METALLURGICAL FEATURES OF SHEET INGOT CAST BY THE AIRSLIP™ AIR-CASTING PROCESS

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The drive for superior quality rolling ingot that eliminates the need for scalping and edge trimming has brought about the application of the AirSlip™ air-casting process to the production of sheet ingot. Most of the early work has centered on AA5052 alloy, but AA5182 and AA3004 have also been cast. AA5052 alloy cast in the 12 x 37 inch size is characterized by a very smooth surface and a minimal segregation zone.

Introduction

The AirSlip air-casting process was first introduced in 1983 (1). A variant of hot-top casting, the AirSlip process employs a permeable graphite insert through which gas and lubricant are passed (2). This creates an insulating barrier between molten metal and the mold wall which severely retards primary cooling. The gas barrier also serves to minimize contact between the newly formed ingot shell and the mold wall. The resultant metallurgical structure featues a very smooth surface, minimal subsurface segregation, and a fine grain structure.

The AirSlip process has been expanded to include a wide range of sizes and alloys for billet production (3,4). Hard alloys are also produced commercially with this process. As of September 1986, there were 138 MaxiCast™ hot-top systems operating world-wide. Of these, 48 were equipped with the AirSlip air-casting process.

Sheet Ingot Casting

6 x 15 Inch

Sheet ingot casting first began in 1983. The first size employed was 6 x 15 inch. This size incorporated full-radius ends and was a natural outgrowth of the initial work done with 6" diameter rounds. Preliminary casts were made with alloy AA6063. Later, alloys AA5182 and AA3004 were produced in this size.

Metallurgical examinations of the cast structures were most encouraging. It was found that these ingots had similar characteristics to AirSlip billet. AA5182 alloy surfaces were very smooth and uniform. Subsurface segregation extended .010" deep or less, and the grain structure was fine and equiaxed.

6 x 6 Inch

Concomitant with the 6 x 15 inch work, development began on 6 x 6 inch square bar. This entailed the first deployment of small radius corners. Alloys cast included AA6063, AA5182, AA5056, AA6201, and AA1350.

12 x 37 Inch

Casting of this size began in October 1985 using alloy AA5182. The short-mold feature of AirSlip technology required special consideration for successful start-up practices to be developed. Bottom block design, metal distribution, and water flow control were all found to be important. Initial casting was done with a 1,500 pound induction furnace, Wagstaff's largest at the time. This severely limited the maximum cast length obtainable.

In December 1985, Wagstaff Engineering commissioned its new facility for casting research and development (Figure 1). This facility contains an integrated casting complex for maximum flexibility. A 20,000 pound furnace and a 5,000 pound furnace service the large casting pit. A second pit is served by either of two smaller induction furnaces or the 5,000 pound reverberatory furnace. In-line metal treatment to the large pit is accomplished with a MINT® I degassing unit and a SELEE® ceramic foam filter (5).

Metallurgical Features

Surface

The dramatic difference between ingot cast by the AirSlip process and conventionally poured DC ingot is the surface texture. AA5052 alloy ingot cast by the AirSlip process has a very smooth skin. It is free from exuded eutectic material characteristic of DC ingot. Contrast the surface of 12 x 37 inch AirSlip cast AA5052 with DC cast surfaces (Figure 2).

