Ergonomic Improvements Applied in a Steel Manufacturing Facility

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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In the United States, work-related musculoskeletal disorders (MSDs) such as lower back pain, shoulder pain and carpal tunnel syndromes are highly prevalent. Around 33% of all workplace injuries and illnesses that require days away from work are the result of MSDs.[6] Previous research has reported significant MSD issues among steel manufacturing workers, as the nature of their daily tasks often involves repetitive motions, awkward postures and forceful exertions.[1,5,7,14] Over the past three years, the authors have investigated occupational risk factors and ergonomic issues in the steel manufacturing industry and explored potential solutions and interventions that could be implemented to mediate MSD risks among steelworkers.[16,17] Previously, the design of ergonomic intervention has been successfully implemented in a number of industries such as agriculture,[10,11] construction,[12] fishing[15] and retail.[2] The authors believe such an approach could also be implemented in the steelmaking industry. The objectives of the current study were: (1) to study the ergonomic improvements/interventions that were made to reduce MSD risks among steelworkers at the observed steel plant; (2) to understand the working principles and the effectiveness of these improvements/interventions; and (3) to improve the understanding of the steelmaking industry and its safety and health challenges among college students.

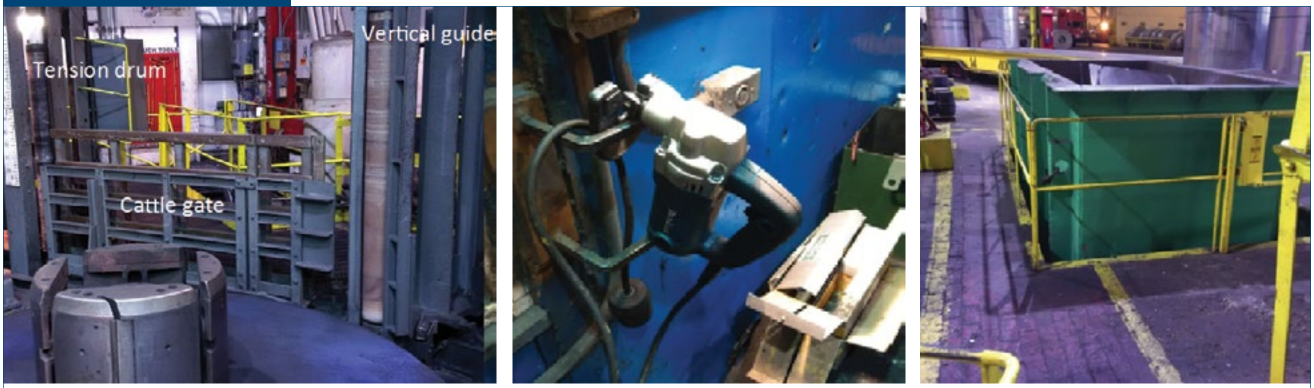
Ergonomic Improvements

Annealing — In the steelmaking industry, annealing is a heating process whereby a metal is heated to a specific temperature/color and then allowed to slowly cool down. This process softens the metal, allowing it to be cut and shaped more easily. In the annealing process, steel coils are heated to a high temperature for a specified period of time.

In the steel mill the authors visited, before implementing any ergonomic intervention, the operators of the annealing jobsite used to handle steel head and tail ends by hand. Their tasks often included unwrapping the steel coil (done by a mechanical structure), manually feeding the head end of the steel coil through a vertical guide, dragging and feeding the coil into the tension drum and wrapping the coil again (done by a mechanical structure). During this process, a worker had to lift a considerable amount of weight in order to pull the coil and carry the weight. Risks of this task include laceration (due to sharp steel coil edges) and musculoskeletal injuries (due to high loading and awkward body postures). In addition, when carrying the steel coil, in order to avoid the lower edge of metal touching the ground (which makes it difficult to pull), operators had to put the lower edge of the steel coil on top of their steel-toe boot to help carry the weight. This motion also elevates the risk of laceration and discomfort in their feet and legs.

By considering all the aforementioned hazards, a custom-made

Figure 1



(a) (b) (c)

A demonstration of the "Cattle Gate" intervention (a); a portable metal-cutting tool (b); and the lowered scrap bin (c).

safety device, nicknamed the "Cattle Gate," was made to better handle this issue. As shown in Fig. 1a, the Cattle Gate is a feeding device that automatically guides and feeds the head end of the steel coil into the tension drum. With the use of Cattle Gate, this unwrapping and wrapping process works automatically in a cassette-like fashion. After implementing this device, the only manual task that operators need to perform is leading the head end of the steel coil toward the vertical guide (Fig. 1a) (without holding the weight of the steel). Implementing such an intervention helped eliminate manual tasks in the process of annealing; and, therefore, diminished occupational injury risks such as laceration, contusion, burn (due to handling high-temperature steel coils) and amputation, as well as MSDs.[3] In addition to the Cattle Gate, to further reduce manual material handling and the associated musculoskeletal injury risks, safety professionals of this steel mill also implemented two jib cranes and an automatic cutting device (Fig. 1b). The last intervention that the safety professional made in this jobsite was to lower the height of the scrap bin by putting it in a ~3 foot deep pit (Fig. 1c). This intervention reduced the over-the-shoulder throwing activities that workers used to perform. By implementing all these changes, the injury rate at the annealing jobsite has dropped significantly.

