

Development of High Fatigue Strength for Powder-Forged Connecting Rods

Kentaro Takada and Ryosuke Kogure
Honda R&D Co., Ltd.

Masaaki Sato and Minoru Takada
Kobe Steel, Ltd.

Copyright © 2008 SAE International

Abstract

Technology has been developed to increase the fatigue strength of powder-forged connecting rods.

The fatigue strength of powder-forged materials was increased without adding special alloy components or lowering workability by adjusting the ratios of the conventional main mixed powders (iron, carbon, copper). In addition to solid solution strengthening of the ferrite using copper, reducing porosity, which is a material surface defect, is also an effective method of increasing fatigue strength. Reducing carbon content greatly reduced the occurrence of defects in the forging stage.

The results of this research showed that the fatigue strength of high strength powder-forged connecting rods can be increased by 30% or more over that of conventional materials, allowing powder-forged connecting rods to be applied to even higher output and higher load engines than before.

1. Introduction

The need for enhanced automotive engine fuel economy has been increasing rapidly in recent years in response to concerns over protecting the global environment and soaring fuel costs. Reducing the weight of components is an important means of increasing fuel economy. In particular, reducing the weight of the main moving components, such as the pistons, crankshaft, and connecting rod, has significant ripple effects on reducing overall engine weight and enhancing performance.

In Europe and Japan, hot forging technology has advanced, and is often used to increase the steel material strength in order to reduce the connecting rod weight. Recently, connecting rods with a streamlined shape have been developed by using steel materials with a greatly reduced

toughness and fracture-splitting the big end of the connecting rod⁽¹⁾⁻⁽³⁾.

In contrast, powder forging is the main method used in North America, and specifications that make use of the brittleness of the materials to allow fracture-splitting of the big end of the connecting rod have been used from an early stage. The strength of powder-forged materials can be enhanced by increasing the amounts of additive alloy elements⁽⁴⁾ or adding new components. However, alloying increases costs, and as the hardness increases, the machinability decreases, making it impractical for mass production.

For these reasons, the material component design was reviewed from the perspective of forgeability, using only the conventional material component powders. As a result, technology was found that dramatically increases the fatigue strength without lowering machinability. This paper reports these technical details.

2. Development Goals and Strategy for Achieving Goals

2.1. Development Goals

Conventional powder-forged connecting rods have a lower strength than that of hot-forged connecting rods, which meant that the connecting rods for the same engine could not be designed with the same weight. Therefore, the goal of this study was to obtain fatigue strength equal to or greater than that of hot-forged connecting rods. This is an increase in fatigue strength of 30% or more compared to Honda's conventional powder-forged connecting rods. An additional aim was to utilize existing mass production lines without modifications, so the goal was to develop a material with the

same characteristics as conventional powder-forged connecting rods with respect to machinability, big-end fracture surface, and rod and cap assembly after fracture splitting.

2.2. Approach toward Material Component Design

The main components of conventional powder-forged connecting rods are Fe-0.5%C-2.0%Cu, and MnS as the free-cutting component.

Possible methods for increasing the strength of this type of connecting rod are as follows.

- (1) Increasing the base material strength by increasing the C and Cu contents
- (2) Increasing the hardenability by adding Cr, Si, and Mn
- (3) Strengthening the base by adding V, Ti, and Nb to precipitate carbides

However, the base material strengthening method (1) causes the machinability to drop as the hardness rises. For this reason, there are reports of adding MnS powder or other special powders that effectively increase machinability⁽⁵⁾. Elements (Cr, Si, Mn) that are effective at increasing hardenability (2) oxidize easily during the sintering process, and these oxides form defects that lower the connecting rod strength, so this method is not appropriate. In addition, elements (V, Ti, Nb) that strengthen the base through carbide precipitation (3) must not only be alloyed and then mixed in powder form, but also reduce the compressibility of the powder mixture.

For these reasons, optimization of the powder mixing ratios, without changing the main components (Fe, C, Cu) from the conventional material, was investigated.

2.3. Reduction of Porosity by Material Design

Density is generally an important factor affecting the fatigue strength of powder-forged materials. Figure 1 shows the connecting rod production process. The porosity present in the outermost surface layers of the connecting rod after powder forging is crushed and eliminated by shot peening, but porosity remains in the inner layers. This remaining porosity becomes a starting point for fatigue fractures, which lowers the fatigue strength.

