Enhancing Safety of Industrial Tensile Testing Machines

Hazards are ever-present in the steel plant environment, and a heightened awareness and emphasis on safety is a necessary priority for our industry. This monthly column, coordinated by members of the AIST Safety & Health Technology Committee, focuses on procedures and practices to promote a safe working environment for everyone.

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Comments are welcome. If you have questions about this topic or other safety issues, please contact safetyfirst@aist.org. Please include your full name, company name, mailing address and email in all correspondence.

Don B. Daily Memorial Fund — To Promote Steel Industry Safety and Health

This article is the first in a series of Safety First articles featuring the reports from the recipients of the 2013 Don B. Daily Memorial Fund.

Identification of Problem

Improving the safety of employees at industrial production facilities is a continuous process. One area of potential hazard is the large-scale mechanical testing equipment found in many steel production facilities for in-house quality assurance. While modern large tensile testing machines are oriented horizontally, allowing for easy loading and positioning of samples, the high cost of a new machine (a quarter of a million dollars or more) means that many facilities continue to use older machines which orient the sample in a vertical position (Figure 1). Loading and positioning of large test samples, which can weigh more than 30 lbs. (14 kg), can cause strain on the operator and present pinch-point hazards if the operator must reach into the device to hold the sample in position while the hydraulic grips are being tightened.

A team of four undergraduate students from the Mechanical Engineering and Materials Science and Engineering Departments at the University of Alabama at Birmingham (UAB) worked with a faculty mentor and a local steel facility to design and build a device for use with the company's older, 600-kN tensile machine. The device is designed to mechanically extend the reach of the operator while keeping his or her hand outside the machine. Although the device was built to work with one specific tensile machine, the design is flexible enough so that it could be easily modified to fit other machines with similar risks.

Figure 1

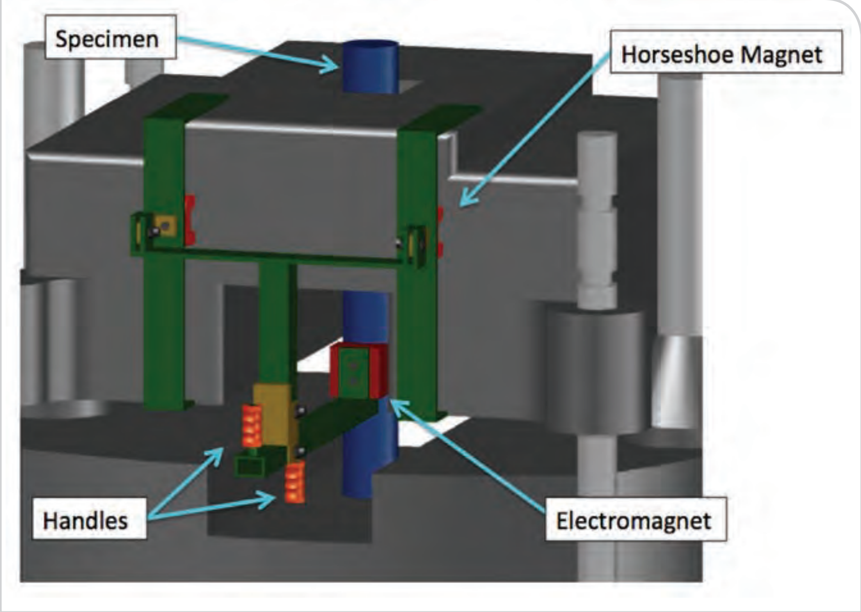
Vertical-style 600-kN tensile testing machine.

The Design Process

The design team began by visiting the facility to observe the tensile testing machine in operation and an employee's interaction with the machine. In order to meet industrial standards, the test bar must rest in the center of the grips. The team's objective was to design a device that would stabilize the sample during the loading while keeping the operator's hand and arm outside the machine. The team also spoke directly with the customer, whose design requirements included no permanent alteration to the tensile machine, and a device that was removable, did not take up unnecessary space, was not in the way of the operator, and added little or no additional time to the current operating procedure.

The team developed an idea for a device based on a long metal arm with a handle at one end that the operator can use to hold and manipulate the sample from a safe distance. Initially, a variety of mechanisms were considered for attaching the device to the test specimen, including different types of clamps or a permanent magnet; however, an electromagnet was ultimately selected because it gives the operator the ability to release the device from the specimen safely and without strain simply by terminating the magnet's power source. Hinges at the joints of the device allow movement so that the operator can position the specimen. In order to comply with the customer's requirement that no holes be drilled in the machine, permanent magnets were selected to mount the device to the machine. A CAD drawing of the final design is shown in Figure 2.