In terms of productivity, the use of the Cattle Gate enhanced the automation of the production line, which increased its productivity. Moreover, before utilizing the Cattle Gate, this production site used to only produce single-wide steel coils (Fig. 2a) because of the weight-handling capacities of operators. By eliminating human operation in this process, now the company is able to produce double-wide steel coils as well (Fig. 2b).

Steel Sample Cutting — One of the authors' previous studies identified the steel sample-cutting task at the steel inspection area as one task that could potentially elevate the risk of MSDs in the trunk and upper extremities.[16] It was reported that, to perform this task, the worker has to use a large pushing force while maintaining an awkward trunk position (Figure 3a). Results of that study suggested that an effective cutting tool or method that requires a smaller amount of force exertion and an improved trunk posture should be implemented. One of the main goals of the current study was to find if any changes were made to improve this task at the steel mill. During the current visit, the authors found that the on-site safety professionals designed an ergonomic intervention to improve workers' trunk posture and to reduce the force exertion required for this task.[17] As shown in Fig. 3b, this new steel-cutting tool is attached to a mechanical extension with wheels on the ground that can carry the weight of the tool. This new tool allows workers to perform the task in a more neutral, upright standing posture and use less forward pushing force to operate. In order to cut a steel sample, the worker first needs to move the saw and align it with the edge of the steel

Figure 2

(a) (b)

A single-wide steel coil (a) and a double-wide steel coil (b).

coil. Then, the worker will lift the edge of the coil and place it above the surface of the cutting tool (~5 inches above the ground). Some workers use their foot to elevate the steel coil, while others use a suction cup handle to lift it. Then the sample could be cut by simply applying pushing force in a standing posture.

Compared to the traditional steel-cutting approach (i.e., without interventions) (Fig. 3a), using this intervention could help workers eliminate hand gripping and awkward trunk postures (i.e., trunk rotation). This walk-behind shear works similar to the proposed intervention in the previous study,[17] as they both allow for pushing with both hands in a standing posture. Also, in both interventions, the worker is not required to lift the cutting tool during sample cutting. Therefore, conclusions from the authors' previous study should also apply for this walk-behind shear (i.e., this intervention generates significant improvement in body posture and significant reduction in required force exertion).

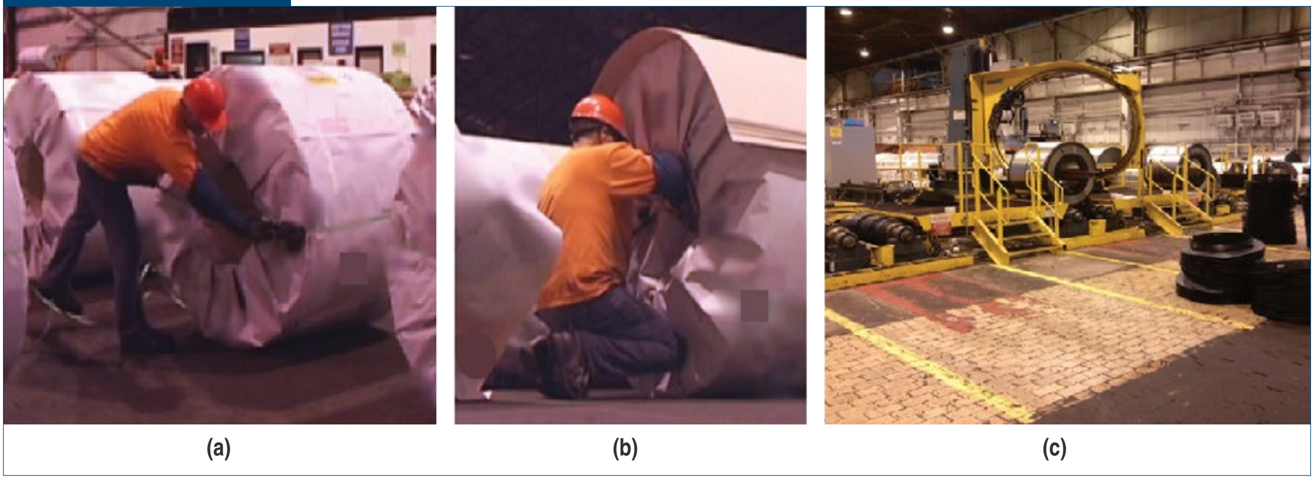
This new method does create one new concern: when feeding the steel coil to the cutting tool, workers may have to perform deep trunk bending and use a suction cup (Fig. 3c) to lift the steel coil; some workers try to avoid trunk bending by using their feet to hold the steel coil and feed it into the cutting tool. The on-site safety manager and the authors believe that there is a need to further improve this task, as repetitive deep trunk bending could elevate the risk of lower back injury and using a foot to hold the steel coil may create discomfort among lower extremities and increase the risk of laceration. A possible improvement could be to attach an extension handle to the suction cup lifter so this task could be performed in a standing position (Fig. 3c). In this situation, a worker can secure the suction cup lifter onto the steel coil, and lift the extension handle to place the edge of the steel coil over the cutting blade, all in a upright standing posture.

