Somaloy®

Soft Magnetic Composite (SMC) material for electromagnetic applications, by Höganäs AB

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Material overview

Höganäs AB Somaloy® is a family of SMC materials, which are made of high purity iron powders with nanometre-size inorganic surface insulation, as shown in Figure 1. The iron powders are available in several grades with particle sizes of between 50 – 250 micrometres. The Somaloy® family is grouped into performance levels based on the coating properties: 1P, 3P and 5P. The resultant performance of the powders is highly dependent on this coating and its sensitivity to the compaction and heat-treatment processes. The additives - such as lubricants for powder filling and ejection from the die tool post compaction, for example - and the heat-treatment process, must be optimal to yield the desired performance from the component.

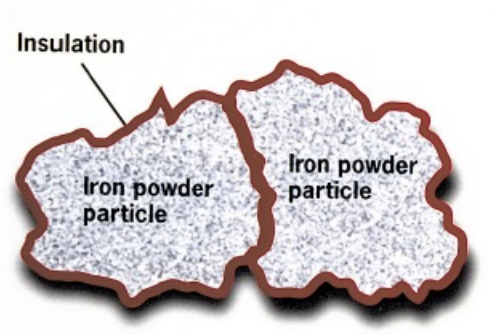

Figure 1. SMC powder particle with electrically resistive coating.

During the compaction phase, there is a physical limit on the pressure that should be applied to the powder in the die tool, which is determined by the pressing force and the part geometry. Under compaction forces that exceed the material limits, the coating will breakdown and the resultant component will not have the electromagnetic properties expected. Where heat-treatment is concerned, the maximum permissible temperature is important for fully stress relieving the grain boundaries after compaction has taken place. This will reduce hysteresis loss and improve permeability, through the removal of impurities, such as lubricants, for example. Exceeding this temperature will breakdown the coating and reduce the electromagnetic performance, along with introducing mechanical defects into the component.

The 1P material provides a base level of performance with a cost-efficient approach. A simple coating is applied, and the heat-treatment of the part is conducted in an air-atmosphere with a maximum temperature of approximately 500 ºC.

The 3P grade uses a different additive to 1P to allow for a special steam-atmosphere during the heat-treatment. This brings maximal mechanical strength to the component by a forced oxidation deep into the material structure. The maximum temperature for the heat-treatment 3P is approximately 500 ºC.

The most advanced SMC material grade is the 5P, which exhibits the lowest specific loss in the family. A special particle coating is designed to withstand heat-treatment temperatures up to 650 ºC, resulting in a component with minimal residual stress post heat-treatment, and the lowest hysteresis losses available for current SMC products.

Process overview

The powder process involves the creation of a base powder mix, which includes all the necessary elements for producing a robust SMC component, compaction and, finally, heat-treatment.

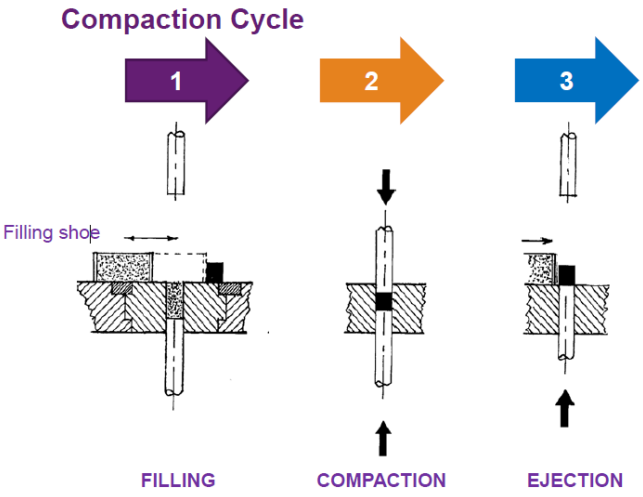

Figure 2. The PM Powder Metallurgy forming process in three steps

The compaction process is depicted in Figure 2, where powder is fed into a die tool cavity before being compacted under high pressure to form the final net-shape component. This is then ejected from the tool and transferred to the heat-treatment. Heat-treatment is conducted under a strictly controlled temperature profile to evaporate compaction lubricants, relax grains boundaries and harden the structure. The furnace can have a specific environment, where gases present in the atmosphere improve the component performance.

The component density is related to the actual pressure of compaction. The higher the component density the more magnetically active material is present. The performance of the material, in terms of loss, at a given frequency is determined by the size of the particles in the initial mix; for lower frequency applications, large particle sizes are best suited. Conversely, high frequency applications will benefit from smaller particle sizes, with an overall larger surface area available for coating. The properties and performance of the SMC material depends upon the powder mixes, discussed below.

Comparing SMC data to electric steel-sheets

SMC data is measured on single ring components (OD55/ ID45/H5 mm) via square cross-section. The measured SMC sample is a full magnetic core component that can be compared to a punched and stacked electric steel-sheet pack representing the same geometry. Data for electric steel-sheets are normally given for a single sheet, tested with an Epstein frame test. SMC is not tested by this method and thereby data is not directly comparable. Additional design factors aimed for electric steel-sheet stacks does not apply for SMC.

Somaloy® Product portfolio

Somaloy material	Density [g/cm³]	Resistivity [µOhm m]	TRS ambient [MPa]	B@ 10000 A/m [T]	μ_{max}	Core losses @ 1T [W/kg]				
						Cross-section 5x5 mm				15x15 mm
						100 Hz	400 Hz	1000 Hz	2000 Hz	1000 Hz
Large particles #40										
Somaloy 700HR 5P	7.50	700	60	1.57	600	6.6	30	92	241	106
Somaloy 1000 5P	7.52	90	65	1.59	720	6.6	31	103	-	217
Somaloy 700HR 1P	7.45	1000	35	1.53	440	10.0	43	125	307	136
Somaloy 700 1P	7.45	400	40	1.56	540	9.9	43	126	312	152
Somaloy 700HR 3P	7.52	600	120	1.57	770	10.4	45	130	319	147
Somaloy 700 3P	7.57	200	125	1.61	850	10.2	45	132	331	183
Somaloy 1000 3P	7.56	70	140	1.63	950	10.3	46	143	-	288

Somaloy material	Density [g/cm³]	Resistivity [µOhm m]	TRS ambient [MPa]	B@ 10000 A/m [T]	μ_{max}	Core losses [W/kg]				
						Cross-section 5x5 mm				15x15 mm
						100 Hz 1 T	1 kHz 1 T	5 kHz 0.5 T	10 kHz 0.1 T	1 kHz 1 T
Medium particles #100										
Somaloy 130i 5P	7.44	20000	35	1.47	350	8.0	93	205	24	94
Somaloy 130i 1P	7.35	8000	33	1.40	290	12.0	132	264	29	134
Somaloy 500 1P	7.37	70	50	1.51	500	12.6	156	387	-	305
Fine particles #200										
Somaloy 110i 1P	7.26	7600	34	1.33	220	14.4	153	276	27	155
Somaloy 110i 5P	7.30	18000	42	1.33	220	9.9	108	209	18	109

Typical product data 800 MPa compaction pressure, magnetic data measured according to CEI/IEC 60404