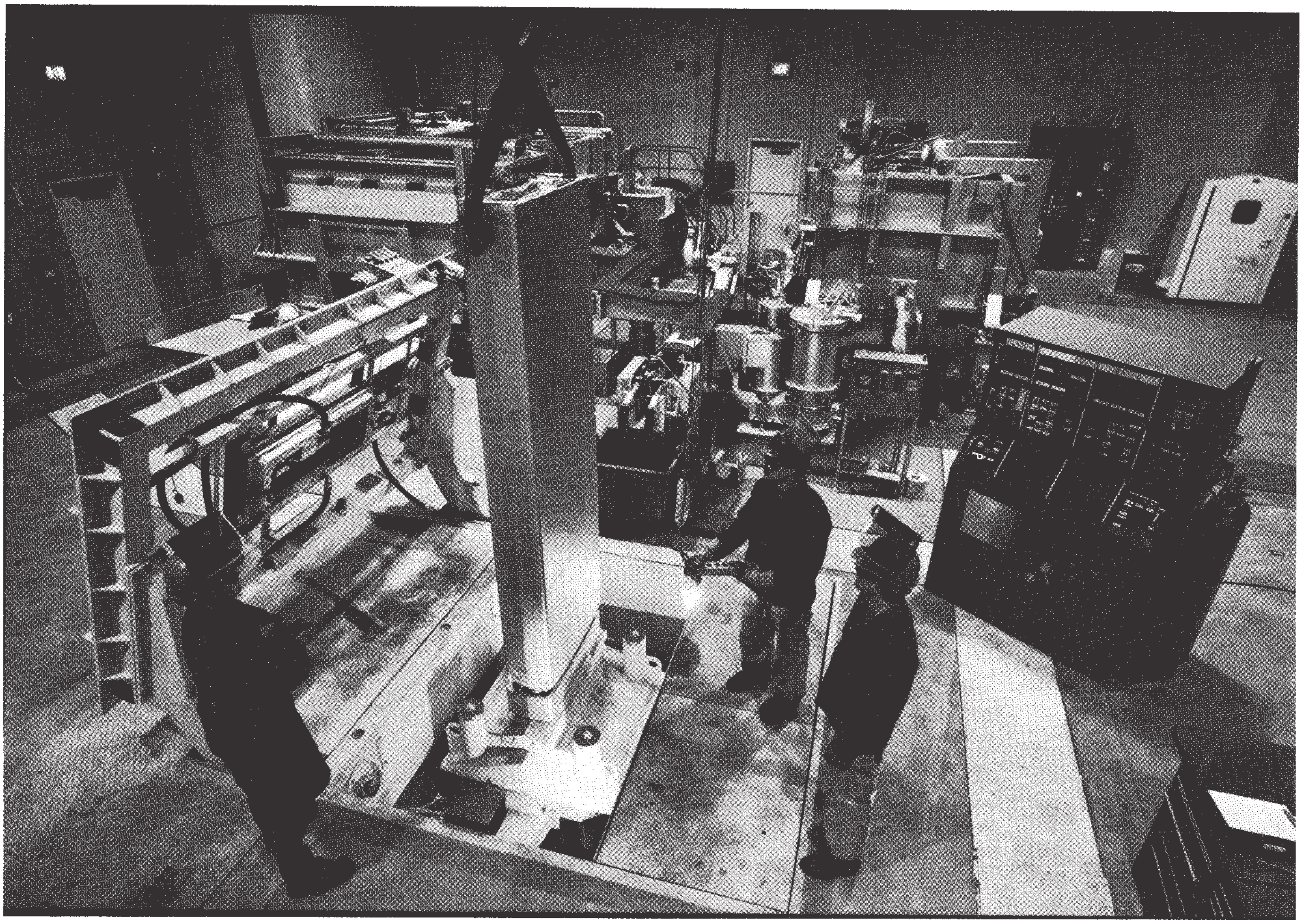

Figure 1 - New casting laboratory at Wagstaff Engineering, Spokane, Washington

Alloy AA5182 surfaces (Figure 3) are similar to those obtained with AirSlip cast AA5052. Due to the higher magnesium content of AA5182, this alloy has been more difficult to produce satisfactorily. If not controlled, oxide generation in the mold cavity can release onto the cast surface. The mark in Figure 3(b) is from lifting tongs.

Alloy AA3004 produces a markedly different AirSlip surface than the 5XXX series alloys. AA3004 has a fine, interwoven network of exuded material superimposed on the primary ingot shell (Figure 4). The amount of exuded material can be lessened by further reduction of primary cooling through both mold design and process variables.

Peripheral Segregation

Peripheral segregation for each of the three alloys varied depending on mold design, casting parameters, and sample location.

Liquation depths on the middle of the rolling faces of 12 x 37 inch AirSlip ingot varied from .007" to .014" for AA5052 alloy. Although variations were found between different ingots, uniformity within a given sample was excellent. Contrast this with the non-uniform segregation zone on a 13 x 54 inch DC cast ingot (Figure 5).

Alloy AA5182 had a deeper segregated zone than AA5052. On the middle of the rolling face, this measured from .020" to .024". However, intra-sample uniformity was excellent. Sub-surface segregation on the ingot ends was only .010" (Figure 6). This suggests that peripheral segregation on the rolling face could be further reduced through improved mold design and process control.

A depth of .014" of enriched material was typically observed on AA3004 surfaces. Where no exuded material was present on the surface, perpheral segregation measured a mere .0012" (Figure 7). This is in contrast to the 5XXX series where the liquated zone is continuous rather than in the form of a network.

