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June 2, 1983

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MACHINEABILITY COMPARISON FOR AISI 4137 M/700 PARTS

In a letter dated February 25, you asked us to look for differences between several samples of AISI 4137 (modified) alloy steel with a sulfur content specified at between 0.06 and 1.0%.

While the samples with poor machining properties (Heats 8075064 and 8086110) tended to be somewhat harder (average RB 92 versus 87), this was not considered significant. Grain size, specified as "coarse grain" in the specification was found to be about the same for all samples. The two different receivers (good machining) had the same grain size of ASTM 6-7.

As you know, coarse grained material machines somewhat better than fine grained material. Generally, coarse grain size is considered ASTM size 1-5 while the fine grain size is 6-10. The above numbers indicate that most of the material on the orders in question were fine grained. Some improvement in machineability could be obtained by requiring a grain size larger than ASTM 5. In addition to grain size, there is some question about the texture of the pearlite. All other things being equal, a coarse textured pearlite has significantly easier machining characteristics than finely laminated pearlite. Our micrographs indicate that the typical pearlite in the samples you sent was quite fine.

As you noted in your letter, the sulfur content in those steels difficult to machine was low and, in fact, did not meet your specification. Photo micrographs show that the typical good machining steels had uniformily distributed elongated stringers of manganese sulfides, while poor machining types had little or no sulfide stringers to help break metal chips. The attached photomicrographs are typical. Normally, to help the higher sulfur be even more effective in improving machineability, the manganese analysis would be 1.35 to 1.65%. However, in alloy steels such as AISI 4137, the sulfur addition is added in the molten metal ladle and no manganese adjustment is made since it requires major melting practice changes. As a rule with no added manganese, only a limited amount of manganese sulfide stringers is formed. In the low alloy steels like the AISI 4137, large amounts of manganese, while improving machineability, also have the adverse effect of leaving a very rough, torn surface. As a result, the practice is to leave the manganese as it is in the regular grade of 4137 and resulfurize moderately.

Tramp elements enter into the picture; generally, toughening the metal and making it somewhat more difficult to machine. Your analysis shows that trace elements (nickel and copper) were higher in the Canton steel (which had poor machineability) and quite low in the samples taken from the receivers. The Republic steel mill at Buffalo was essentially a carbon steel mill and only made special alloy steels such as your resulfurized 4137 infrequently on special order. The scrap used in this plant was, for the most part, carbon steel so there was little recycled alloy steel and little build up of tramp elements. The Canton mill is exclusively alloy steel so the recycled scrap is also alloy. The result is that tramp elements are high. On the other hand, the Chicago mill is a combination plant with moderate alloy recycling and only modest accumulation of tramp elements.

We have talked at length with Mr. Everett Shields of Republic Steel Company. He has been most helpful in suggesting various ways to not only insure good machineability but also to improve it. I suggest that you contact him and discuss this problem and possibly this letter with him. The ultimate goal would be to develop a specification which would assure a uniform (and hopefully improved) machineability with little or no price increase.

To recap our findings:

- Grain size tended toward fine rather than coarse. A check on the aluminum content (should be less than 0.01%) will indicate if the material is aluminum killed, resulting in a fine grain size.
- Seventy-five percent pearlite is OK, especially if you can get a larger grain size. The coarse pearlite will likely follow.

- Sulfur content should be toward the high end of your specification (0.06/0.10% sulfur).

- Minimize tramp elements by selecting the mill which provides the "cleanest" melting practice.

Some producers of improved machining bar, especially low alloy bars, are now treating with calcium in the ladle. The result is to spherodize certain nonmetallic impurities such as sulfides, aluminates, and other mixed oxides and produce a bar stock material which gives less tool wear and, at the same, increases machineability as much as 40%. Usually this calcium treatment provides machining savings in excess of its cost. Republic Steel calls their calcium material IMP. You may wish to discuss this with Mr. Shields of Republic when you talk with him.

Please call me if I can be of further service.

