CSEM Instruments
Advanced Mechanical Surface Testing

APPLICATIONS BULLETIN

Special Issue: Automotive Applications

Tribometer Lifetime Study of Wheel Bearings

In automotive applications, bearings form an integral part of many sub-assemblies, e.g., axle, engine, gearbox, etc. and their accurate characteristion needs to take into account the final configuration of the bearing system. In the case of ball and tapered roller bearings, different types of loading may be applied at any one time, such as radial, axial or other combination. The ratio of the radial to the axial load, the setting and the bearing included cup angle determine the load zone in a given bearing. This load zone is defined by an angle which delimits the rollers or balls carrying the load. If all the balls are in contact and carry the load then the load zone is referred to as being 360 degrees.

Within the industry, the bearing life is defined as the length of time, or the number of revolutions, required to produce a fatigue spall of a size corresponding to an area of 6 mm^2. Such a lifetime will depend on many factors such as applied load, speed, lubrication, fitting, setting, operating temperature, contamination, maintenance, as well as environmental considerations. Due to all these factors, the life of an individual bearing is impossible to predict precisely and experience has shown that several bearings which appear identical can exhibit considerable life scatter when tested under identical conditions.

The pin-on-disk Tribometer has proved ideal for investigating the evolution of friction and wear in a wide range of typical bearings as a function of the axial load. Fig. 1 shows a typical friction trace for a single row bearing after 1 million revolutions. The friction coefficient, μ, soon stabilises after running-in, after which it gradually decreases. Other studies have shown that the value stabilises after several million laps.

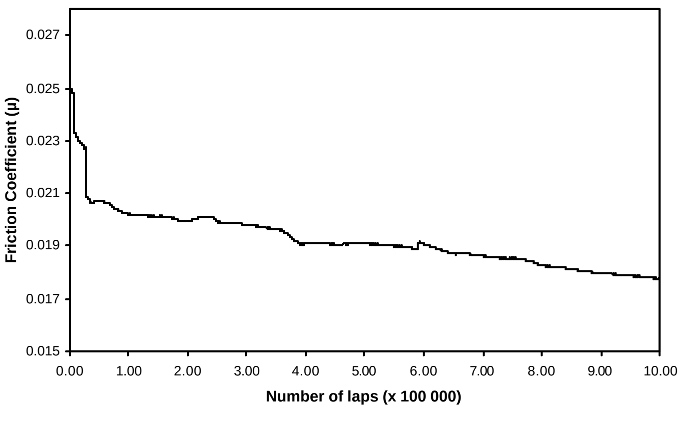


Figure 1 : Friction coefficient vs. number of laps (x 100 000) for a single row bearing tested with the pin-on-disk Tribometer. Note the initial running-in period and the gentle decrease in friction coefficient. Tests were carried out with an applied load of 50 N and speed 28 cm/s.

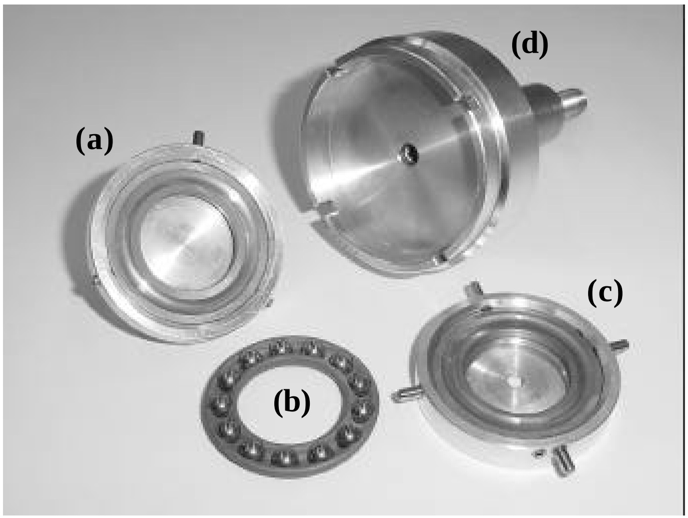


Figure 2 : The component parts of a single row bearing: upper casing (a), inner bearing (b), and lower casing (c) which is located in a specially modified sample support shaft (d).

