Disruptive diversion on the road to PM's 'grail' of full density

Innovation is often held to be essential to the survival of Western industry. But one man's innovation can be another man's ruin. Wrought component makers should be eyeing the development of an activated metal powder system with concern as the PM industry reaches for the prize of full density. In this brief essay Ira Friedman looks at disruptive technologies as an introduction to the new PM process...

Ira Friedman

In his book, *The Innovator's Solution*, Professor Clayton Christiansen of Harvard Business School discusses disruptive innovations which he characterises as technologies which are simpler, more convenient and less expensive and which appeal to new or less demanding customers.

He says: "Once the disruptive product gains a foothold in new or low-end markets, the improvement cycle begins. And because the pace of technological progress outstrips the customers' abilities to use it, the previously not good enough technology eventually improves enough to intersect with the needs of more demanding customers."

One example he cites of a disruptive technology is how minimills upended integrated steel companies. His citation offers a classic example of why established leaders are so easy to beat if the idea for a new product is shaped into a disruption.

In the book Christiansen says: "Historically, most of the world's steel has come from massive integrated mills that do everything from reacting iron ore, coke and limestone in blast furnaces to rolling finished products at the other end. It costs about $8 billion to build a huge new integrated mill today.

"Minimills, in contrast, melt scrap in electric arc furnaces-cylinders that are approximately 20 metres in diameter and 10 metres tall. Because they can produce molten steel in such a small chamber, minimills don't need the massive-scale rolling and finishing operations that that are required to handle the output of efficient blast furnaces -which is why they are called minimills. Most importantly though, minimills' straightforward technology can make steel of any given quality for 20 per cent lower cost than an integrated mill.

Once the disruptive product gains a foothold in new or low-end markets, the improvement cycle begins and the pace of technological change carries it forward

"Steel is a commodity. You would think that every integrated steel mill in the world would have aggressively adopted the straightforward, lower cost minimill technology. Yet as of 2000 not a single integrated steel company in the world had successfully invested in a minimill, even as the minimills had grown to account for nearly half of North American steel production and a significant share of other markets as well.

"We can explain why something that makes so much sense has been so difficult for the integrated mills. Minimills first became technologically viable in the mid-1960's. Because they melt scrap of uncertain and varying chemistry in their electric arc furnaces, the quality of the steel that minimills initially could produce was poor. In fact the only market that would accept the output of the minimills was the concrete reinforcing bar (rebar) market. The specifications for rebar are loose, so this was an ideal market for products of low and variable quality.

"As the minimills attacked the rebar market, the integrated mills were happy to be rid of that dog-eat-dog business. Because of the differences in their cost structures and the opportunities for investment that each faced, the rebar market looked very different to the disruptee and the disruptor.

"For integrated producers, gross margins on rebar often hovered near 7 per cent, and the entire product category accounted for only 4 per cent of the industry's

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tonnage. It was the least attractive of any tier of the market in which they might invest to grow. So as the minimills established a foothold in the rebar market, the integrated mills reconfigured their rebar lines to make more profitable products."

When the minimills captured the entire rebar market, their margins dropped because no one minimill any longer had a significant competitive advantage, he goes on.

"Soon, however, the minimills looked upmarket, and what they saw there spelled relief (opportunity). If they could make bigger and better steel-shapes like angle irons and thicker bars and rods, they could roll tons of money because in that tier of the market, the integrated mills were earning gross margins of about 12 per cent-nearly double the margins they had been able to earn in rebar. The market was also twice as big as the rebar segment, accounting for about 8 per cent of industry tonnage.

"As the minimills figured out how to make bigger and better steel and attacked that tier of the market, the integrated mills were almost relieved to be rid of the bar and rod business as well.

"It was a dog-eat-dog commodity compared with their higher margin products, whereas for the minimills, it was an attractive opportunity compared with their lower margin rebar. So as the minimills expanded their capacity to make angle iron and thicker bars and rods, the integrated mills shut their lines down or reconfigured them to make more profitable products. With a 20 per cent cost advantage the minimills, the minimills enjoyed significant profits."

Examples are everywhere

Christiansen goes on to repeat similar experience in structural beams and finally, the sheet steel business. Market capitalisation of Nucor, the leading minimill, now dwarfs that of US Steel, the largest integrated steel company. Bethlehem Steel went bankrupt and no longer exists as an independent entity.