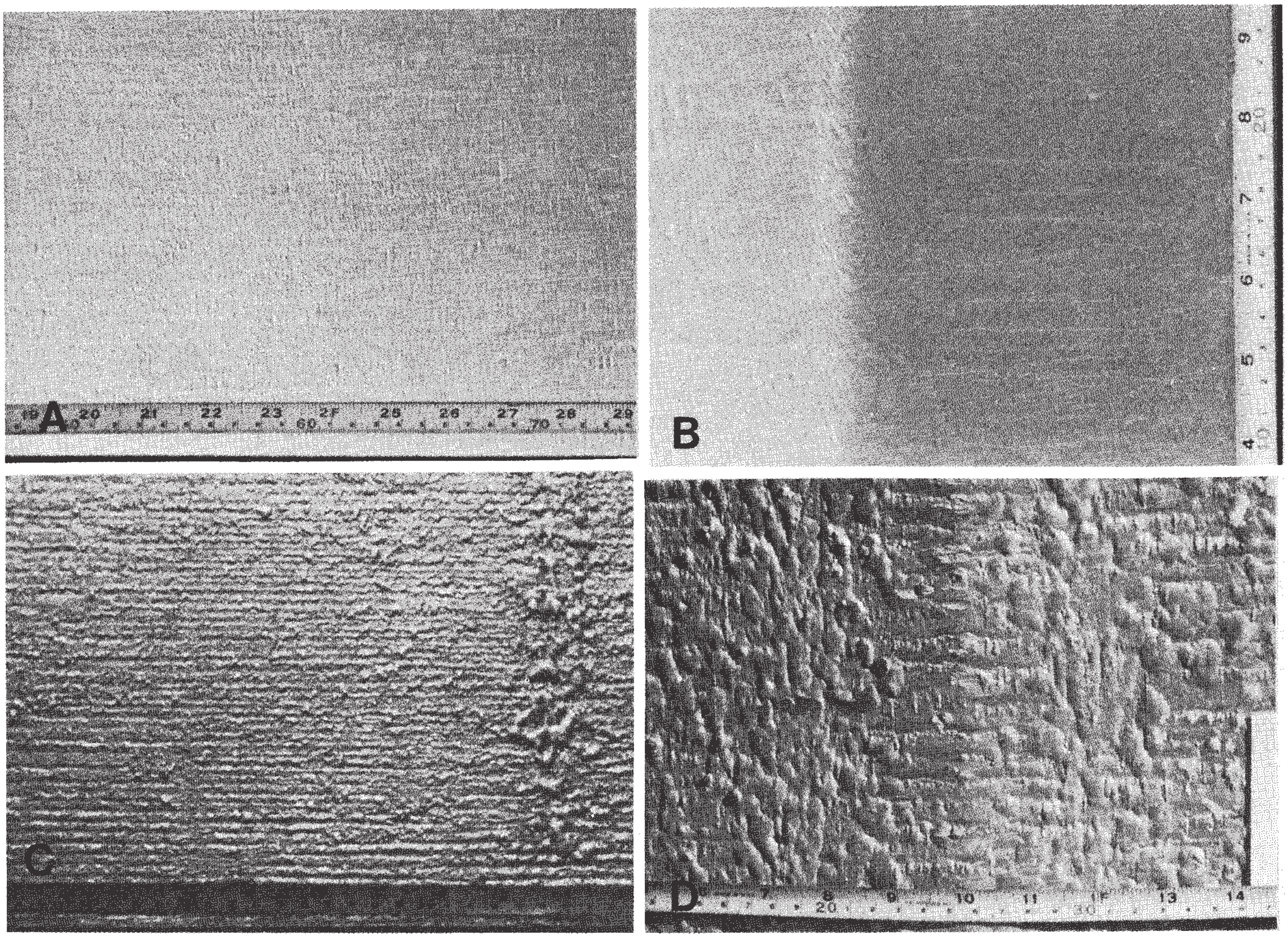

Figure 2 - As-cast surfaces of AA5052 alloy sheet ingot: a) 12 x 37" AirSlip rolling face b) 12 x 37" AirSlip ingot edge, c) 13 x 54" DC rolling face, d) 20 x 60" DC ingot edge.

