

NEW HIGH PERFORMANCE P/M ALLOY SUBSTITUTES FOR MALLEABLE AND DUCTILE CAST IRONS

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Abstract – Ferrous P/M alloys generally do not exhibit a good combination of strength, ductility, and impact toughness. A series of new P/M alloy systems has been developed to match the performance characteristics of malleable and ductile cast irons. The new materials maintain excellent tensile ductility at high strength levels while possessing good impact resistance. The performance characteristics and benefits of the new P/M materials will be presented.

KEYWORDS: FERROUS P/M, ALLOYS

I. INTRODUCTION

Gray, malleable, and ductile cast irons are used widely in automotive applications. Gray irons have moderate strength and ductility and P/M copper steels have comparable properties. However, malleable and ductile cast irons have significantly higher mechanical properties compared with gray cast iron, their strength/ductility values depend on whether the cast irons are in the ferritic, pearlitic, or martensitic condition ; ultimate tensile strengths range from 650 to 1000 MPa, yield strengths from 500 to 700 MPa, and elongation values from 2 to 4%.

Ferrous P/M materials, generally, are unable to match the combination of strength and ductility of these higher performance cast irons. Hanejko has shown that while a warm compacted FLN4-4405 material sintered at 1260 °C meets the ultimate strength of a heat treated malleable cast iron (900 MPa), and almost meets the yield strength (690 MPa), it falls short of the 4% elongation of the cast iron [1,2]. When sintered at 1120 °C, the FLN4-4405 material exceeds the strength of the pearlitic malleable iron but has much less ductility (2.5% compared with 8%).

The material development program reviewed in the present paper was aimed at meeting the performance characteristics of malleable and ductile irons without the need for warm compaction. Warm compaction processing of the materials covered in the present paper will result in higher densities and hence increased mechanical properties compared with those reported here. The performance of three new commercial products, marketed under the Ancorloy tradename, will be compared with a number of selected high performance ferrous P/M alloys. These powders are the first in the Ancorloy MD series of binder-treated press-ready premixes.

II. EXPERIMENTAL PROCEDURE

Press-ready, binder-treated premixes were made with 0.75 w/o additions of an ethylenebis-stearamide wax (Acrawax C). The as-sintered materials had the nominal compositions listed in Table 1.

Table 1: Nominal Compositions of the Materials (w/o)

Material	Fe	Si	Cr	Mn	Ni	Mo	C
MDA	Bal.	0.7	0.06	0.17	0.05	0.03	0.85
MDB	Bal.	0.7	0.03	0.13	2.0	0.85	0.55
MDC	Bal.	0.7	0.03	0.13	4.0	0.85	0.55
MDD	Bal.	0.7	0.03	0.13	2.0	0.85	0.25

Tensile and room temperature unnotched Charpy impact properties of the materials were evaluated for samples compacted at 415, 550, and 690 MPa. Materials MDA, MDB, and MDD were tested in the as-sintered condition whereas material MDC was tested after tempering at 190 °C for one hour. Sintering was carried out at 1260 °C in a laboratory Hayes pusher furnace for 30 minutes at temperature in a 75 v/o hydrogen : 25 v/o nitrogen atmosphere.

The as-sintered, and sintered and tempered tensile properties were based on flat, unmachined (dog-bone) specimens conforming to ASTM E 8 (MPIF Std. 10). Tensile testing was performed on a Tinius Olsen machine at a crosshead speed of 0.6 mm/min. Data from an extensometer attached to the specimens permitted automated readouts of the 0.2% offset yield strength, ultimate tensile strength, and percentage elongation values.

Impact testing was performed at ambient temperature (approximately 20 °C) using standard unnotched Charpy specimens in accordance with ASTM E 23 (MPIF Std. 40).

The reported values for tensile and impact properties were, in all cases, based on a minimum of three measurements and, in most cases, five measurements per condition.

The ultimate tensile strength and yield strength of materials MDA, MDB, and MDD are compared in Figure 1a, their tensile elongation in Figure 1b, and apparent hardness in Figure 1c. Material MDD has better tensile strength than material MDA while exhibiting higher tensile ductility. Material MDB has even higher tensile strength but does so at the expense of some ductility.