Similar stories exist in every industry from the displacement of the vacuum tube by the transistor in radios, television sets, computers and a host of other products; the inroads made by PC's against minicomputers and mainframes; digital photography vs. film, injection moulded plastics vs. metal castings or glass containers or the budget airlines like Southwest Jet Blue, Ryanair and others against giant, but bankrupt, United Airlines and US Airways.

Powder metallurgy is also a disruptive technology which has been displacing machined components since its inception. The technology keeps making inroads through the development of better powders, lubricants, pressing methods, tooling, furnaces, and densification methods such as coining and forging. Most of these efforts are aimed at achieving higher densities which equate to higher mechanical properties.

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The ability to manufacture fully dense gears will mean big changes for powder fabricators.

Powder metallurgy can become more disruptive as it lowers costs and improves quality. Other fabrication methods are moving targets. Improvements in cold heading, screw machining, NC machining and other methods represent a counter threat as do lower cost manufacturers overseas.

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Some improvements have been characterised as "revolutionary". Some have been incremental. Most increase costs in order to achieve higher densities and properties. Powder metallurgy can become more disruptive as it lowers costs and improves quality.

Other fabrication methods are moving targets. Improvements in cold heading, screw machining, NC machining and other manufacturing methods represent a counter threat as do lower cost manufacturers overseas.

China graduates more engineers than the US and countries like China, Korea, India, many Eastern European countries and others not only have lower labour costs, but they can afford to buy the same presses and furnaces as North American and Western European powder metal part manufacturers.

Their progress is beneficial because it permits the managers and workers higher standards of living in these developing countries and allows them to become more affluent consumers.

The principal advantages of companies in North America, Western Europe, Japan and other highly industrialised countries are innovation, quality, reliability, service and delivery. But here again the competition is a moving target. For the powder metal parts producers and all other participants in the food chain to survive and thrive, they need to innovate.

The development of Activated Nanotech (ANP powder and parts* by Material Technologies, Inc, of Red Bank, New Jersey and Engineered Pressed Materials of St Marys, Pennsylvania, that allow the production of net shape parts with wrought properties produced by simple high temperature pressing and sintering makes powder metallurgy a much more disruptive force in the marketplace.

ANP parts allow PM parts to show densities, tensile strengths, transverse rupture strengths, notched Charpy impact values, and other characteristics low alloy sintered steel has never demonstrated.

Such parts do not require impregnation, because they are fully dense and they can be heat treated, plated or surface conditioned just like wrought steel.

These values will improve with further development and it is probable that through grain size control, homogeneity

The author

Ira Friedman is the President of Material Technologies, Inc, based in Red Bank, New Jersey, and is one of the collaborators in the Activated Nanotech Powders project.

and other techniques that ANP parts will exceed those of wrought product.

In business there is no free lunch and investment is required in powder characterisation, the effect of furnace kinetics and other variables. New tooling is needed because while parts that sinter to full density normally have higher shrinkage than less dense parts, it is a key feature of ANP ™ that it maintains tight dimensional control.

A requirement of the process is sintering in the 2200°F to 2470°F range, so high-temperature furnaces are needed to expand existing capacity.

Other than that, conventional presses and existing high-temperature furnaces can be used to make fully dense PM parts which have properties of wrought product and the potential for PM to become more disruptive as did the minimills, the transistor, digital photography, plastic injection moulding and others is there.

This development is not meant to cannibalise the PM industry. With certain exceptions, PM parts which are good enough for the task at hand should be made with conventional, non-activated powders using lower sintering temperatures.

ANP parts should primarily target higher margin machined or cast components where properties and value are appreciated by the customer whom is willing to pay for performance.

End-use customers should not care whether the part was made by stamping, machining, forging or casting. But they do care about properties. If ANP can deliver equivalent properties at lower cost or superior properties at comparable cost then it should capture a significant shore of the low alloy steel component market.

There are cases where the unique lubricants combined with the unique properties of ANP powder allow for significant improvement in tool life and easier removal of lubricant. ANP powder requires significantly less lubricant than its conventional counterpart. In such cases where lower pressing pressures can be utilised to achieve equivalent or higher densities, ANP can provide significantly improved tool life.

How disruptive ANP parts become and in what time frame depend on the PM industry's willingness to innovate and commercialise the process. ANP could provide defensive economics against improved performance of wrought products such as the battle for market share in forged products, conceivably eliminating the need for forging of sintered parts or permitting a simple coining operation.

One thing is certain - that is that through such innovation, the ultimate consumer is the beneficiary and progressive companies can gain sustainable competitive advantage through use of this unique material.

Ira L Friedman