Specially fabricated holders are used to mount the bearing and outer casings (see Fig. 2) and the complete ‘sandwich’ is supported in a modified support shaft. A flat pin is used to apply the static 50 N load as shown in Fig. 3. The required load zone of the bearing can be varied by changing the contact area and lateral position of the pin in order to simulate in-service conditions more accurately.

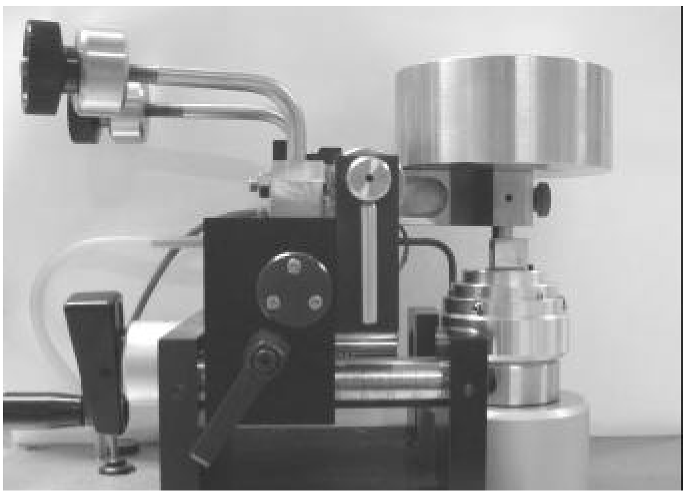


Figure 3 : The bearing shown in Fig. 2 mounted on the Tribometer for the test conditions summarised in Fig. 1.

Elasto-plastic properties of polymeric varnishes

The Nano Scratch Tester has become accepted as the preferred method for assessing the scratch resistance and elasto-plastic properties of automobile varnish coatings (see also App. Bull. No. 15, Oct. 2000). The mar resistance, which is related to the relatively fine surface scratches which spoil the appearance of the coating, can be fully investigated.

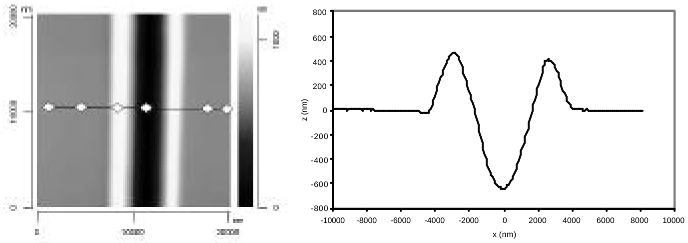


Figure 1: Typical Nano Scratch test data for a constant load scratch (10 mN) made on a polymer topcoat with a spherical diamond stylus of tip radius 2 µm.

Mar resistance depends on a complex interplay between viscoelastic or thermal recovery, yield or plastic flow, and fracture. Polymers are challenging because they exhibit a range of mechanical properties from near liquid through rubbery materials to brittle solids. The mechanical properties are rate and temperature dependent and viscoelastic recovery can cause scratches to change with time.

Fig. 1 shows a typical nano-scratch on a polymeric topcoat whilst a complete nano scratch test result is shown in Fig. 2 where a distinct change in the frictional force and penetration depth signals corresponds to first failure of the coating (seen as a rupture along the scratch path). This point corresponds to an applied load of approximately 21 mN and an optical microscope image of the resulting deformation is also shown. Note the significant viscoelastic relaxation after testing (the difference between the penetration, P_D, and residual depth, R_D, signals).