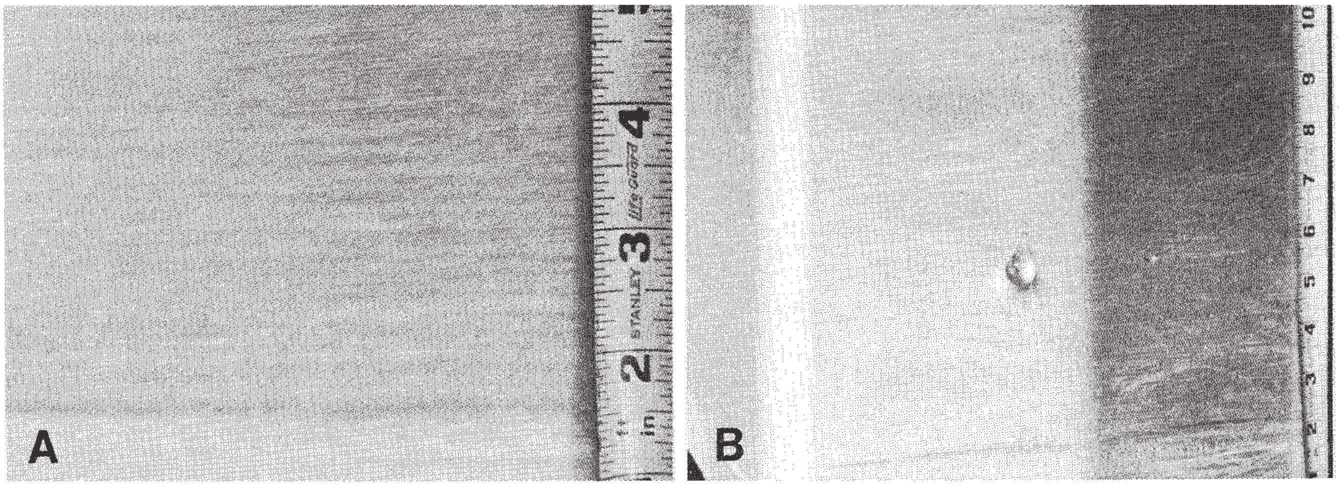

Figure 3 - As-cast surfaces of AA5182 alloy, 12 x 37" AirSlip sheet ingot: a) rolling face, b) ingot edge.

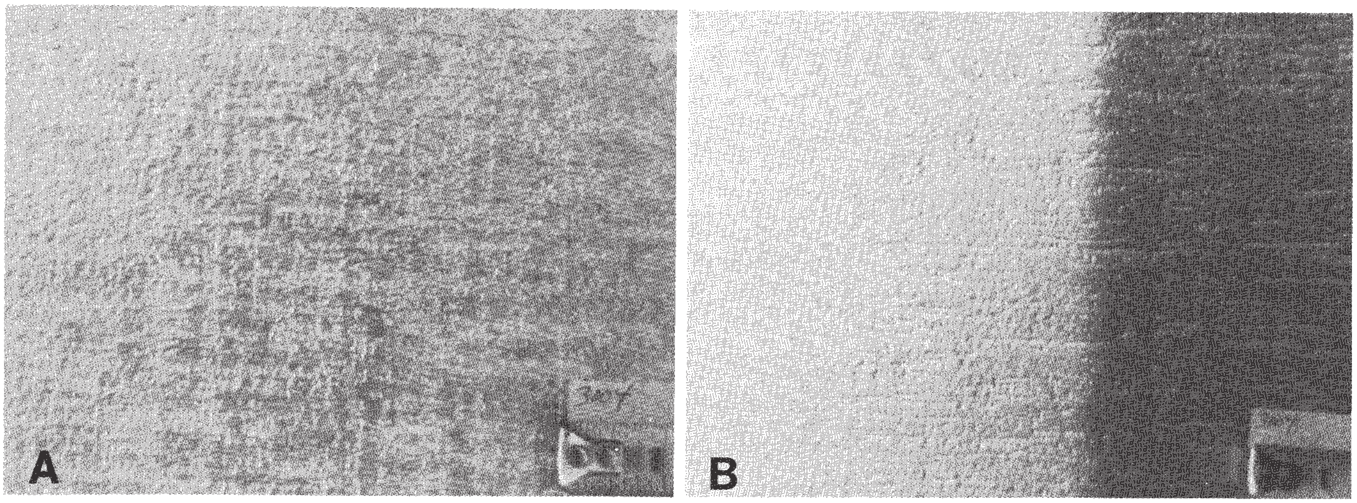

Figure 4 - As-cast surfaces of AA3004 alloy, 12 x 37" AirSlip sheet ingot: a) rolling face, b) ingot edge.

