

Development Trends of Soft Magnetic Iron

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Various soft magnetic or electromagnetically controlled devices for automobiles are desired to provide for safe and superior results that are produced a large electromagnetic force with low electric power. This study will try to surface various basic ideas developed in combination of state-of-the-art electromagnetic progress such as coil geometries and materials. This paper describes the recent development trends of soft magnetic steel and the achievement of one developed steel (DCHC) series.

Introduction

Recently automobiles are being heavily equipped with various systems operated electrically, electronically and/or electrohydraulically to control valves, control and fuel economy. Such systems include integrated controlled automatic transmission, electronic power steering (EPS) and anti-lock braking systems (ABS)^{1,2}.

In the early years (1970s, 1980s) when electric and electronic devices started to be used in automobiles, the main purpose was to improve and upgrade the performance of individual systems. Highly complicated vehicles started to appear soon. However, in today's era without high-speed fittings and movements coordinated among different systems, heavy electromechanical and/or electrohydraulically controlled components are becoming increasingly important.

Among these electromechanical and/or electrohydraulically controlled systems, components that utilize electromagnetic force (magnets) are more in their ability to generate magnetic fields. Many conventional cores consist of low carbon steel, containing about 0.1% of carbon, to improve the response to control signals and increase energy efficiency.³ With the remarkable advancement of electromagnetic control in recent years, it has become essential to electromagnetically components to have even higher performance and lower power consumption.

This paper describes the trend of soft magnetic materials, such as those for low carbon steel as electromagnetically components, and introduces the characteristics of the new, low-carbon soft magnetic materials in the DCHC (Ultra Low Carbon Cold Heading Steel) series developed by Tokai Steel.

2. Description of soft magnetic materials

Fig. 1 depicts the structure of a solenoid device

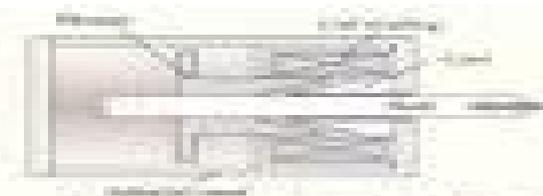


Fig. 1. Example of solenoid device.

by hydraulic control. This is a typical example of the electromagnetically components used in automobiles. Soft magnetic materials are usually used for low carbon steel, low magnetic conductance and for the fittings including cores.

Early solenoid devices for automobiles were mainly used for controlling the oil flow by small solenoids. Thus, the controllability and reliability of low cost materials were more important than their magnetic characteristics. As a result, low carbon steels such as SAE1010, SAE1015, SAE1020 and SAE1025 (JIS-C 1008) were used for the solenoids.

Recent solenoid devices, however, must be able to control hydraulic media, and water. In advance this, the small control is being replaced by larger control in many cases.^{4,5} On the other hand, the control current must be proportional to the galling force (electromagnetic force) of the low carbon, which increases with magnetic materials having low permeability (low magnetic inductance). The latest low cost materials for these solenoids are required to have magnetic characteristics better than those of SAE1020 (JIS-C 1020), making it difficult to use low carbon steel directly used for small control, to satisfy the required characteristics of magnetic materials and accuracy (Fig. 2).

In the mid-1980s, Tokai Steel started to totally eliminate carbon that can adversely affect the magnetic characteristics of soft magnetic materials and developed a soft magnetic material, DCHC (Steel) series from which can achieve the best characteristics among 50 grades (0.005% to 0.050% carbon).⁶ The company has studied parts forming using a forging process and parts fabrication from the material is being widely used as a soft magnetic material for coil forging.

In the late 1990s, there was an increasing need for

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