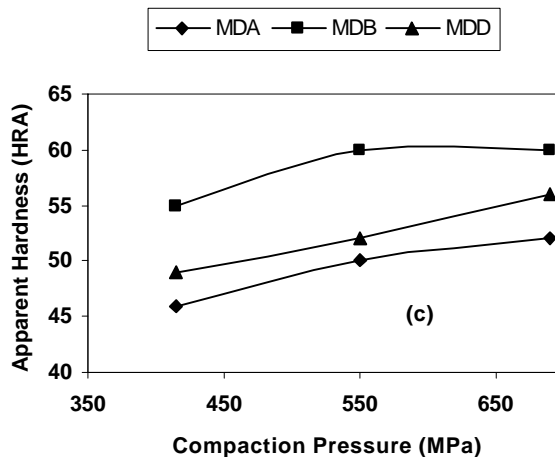
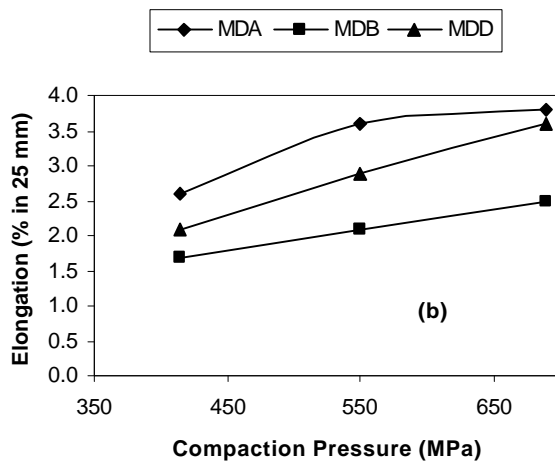
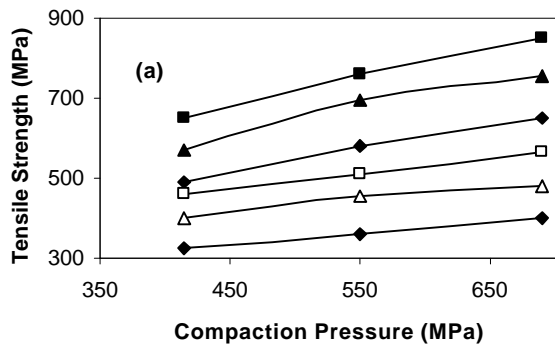
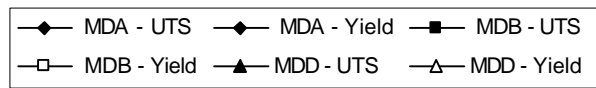


Fig.1 – Ultimate tensile strength, yield strength, and apparent hardness vs. compaction pressure for materials MDA, MDB, and MDD.

However, the combination of tensile strength and tensile ductility for each of the materials in their own right is noteworthy. Material MDA has better ductility for a given

strength than some copper steels currently used to replace the higher end gray iron cast irons and material MDD extends the range further into the realm of ductile and malleable irons.

In order to establish a frame of reference for the new MDB and MDC alloys, their tensile and impact properties were compared with those of selected high performance ferrous P/M alloys [3,4,5,6]. The materials selected for comparison with materials MDB and MDC were:

1. Ancorloy 4 + 0.6 w/o graphite – sintered at 1120 °C (ref. 3),
2. Ancorloy HP-1 + 0.6 w/o graphite – sintered at 1120 °C (ref. 4),
3. Distaloy HP-1 with 0.5 w/o combined carbon – sintered at 1250 °C (ref. 5), and
4. FLN4-4405 and FLN6-4405 – sintered at 1315 °C (ref. 6).

The ultimate tensile strengths of the various materials are compared in Figure 2a. Material MDC matched the tensile strength of Distaloy HP-1 and FLN6-4405. The diffusion-alloyed material is a hybrid alloy based on a 1.5 w/o prealloyed steel to which 4 w/o nickel and 2 w/o copper have been partially alloyed. The FLN6-4405 material is a hybrid alloy based on a 0.85 w/o molybdenum prealloyed steel to which 6 w/o nickel has been admixed. Material MDC is less highly alloyed than these two materials that exhibited comparable strength.

Material MDB matched the tensile strength of Ancorloy 4, FLN4-4405, and fell just short of matching the strength of Ancorloy HP-1. Each of these materials is more highly alloyed than material MDB.

The only material that reached the yield strength achieved by material MDC was the hybrid alloy FLN6-4405 as illustrated in Figure 2b. The high temperature sintered, high performance diffusion-alloyed material, Distaloy HP-1 fell considerably short of matching the yield strength of the top two materials. The yield strength of material MDB matched that of Ancorloy 4, Ancorloy HP-1, and the hybrid alloy FLN4-4405, all of which are more highly alloyed.

