Hot mill manufacturers are required to accurately identify bars, billets, blooms, slabs and other hot products both for mill record-keeping purposes and for their customers. They are also required to mark these products with certain identification markings. These markings provide an “identity” for the product, thus enabling the manufacturer and the end-user to look up the manufacturing origin and history of the product in a database.

Technology is now available that enables bar code identification to be created “on-site and on demand” and to be automatically and permanently attached to these hot products by the use of special tags. These tags can be marked with text, graphic images and bar codes. The addition of this tag identification further enables the use of downstream bar code reading systems to automatically scan the bar code for automatic identification of the product at key manufacturing nodes, and also enables the ability to automatically update the database with manufacturing process results at these nodes.

This paper discusses the evolution of tag identification, and also discusses the equipment to automatically create and attach bar code tags to hot mill products.

History

Manual hot product marking is a hot and hazardous operation. A worker in an aluminized heat protection suit typically walks along a gang of hot billets or slabs and applies hand-marked identification using a high-temperature crayon, a high-temperature stencil board with spray paint, or a combination of both. Human errors occur often, and the potential for burn injuries and high-temperature ailments such as heat stroke is present. In the 1970s, hot mills started using a new type of identification — high-temperature tags. In the beginning, these tags consisted of a steel strip backing, coated with a high-temperature white coating. These tags were preprinted off-site with black text markings using a specialized ribbon-type printer — typically with a man-readable sequential identification number accompanied by other known non-changing fields such as a plant location. These tags could be manually attached to the hot product using a nail gun. When the tag was applied, the mill had to “capture” the pre-printed tag sequential ID number and merge it in a database with the balance of all the prior manufacturing history for the product. This was awkward, but doable, and it was better than hand marking.

Later, as ribbon printers became more sophisticated, ribbon-printed bar code sequential ID tags became possible. The tag could now be read by a handheld scanner.

In the 1990s, a new breed of tag and marking technology was developed. These tags consisted of a stainless steel strip backing, coated with a high-temperature-resistant, laser-markable white coating. The tag is printed using a scanned CO₂ laser beam to quickly create a tag “on-site and on demand.” Much like an office laser printer, laser tag printers can print any combination of text, graphics and bar codes in high resolution.

The advent of automated “on-site and on demand” tag printing for hot mill products eliminates the requirement to manually merge a preprinted ID number with the product database. The mill computer can now download tag data to the tag marker to dynamically create the tag on demand, dynamically create a suitable product ID number on demand, and dynamically fill in critical manufacturing data on the tag for each product in real time as it arrives at the...
Tagging station,. The laser marker can also use the downloaded data to automatically compose an ID bar code suitable for downstream automatic scanning.

**Tag Variations**

The factory “raw material” from which all tags are made is called the “tag stock.” A large (typically 1,500–3,600 m) roll of 0.20-mm-thick stainless steel backing strip (75-mm and 100-mm standard widths) is uncoiled and cleaned by multiple baths, dried, coated with white laser-markable high-temperature coating and then oven-cured to bake the coating onto the surface. Depending on the final type of tag desired, additional processes may also be performed to achieve, for example, bare edges or perforations. This large roll of processed material is then further processed into smaller rolls or boxes of individual tags suitable for distribution to users.

Tags can be supplied to users in several different ways:

- Continuous tag stock supplied in a standard roll (90-m roll weighing 18 kg).
- “Nick-and-notch” tag stock supplied in a roll (typically 90-m roll weighing 18 kg). This can vary by tag size.
- Individual tags supplied in a box (varies by tag size and type, but for example, a box of 250 preformed slab tabs weighs about 18 kg).

Tag types fall into these basic categories:

- Plain tags — usually these are nick-and-notch tags (see explanation following).
- Bare edge tags (tags with one or two bare edges for welding purposes).
- Preform edge tags (tags with one or more reinforced ends for welding purposes).
- Perforated tags (tags with holes or slots) — usually these tags are nick-and-notch tags.

**Plain Tags** — Plain tags are usually nick-and-notch tags, are supplied in a continuous roll and are intended for manual usage. At regular intervals along the tag length, a “nick” line is pressed into the tag. At both ends of the “nick” line (at the edges of the tag), a “notch” is provided as an optic sensor trigger so that the laser tag printer can sense the individual tag length.