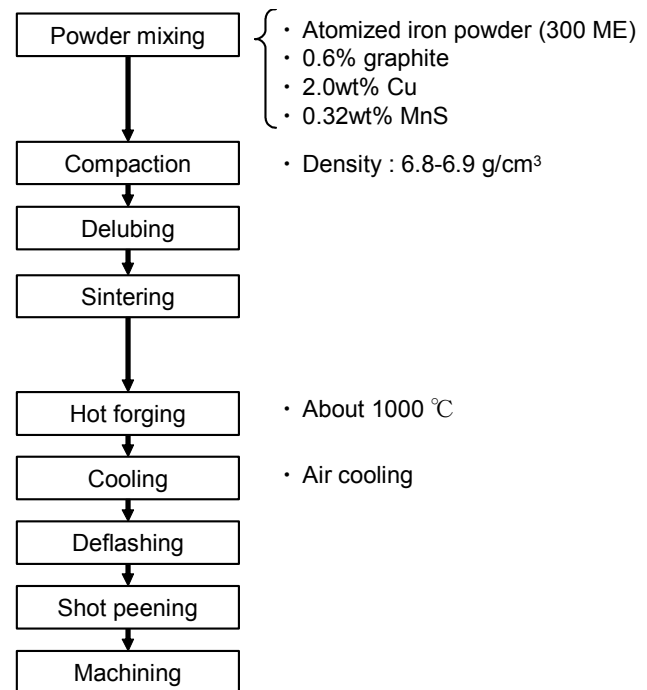


Fig. 1 Production process and condition of connecting rod

Figure 2 shows the porosity in the I-Beam portion of a conventional powder-forged connecting rod. The center portion of the materials, which exhibits a large degree of deformation, is almost completely filled. However, the surface layers contact the forging die, causing the temperature to drop and increasing the deformation resistance, so the gaps in these portions that form during sintering resist crushing and easily remain as porosity.

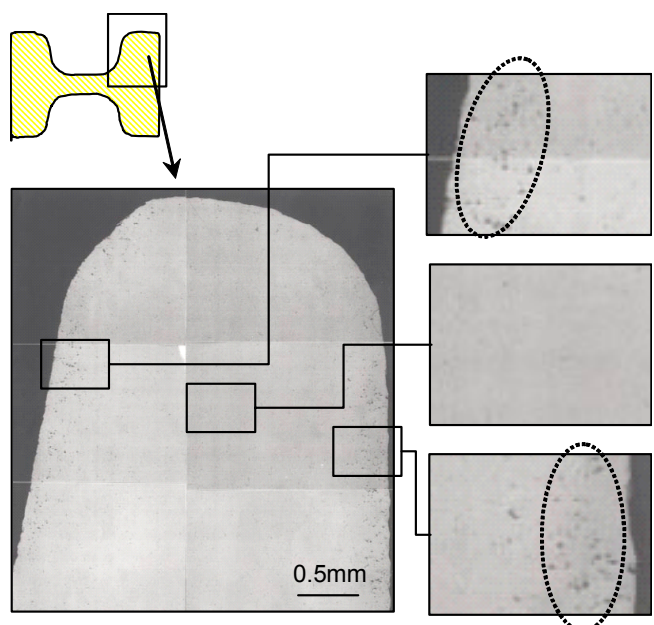


Fig. 2 Porosity of connecting rod "I-Beam" (after shot peening)

Figure 3 shows the relationship between the forging temperature and the deformation resistance for C contents of 0.30% and 0.68%. Reducing the C content lowers the deformation resistance within the temperature range of 850 to 900°C⁽⁶⁾, so porosity existing in the surface layers is considered to be less than that of the conventional materials.

Based on these results, this development investigated lowering the C content as a means of reducing porosity and raising the fatigue strength.

