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FRACTOGRAPHY

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Foreword

The Current Japanese Materials Research (CJMR) series is a new publication edited by the Society of Materials Science, Japan, and published by Elsevier Science Publishers, UK, aiming at the overseas circulation of current Japanese achievement in the field of materials science and technology. This sixth volume of the series deals with *Fractography*. All the papers have been selected to present the most important and substantial results obtained by the authors, in order to help readers to understand the current status and recent developments of fractography and its related fields.

Although many international meetings are held every year in various specialized fields, it cannot be denied that most research results in Japan are published only in Japanese and tend, therefore, to be confined to the domestic audience. The publication of the CJMR series is an attempt to offer these results to colleagues abroad and thereby encourage the exchange of knowledge between us. I hope that our efforts will interest engineers and scientists in different countries and may contribute to the progress of materials science and technology throughout the world.

HIROSHI JINNO
President, Society of Materials Science, Japan

Preface

Much work on fractography has been carried out in Japan in conjunction with fracture mechanisms, fracture mechanics and failure analysis during the last two decades, and a large amount of fractographic data has been accumulated for effective utilization in both basic research and practical applications.

The Committee on Fractography of the JSMS (Society of Materials Science, Japan) has been working for some years to promote fractographic research and applications in this country. Its origin dates back to 1969, when the Subcommittee on Fractography started as a section of the JSME (Japan Society of Mechanical Engineers), whose members cover researchers and engineers actively working on fractography in Japan. It aimed primarily at an exchange of information on fractography and compilation of fractographic data, but a co-operative investigation was also conducted on quantitative analysis of fatigue fracture surfaces, focusing attention mainly on the striation analysis of aluminum alloys as well as that of ferrous alloys, whose striation analysis was not common at that time. The results of the co-operative investigation were reported at the international conference organized by the Electron Microscopy Society of America in Los Angeles in 1972 as well as at meetings and in the *Journal of JSME*.

The subcommittee was then expanded and transferred to the JSMS as the Committee on Fractography in 1975. This committee has had four regular meetings a year and has continued the exchange of information and the compilation of fractographic data. The committee has also presented symposia on fractography about once every 2 years,

and most of the reports read at these symposia have been published in the special issues on fractography of the *Journal of JSMS*. Some of the work by the committee members was also presented at the ASTM Symposium on Fractography in Failure Analysis (Toronto, 1977, STP-645). Besides this committee work, several subcommittees also have been working on the initial stage of fatigue crack propagation, fracture at high temperature, fracture of high-strength materials, the relationship between fracture and microstructure, failure analysis, environmental fracture, and the fracture of nonmetallic materials (such as ceramics). The first three of these have finished their work and the others are now working actively.

This volume includes the recent work of some of these subcommittees on survey and analysis. The remaining part of this volume is devoted to recent work carried out by individual members of the committee. This covers various aspects of fractography from basic research to practical applications, including analyses of fatigue fracture, creep and high-temperature fracture, unstable fracture, environmentally assisted cracking, as well as material characterization and failure analysis, and will give a broad picture of the present state of fractographic research and applications in Japan.

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Report from the Subcommittee on Microstructure and Fracture, No. 1: Stage 2 Fatigue Crack Propagation and Fractography

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ABSTRACT

This report reviews studies on the stage 2 fatigue crack propagation characteristics that have been done in Japan over the last decade, consisting mainly of those on iron and steel materials. Many of the studies carried out from 1976 to 1980 concentrated on the relationship between the crack propagation characteristics and fracture mechanism, while many of those done thereafter have focused on the role of oxide-induced crack closure on the fatigue crack propagation characteristics. The findings from these studies are contributing to fracture analysis in service and to the establishment of design criteria for fatigue crack propagation curves.

This report reviews the results of studies on fatigue crack propagation characteristics at the stage 2 level by means of fractography, which have been carried out over the last decade mainly by members of the Subcommittee on Microstructure and Fracture that was established by the Committee on Fractography of the Society of Materials Science, Japan.

Since most of such studies in Japan are related to iron and steel materials, this review also focuses on the results from iron and steel materials, which will be described in chronological order.

STUDIES CARRIED OUT FROM 1976 TO 1980

Murakami *et al.* [1–3] and Kitsunai [4, 5] did detailed studies on the relationship between fatigue crack propagation characteristics and the

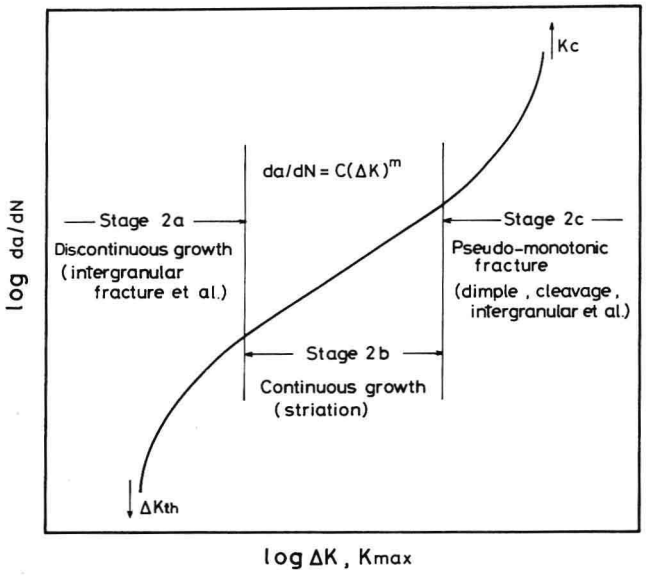

FIG. 1. Classification of stage 2 fatigue crack propagation processes based on the fracture mechanism.

fracture mechanism at the stage 2 level, with extensive work on the threshold, ΔK_{th}, and the fracture toughness, K_c, by means of fractography, using carbon steels with a wide variation in carbon content. As a result, it was found that the fatigue crack propagation could be classified into that at stages 2a, 2b and 2c, according to changes in the fracture mechanism dependent on ΔK (stages 2a and 2b) and K_{max} (stage 2c). Figure 1 shows that fractures with discontinuous propagation, represented by intergranular fracture acting as the unit of a micro-structure, are dominant at stage 2a, which includes ΔK_{th}, while fractures with continuous propagation caused by striations that are hardly dependent on the microstructure are dominant at stage 2b. Figure 1 also shows that monotonic fractures such as dimples, cleavages and intergranular fractures, which reflect differences in the microstructure, are dominant at stage 2c culminating at K_c. It has also been determined that the law of Paris expressed below is valid at stage 2b.

$$da/dN = C(\Delta K)^m \tag{1}$$