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THE CHRYSOTILE CONTENT OF THE WEAR DEBRIS OF BRAKE LININGS

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D. M. ROWSON*
The Higher Petroleum Institute, Tobruk (Libya)

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Summary

Electron microscopy of the wear debris from brake linings has indicated that the particle size is about 10 nm, the characteristic chrysotile asbestos fibre being almost absent. No evidence of the chrysotile structure was found by either X-ray diffraction or thermal analysis and it is suggested that the structure has been reduced to an amorphous state or to forsterite.

1. Introduction

Present day drum linings and disc brake pads for road vehicles are moulded friction materials containing chrysotile asbestos in fibrous form with other mineral and metallic fillers, the whole being bonded with thermosetting resins. Some 20 - 50 wt.% of the friction material is asbestos so that the debris produced in braking by the wear of the friction material is a potential source of asbestos fibre in the environment as suggested by Sullivan and Athanassiadis [1].

The design of disc brakes is such that the wear dust is discharged directly into the atmosphere, whilst with drum brakes only a fraction is discharged, the remainder being retained in the drum. Lynch [2] has demonstrated the very low asbestos fibre content of the dust (usually less than 1%) for both types of brake, whilst Hickish and Knight [3] have shown that personal exposure to asbestos fibres by mechanics engaged in brake maintenance is well below the maximum exposure recommended by the Hygiene Society [4]. The above workers have suggested that the low chrysotile fibre content arises because of the transformation of chrysotile to a different mineral form during braking, leaving only trace quantities of the original fibres in the dust. Lynch [2] did report, however, that it was not possible to collect all the wear dust produced in his tests.

In the present work wear tests have been run under controlled conditions to give a high collection efficiency for the wear debris. Several techniques have been used to examine the "asbestos" component of the debris.

*Present address: Department of Physics, University of Aston in Birmingham, Gosta Green, Birmingham, Gt. Britain.

2. Collection of wear debris

A disc brake assembly was mounted on an inertia dynamometer [5] so that automobile braking could be simulated in the laboratory. A box surrounded the disc brake assembly and was made airtight by appropriate seals. The heat generated during working was dissipated by a coolant air stream. The air was drawn by an extraction fan through a commercial glass-fibre filter into the box and over the brake assembly. In addition this air stream carried the wear debris onto a filter paper supported on a metal gauze. The filter paper was Whatman no. 90 of 9 cm diameter, the throughput of air being 1700 l min^{-1}.

The debris was produced under conditions of constant (angular) deceleration usually from an initial speed of 880 rev min^{-1} to rest. The brake application temperature, measured by thermocouples rubbing on the brake disc, was 175 °C. These conditions are typical of those which obtain in normal driving of a saloon car. Debris was also produced for a brake application temperature of 40 °C. The examination of the debris reported later showed no significant differences for the two temperatures. The debris consisted of material worn from the brake pads together with iron worn from the disc against which the pads rubbed.

3. Debris analysis

The use of the apparatus to measure the wear rates of frictional material and the elemental identification of the components of the material in the wear debris by neutron activation analysis (NAA) has been reported elsewhere [6]. The following points are relevant to this work.

(a) More than 80% of the wear debris produced was collected and analysed.

(b) The quantity of asbestos in both the friction material and the wear debris was determined by NAA through the trace element concentration. The element chosen was scandium which is present at a level of 4.2 ppm in the raw chrysotile fibre. Previous work had shown that the scandium content did not alter on heating the fibre to a temperature of 900 °C so that it is possible to measure the proportion of the original asbestos fibre present in the debris independently of any chemical or physical transformation during the wear process.

(c) All other components of the friction material were present in the wear debris and the proportions were the same as those for the original friction material.

(d) Some 20 wt.% of the wear debris was iron worn from the disc against which the pad rubbed.

(e) Contamination of the wear debris was insignificant.

3.1. Electron microscopy

Samples of unused and used pad surfaces and of wear debris were prepared as dilute suspensions in distilled water. Ultrasonic vibration was used to disperse the particles. There was no significant difference between the micrographs of the used and unused pad surfaces. In all such micrographs there was a profusion of asbestos fibres and fibrils (Fig. 1) and this was further illustrated by characteristic electron diffraction patterns. The micrographs of the wear debris (Fig. 2) showed particles of size 10 - 20 nm together with larger agglomerates. There were no fibres present [7].



Fig. 1. Electron micrograph of pad surface sample. Magnification 10 000×.

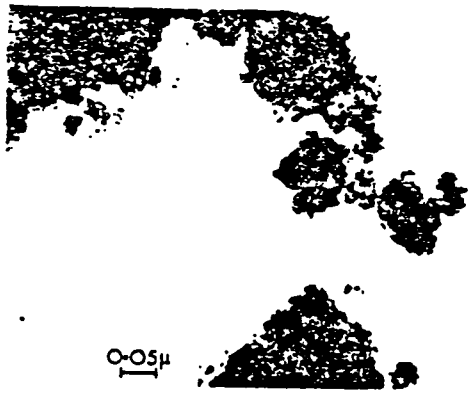


Fig. 2. Electron micrograph of wear debris. Magnification 100 000×.