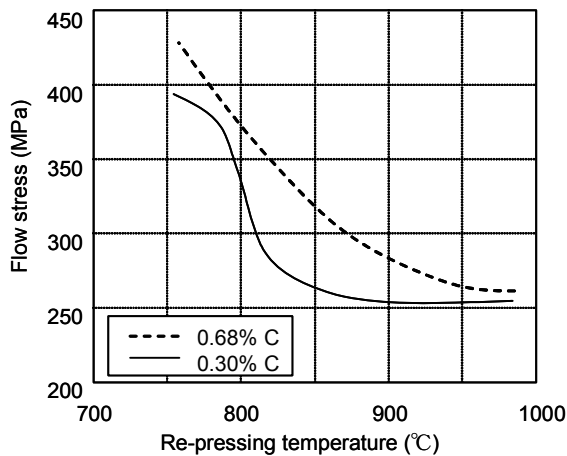


Fig.3 Relationship between flow stress and pressing temperature

3. Results and Analysis

3.1. Relationship between C, Cu Content and Hardness, Fatigue Strength

First, test pieces were used to investigate the hardness and fatigue strength relative to the ratios of C and Cu. The powder mixture consisted of atomized pure iron powder (300 M), 0.6% graphite by weight, 2.0% Cu powder by weight, and 0.32% MnS alloy powder by weight. Figure 4 shows the hardness and rotary bending fatigue strength relative to the C and Cu contents. Both the fatigue strength and the hardness increase with the C or Cu content, but the C content have a greater effect on the increase in hardness than the Cu content. Thus, minimizing the C content and increasing the Cu content is an effective means of increasing the fatigue strength, while at the same time preventing a rise in hardness, which greatly influences the machinability. Figure 5 shows the difference in structure due to the different C content. Reducing the C content reduces the hard pearlite, which is a cause of increased hardness, and at the same time allows a greater solid solution of Cu to the inside of the austenite, which strengthens the soft ferrite.

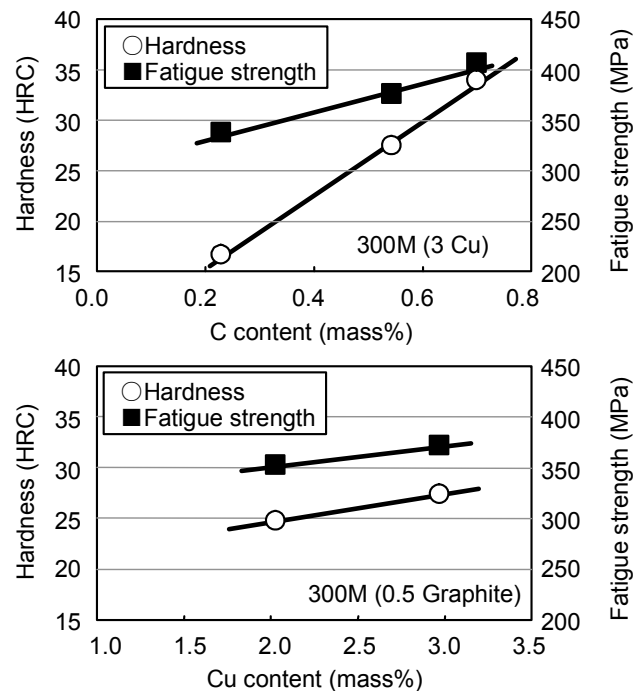


Fig. 4 Relationship between C, Cu content and hardness, fatigue strength

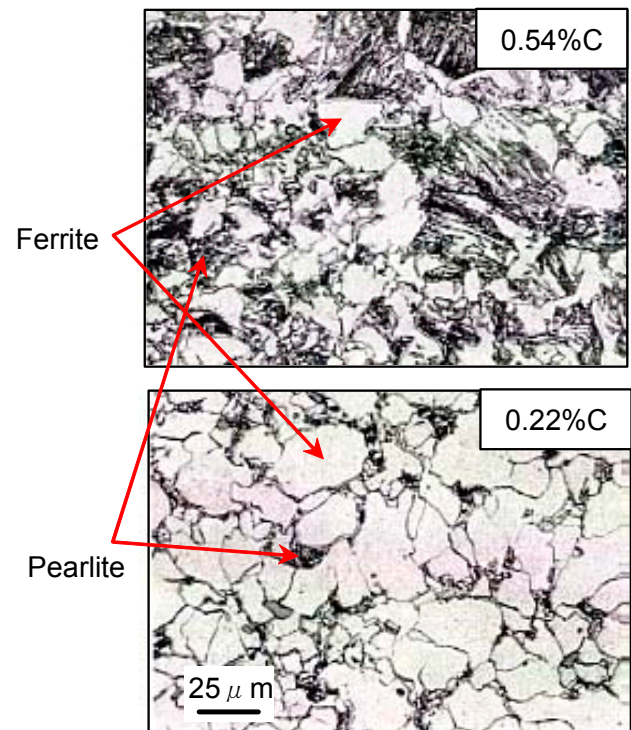


Fig. 5 Change in microstructure due to decreased C% of powder-forged test pieces (originally at 400X)