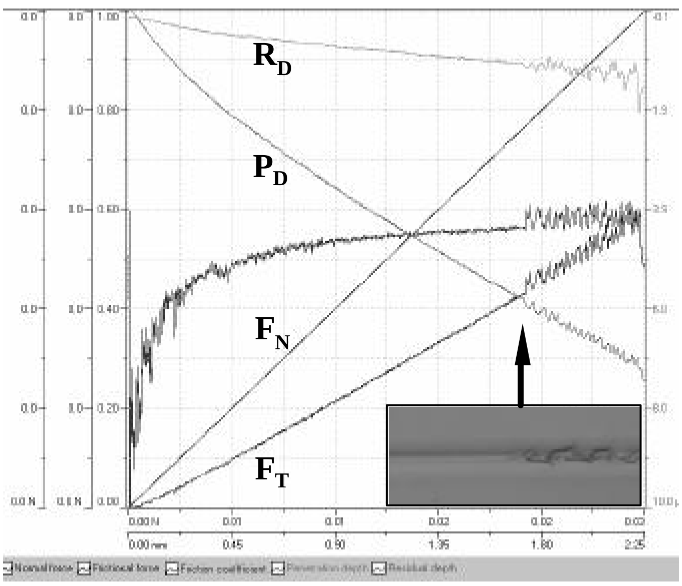
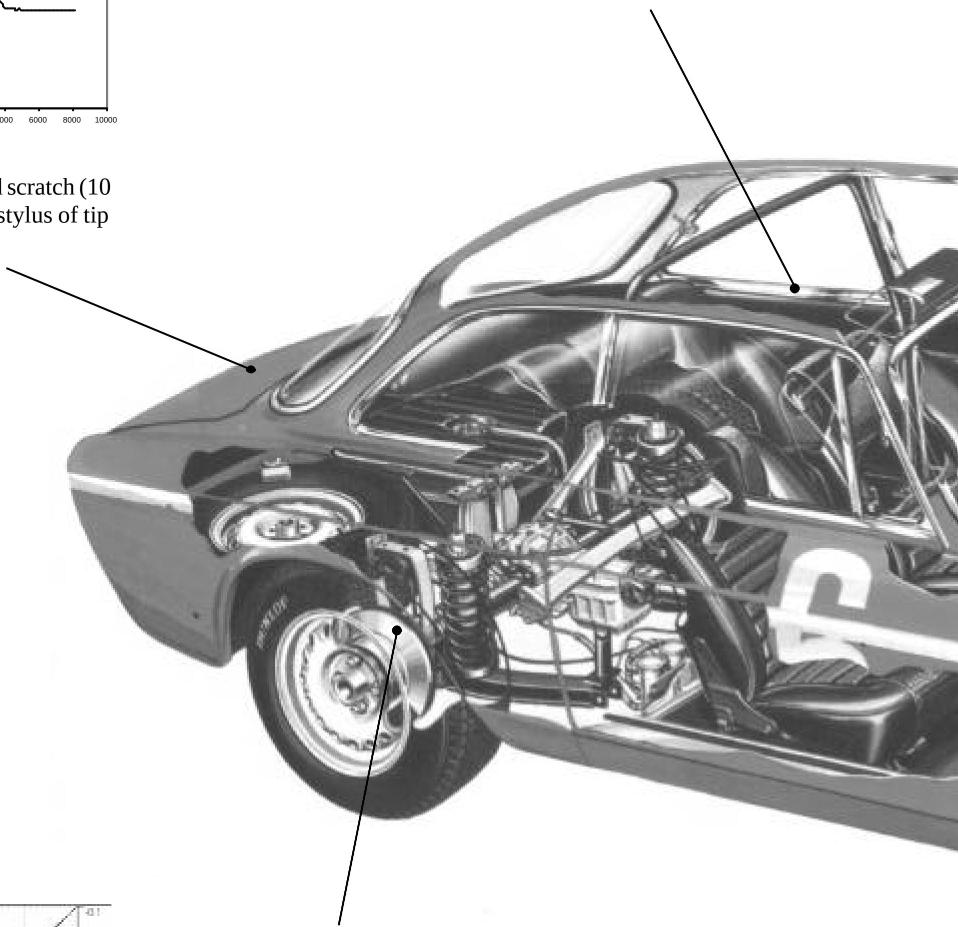


Figure 2 : Typical Nano Scratch test data for a progressive load scratch (0 - 30 mN) made on a polymer topcoat with a spherical diamond stylus of tip radius 2 µm.

Wear properties of rubber seals

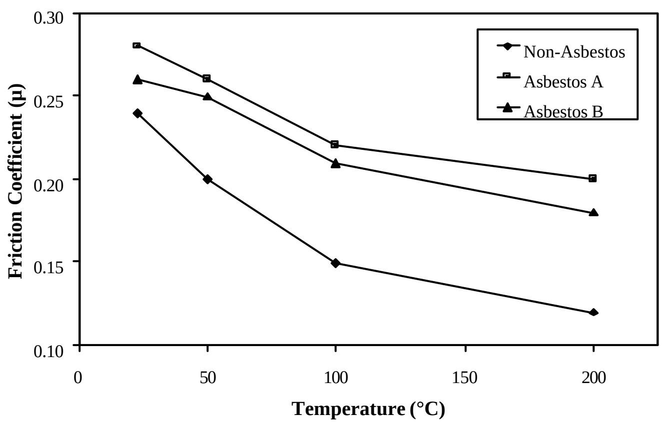
The wear properties of rubber seals in contact with window glass can be investigated with the Tribometer in order to improve durability and develop low coefficients of friction which reduce noise and require less energy for opening/closing of the window.