3.2. X-ray diffraction

Crystalline chrysotile asbestos was identified in the pad material but not in the wear debris. Since the absence of the characteristic chrysotile diffraction pattern may be due to particles which are very small and highly strained

rather than to the absence of chrysotile material, wear debris was heated *in vacuo* at 1100 °C in an attempt to increase the particle size of any crystalline components of the debris. X-ray diffraction of this material showed well-defined lines and the mineral forsterite was positively identified. When chrysotile asbestos fibre is heated it loses its water of crystallization at about 650 °C and at 780 °C is transformed into forsterite according to the reaction

$$\underset{\text{chrysotile}}{2\,(3MgO\cdot 2SiO_2\cdot 2H_2O)} \rightarrow \underset{\text{forsterite}}{3\,(2MgO\cdot SiO_2)} + SiO_2 + 4H_2O$$

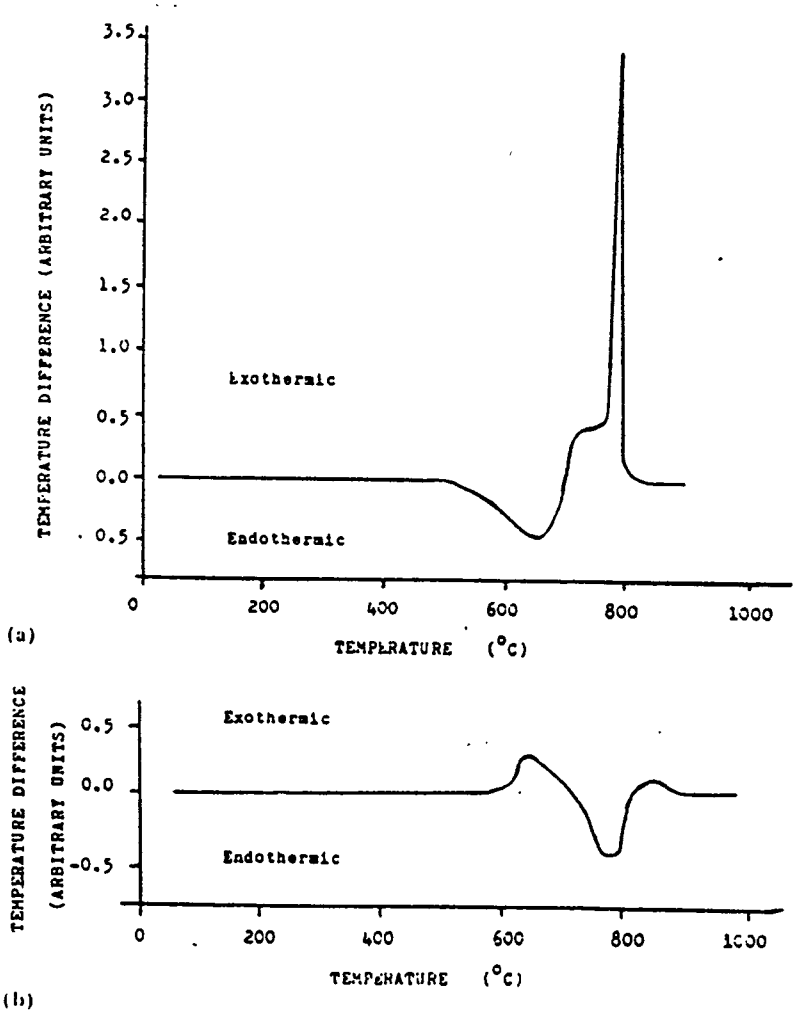


Fig. 3. (a) DTA curve of chrysotile asbestos (run in nitrogen). (b) DTA curve of wear debris (run in nitrogen).

3.3. *Thermal analysis*

The dehydroxylation of chrysotile asbestos which occurs at about 650 °C is an endothermic reaction accompanied by a mass loss of about 13% of that of the original sample. The transformation to forsterite which occurs at 780 °C is exothermic. These energy and mass changes are observed directly by differential thermal analysis (DTA) and thermogravimetric analysis (TGA) respectively. Figures 3(a) and 4(a) show the behaviour of 80 mg of chrysotile asbestos when slowly heated from room temperature to 950 °C, the changes indicated above being clearly displayed. When debris containing the equivalent of 50 mg of chrysotile asbestos was heated the results were as shown in Figs. 3(b) and 4(b). Neither the endothermic reaction at 650 °C nor the exothermic reaction at 780 °C is observed on the DTA trace. Further,