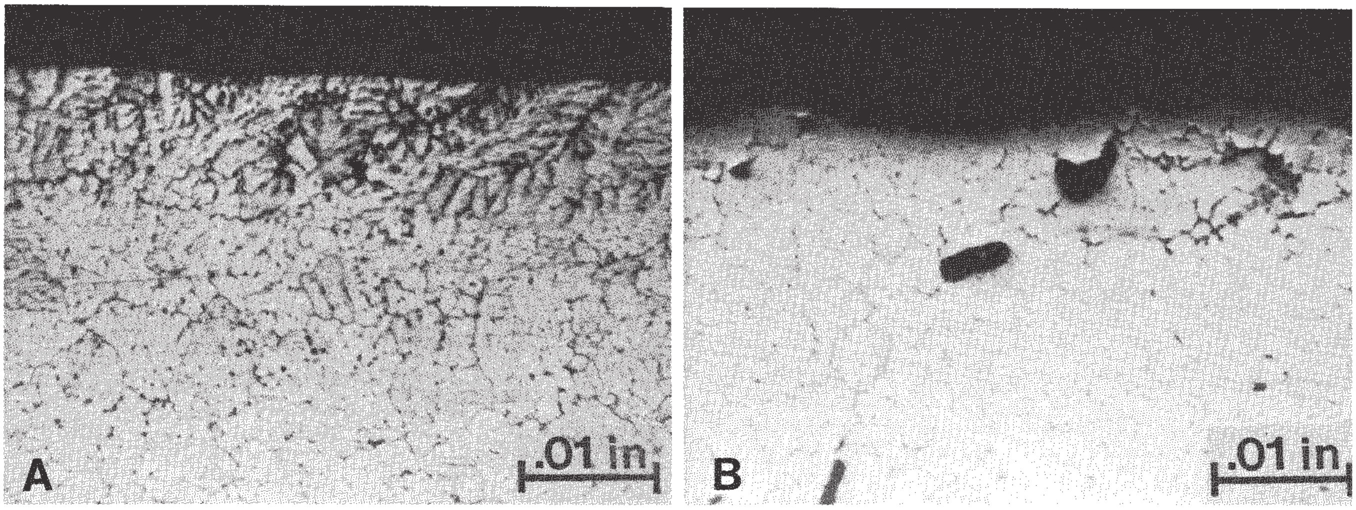

Figure 5 - Peripheral segregation on rolling face of AA5052 alloy sheet ingot: a) 12 x 37" AirSlip, b) 13 x 54" DC.