Plain tags are typically applied by a method not requiring special tag features for attachment. For example, a nail gun can be used to simply nail through the tag in order to attach it to a billet. The tag layout can even include a “Nail Here” graphic bulls-eye to guide workers so they don’t nail through the bar code or other critical data.
A worker uses a local laser tag printer to print a tag, and the printed tag advances out the side of the laser printer. The worker can then simply bend the tag at the nick line to break the tag off for application.

**Bare Edge Tags** — Bare edge tags are usually supplied in a continuous roll. For manual attachment, the tag material will be nick-and-notch material. For automatic attachment, the tag material will be sheared and therefore will not include nick-and-notch.

Bare edge tags are typically attached to hot steel by MIG welding, either manually or automatically. The bare edge provides an excellent conductive surface to strike the initial MIG weld arc. The weld bead then melts through the tag and forms a weld puddle that bonds the tag securely to the product surface. Bare edge tags are usually used for smaller hot mill products such as bars, billets and blooms.

For billet tags, the tag size is usually 32 x 100 mm with one or two bare edges for one or two welds (approximately 2,880 tags per roll of tag stock).

If product end face size permits, the tag size may increase to 50 x 100 mm with one or two bare edges (approximately 1,800 tags per roll of tag stock). Custom tag sizes are possible.

A second bare edge and weld provides the advantage of an additional, redundant weld attachment, but also has the disadvantage that it decreases the white marking width and therefore also decreases the maximum possible length of bar code (and the maximum possible data content in the bar code as well).

**Preform Tags** — Preform tags are supplied as individual tags shipped in a box — typically 250 tags to a box for slab tags. These tags are usually loaded into a magazine-type feeder in an automatic tagging machine.

Preform edge tags are also typically attached to hot steel by MIG welding, either manually or automatically.

The preform is a 1.5-mm-thick x 19-mm-wide steel strip with weld holes that is spot-welded to the tag ends. Holes are provided in the preform for welding sockets. The preform provides a good conductive surface to strike the initial MIG weld arc, as well as providing the hole or “socket” into which the weld puddle can fill for better bond. Preform tags are used for larger hot mill products such as...
slabs. For slab tags, the tag size is usually 75 x 350 mm with two preforms at the ends of the tag. The laser-markable area of the tag is 75 x 313 mm. Custom tag sizes are available. Two welds (one center weld per end) or four welds (two corner welds per end) are possible. More welds are used when additional redundancy of attachment is desired.

Perforated Tags — Perforated tags are usually supplied in a continuous roll and are intended for manual usage. These tags are punched with additional holes or slots for various purposes. For example, holes may be provided to rivet a tag onto a part, or wire a tag onto a bundle. Slots may be provided to slide a tag onto the eye band of a coil. It is possible to provide tags that include special break-off coupons with duplicate data for archival record keeping. Examples of perforated plain tags are shown in Figure 3.

Manual Attachment Methods
Manually applied tags are typically printed by a small laser tag printer. Desktop units and floor-standing units are available.

Attachment methods for manually applied tags include high-temperature adhesive, nails, welded studs and MIG-weld attachment. Also, as discussed previously, perforated tags can be attached to hot products by nail or welded stud, to bundled products by wire, or to banded products by band attachment.

High-temperature Adhesives — High-temperature adhesives are usually silicone-adhesive based, and therefore are limited to mill products that have cooled down to well below 150°C (300°F). A puddle of adhesive is applied to the back of the tag, and the tag is simply pressed onto the face of the product. Many users find this simple method to be inexpensive and
effective for in-plant tracking of relatively cool product.

**Nail Guns** — Nail guns using either pneumatic or powder-charged actuation can be used to nail tags onto hot products immediately after casting, as well as ambient products, and temperatures in between. In many applications, a tag holder fixture is provided to set on the hot product to hold the tag in position while it is nailed.

**Stud Welding Guns** — Stud welding guns can be used to spot-weld a stud and tag to a hot product. The stud is loaded into the gun, a perforated tag is threaded over the stud, and then the stud is pressed against and welded to the product. A large-diameter head on the stud retains the tag.

**MIG Welding Guns** — MIG welding guns are used to weld a tag to a hot product. Bare edge or preform tags are usually used with MIG welding. In many applications, a tag holder fixture is provided to set on the hot product to hold the tag in position while it is welded.

