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# The Effect of High Pressure on the Isothermal Transformation in High Purity Fe-C Alloys and Commercial Steels\*

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## Synopsis

The effects of high pressure on the isothermal transformation were investigated for three kinds of high purity Fe-C alloys and commercial steels which had corresponding carbon contents to the alloys. The experiments were carried out at 29 or 38.5 kbar using a "girdle" type high pressure apparatus, and the transformation behaviours of these alloys and steels were examined.

The results obtained were as follows;

The rates of isothermal transformation both in Fe-C alloys and commercial steels were retarded by an increase of pressure. This retardation was much larger in the Commercial steels. By increasing the pressure from 29 to 38.5 kbar, the incubation time increased by approximately five times for all alloys and steels. The structures obtained in the isothermal transformation at high pressure and at relatively higher temperatures could be explained from the phase equilibrium diagram under high pressure which showed some changes from that at atmospheric pressure. At relatively lower temperatures, singular structures so-called "aggregate" or "columnar bainite" were observed as a result of high pressure isothermal transformation, in place of acicular bainite in the case of atmospheric pressure. The temperature ranges in which these structures appeared were also determined. Furthermore, in the case of a commercial steel containing 1.1% C, it was observed that the shape of carbides always changed from spherical to acicular with an increase of pressure from 29 to 38.5 kbar.

## 1. Introduction

It is known that the pressure, one of the thermodynamic variables, affects the phase equilibrium and the kinetics of transformation in metals and alloys; for example, a hcp( $\epsilon$ ) structure in pure iron and iron alloys is observed even at the room temperature in high pressure treatment.<sup>1-4)</sup>

The transformation behaviour of austenite to pearlite, bainite and martensite in steels has been studied extensively at atmospheric pressure. On the other hand, there are some papers<sup>5-7)</sup> discussing the effects of pressure on the decomposition of austenite, in which it is described that the decomposition was retarded with an increase of pressure.

Radcliffe *et al.*<sup>5)</sup> examined the isothermal transformation of austenite at 42 kbar for high purity Fe-C alloys containing 0.08 to 1.23% C, and reported that the irregular ferrite-carbide "aggregates" appeared in the temperature range in which the formation of bainitic structure would be expected at atmospheric pressure, and that no acicular bainite could be observed even at the pressure as decreased as 15 kbar. Nilan<sup>6)</sup> found the other singular structure, which he named as "columnar bainite", at 24 and 30 kbar in the temperature range in which acicular bainite would be originally observed in plain carbon steel at atmospheric pressure. The differences in the appearance of structure between them are thought to be due to

the differences in their experimental condition such as pressure range, experimental apparatus and chemical composition of materials. Hilliard and Cahn<sup>7)</sup> determined the growth rate of pearlite in high purity Fe-C alloys and commercial steels at 34 kbar, and reported that the retardation on the growth of pearlite by pressure was far greater in the latter and also that those activation volumes for the diffusion of carbon which controls the growth rate of pearlite was considerably larger in commercial steels. These results both indicate that the effect of pressure on this reaction is more outstanding in commercial steels than in Fe-C alloys. Therefore, it is supposed that if the same effect as described above is brought on the bainite reaction, the changes of structure in commercial steels at high pressure would be expected to show some difference to the one in Fe-C alloys.

Tanaka<sup>8)</sup> reviewed the phase equilibria in Fe-C system at atmospheric pressure in detail, and suggested the decomposition behaviour of austenite. On the other hand, under high pressure, the phase equilibria near the eutectoid point was reported by some researchers,<sup>5,7,9,10)</sup> and those results showed that the eutectoid point tended to shift to lower temperature and that the composition of carbon at that point decreased with an increase of pressure.

Figure 1 is composed of the phase diagram<sup>10)</sup> and Ms point<sup>11)</sup> at atmospheric and high pressure on Fe-C alloys which were decided experimentally or calculated from thermodynamic data.

The purpose of the present study is in the effects of high pressure on the isothermal transformation be-

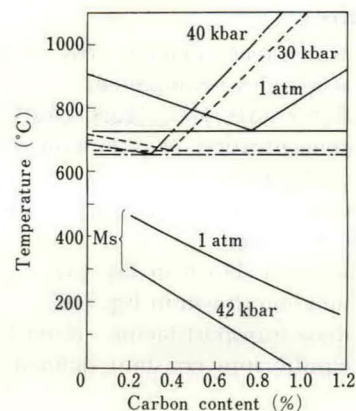


Fig. 1. Effect of pressure on phase equilibria<sup>10)</sup> and Ms<sup>11)</sup> temperature in the Fe-C system. These were determined experimentally and calculated from thermodynamic data respectively

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