Opticore™: Next Generation Non-Oriented Electrical Steels made using SODA™ Technology

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Arcanum Alloys Inc., of greater Grand Rapids, Michigan, has developed a proprietary new method of manufacturing steel. This method, termed Spatially Optimized Diffusion Alloying (SODA), allows for the production of numerous alloys without the specialized manufacturing equipment typically required to do so. The SODA process introduces the alloying elements directly to a finished or semi-finished form via chemical vapor deposition at elevated temperatures.

Using SODA technology, both traditional and unique high-performance alloys can be produced without the massive capital expenses typically required to produce a new alloy product category. Electrical steels containing mostly Iron and Silicon, but often also Aluminum and Manganese to some degree, are famous to electrical engineers for their ability to combine high magnetic induction (also called magnetic flux density) with low core loss (below, Figure 1 Right). For this reason, they are commonly used in electric motors, generators, and transformers. In most cases, these products are produced from sheet steel which is stamped and stacked into a transformer, choke, or electric motor core. Conventionally as more Silicon (and/or aluminum) is added to the steel, issues with casting, gauge reduction, and coil strip oxidation arise. For this reason, the silicon content of electrical steels made by conventional melt-phase methods does not exceed 3.5%wt.

It is well understood that Electrical steels, especially those used in systems operating at higher frequencies, see a substantial reduction of core loss (thus providing improved electrical efficiency at the system level) via reduced lamination (sheet) gauge and increased silicon, aluminum, or manganese concentration as application frequency is increased, core loss via eddy current (amongst other mechanisms) losses increase. These losses result from the alternating magnetic field in the electrical steel according to Lenz’s law.

Therefore, if a magnetic material is divided into insulated layers (akin to replacing a single insulated lamination at 0.50-mm with five insulated laminations at 0.10-mm), the induced voltage and eddy-currents are spread out over 5 times the area, lowering total loss dramatically. For this reason, thin laminations are desirable in many applications. However, since yield stress increases with alloy content (see Figure 1, left for the impact of silicon), thin gauge electrical steel
with an elevated silicon concentration is not readily available to the market, and is very expensive when it is.

Using SODA technology, Arcanum Alloys has demonstrated the ability to create thin electrical steel alloys with compositions not currently possible to produce via traditional methods. These alloy compositions improve the permeability of the steel without sacrificing core loss. Improved permeability means that more magnetic force can be generated by less electric current. In terms of applications, this is equivalent to more operational hours with the same amount of power (i.e. battery size), or higher performance with the same amount of power. Figure 2 shows typical core losses achieved by two grades of Opticore at various frequencies.

![Figure 2. Core loss as a function of frequency for two lightgauge Opticore grades of non-oriented electrical steel. The same curves are described by the Steinmetz equation: \( P_v = f^a \times B^b \), where \( v, a, \) and \( b \) are coefficients corresponding to a particular grade of electrical steel at a given temperature.](image)

Surface Optimized Diffusion Alloy technology enables not only novel alloy configurations, but also traditional configurations made without traditional production upgrades. This means that for steel mills contemplating whether to move into existing electrical steel markets, the need for new casting and rolling-mill equipment is eliminated. Adding Silicon and Aluminum to steel causes difficulties in casting where breakouts and slab cracking are common without tight temperature and composition controls. Hot and cold reduction of the strip is also made more difficult by the added Silicon and Aluminum. The demand for electrical steel at all gauges and grades increasing, but most notably high-performance grades which are seeing double-digit market growth rates. For this reason, more and more steel mills are considering a move into electrical steels. Arcanum Alloys’ technology is a means of shortening the timeline and reducing costs to enter these markets.

**Reference**