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IRRADIATION TECHNIQUE OF MACHINE PARTS FOR WEAR MEASUREMENTS IN MECHANICAL ENGINEERING

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Abstract.- Thin layer activation of machine components for wear studies have been performed at the Karlsruhe Isochronous Cyclotron for more than ten years. In response to industrial needs the technical equipment has been developed to an optimum of reliability and precision and an activation service including routine quality control is now established.

1. Introduction.- The steadily increasing demand of cyclotron beam time for activated engine components indicates that the measuring methods of wear by means of radionuclides is finding widespread industrial use. It has become a standard method, sometimes in conjunction with classical methods, and is applied effectively for solving immediate practical problems.

During the last ten years the radionuclide technique for wear measurement was advantageously employed by the auto, truck and marine diesel engine manufacturers for the development of new engines and transmissions. Hence irradiations were predominantly applied to components of combustion engines such as cylinder liners, motor blocks, piston, piston rings, camshafts, journal-bearings etc.

The handling, transport and storage of the activated machine parts are safe and simple. For example, in some cases the wear behaviour studies can be carried out in machine shops without any special radiation protection measures.

Due to the radionuclide technique time savings in the development of new motors are reported to amount up to 80%.

The method of measuring surface loss of materials due to wear by means of radionuclides and the principles of activation are also described in the contribution of G.Schatz to this conference.

2. Activation Service.- The specifications of each activation are dictated by the required precision and sensitivity of wear measurement. The correct transfer for the parameters describing the measurement problem to activation data is therefore of decisive importance, not the least for reasons of activation cost.

Hence a clear understanding between the user and the manufacturer of the activated component is essential.

The physics and technology of activation is of no interest to the user itself. The user wants to buy irradiation as a service in the form of the properly activated machine part. In response to this need of engineering industry and some research laboratories a well organized activation service, including routine quality control was established at Karlsruhe.

The appropriate design of the activation requires software as, for example, excitation functions, activity yields, gamma spectra and control specifications. This software is at Karlsruhe based upon a period of over 10 years in which the evolution of measurement methods of wear by means of radionuclides together with the irradiation technique have passed beyond the development stage.

3. Irradiation technique.- The essential irradiation parameters are the chosen projectile particles and their energy, the beam current and the irradiation time.

The particles are mostly chosen to be protons. The advantages of proton activation are the reduced production of disturbing isotopes as compared with activation by deuterons or alpha particles and, especially for ferrous materials, the higher yield of radionuclides.

The distribution of the activity should be homogeneous in the required thickness of the layer. This is achieved by adapting the incident energy of the projectiles. The particle energy varies between 10 and 50 MeV for most materials, as can be seen from table 1.

Table 1: Some nuclear reactions used for wear studies of different materials.

material	projectile	energy at maximum of cross section MeV	radionuclide	half life d	energies of main gamma rays keV
Al	α	47	^{22}Na	845	511; 1275
Ti	p	11	^{48}V	16.0	511; 940; 1312
Cr	p	25	^{51}Cr	27.7	320
Fe	p	12	^{56}Co	77.3	511; 847; 1238
Ni	p	19	^{57}Co	270	127; 136
Cu	p	10	^{65}Zn	244	1115
Zn	p	25	^{65}Zn	244	1115
Mo	p	25	^{95m}Tc	61	204; 582
Sn	p	14	^{120m}Sb	5.76	
W	p	25	^{184}Re	38	792; 895; 903
Pb	d	30	^{206}Bi	6.24	803; 881
brass	p	10	^{65}Zn	244	1115
stainless steel	p	12	^{56}Co	77.3	511; 847; 1238

The beam current has to be carefully chosen (usually few μA) so that the absorbed power does not destroy the original wear characteristics of the surface. The required irradiation time rarely exceeds a few hours. The area to be activated is often much larger than the cross section of the beam. Activation of a larger area is achieved by moving the target continuously during irradiation. The machine part to be irradiated may be very large and heavy (up to some 100 kg).

The requirements of size, weight and sometimes complicated movements are most easily met by irradiating the parts in air. The beam leaves the evacuated beam pipe trough a thin metal window, travels through air for several tens of cm and then hits the machine part.

In order to obtain a correct depth profile and a uniform distribution of the activity over the irradiated zone the targets have to be precisely adjusted to the beam. This adjustment is performed in two steps. The first step is the preadjustment of the machine part to a laser beam representing the beam axis. In the second step one has to adjust the charged particle beam to the laser spot under remote control by television cameras. In this way the achieved precision of the beam spot on the machine part is about 0.2 mm.

In order to gain flexibility and effectiveness in the use of cyclotron operation time the target stand is provided with an automated positioning device for the activation in series of several preadjusted engine parts. Due to this serial irradiation technique of up to 8 pieces a considerable cost reduction is achieved.

The beam diagnostic system is equipped with a position control using beam scanners to prevent deviations resulting from operational fluctuations during the irradiation. The maximum beam current and the beam current integration is computer controlled.

4. Quality Control.- The quality control according to the agreed quality specifications is carried out for each irradiated machine component.

The total activity versus surface loss curve is determined for each individual machine component which is to be used for wear measurements by monitoring the residual activity at the component (so - called Thin Layer Difference Method), because the precision of test in this method is directly proportional to the accuracy of the measured activity depth. In the same irradiation, and under the same conditions, a pin or foil packet is irradiated from which the depth distribution of the procuced species is determined.

The gamma spectra, the total activity and the specific activity of the produced radionuclides are also measured.

The uniformity and correct position of the activated zone on the target are controlled usually by autoradiographical methods.