Many applications exist in the power industry which require the use of multiple materials in a single component. Dissimilar welds between carbon steel and stainless steel and protective coatings on the leading edge of turbine blades for enhanced erosion resistance represent just two of many possible examples. In these applications, the sharp change in interface microstructure and properties between the two distinct materials is often the source of premature failure. This interfacial failure problem can be avoided with components that employ a gradual, controlled variation in material composition, often referred to as Functionally Graded Materials (FGMs). Although techniques for producing functionally graded coatings are available, until recently no fabrication technique existed for manufacturing structural components using FGM concepts.

Under sponsorship from the National Science Foundation, Lehigh University has been developing a new FGM fabrication technique, known as Laser Engineered Net Shaping (LENS), for producing structural components. This effort is under the direction of Dr. John DuPont, of the Energy Research Center and the Department of Materials Science and Engineering.

DuPont explains, "Most conventional manufacturing processes used to fabricate components for the power industry, such as casting, welding and forging, have an adverse effect on the properties of the component. For instance, alloying elements that are added for strength and/or corrosion resistance in welds and castings are not uniformly distributed and may not be retained in solution. As a result, the mechanical properties and corrosion resistance will vary throughout the component in an uncontrolled manner, often leading to premature failure. Forging operations also produce anisotropic mechanical behavior in which the strength and toughness are inferior within a given direction. In addition, most conventional manufacturing processes are not capable of locally altering the composition and resultant microstructure at different locations within the part in order to tailor the properties for enhanced performance. For example, if a wear or corrosion resistant surface is needed, this must be accomplished through an additional processing step, and a sharp interface is produced between the coating and underlying substrate which is often susceptible to premature failure. Thus, development of a manufacturing process that can produce parts with uniform microstructures and graded properties could significantly improve component performance in power generation applications. This potential advantage has been the impetus behind development of Laser Engineered Net Shaping processes."

The LENS process employs a laser to create a molten pool on a substrate. Powder is injected into the liquid pool as the component under fabrication travels through a programmed path in the x-y plane to trace out the current layer shape. The travel path of the component is controlled by a CAD/CAM system. After completing a single layer, the laser focal point and powder feeder are incremented in the upward
direction in an amount determined by the desired layer thickness. The component then traces out the new programmed path geometry and a new layer is added onto the previous layer. Adjacent layers are fused into a continuous shape by localized melting and rapid re-solidification with the laser. The substrate is removed when the final part is constructed. Because multiple powder feeders are used during the process, the composition of the part can be changed from location to location by simply controlling the relative feed rates of the individual powder feeders.

Recent work has demonstrated this process is capable of producing components with complex shapes, graded layers of multiple materials for enhanced performance, and significant reduction in fabrication time. A wide range of alloys, cermets, and refractory metals can be deposited. In addition, the rapid solidification conditions associated with laser processing and use of powder filler metals can produce parts with uniform and refined microstructures for further property enhancements.

DuPont and his graduate students have demonstrated that the process can be used to fabricate high temperature alloys and components with multiple materials that were previously thought to be incompatible. As an example, they have produced a high temperature titanium-aluminide alloy that was fabricated with the LENS process. During fabrication, titanium carbide (TiC) particles were co-deposited along with the titanium aluminide alloy directly into the melt pool for enhanced strength and hardness. Tests conducted on this alloy showed that the hardness increased by a factor of two with the addition of the reinforcing particles.

Recent work has shown that the LENS process can also be used to fabricate parts containing dissimilar alloys. In a recent trial, a component was formed from iron and copper – two metals that are typically considered incompatible. With other fabrication processes such as casting and welding, the addition of copper onto steel would produce cracking at the interface due to the metallurgical incompatibility between the two elements. However, DuPont’s research has shown that LENS processing conditions can be identified to produce crack-free transitions between steel and copper. The localized deposition of copper onto tool steel is being considered in the tool and die industry in order to enhance the effective thermal conductivity of die materials.

DuPont adds, “Over the last two years, the Energy Research Center has acquired a LENS unit and is exploring the process for fabrication of a variety of components and multiple-material systems. We are interested in using this new technology to develop techniques to manufacture various parts for power generation applications. Candidate components include burner tips and turbine blades with graded coatings for improved corrosion and wear properties. Another intriguing possibility is the use of LENS technology to provide graded “dutchmen” for welding applications. These have carbon steel on one side and stainless steel on the other, with a gradual change in composition from one to the other. Such a dutchman could be used to join carbon steel and stainless steel tubes and would avoid the sharp change in properties across the weld joint which is responsible for dissimilar metal weld failures.”

“We plan to host a LENS workshop in the Fall to discuss application of this new technology for these and other applications. Details of the workshop will be posted at the ERC’s website www.lehigh.edu/~inenr/inenr.htm”