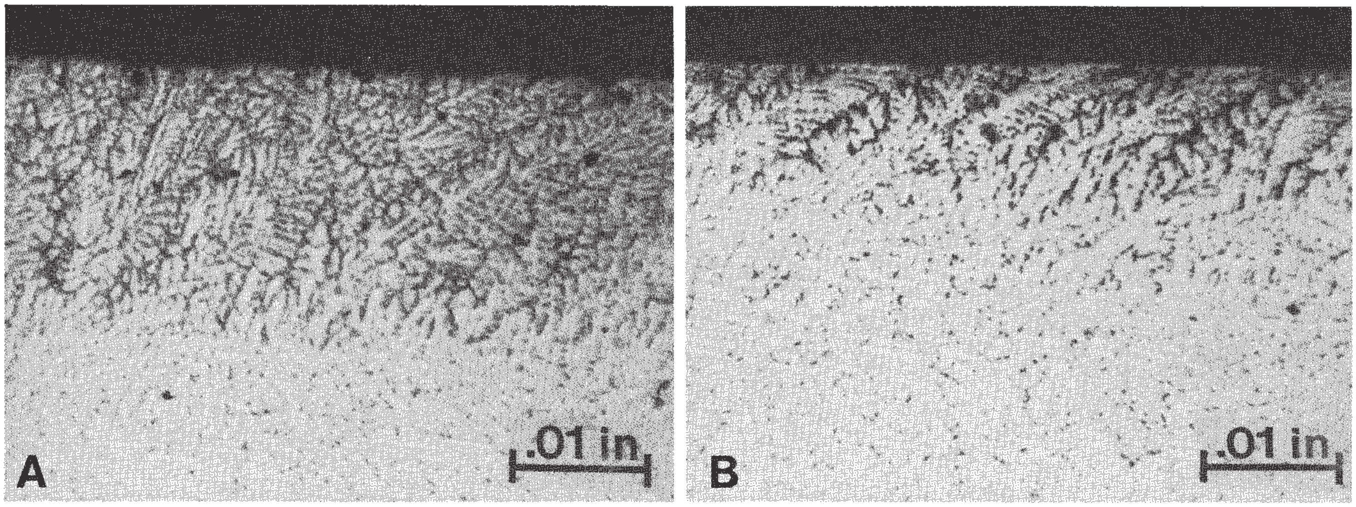

Figure 6 - Peripheral segregation on AA5182 alloy, 12 x 37" AirSlip sheet ingot: a) rolling face, b) ingot edge.

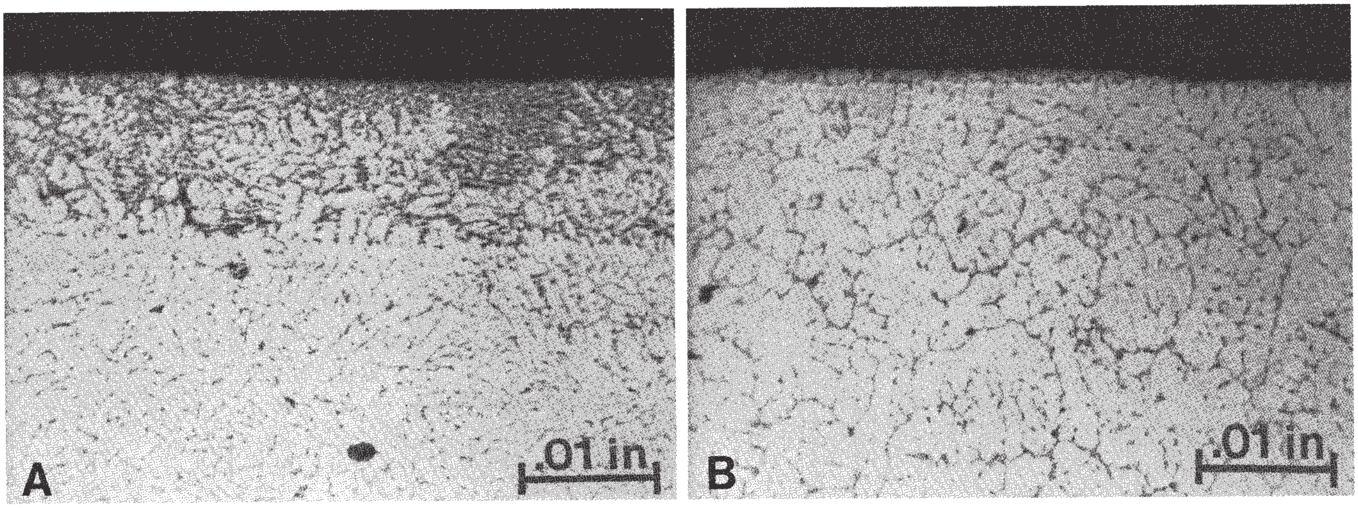

Figure 7 - Peripheral segregation on AA3004 alloy, 12 x 37" AirSlip sheet ingot rolling face a) with surface exudations, b) without surface exudations.

Solidification profiles for 12 x 37 inch AirSlip AA3004 and 6 x 15 inch AirSlip AA5182 are shown in Figure 8. Differences in profiles are attributable to differences in composition, mold geometry, metal distribution, and process parameters. Common to both is the noticeable absence of an initial steep slope near the surface associated with primary (or mold) cooling.

Virtually all the cooling occurs by direct water impingement at the mold exit (secondary cooling). The zinc sump pictured in Figure 8(a) has been enhanced for contrast.

Internal Structure

Figure No. 9 compares the grain structure of 12 x 37 inch AirSlip AA5052 with 13 x 54 inch DC. The DC mold is 8% thicker than the AirSlip mold which contributes to the coarser structure of the DC cast ingot. Differences in ingot width can be ignored since the samples were taken from the centers of each ingot where the solidfication profiles are flat in the long-transverse direction.

Figure No. 10 shows photomicrographs of the centers of 12 x 37 inch AirSlip ingot, alloys AA5182 and AA3004. As of this writing, insufficient data exists to make a thorough comparison between AirSlip ingot and DC ingot from a microstructural standpoint.

