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FOR IMMEDIATE RELEASE

Detailed Study of Safety-Critical Component Demonstrates Superiority of Forged Steel over Competing Materials/Processes

Detroit, MI, June, 2005 – A study conducted at the University of Toledo, sponsored by the Bar Applications Group of American Iron and Steel Institute (AISI) and the Forging Industry Educational and Research Foundation (FIERF), demonstrated the superior fatigue properties of forged steel over aluminum and iron castings. The study focused specifically on safety-critical steering knuckles, and it explored forged versus competiting material and manufacturing processes technologies using experimental, numerical and analytical tools. It showed that forged steel was superior in terms of strength, durability, and cost. It demonstrated that optimization of steering knuckles can achieve weight and cost reductions of at least 12% and 5%, respectively with no performance degradation.

According to David Anderson, director of AISI's Bar and Rod Programs, "It is not unusual to find a range of different materials and manufacturing technologies employed within modern chassis systems components, many of which are considered critical to the safe operation of the vehicle.

"Engineers must deal with the issue of time-varying loadings of safety-critical components during a major portion of their service life," said Anderson, "and fatigue behavior is a key consideration. Engineers need to model and design for mechanical fatigue early in the product design stage.

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Anderson explained, "As emphasis on fuel economy, safety, and cost continue to grow, engineers turn to analytical approaches, as opposed to expensive and time-consuming experimental assessments, for optimization. One of the objectives of this study was to develop a general durability assessment methodology for safety-critical automotive components.

Scope of the Study

The University of Toledo research team selected vehicle steering knuckles of three materials/processes as the example parts for this study. These included a forged steel SAE Grade 11V37 steering knuckle weighing 2.4 kg from the rear suspension of a 4-cylinder sedan, a cast aluminum ASTM A356-T6 steering knuckle weighing 2.4 kg from the front suspension of a 6-cylinder minivan and a cast iron ASTM A536 Grade 65-45-12 steering knuckle weighing 4.7 kg from the front suspension of a 4-cylinder sedan. Figure 1 shows the three components.

For specimen testing, strain-controlled monotonic and fatigue tests were based on ASTM standard test methods and recommended practices. The data obtained made it possible to compare deformation response, fatigue performance, and failure mechanisms of the base materials and manufacturing processes, without introducing the effects and interaction of complex design parameters.

The analytical work consisted of finite element analysis (FEA), durability assessment and optimization analysis. Linear and nonlinear finite element analyses of the steering knuckles were conducted to obtain critical locations of, and stress and strain distributions of each component. A general life prediction methodology for the subject components was developed, where material monotonic and cyclic data and results of the FEA were used in life prediction methods applicable to safety-critical automotive components.

Professor Ali Fatemi and research assistant Mehrdad Zoroufi, Department of Mechanical, Industrial, and Manufacturing Engineering, University of Toledo conducted the study and prepared the report for the Forging Industry Educational and Research Foundation (FIERF) and AISI.

What follows is a succinct summary of study results and conclusions:

Concerning material fatigue behavior:

- Forged steel is considerably stronger and more ductile than cast aluminum and cast iron.
- Forged steel exhibits higher cyclic strength and higher resistance to plastic deformation.
- The S-N fatigue resistance of forged steel is significantly better than the two cast materials.
- With respect to low cyclic fatigue, forged steel is superior to cast aluminum or cast iron.

Concerning analysis:

- Linear elastic FEA is not sufficient for reliable fatigue life predictions.
- FEA simulation for cyclic loading is important for fatigue analysis.

Concerning component fatigue behavior:

- Crack growth life was found to be a significant portion of the cast aluminum steering knuckle fatigue life but insignificant for the forged steel steering knuckle.
- For the same stress amplitude level, the forged steel steering knuckle exhibits about two orders of magnitude longer life than the cast aluminum part.
- Failure locations in the component tests agreed with FEA predictions.

Concerning fatigue life predictions:

- The nominal stress approach cannot be used for complex component geometries.
- Local stress or strain approaches in conjunction with FEA results were found to provide better life predictions.
- Linear elastic FEA, when modified to correct for plastic deformation, is an effective and capable approach for life prediction of components with complex geometries and/or loadings.

Concerning Optimization:

- Material and manufacturing process considerations are major constituents of a general optimization procedure with durability constraints for automotive components.
- Steel material alternatives identified in the study provide higher fatigue strength.
- Added manufacturing operations such as surface hardening and surface rolling to induce compressive residual stress can improve fatigue strength of forged steel components in critical stress areas.
- Optimization of the steering knuckle can achieve weight and cost reductions of at least 12% and 5%, respectively with no performance degradation.
- The approach followed in the study is applicable to other safety-critical automotive components.

More detailed discussion of the above conclusions is available in the complete report available through the American Iron and Steel Institute.

Established in 1961, Forging Industry Educational and Research Foundation (FIERF) is a 501(c)(3) tax-exempt organization. Operating as a "supporting organization" to the Forging Industry Association, the Foundation's Goal is: "To enhance knowledge and application of forged products throughout industry, to offer to the forging industry a medium for pooling resources to attack forging industry problems and to improve products, methods and productivity." For more information, visit the FIERF website at www.forgings.org.

AISI serves as the voice of the North American steel industry in the public policy arena and advances the case for steel in the marketplace as the preferred material of choice. AISI also plays a lead role in the development and application of new steels and steelmaking technology. AISI is comprised of 32 member companies, including integrated and electric furnace steelmakers, and 118 associate and affiliate members who are suppliers to or customers of the steel industry. AISI's member companies represent approximately 75 percent of both U.S. and North American steel capacity. For more news about steel and its applications, view AISI's website at www.steel.org

Under the auspices of the American Iron and Steel Institute, the Bar and Rod Market Development Group strives to grow the market for value-added steel bar and rod products. With six member companies, the group pursues this goal through two task forces committed to developing innovative solutions to the challenges facing their clients and the steel industry. These task forces are Automotive/Heavy Equipment and Construction/Infrastructure. For more news or information, view the American Iron and Steel Institute/Automotive Applications Committee's website at www.autosteel.org.

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