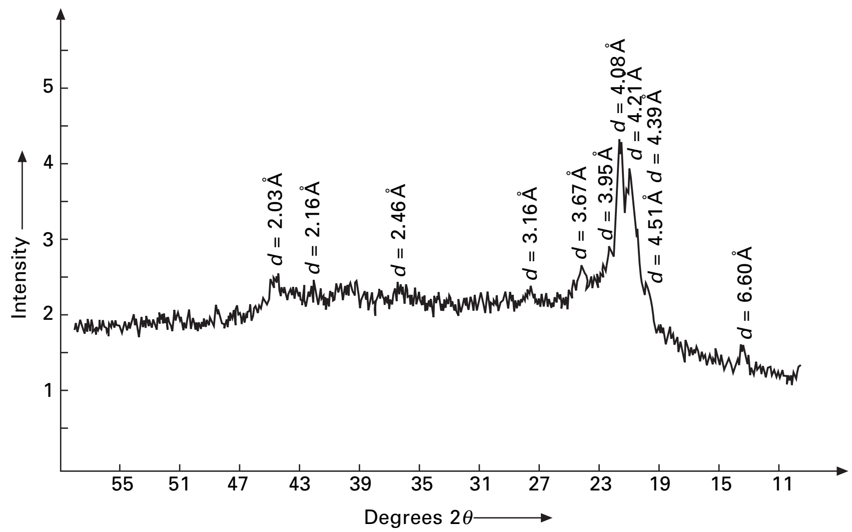


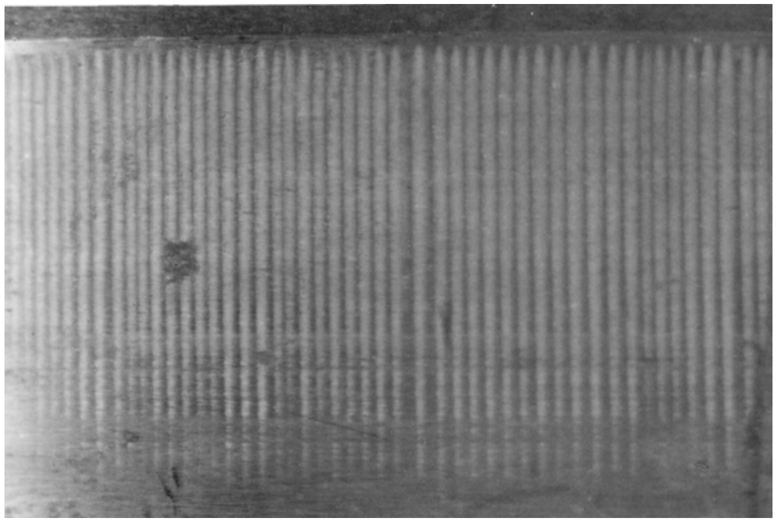
6.6 X-ray diffraction pattern of soap residue of grease from NU 326 bearing after operation under electrical fields for 250 h.

6.4 Effect of current on formation of corrugated patterns on the roller track of races of roller bearings

The passage of current causes local surface heating, which leads to low-temperature tempering, and accelerates formation of corrugations with time (Fig. 6.7). As rolling continues, corrosion increases due to the decomposition of grease 'A' and small particles of material are pulled out from track surfaces at the points of asperity contacts between the races and rollers, which develop scores on the surfaces, besides forming corrugations/flutings on the surfaces. After long operation, the softer tempered surfaces of the races become harder, and thus harder/re-hardened particles due to localized high temperature and load erupt from the craters and intensify the depth of corrugations.

In the presence of low-resistivity lubricant ($10^5 \Omega$ m), in the close asperity contacts between rolling elements and races, current intensity is increased by short-circuiting at the line of contacts that leads to the formation of corrugations in due course. After the formation of corrugations in one half of the races – the resistance becomes higher due to a decrease in contact area – the current leaks through the other half, and thus fully fledged corrugations are formed on the surfaces.