Coil Wrapping — After steel coils are made, according to the specific requirements of customers, coils need to be wrapped with paper or plastic wrapping materials. During the authors' previous visit, this task was performed with only manual labor and the coil-wrapping task was identified as one of the tasks that generates high risk of musculoskeletal injuries. This task requires workers to perform repetitive trunk flexion, side bending and rotation (Figs. 4a and 4b). All of these trunk postures and the associated lumbar muscle fatigue are linked to a higher risk of lower back problems.[13,17] In the authors' previous study, they proposed introducing a hydraulic lift to raise the height of the steel coil, therefore creating more neutral trunk postures.[17] Results of the previous investigation showed that, by increasing the height of the steel coil, significantly smaller back muscle activities were recorded and trunk flexion and side bending angles were significantly reduced.

Figure 3

An example of the traditional approach of cutting steel samples (a), the ergonomic intervention implemented for this task (b) and the potential change for the suction cup (c).

Figure 4



A demonstration of workers' body postures while wrapping steel coils (a and b) and the newly implemented automatic coil-wrapping machine (c).

During the current visit, it was found that an automatic steel coil-wrapping machine was used to replace manual labor. Named the coil master wrapping machine (Fig. 4c), this equipment is able to wrap the steel coils with various wrapping materials in a completely automatic manner. Its work process is as follows: a tractor first brings a steel coil and sets it on top of the loading deck. A worker then attaches the selected wrapping film onto the coil and walks off the platform. The operator of the coil master wrapping machine then presses the start button to initiate the process. The machine has a track to carry a film-dispensing shuttle through the eye of the coil, while the coil is slowly rotated on its axis on a set of rollers. This machine can wrap several sizes of coil, and the speed of the film-dispensing shuttle can reach up to 4.2 m/second. According to the authors' interview with the on-site safety professional, the overall productivities between using the machine versus manual labor are similar, but using this machine eliminates all risks of musculoskeletal injuries. Partially due to the high cost of this machine, about 50% of the steel coils are still being wrapped manually. In the future, this number could decrease further.

Discussion and Conclusion

Ergonomic interventions including the redesign of tools, tasks and work methods have been applied in numerous industries to improve the safety and health of workers. The current study investigated the ergonomic improvements that safety professionals made to the steelmaking industry. The current study investigated several jobsites in a steel mill, and several ergonomic improvements were made in the annealing jobsite. The use of the Cattle Gate and jib cranes eliminated some of the most problematic material handling tasks that workers had to perform. The use of powered cutting tools and a lowered scrap bin reduced the physical demand of the related tasks. These changes are typical examples of removing the hazard from its source. For the steel sample-cutting task, the main MSD concerns were awkward trunk postures and high-force exertions. To resolve these issues, safety professionals applied ergonomically redesigned tools and a combined new work method to reduce the risk exposure. These changes used similar principles as suggested by a previous laboratory study;[17] and they also follow the principle of controlling the hazard at its path. Finally, for the coil-wrapping task, the use of the automatic wrapping machine eliminated the manual wrapping tasks; therefore, it is a typical example of dealing the hazard from its source by removing the hazard from the work space.

The design and application of ergonomic interventions often involves capital investment; depending on the nature of the tasks and the complexity of the interventions, the investment can range from hundreds to millions of dollars. In the current study, the redesigned steel-cutting hand tool involves only a small cost; however, the cost of the coil-wrapping machine is between one half to a million USD. It needs to be recognized that there is not a strong association between the cost of the intervention and its effectiveness. The safety professionals in this particular steel mill have made significant and continuous efforts to improve the safety and health conditions of the steelworkers. The numerous improvements they have made over the years have significantly reduced the injury rate of the plant. This study also demonstrated that ergonomic principles and interventions can be effectively used to reduce occupational injuries among steel manufacturing workers.

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