Figure 2



CAD rendering of finished device.

When determining the actual dimensions of the components, the primary considerations were safety and reliability, while minimizing weight, cost and complexity of the device. To minimize deflection and maximize ease of fabrication, the main arm of the device was designed using square tubing made from medium-carbon steel. The weight of the device was used to select appropriate magnets that would be strong enough to hold the device to the machine. An electromagnet was selected that could be easily mounted to the device and could make sufficient contact with the specimen's curved surface. To remove the device from the work area without having to completely remove the device from the machine, the hinges at the bottom and the top of the machine were designed so that the operator not only had control of the specimen, but the device could rotate and fold above the tensile machine. To aid in the ease of rotation, shoulder bolts were used at all hinge locations which allow the device to rotate freely. The maximum forces expected on the device were calculated using finite element analysis performed in SolidWorks SimulationXpress, and were found to be well within range for the selected materials. Two final modifications to the design were adding a safety chain to ensure that the device remained in the folded position and would not accidentally come down during operation, and placing a remote kill switch for the electromagnet's power source directly on the device to avoid having to plug in a cord.

Fabrication and Testing

The device was designed to be fabricated, assembled, repaired, and modified with tools and materials readily available at a steel facility. The majority of the steel required can be obtained in two pieces: a 4.0-square-inch (25.8 cm^2) piece of steel plate that is 0.25 inch (0.635 cm) thick, and a 36-inch (91.44 cm) piece of 1.5-square-inch (3.81 cm^2) tubing that is 0.25 inch (0.635 cm) thick. There was a critical need for the device to rest level on the machine so the magnet could make sufficient contact with the specimen. The cuts made for the parts were held to the highest tolerance while machining in order for the parts to be deemed usable. Appropriate bolts were selected based on calculated sheer forces, and holes were drilled in the steel to accommodate them. After the

Figure 3

Finished device in use: in active position (left) and storage position (right).

pieces were cut to size, arc welding was used to join them together. Finally, the device was assembled.

When the assembled device was initially presented to the customer and tested on the machine for the first time, an additional concern was raised. As a routine part of tensile testing, the test specimen breaks and releases a large amount of energy, causing the machine to jerk, which could result in the device being dislodged from the machine. This was addressed by creating C-mount attachments that can be added to the device, as shown in Figure 2. These C-mounts keep the device stable in the vertical direction. The mounts were created as separate attachments so that the design of the device can transfer to other machines by modifying only the sizing of the C-mount attachments.

The final device as-built can be seen in Figure 3. The device was polished to remove any sharp edges before it was painted green and gold, the school colors of UAB. The electromagnet located at the end of the arm is rated for 280 lbs. (127 kg). This was chosen by calculating the magnetic flux needed to hold the weight of the heaviest test specimen plus a 30% factor of safety. The arm is square tubing made out of A36 medium-carbon steel; the arm is 20 inches (51 cm) long with a cross-section of 1.5 x 1.5 inches (3.81 x 3.81 cm) and 0.25 inch (0.635 cm) thick. The arm of the device is calculated to deflect only 0.023 inch (0.058 cm) under maximum load, well within the design criteria.

These dimensions were also selected to maximize ease of fabrication of the device, usability and structural integrity at the joint locations throughout the device. The finished device weighs just over 24 lbs. (11 kg). The horseshoe magnets, which have a combined pull of 140 lbs. (63.5 kg), were selected to support the weight of the device plus the weight of the specimen with the same 30% factor of safety, and did prove to hold the device securely in place during testing. The added C-mounts are attached using the same set of bolts as the permanent magnets. The mounts are also made of A36 medium-carbon steel. Some of the material used to make the device was donated to the project, but the estimated cost of materials to create a similar device is around US$1,000.

Once fabrication was completed, the device was taken to the customer's facility for fitting. The customer appreciated the craftsmanship, ease of operation and simple design of the device, and was particularly impressed with the careful measurements and construction that produced a secure fit of the C-mounts. The finished product was delivered to the customer after completion of the design course for further field testing. Discussion with other steel facilities around the country is ongoing about locations where a similar device could be useful. A parts list and assembly directions for the device are available from the authors.

Conclusion

Improving the safety of workers in all aspects of the steel industry must be a continuous process. The device described here is one economical method to improve the safety and ease of use of older model vertical tensile test machines still commonly found in mechanical testing labs. The device stabilizes and supports large samples during the loading processes without exposing the operator to pinch-point hazards. It is hoped that the device will be adopted or adapted by other facilities and will encourage a culture of increased safety in metallurgical testing environments. ✦