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When the bubble bursts

The problem of pesky hydrogen bubbles in steel becomes particularly acute when the products are steel rails according to NRC physical chemist Stirling Whiteway. Dr. Whiteway, of the Council's Atlantic Research Laboratory (ARL) in Halifax, has been looking into the problem for Nova Scotia's Sydney Steel Company (SYSCO). Hydrogen, the smallest of the elements, sneaks into the molten metal in its atomic form, usually from water vapor, and is capable of moving through the spaces between the iron atoms (picture stacks of bowling balls, and a ping pong ball moving through the spaces between the large balls). As the steel cools and hardens, its ability to hold hydrogen in these spaces decreases. When two atoms meet in larger holes caused by grain boundaries and other defects, the tendency for them to rejoin to form a hydrogen molecule (H_2) is great. As other hydrogen molecules gather in the pocket, a micro bubble forms, exerting pressures of 100 atmospheres or more. The stress imposed can exceed the strength of the steel, which literally starts to zip open, forming a small crack. If a steel rail containing such a crack is placed in service, the additional stress of heavy car loads or cold weather operation can spell disaster. Obviously, then, it is important to remove the hydrogen before the steel cools.

"As early as 1931, rail makers in Sydney had developed strategies for getting the hydrogen out by simply allowing finished rails to sit at high temperatures after the steel had been rolled," says Whiteway. "Given enough time, the hydrogen diffuses out. But this process was at the end of the rail production line and by 1975 it was becoming increasingly inconvenient and expensive to carry out."

SYSCO proposed instead that the hydrogen be baked out at the "bloom" stage, when the steel is still in a massive form about 25 x 40 x 600 cm. This strategy depended upon the ability to keep the temperature high enough in the stockpiled blooms for a sufficient period of time to allow the hydrogen to diffuse out. Because it had to be proved to the railway companies, a project guided by Dr. Whiteway was undertaken to obtain the necessary data.

"That's where ARL's research into the diffusion of gases helped," explains Whiteway. "In our laboratory research, we measured the diffusion coefficient of hydrogen for different compositions of rail steel, information that is crucial for predicting how fast hydrogen will move out of the steel. For more information we brought in Prof. R. Hay of the École Polytechnique in Montreal, an expert in acoustic emission monitoring for the detection of flaws in metals. Hay was able to adapt the method to actually detect the formation of tiny microcracks, the process of metal unzipping due to the pressure of the hydrogen molecules."

In the end, Sydney Steel was convinced of the value of the new process, and, more important, the product customers, the railway companies, were also convinced. □

Sadiq Hasnain

At NRC's Atlantic Research Laboratory in Halifax, Stirling Whiteway (left) and Joe Uher have apparatus for measuring the diffusion coefficient of hydrogen in steel. *(Walter Crosby, ARL)*

Stirling Whiteway (à gauche) et Joe Uher, du Laboratoire de recherches de l'Atlantique du CNRC, à Halifax, mesurent le coefficient de diffusion de l'hydrogène dans l'acier. *(Walter Crosby, LRA)*