RADIONUCLIDE TECHNIQUE IN MECHANICAL ENGINEERING (RTM)

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Abstract

New developments at KfK Cyclotron in the field of the thin-layer activation technique for modern engineering materials, the various measurement methods and the wear measurement device will be presented. A sophisticated method for the radioactive surface labelling of modern synthetic materials such as plastics, polymers and rubber has been established in a fruitful cooperation with the Kurchatov Institute, Moscow. First results of the application of this technique to measurements of machine parts will be reported. The outstanding properties of the RTM on-line wear diagnostics shall be demonstrated by the results of dedicated measurements performed last time at the KfK facilities.

1. INTRODUCTION

A subject of increasing application of cyclotron machines is RTM, the measuring system that enables wear and corrosion diagnostics of components of operating machines, apparatus or processing plants. The three components of the system, the thin layer activation at the cyclotron, the measuring methods and the measuring instruments for application in industry have already been presented in detail on the last International Conference on Cyclotrons [1]. So this contribution deals with recent development work in RTM at the Cyclotron Laboratory of KfK. [2)-5)]

2. DEVELOPMENT WORK

Beside the work in activation service, supplying irradiated parts to the industry and the efforts in know how transfer within the frame of cooperation contracts, nearly 40% of the total man power of the RTM-Group is engaged in development work to the subjects activation technique, irradiation equipment, measurement methods and device to new areas of application, new components and new materials coming into use in industry. All developments are performed in cooperation with a representative industrial company to ensure that the actual requirements of the industry are fulfilled and the results of the developments can be used directly and profitably by the industry. A typical example of development work is the running project for the contruction of a test bench for refrigerating machines, based on RTM. Such test benches are required by industry for the urgent development of advanced refrigerators, free of Chloro-Fluoro-Carbons (C-F-C), because of the well - known environmental impact of C-F-C.

This project is performed in a cooperation with the industrial manufacturer of refrigerating machines, dkk-Scharfenstein, and a working group of the Institute For Surface Modification, Leipzig, specialized on wear problems of compressors.A prototype of a suitable test bench has been established. The optimizing work on this is going on.

Since the successful development of thin layer activation technique for the application to ceramic materials [1)] we concentrated on the radioactive labelling of synthetic materials, all kinds of polymers, elastomers, rubber. The interest in this is mainly coming from the car, engine and gearing manufacturer. The replacement of iron parts by parts of synthetic materials in mechanical systems is reducing the weight of such devices at least by a factor three.

All irradiation tests using the conventional thin layer activation method via nuclear reaction in the synthetic materials failed because of the high sensitivity of these materials to the applied particle irradiation at the KfK-Cyclotron. So, in cooperation with the Kurchatov Institute, Moscow, a project for the development of surface labelling by directed implantation of radioactive ions of Be-7 ($T_{1/2}$ = 53 d, $E\gamma$ = 478 keV) has been started. This method of labelling promises by a factor of 10^5 less radiation effects in the sensitive material, compared to the conventional activation method. The principle of Be-7 recoil implantation, based on the nuclear reaction B -10 (p,α) Be-7, is well known and is illustrated in Fig. 1. The external beam of B-10 ions (6 - 10 MeV/nucleon) from the cyclotron is producing in the hydrogen converter Be-7 ions with a recoil energy in direction of the primary beam. The absorber behind

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the converter is stopping the B-10 ions of the primary beam, which passed the converter without any reaction. The pure Be-7 beam is hiting the machine part to be labelled.

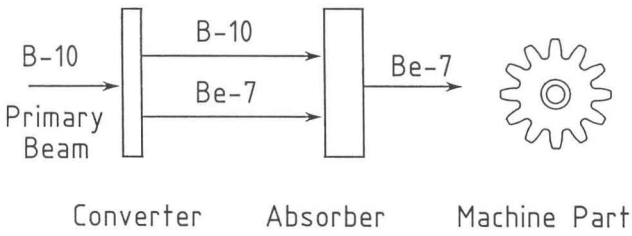

Fig. 1: The principle of Be-7 recoil implantation for the radioactive surface labelling of synthetic materials. The external beam of B-10 ions from the cyclotron is producing Be-7 ions, according to the reaction B-10(p,α) Be-7, with a recoil energy of the Be-7 ions in primary beam direction.The absorber is stopping the B-10 ions which passed the converter without any reaction.The pure Be-7 beam is hiting the machine part to be labelled.

After some improvements of the converter-absorber system the material investigations of Be-7 implanted samples of Polyamid, Elastomer (Viton) and synthetic rubber did not show any defects from the radioactive labelling. The material tests have been performed by KfK as well as by a private material test institute [6] specialized on synthetic materials.