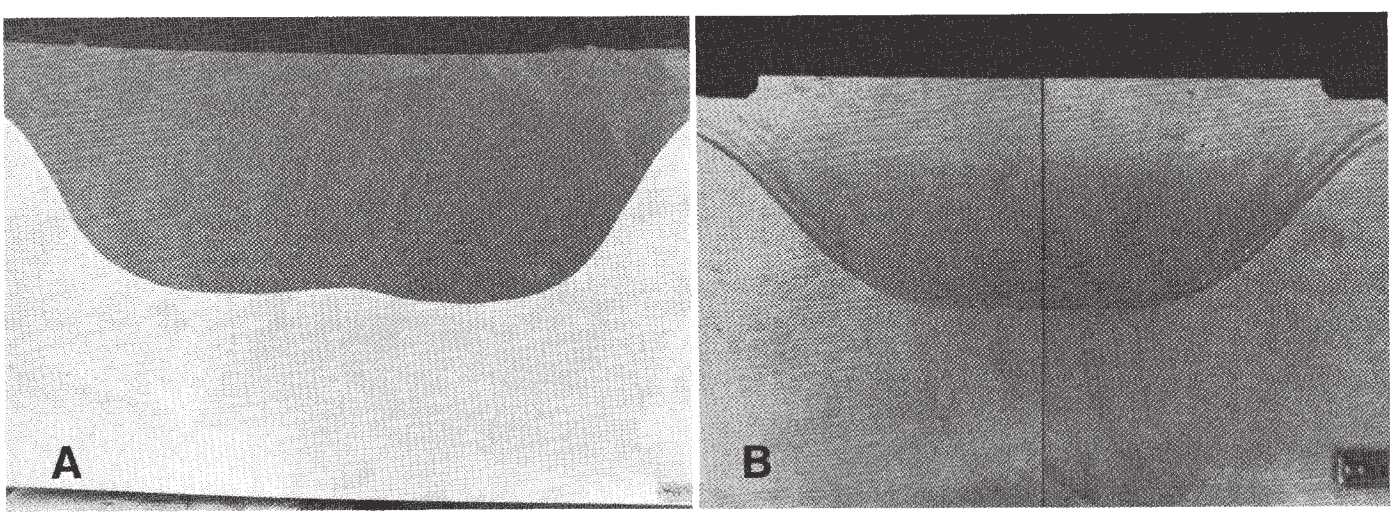

Figure 8 - Solidification profiles of AirSlip sheet ingot: a) 12 x 37", AA3004 alloy, b) 6 x 15", AA5182 alloy.

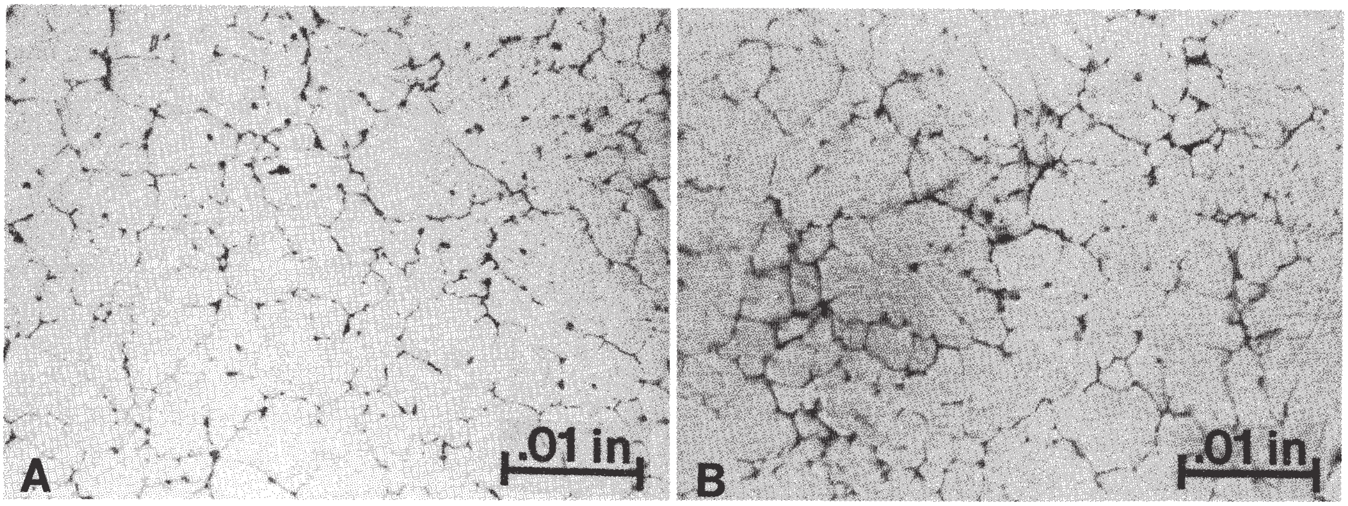

Figure 9 - Internal structure of as-cast AA5052 alloy sheet ingot: a) 12 x 37" AirSlip ingot center, b) 13 x 54" DC ingot center.