The obvious advantages of welding and nailing attachment methods over adhesive methods are:

- Welding or nailing attachment typically works at product temperatures ranging from ambient to approximately 1,000°C (1,832°F).
- The welded/nailed tag survives extreme environmental conditions such as rain, snow and ice (especially on hot product).
- The welded/nailed tag survives long-term outdoor storage.
- The welded/nailed tag survives extreme transport conditions, such as exposed truck, ocean and rail freight shipment.

**Automatic Tag Attachment Methods**

For automatically applied tags, the preferred attachment methods are MIG welding attachment and nail attachment. MIG welding is the preferred attachment method for carbon and low-alloy steels. High-alloy steels, including stainless steels with poor welding characteristics, require nail attachment.

**Automatic Tag Welding** — A typical automatic tag welding machine is positioned to attach a tag to the end of a billet or slab. The position of the product is well-defined; for example, a billet is usually end-indexed, and it is positioned in a walking beam V or against a side stop. Obviously, if the tag is applied at a fixed end stop, a “window” must be cut in the stop to allow tagging access to the end of the product.

The mill computer typically downloads the message data to the tag machine as a number of fields — pieces of data such as “Heat” and “Cut,” etc. — separated by commas in the download string. The tag printer then properly inserts those data pieces into the tag format (the data table that defines how the tag will be printed). The tag format is typically resident in the tag machine and not downloaded, although a downloaded tag format is possible. The tag format defines the X/Y location of each piece of data on the tag, such as the font size/width/pitch and rotation, etc. The tag printer can also be set up to use a data piece (or to string together data pieces) to generate a bar code. The tag format defines the type of bar code symbology, the X/Y location of the bar code, as well as the scale and height. Also, graphical images (for example, a company logo) may be present in the tag format, located by X/Y position and scale. The download and data formatting of the tag takes less than a second to accomplish.

The tag is then printed by the “tag prep” section of the machine. For a 50-watt CO2 laser marking system, a print time of approximately 0.4 seconds/cm² of marking area is typical. After printing, tag material is advanced to a shear position, the tag is gripped by a vacuum platen, and the tag is then sheared off.

The tag prep vacuum platen transfers the tag to a “tag applicator” section of the machine, where the tag is handed off to the applicator vacuum platen. The applicator platen extends by air cylinder to firmly press the tag against the front surface of the hot product. The MIG weld nozzle(s) shrouds the weld area in a protective inert gas (typically argon) and applies one or more weld puddles, each typically about 12 mm in diameter. The tag is now securely attached to the product. The applicator retracts. An optional bar code scanner can be used immediately after tagging to verify tag application and readability, if desired. The tagged product can now be removed from the marking station, and the tagging process repeats for each product piece arriving at the tagging station.

**Automatic Tag Nailing** — A typical automatic tag nailing machine is positioned to attach a tag to the end of a billet or slab with the same basic product position requirements as described above for welding. The tag data is downloaded and the tag is printed, sheared and transferred to the tag applicator section of the machine, in the same fashion as described above for welding.

For nailed application, the applicator platen extends by air cylinder to firmly press the tag
against the front surface of the hot product, and instead of a weld, a nail is pneumatically driven through the tag to secure the tag to the hot steel. The tag is now securely attached to the product. The applicator retracts. An optional bar code scanner can be used immediately after tagging to verify tag application and readability, if desired. The now-identified product can then be removed from the marking station, and the process repeats for each product arriving at the tagging station.

**Pitfalls**
The tags discussed herein are an excellent way to apply bar codes to hot mill products, but it is necessary to evaluate the downstream manufacturing processes that the tag and bar code must survive. Following is a partial list of potential hot mill pitfalls:

1. Tags will not survive bumping slabs or billets. If roller conveyor systems are not maintained, and the conveyor operator must “bump” slabs or billets to maintain product motion, then end tags will be physically damaged beyond readability.
2. Tags will not survive shot blast.
3. Tags will not survive scarfing.
4. In most cases, tags will not survive reheat.
5. In some cases, tag remnants may partially survive reheat when it is desired that the tag completely disintegrate.

In item 1, proper conveyor maintenance must be maintained, or product bumping will cause any end-of-product tag identification system to fail. In this case, the tag can possibly be side-mounted on the product — again, if the downstream processes permit.