Tests have been performed with the Linear Tribometer option which can precisely simulate the forward-backwards movement and typical contact pressures of a rubber seal sliding against glass (coated). Some interesting observations have been made concerning different rubber formulations, as well as the effects of sliding speed on the friction coefficient.



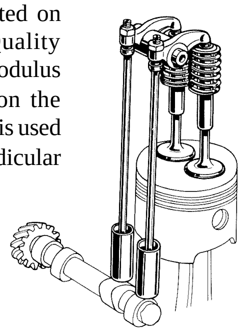
Brake Pads

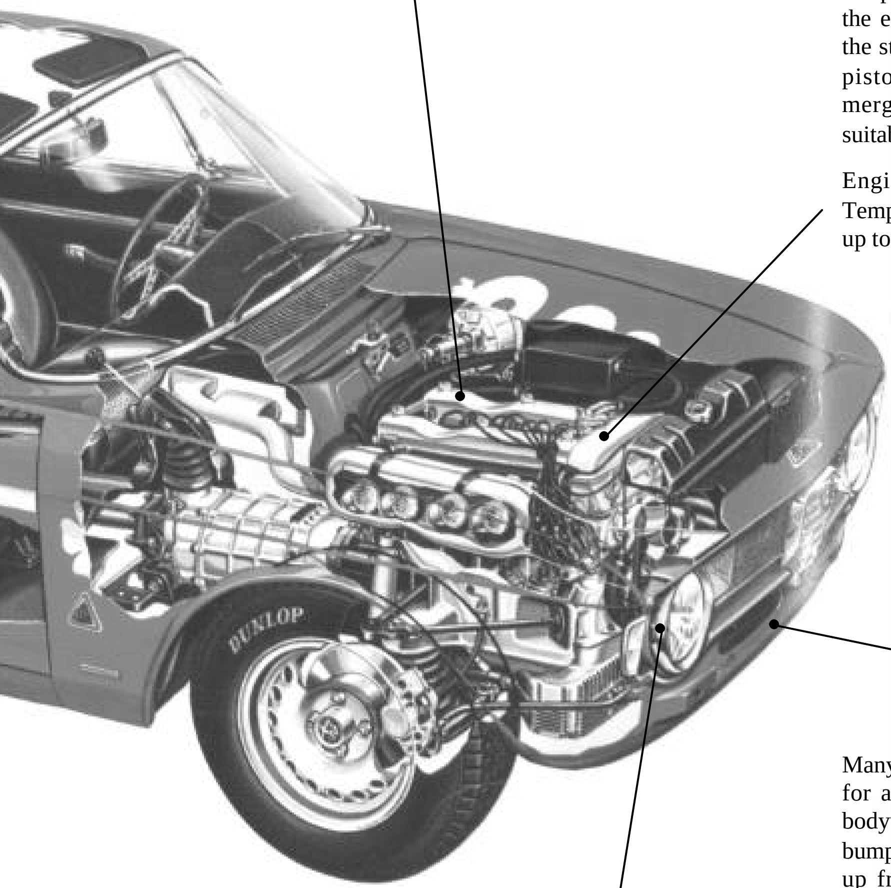
Different compositions of brake pad material (e.g., with or without asbestos) can be tested in terms of friction and wear using the High Temperature Tribometer which allows such properties to be correlated directly to in-service conditions.



Hardness of DLC-coated tappets

Recent advances in coating technology has allowed durable DLC films to be deposited on tappets to reduce friction and wear. Quality control demands that the hardness and modulus of such coatings be measured directly on the actual workpiece. A special sample support is used to hold the required contact faces perpendicular to the indenter tip.