At each revolution of the shaft, part of the circumference of the inner race passes through a zone of maximum radial force, and Hertizian pressure between the rolling elements and raceways (at the line contacts) leads to a maximum shear stress. The maximum shear stress is taken as the criterion



6.7 Corrugation pattern on the inner race of NU 326 motor bearing after about 6000 h of operation.

for yielding and this occurs in the subsurface at a depth approximately equal to half the radius of the contact surface. It is generally at this point that failure of material, if occurring, will initiate. As soon as the fatigue spall appears on the surface, the actual area of the asperity contact between the rolling-element and the race is reduced, which reduces electrical contact resistance and increases flow of current. Furthermore, there is a gradual increase in the width of corrugation by deformation at the asperity contact due to an increase in contact pressure per unit area, which leads to further reduction in electrical contact resistance and increase in flow of high-intensity current. These intensify the corrugation pattern in due course.

When a bearing is significantly loaded, the deformation is made by rolling elements (K) on the races in the loaded zone. The process of deformation, which leads to the formation of a corrugation pattern on the surfaces at the line contacts due to a decrease in contact resistance, is accelerated by the passage of high-intensity current, corrosion and oxidation of surfaces, lubricant characteristics and quality of a bearing.

The pitch of corrugations on the roller tracks depends on the bearing kinematics, the frequency of rotation, the position of plane of action of radial loading, the bearing quality and the lubricant characteristics, and is given as:[8,9]

$$\Delta_{ir} = \pi Dd\ / SF_s Kp(D + d) \qquad [6.1]$$

$$\Delta_{or} = \pi Dd\ / SF_s Kp(D - d) \qquad [6.2]$$

$$\Delta_{re} = \pi d / SF_s\ p \qquad [6.3]$$

The width of corrugations on the surface is not affected by frequency of rotation and depends on the load conditions and bearing kinematics. The width of corrugations on the inner and outer races is given as:[8,9]

$$W_{ir} = 2.15\ [Pd\ (D - d)/pKELD]^{1/2} \qquad [6.4]$$

$$W_{or} = 2.15\ [Pd(D + d)/pKELD]^{1/2} \qquad [6.5]$$

$$W_{re} = W_{or} + \theta W_{ir} \qquad [6.6]$$

where θ, the overlapping coefficient, varies from 0 to 1.

The pitch and width of corrugations are smaller on the inner race than on the outer race. Also pitch and width of corrugations on rollers are affected by corrugation pattern already formed on the races.

6.5 Effect of current leakage on electro-adhesion forces in rolling friction and magnetic flux density distribution on bearing surfaces

The mechanism of adhesion, friction and wear on bearing surfaces in the presence of lubricating film is quite complex. The process of adhesion involves the formation of a junction between the asperities contact, which may finally lead to elastic and plastic deformation under load. Energies of atomic nature are exchanged at the asperities, which may be affected by cage and roller slip due to close interaction of rolling elements with the races.[10]

It is rather difficult to estimate the electro-adhesion forces in the rolling friction. But these can be assessed with a reasonable accuracy by SRV (Schmierstoff –lubricant–material) analysis; the change in coefficient of friction, profile depth and ball scar diameter of the used greases recovered from the active zone of the bearings. This is because of the activity of the zinc additive, i.e. zinc dithiosphosphate or zinc dialkyldithiophosphate (ZDTP) used as a multifunction additive in the grease. Under pure rolling friction it protects the rubbing metal surfaces and contributes to friction and wear reduction, and depends, partly, on the amount of additive absorbed on these surfaces. Physisorption and chemisorption processes precede the chemical reactions with the metal; therefore, it is probable that load-carrying capacity is related to these processes. Correlation between ZDTP adsorption data and wear shows that ZDTP is reversibly physiosorbed on iron at 25 °C, but at 50 °C undergoes chemisorption reactions. On the other hand, decomposition of ZDTP in the lithium base greases under the influence of electrical fields leads to the formation of lithium zinc silicate ($Li_{3.6}Zn_{0.2}SiO_2$) in the presence of high relative percentage of free lithium and silica impurity in the grease under a high temperature in the asperity contacts along with the formation of gamma lithium iron oxide. Besides this, the original structure of lithium