Working Towards Developing Optimum Milling Process Parameters for Samarium Cobalt Magnet Materials*

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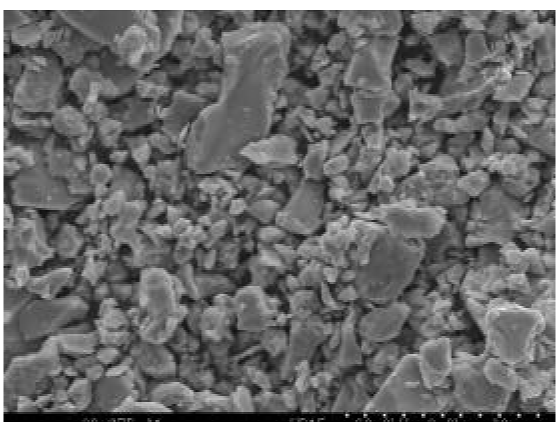
This work was conducted to optimize the processing parameters for an Attritor ball mill used in the production of rare earth samarium cobalt magnets. The production of powder metallurgy rare-earth permanent magnets requires the Sm-Co particles to contain only single domain in order to achieve the maximum coercivity of the magnets. The Attritor ball mill uses both impact action and shearing forces for efficient fine grinding.

Due to tighter specifications imposed by the market and the economical drivers associated with scrap cost, attention was placed on developing optimum milling process parameters. Existing milling parameters were empirically developed around a fixed starting quantity of raw material, the consequences of which can result in significant losses associated with shelf life (due to oxidation), and scheduled usage. In an effort to reduce the milling quantity to compensate for the shelf life issues of the powder, an initial baseline study of existing processes were examined. By use of a scanning electron microscope at 2000x, a baseline distribution of current manufacturing particle size is displayed as seen to the left, with the scale equal to 20 μm. The wide-range, bimodal distribution shown in the image helps explain the variation in final gauss level, which in most cases are also bimodal. Data analysis shows the average of the two peeks obtained through SEM analysis is equivalent to the average particle size measured by the Fisher Sub-Sieve analyzer, which is used in current manufacturing practices to measure particle size. To achieve a tighter distribution, four different variables associated with the milling process were studied, such as milling time, revolution per minute (RPM), steel ball media diameter, and liquid media volume as it affects the slurry constant. The large and small particles associated with the bimodal distribution shown in the image caused us to study the input of energy into the ball mill. As the revolutions per minute are reduced to half, consequent tighter distributions are observable through SEM analysis.



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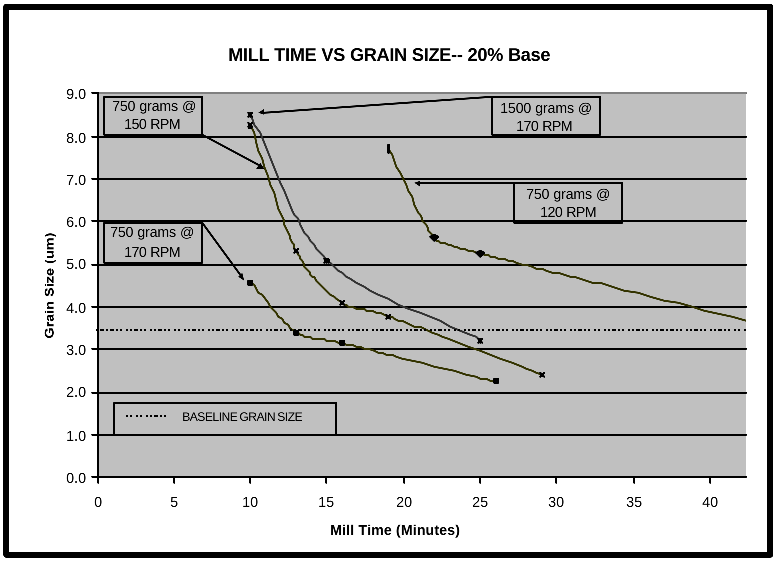
Assuming the direct correlation of lowering input energy through RPM must reduce the shearing forces, it was our goal to decrease initial powder quantities and tighten the particle size distribution. Our initial need was to develop an understanding of the starting material gram weight to milling time. The plotted curves in the Mill Time VS. Grain Size Chart shows the effects of time on the starting material at various points during the milling process. The results of this analysis shows that the selection of 170 RPM varied minutely with time between 750 grams and 1500 grams and provides equivalent performance to the alternate RPM's tested without the economic impact of severely increased milling cycle time.



Further testing at 170 RPM to verify the initial set of data was accomplished and returned equivalent results. This compiled data was further analyzed and has resulted in the Mill Run Time Chart. The curve generated, in the chart to the right is a natural log function and suggests that a series of log function curves exist for any given known Gram Weight to GM WT/ Mill Time ratio. An appropriate curve can be selected from which any other starting gram weight milling cycle time can be calculated. (In other words, once the curve is established, any point on the curve can be calculated).