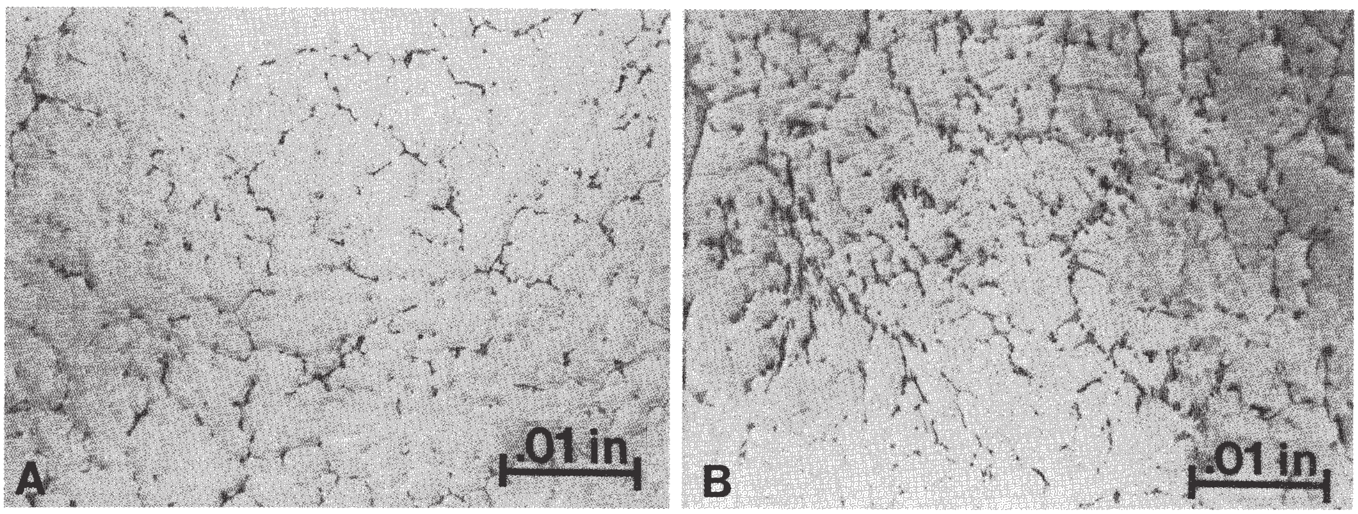

Figure 10 - Internal structure of as-cast 12 x 37" AirSlip sheet ingot: a) alloy AA5182, b) alloy AA3004.

Conclusion

The following points can be made relative to AirSlip sheet ingot state-of-the-art:

1. The AirSlip air-casting process produces sheet ingot with smooth, uniform surfaces on alloys AA5052 and AA5182.

2. AirSlip surfaces on alloy AA3004 are more textured than on 5XXX series alloys.

3. Peripheral segregation lies between .007" and .024", and is a function of composition, casting parameters, and mold design. Alloy AA5182 exhibits the most peripheral segregation.

4. Segregated zones on AA5052 and AA5182 are smooth and continuous.

5. The segregated zone on AA3004 consists of a fine network of material exuded through the primary ingot shell.

6. The surface and sub-surface of AirSlip cast ingot is structurally superior to DC cast ingot.

References

1. "New AirSlip™ Air-Casting Process", Light Metal Age, October 1983, 41.

2. John P. Faunce, Frank E. Wagstaff, Howard Shaw, "New Casting Method for Improving Billet Quality," Light Metals 1984, 1145-1158.

3. J. Martin Ekenes, Frank E. Wagstaff, "Expanding Capabilities of the AirSlip™ Air-Casting Process," Light Metal Age, April 1985, 16-17.

4. John P. Faunce, Alex Valdo, "The AirSlip Casting Mold - An Established Technology," Light Metals 1985, 1317-1330.

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