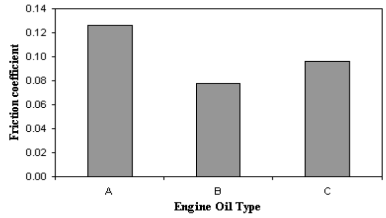




Controlled lubricant studies

Users in the field of automotive engine oils are not necessarily interested only in the lifetime of a particular lubricant but also in a quantitative method of determining the service frictional properties.

Using a standard pin-on-disk Tribometer together with the liquid option allows both the rotating and static partners to be submerged in the lubricant to be tested. An integral heating element and thermocouple can heat up to 150°C. Simulative testing is often used to model in-service conditions. For example, the sample could be a section of the engine cylinder bore and the static partner a piece of a piston ring. Both are submerged in engine oil and a suitable load applied.



Engine operating temperatures can be simulated with the High Temperature Tribometer which is capable of heating the material pair up to 800°C.

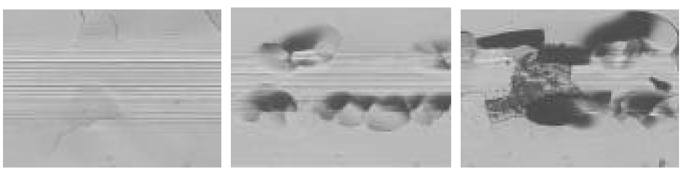
Adhesion of polymeric bumper paint

Many models of automobile now have integral polymer bumpers which, for aesthetic reasons, need to be painted to match the rest of the bodywork. The adhesion of such paints is a critical parameter as the bumper surface must resist gentle impacts as well as dirt particles thrown up from the road. The Micro Scratch Tester is an ideal tool for measuring the adhesive properties of various paints deposited on different polymeric bumper materials. The deformation modes of both coating and substrate can be investigated (see also App. Bull. No. 1, Autumn 1996) and the influence of different compositions analysed.

The example shown is a progressive load (0 - 10 N) scratch test pair, made using a hard metal tip of radius 10 µm. Optical microscopy of the scratch track confirms two different types of failure mode. The first is characterised by rupture of the paint coating whilst the second corresponds to plastic deformation and total delamination.

Scratch resistance of chrome-plated trim

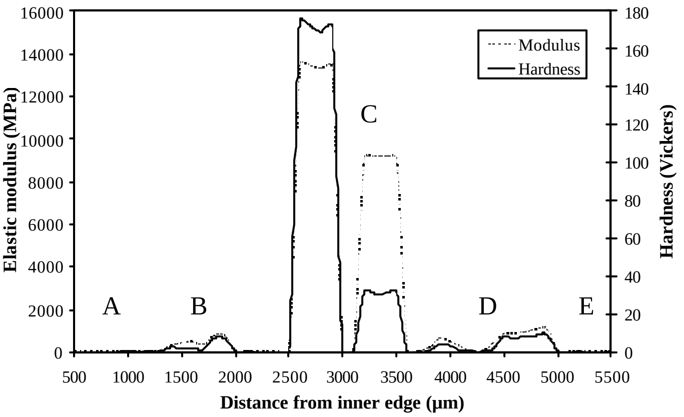
Although traditional chrome plating on steel is being used less and less due to the highly toxic electrolytes required, chromium is now deposited onto polymeric substrates and used for exterior and interior trim and detailing. Scratch testing allows the adhesion of the coating to be accurately measured in terms of critical failure points corresponding to cracking, plastic deformation and delamination.



Mechanical properties of automotive tyre

Automotive tyres are constructed from a complex combination of different materials, each responsible for a certain aspect of the tyre properties. In this example, a section through a typical passenger vehicle tyre has been prepared and polished after mounting in epoxy resin. The Micro Hardness Tester was then used to make a line of indentations across each interface. The prepared sample is shown in Fig.1 and it should be noted that the polishing was done down to 4000 grit paper with water cooling to prevent modification to the rubber. The corresponding hardness and elastic modulus profiles across the sample are also shown.

Owing to the high elasticity of the rubber components, a very slow approach speed (10%/min.) was needed in order to detect the surface correctly. The micro-indentations were made with a maximum load of 0.1 N and a separation between indents of 100 µm. The indenter used was a standard Vickers. The H and E profiles in Fig. 1 show large increases for the steel belts and smaller increases for the carcass and cap plies. The rubber of the inner liner and outer contact surface had a hardness of 0.3 - 0.4 H_V and modulus of 20 - 50 MPa.