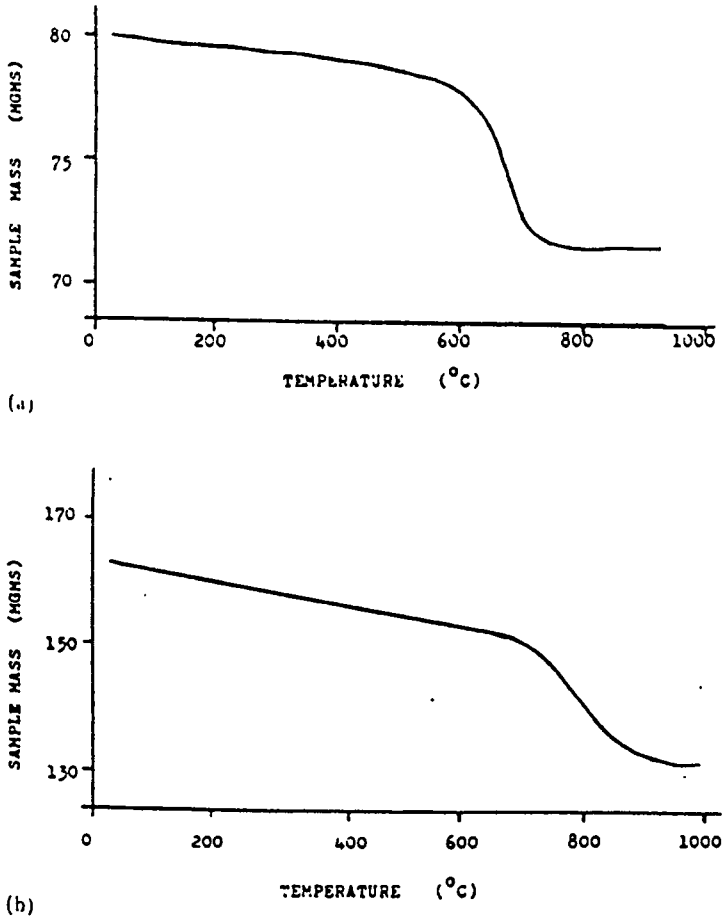


Fig. 4. (a) TGA curve of chrysotile asbestos (run in nitrogen); (b) TGA curve of wear debris (run in nitrogen).

there is no indication on the TGA trace of a mass loss at 650 °C, although there is a mass loss at about 780 °C which is as yet unexplained. There is thus no evidence of the chrysotile → forsterite transformation when wear debris is heated to 950 °C.

All the thermal analyses were carried out in an atmosphere of nitrogen to prevent the effects of oxidative reactions of other components of the friction material masking observation of the chrysotile → forsterite transformation.

4. Discussion

The electron micrographs clearly showed that the wear debris consisted of finely divided particles in the 10 nm range. The larger particles appeared to be agglomerates ranging above 50 nm in size. When examined with an optical microscope the debris appeared relatively coarse grained, but individual particles could be readily subdivided until the limiting resolution of the microscope was reached at about 100 nm. This tendency to agglomerate may explain the high collection efficiency with a Whatman no. 90 filter. It was evident from the micrographs of the pad surface material that the method of sample preparation was adequate and that chrysotile fibrils should have been detected if they had been present in the wear debris. Several samples were prepared and many fields of view were examined. A normal fibril was found in only one field of view suggesting a fibril concentration in the wear debris of less than 0.5 wt.%. This is even less than the low concentration reported by Lynch [2]. This author does not report whether his samples were analysed to confirm the elemental composition. The tests reported here indicate that the debris has the same elemental composition as the original material so that the chrysotile component worn from the pad is present in some chemical form in the debris but certainly not in its original fibril form.

Owing to the severe transient conditions of stress or temperature during the wear process, the crystalline structure of asbestos fibrils will be disrupted. The most frequently occurring chrysotile fibril is a tube of inner diameter 11 nm and outer diameter 26 nm [8]; these magnitudes are similar to those of the particle size of the debris. Further, the particle size is so small that it approaches the limits at which coherent scattering can occur.

The X-ray analysis does not show the presence of chrysotile asbestos and this may be due to the particle size. A further possibility is that frictional heating has decomposed the chrysotile. If the temperature at which the wear products are produced is in the range 650 - 780 °C then the chrysotile will be reduced to an amorphous form with no recognizable crystallinity and if it is above this temperature forsterite may be formed. The presence of forsterite in debris heated to 1100 °C is not definite evidence of the formation of forsterite during wear, but one can assert that the original chrysotile structure is not sufficiently degraded for the magnesium and silica to have reacted appreciably with other components of the debris.

The thermal analyses do not show any behaviour consistent with crystalline chrysotile and this could be because forsterite is present in the wear debris. However, there is insufficient information concerning the behaviour of small particles of either chrysotile or forsterite to be certain of the interpretation of these data.

The elements of the original mineral chrysotile, however, are present in the wear debris. If the health hazard of chrysotile is found to be associated with its chemical behaviour in body tissue rather than with its physical form the implications of these present findings should be considered.

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