ENGINEERING SERVICE DIVISION

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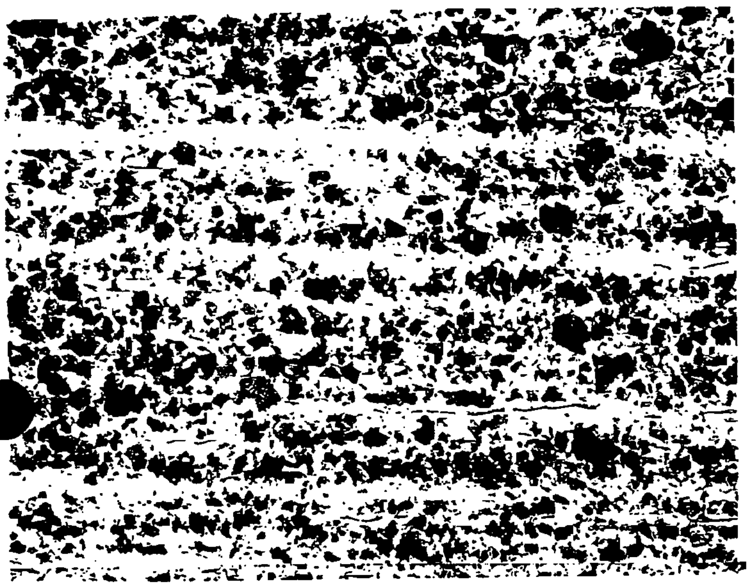
BARBER - PRESALE R 0113906

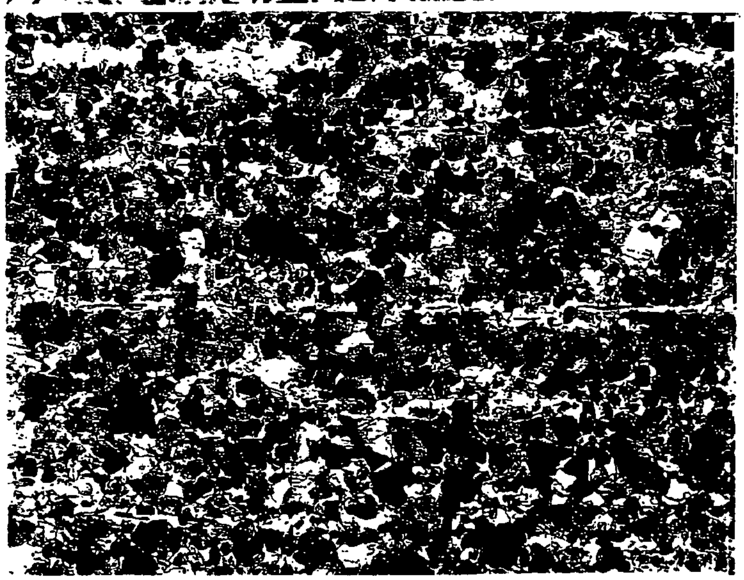
Sample from Canton, Ohio mill
While there are a few stringers of manganese suflide visible, there are not enough to provide good machineability. Structure is pearlite and ferrite. The structure is banded, often found in hot-rolled bar.

100X



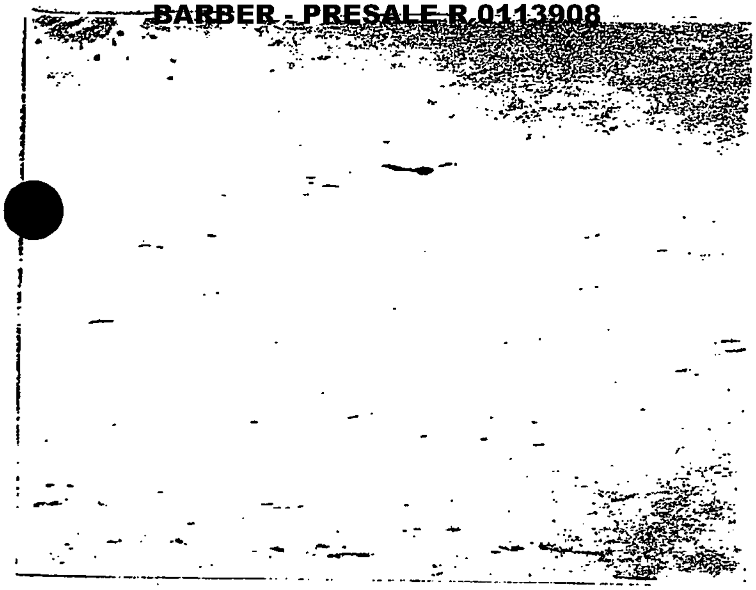
Sample from Republic's Buffalo mill. Structure is banded ferrite and pearlite but contains significant amounts of manganese sulfide for ease of machining.

100X



Same comments as above apply, except that materials are from Republic's Chicago mill.

100X



A photomicrograph typical of heats from Canton, Ohio. Note that the sulfide stringers used to promote easier machining are not as numerous or large as those in heats from other mills. See photos below. AISI 4137 (modified). This material judged to be of poor machineability.

100X

Sulfide distribution and size in this heat from the Buffalo mill is typical of structure giving good machineability. Size and shape distribution are typical for free-machining AISI 4137 (modified). This heat judged to be satisfactory for machining.

100X

Photomicrograph of a heat of AISI 4137 (modified) from the Chicago mill of Republic Steel. Similar to sample above.

100X