The quality of the Be-7 labelling is demonstrated in Fig. 2 by the activity versus depth profile in special Polyamid (EPM),. The linear region of the total activity over the depth of 20 µm near the surface is suitable for precise wear measurements.

In cooperation with the company Audi A.G.and the material test institute Firma Heß, Ingolstadt [6] in situ wear measurements of engine parts, of a Polyamid gear and of a Viton crankshaft seal have been performed on an engine test bench, Fig.3. The results of the demonstration measurements are illustrated by Fig. 4 and Fig. 5.

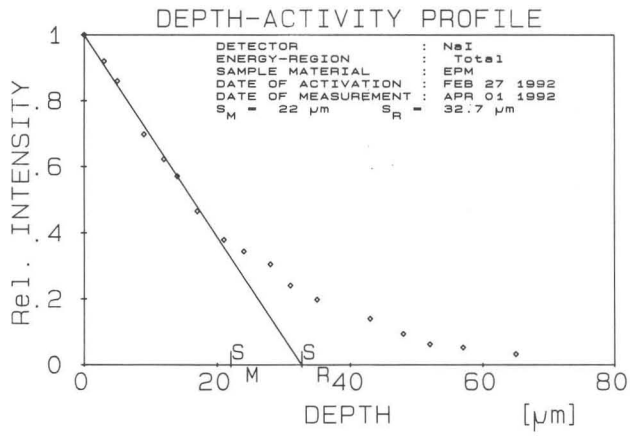

Fig. 2: The activity over depth distribution of implanted Be-7 in EPM-Polyamid is demonstrating the quality of the radioactive labelling by the linear region of 20 µm near the surface suitable for wear measurements.

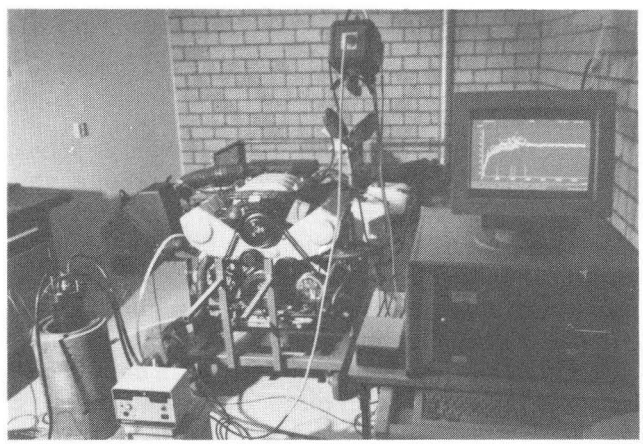

Fig. 3: The wear behavior of Be-7 labelled parts, a gear of Polyamid and a crankshaft seal of Viton (Elastomer), have been measured under real operation conditions in a high-powered engine of Audi on a test bench at the Fa. Heß, as illustrated by the picture. Demonstration measurements and material testing have been performed in cooperation with the Company Audi and Fa. Heß, Ingolstadt.

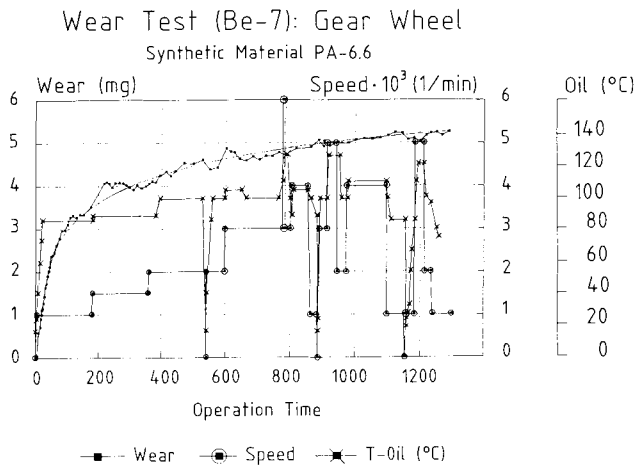

Fig. 4 : The wear behavior of the Polyamid gear over operation time at variated speed and oil temperature in an Audi engine is demonstrating the advantage of RTM on-line wear diagnosis. After the running-in phase the wear of the synthetic gear is undependent of speed and oil temperature. A result of a 24 h RTM wear test, that could not be established by conventional tests over several months.

