Mechanical Properties and Formability of Steel Sheets Made from Obsolete Scrap in Electric Arc Furnaces

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Japan holds approximately 1.4 billion tons of steel in social infrastructure, generating a stable supply of obsolete scrap as these products reach the end of their service lives. However, approximately 7 million tons of iron scrap are exported annually, representing a significant loss of domestic resources. Obsolete scrap inevitably contains residual elements such as copper, nickel, chromium, and molybdenum, originating from product additives and contamination from wiring and motors. Because these elements are unavoidably present in electric arc furnace (EAF) steel produced from obsolete scrap, their use in high-grade steel sheets, particularly for automotive applications, has traditionally been avoided. EAF steel applications have therefore been largely confined to construction and civil engineering uses, where demand is steadily declining. Therefore, expanding into sheet steel applications is increasingly necessary to promote domestic iron resource circulation.

This study investigates the mechanical properties and formability of steel sheets manufactured from obsolete scrap using EAF, aiming to demonstrate the feasibility of expanding EAF steel into automotive and other sheet steel fields. Steel sheets with three different copper content levels (Cu: 0.21%, 0.26%, and 0.30%) were produced at full industrial scale using a 420-ton electric arc furnace. Carbon and manganese contents were adjusted during secondary refining to compensate for strength variations arising from scrap-derived elements, thereby ensuring compliance with 370 MPa grade specifications. The steel with the lowest copper content (Cu: 0.02%), prepared from iron-ore-based raw materials, served as a reference material. Product coils with a thickness of 3.8 mm were manufactured through continuous casting, hot rolling, and pickling processes. Tensile, hole expansion, Erichsen, and deep drawing tests were conducted to evaluate mechanical properties and formability.

All steel sheets satisfied the target specification values regardless of copper content. Yield strength, tensile strength, total elongation, limiting dome height, and limiting drawing ratio remained nearly constant across all copper content levels, confirming that target properties can be consistently achieved through appropriate compositional adjustment even when scrap-derived element content varies.

However, the hole expansion ratio showed a significant difference depending on copper content. Copper-containing steels exhibited substantially higher hole expansion ratios ranging from 122% to 144%, compared to only 85% for the iron-ore-based reference material. Metallographic observations revealed that all specimens had a ferrite-dominated microstructure. The pearlite area fraction varied with carbon content, with higher carbon steels showing larger pearlite fractions. The improvement in hole expansion ratio in copper-containing steels is attributed to two mechanisms: solid-solution strengthening of the ferrite matrix by scrap-derived elements, and a reduction in pearlite area fraction due to lower carbon content, thereby reducing crack initiation sites at ferrite-pearlite phase boundaries during deformation.

These findings demonstrate that scrap-derived residual elements can be effectively utilized through solid-solution strengthening in mass production, enabling steel sheets that meet commercial specifications. This demonstrates considerable potential for expanding EAF steel sheet applications into automotive and other demanding fields, contributing to a reduction in scrap exports and the establishment of a sustainable domestic iron resource circulation system.

Table1 Chemical Composition

(mass%)

	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	Sn
Cu30	0.04	0.02	0.27	0.018	0.003	0.30	0.11	0.13	0.03	0.018
Cu26	0.06	0.02	0.28	0.017	0.001	0.26	0.08	0.13	0.03	0.017
Cu21	0.06	0.02	0.34	0.015	0.001	0.21	0.07	0.10	0.02	0.019
Cu 2	0.09	0.02	0.34	0.012	0.005	0.02	0.02	0.02	0.01	0.001

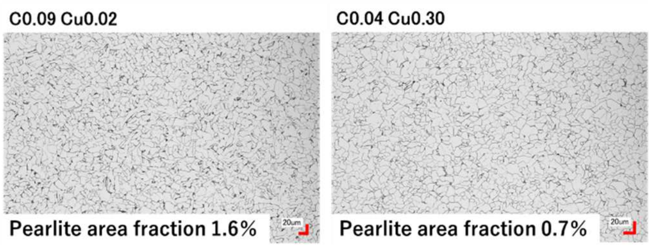

Fig.7 Metallographic observation

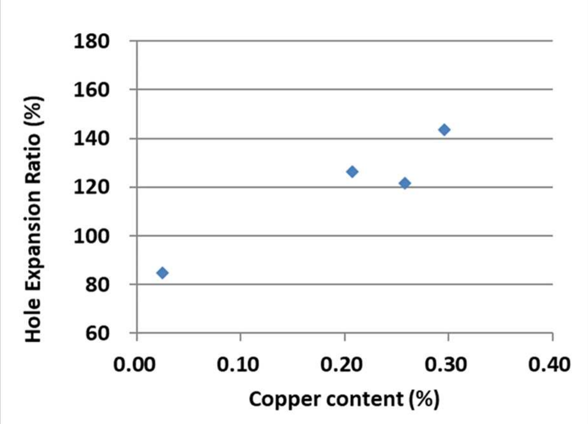

Fig.4 Relationship between copper content and Hole Expansion Ratio