In items 2–5, consider reading the bar code at the entrance to the damaging process, tracking the product through the process, and then reapplying an echo tag with duplicate data at process exit. Some users have had success applying a protective cover to tags during damaging processes and then removing the protective cover at exit. This must be evaluated on an individual basis.

**Bar Codes**
The challenges related to successful bar code implementation in hot mills are:

- How to select and use a suitable code symbology and content.
- How to apply a tag and bar code that will survive and remain readable throughout the process.
- How to “find” the bar code at the downstream reading station.

The user must be knowledgeable about bar code suitability and limitations. Many users initially assume that they can insert “unlimited” text and numerical data into a bar code. This is true only if there is enough room on a tag for a very large code. Code 39 and Code

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**Figure 7**

View of an extended automatic slab tag applicator mechanism (heat shields removed).
128 symbologies both provide the ability to encode text and numerical data, but if text is encoded within the shorter Code 128, then the bar code length grows very quickly. If the resulting bar code is scaled down so that it will fit into a 100-mm-wide tag, the code resolution (space and bar width) becomes so fine that the code is unreadable in a practical sense in a mill environment.

It is generally recommended that the user implement the Code 128 symbology, encoding a maximum of 12 digits (numbers only). This will allow the tag printer to print a robust bar code in a large scale with relatively wide bars and spaces, thus guaranteeing readability downstream. Code 39 is generally not recommended for hot mill use. Reading technology has improved to the point where two-dimensional codes, such as Data Matrix™ (a trademark of RVSJ) codes, can be used to one’s advantage by encoding a larger quantity of data in a smaller area, but the readers for this code may require shorter focal distances than for one-dimensional codes.

Providing that (a) the pitfalls discussed are avoided and (b) the code symbology and content are correctly selected and implemented, then the potential for tag and bar code survival for downstream reading is very good. However, “finding” the bar code in industrial environments is yet another challenge.

Assuming a robust, one-dimensional bar code such as Code 128 will be used, in cases where the product and the code will always remain horizontal (typical for slabs), a video-based bar code scanning system can be used with good results. The primary requirement of a video-based system is that at least one video scan line must pass through all bars of the bar code in order to capture a good read. Therefore the bar code must be oriented horizontally (called “picket fence” orientation) in the video camera’s field of view. The advantage of a video-based system is that, with adequate code lighting and a proper lens, such a system can read a bar code from a very long distance away, say up to 15 m. Thus, the video camera can be located remotely from severe environments. Also, high-speed video scan rates are very adept at capturing codes on moving products. Additionally, when a long focal length lens is used, ample depth of field (DOF) is established; thus, the “in-focus” focal distance from code to camera has a large readable range. For example, a structural shape manufacturer in Spain is using video bar code scanning technology to successfully read bar codes on dog-bone shapes moving directly toward the camera mounted over the reheat entry conveyor.

When there is potential for the bar code tag to arrive at a reading station at any angle (typical for tags attached to the ends of square billets that may be set on any one of four sides, as shown in Figure 4 for example), then a different bar code scanning approach is required. In this case, multiple oscillating line scan bar code scanning systems can be networked together and mounted in such a way to scan a “cross” or “star” pattern at a known pass-through location, thus enabling bar code reading of tags arriving in the viewing area at any angle. This type of scanner setup can successfully read codes up to about 2 m away. These scanners also have auto-focus capability and considerable depth of field range. For example, a billet manufacturer in Mexico is using this method to successfully read billets that are crane-loaded onto a sloped in-feed table to be pushed laterally into the reheat entry conveyor.

Summary

The technology to attach bar code identification tags to continuously cast hot products is routinely used today. An automatic tagging system receives downloaded data from the mill computer, laser-prints a specially coated stainless steel tag, and attaches the tag to the just-cast hot product, typically by welding or nailing. The printed tag can contain man-readable information, graphic images such as company logos, and bar codes. The tag is designed to withstand cool-down of the product in storage. Downstream bar code readers can capture the identification of the product from the tag at various manufacturing nodes. This technology enables real-time automatic identification and tracking of hot mill products where none was available before.

Did you find this article to be of significant relevance to the advancement of steel technology? If so, please consider nominating it for the AIST Hunt-Kelly Outstanding Paper Award at www.aist.org/huntkelly.

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