessed by the average friction value during durability testing
- Friction durability assessed by the stability and trends in average friction values during the durability phase
- Synchroniser wear; although this test is relatively short duration, it may still be possible to gain insight into synchroniser wear by looking at both synchroniser weight loss and the synchroniser clearance change over the duration of the test.
- Shift quality is assessed by examining the performance test profiles, which show the variation of friction with rotational speed. It is desirable to have a flat frictional profile, with a level or slight decrease in friction at low speed providing improved synchroniser engagement, and hence shift quality.

This work utilised five different synchroniser materials from a range of Japanese and European passenger car and commercial vehicle OEM applications. The materials were brass, molybdenum, phenolic, and two different carbon materials, which will be termed carbon 1 and carbon 2 respectively. An image of several representative synchronisers is shown in Figure 3.



Figure 3 – Selected synchroniser rings used in this work (l-r) phenolic, carbon, molybdenum (sitting inside the carbon ring), and brass.

BRASS SYNCHRONISER TESTING

The brass utilised for this work was supplied from a Japanese OEM, which appears to use a copper-zinc matrix with small quantities of aluminium, silicon, and manganese present. Images of the contact surface on the brass ring can be found in Figure 4 and Figure 5.

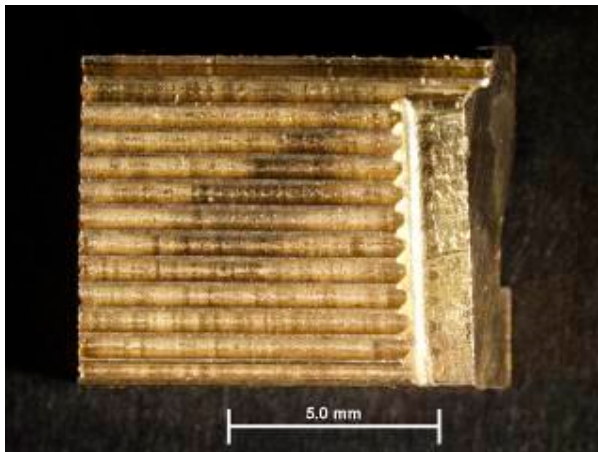


Figure 4 – Section of a Japanese brass synchroniser

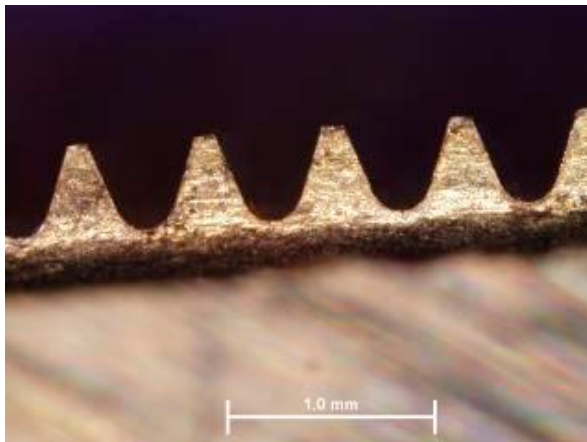


Figure 5 – Cross section of a brass synchroniser

The three fluids were evaluated in the Automax test rig and comparison of the performance of each fluid was then made. Figure 6 shows the dynamic friction coefficient as a function of cycles during the durability portion of the test sequence. The durability phase shows that Fluid A and B have very stable friction curves. Fluid A takes a little longer to break in than fluid B, but remains stable from 3,000 cycles. Fluid C shows poor performance compared to both A and B with friction trending downwards over time.

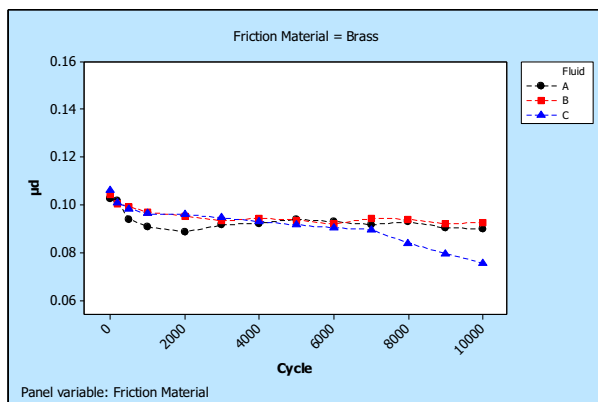


Figure 6 – Durability on brass synchronisers.

Next the performance of the fluids was assessed looking at speed sweeps in relation to friction in both the before- and after-durability phase of the test (Figure 7-8). Ideally, small differences would be noted between the two curves, and fluids A and B showed similar traces before and after. However, Fluid C showed large changes from the initial to the end of test performance denoting poor stability. Furthermore, Fluid C shows large increases in friction at low speeds compared to Fluids A and B. Fluid A demonstrates the best shift quality with friction increases tapering off at low speeds.

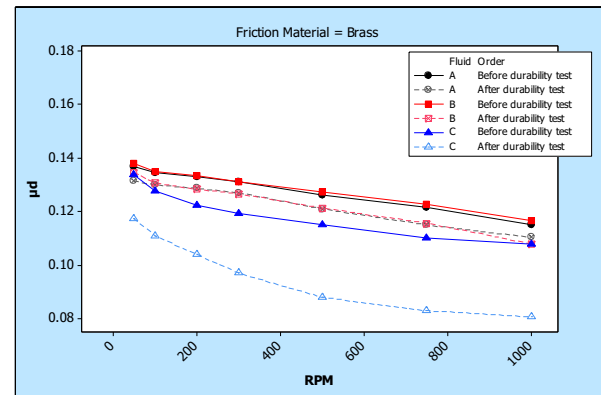


Figure 7 – Before and after durability performance on brass

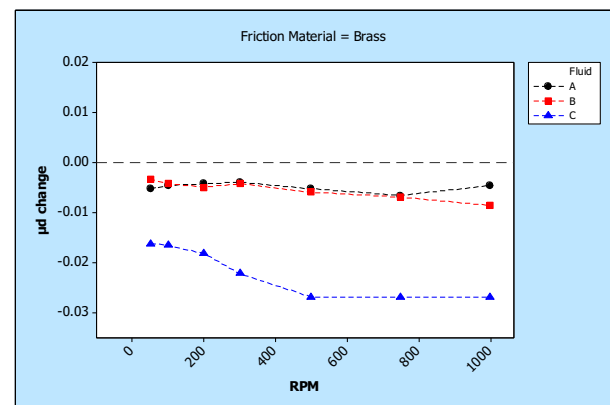


Figure 8 – Change in friction in the before and after durability performance on brass

Wear values were also assessed, and these followed the same performance trends as the friction data (Table 2). Fluid C had the highest wear values and lowest friction profile followed by Fluid B and then Fluid A. Finally the static friction and dynamic friction can be expressed as a ratio. Ideally, a value close to 1.0 would be an indication of good performance. In this series of evaluations the same rank order was observed with Fluid A giving the lowest value at 1.273 followed by Fluid B at 1.361 and then Fluid C at 1.636.