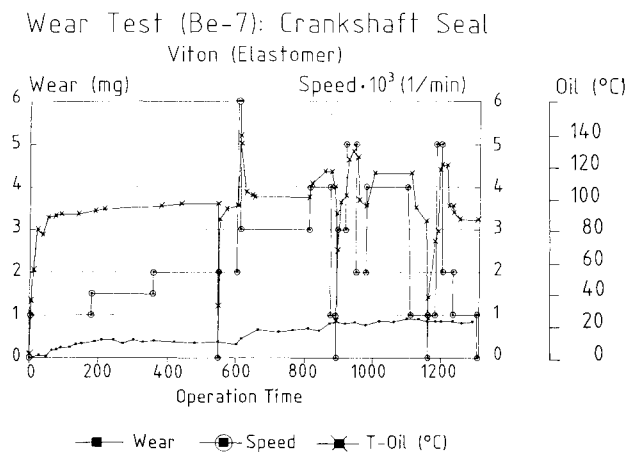

Fig. 5 : .The wear behavior of the Be-7 labelled Viton (Elastomer) seal of the crankshaft in an engine (Audi V 6, 24 Valves) at different speed and oil temperature, was measured in a 24 h wear test and is demonstrating the effectiveness of RTM application.

3. SENSITIVITY AND REACTIVITY OF RTM WEAR DIAGNOSTICS

The experimental investigation of reliability, sensitivity and reactivity in RTM wear diagnostics was performed recently at a typical example of application, the engine wear measurement with the concentration measurement method.

In the running engine (1.6 Liter Diesel engine of 5 Liter oil volume) on the KfK test bench, a suddenly occuring wear was simulated by the injection of a definite liquid activity (Co-56) -, corresponding to a wear mass of 25µg resp.30µg, - in the engine. The concentration wear measurement device was connected to the oil sump, as usual, and was recording continuously the concentration of wear in the oil of the engine. The measurement results for the injection in the oil sump and in the cylinder head, displayed in Fig. 6 resp. Fig. 7, are demonstrating a sufficient reactivity of 120 sec delay at maximum from the occurence of wear (point of injection) to full height of the measurement signal. A wear mass of the minuteness 10µg - corresponding usually to a linear wear of several nanometers - can clearly be resolved by this technique. The reproducibility and reliability is demonstrated by the constant values for wear concentration before and after the injections, as delineated in Fig. 6 and Fig. 7.

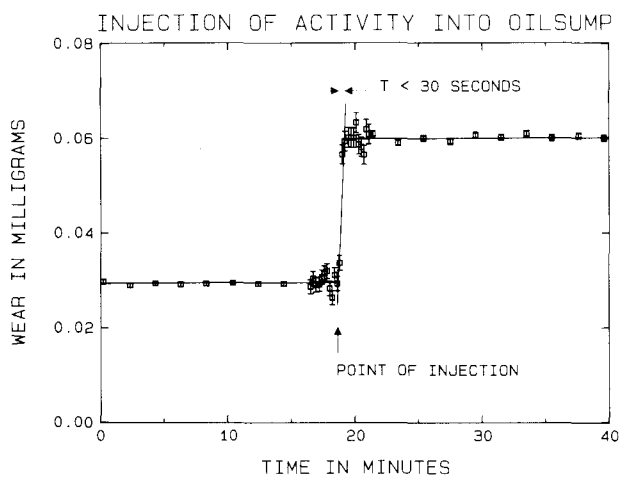

Fig. 6 :.For the demonstration of the sensivity and reactivity of RTM wear diagnosis a definite activity - representing 30 µg wear mass - was injected in the oil sump of the operated engine on the KfK test bench. The applied concentration measurement device registered the full wear mass 30 sec after the injection. A wear mass down to 10 µg - corresponding to a linear wear of several nanometers - can distinctly be resolved.

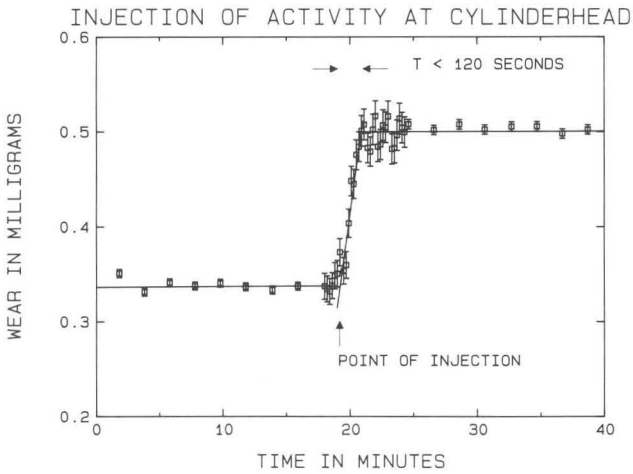

Fig. 7: In case of the activity injection into the cylinder head of the running engine, simulating wear occuring at the camshaft, the reactivity decreased to 120 sec..

4. REFERENCES

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