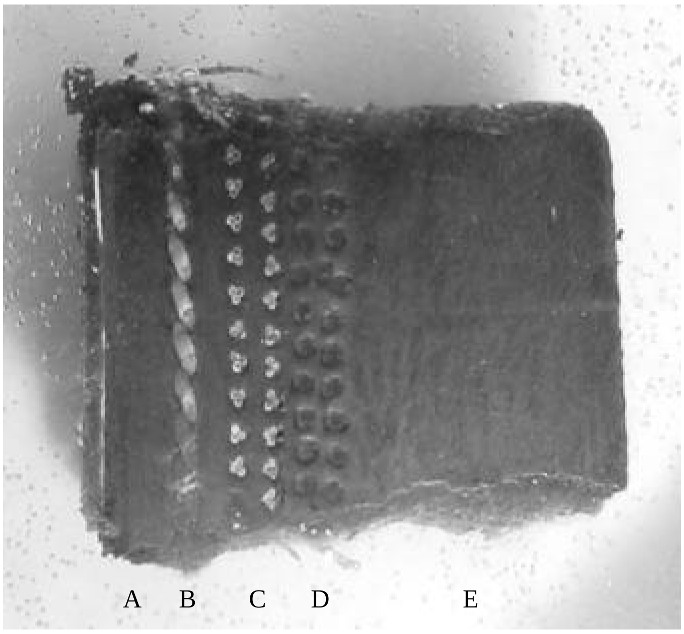


Figure 1 : Polished tyre section mounted in resin and corresponding hardness and modulus profiles made across the surface from left to right. The labelled zones are (A) inner liner, (B) carcass, (C) steel belts, (D) cap plies and (E) undertread.

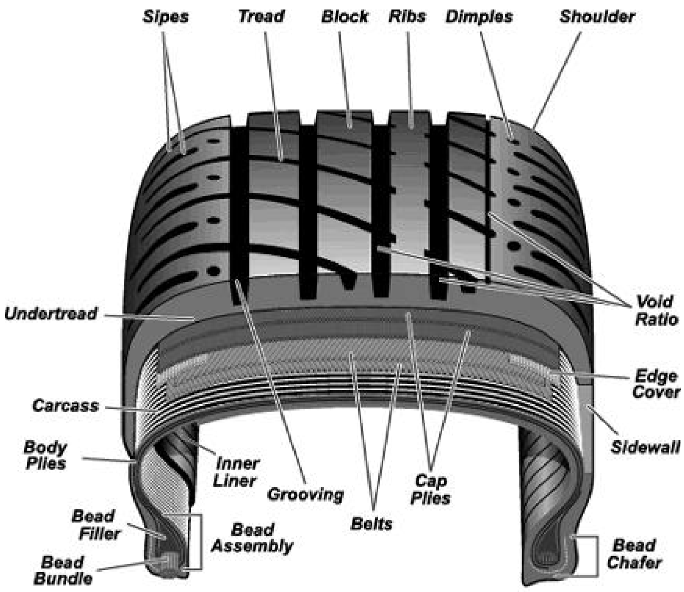


Figure 2 : Schematic representation of a typical automotive tyre showing the layout of carcass, steel belts, cap plies and undertread.

The measured section in Fig. 1 can be better understood by considering the construction of a typical automotive tyre (Fig. 2) which is essentially a *sandwich* of inner liner, carcass (in this case a Kevlar fibre), steel belts, cap plies and undertread. The carcass provides the suspension of the tyre and distributes pressure, whereas the steel belts give dimensional stability, impact resistance and tread stabilisation. Measuring the properties of each component of a tyre *in-situ* after manufacture can yield significant information concerning the pressure distribution and effects of processing at different temperatures.

CSEM Instruments

This Applications Bulletin is published quarterly and features interesting studies, new developments and other applications for our full range of mechanical surface testing instruments.

Editor Dr. Nick Randall

Should you require further information, then please contact:

CSEM Instruments
Jaquet-Droz 1
CH-2007 Neuchâtel
Switzerland

Tel: + 41 32 720 5407
Fax: +41 32 720 5730
email: instruments@csem.ch
http://www.csem-instruments.ch

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6012.05.01 CSEM Instruments / Printed in Switzerland