Materials MDB and MDC had tensile elongation values comparable to those for Ancorloy HP-1, FLN4-4405, and FLN6-4405 as shown in Figure 2c. The tensile ductilities of the Ancorloy 4 and the high temperature sintered Distaloy HP-1 were somewhat lower than for the other materials.

The hybrid alloy FLN6-4405 had the best impact properties. However, as may be seen in Figure 2d, material MDC matched the performance of Distaloy HP-1 and FLN4-4405. Material MDB had comparable impact properties to those of Ancorloy 4.

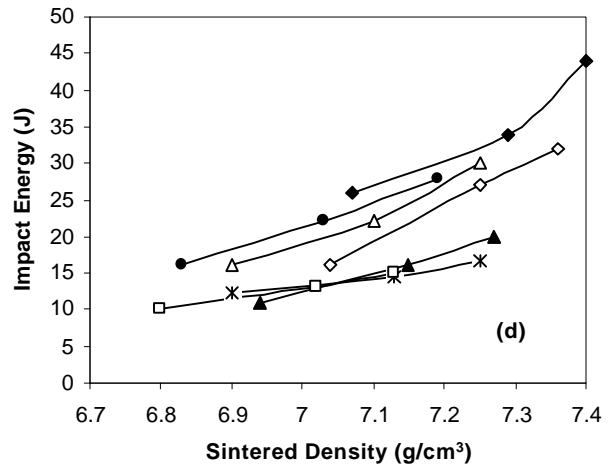
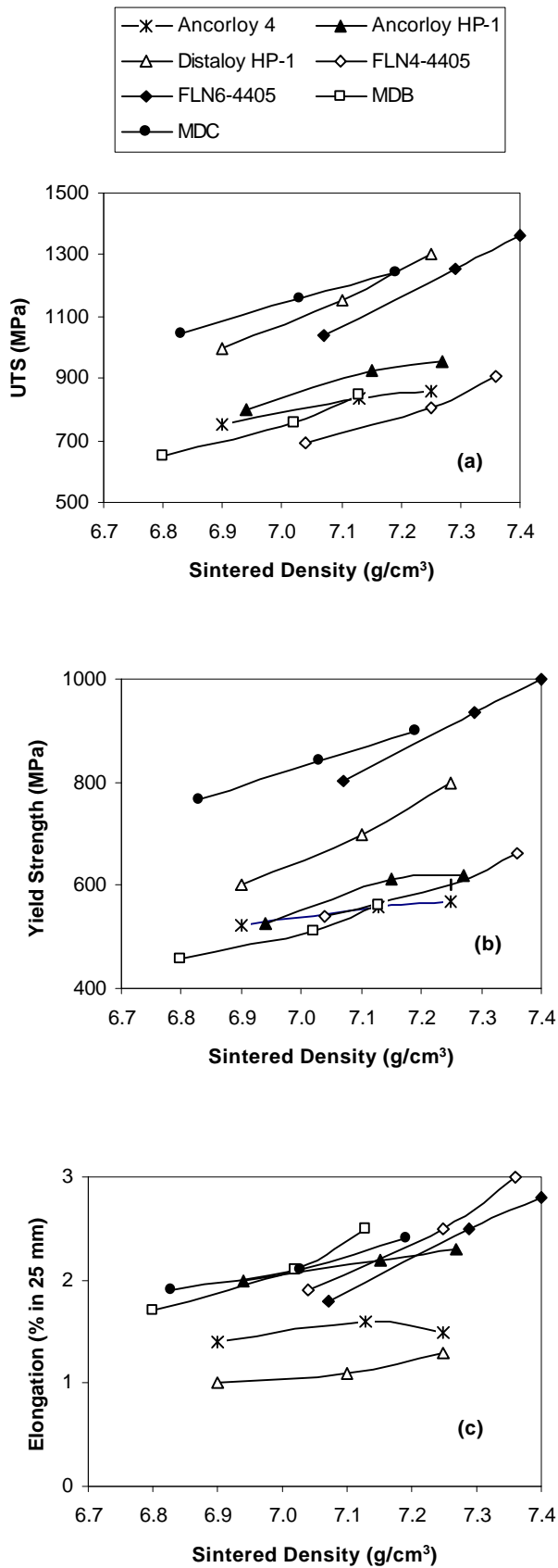


Fig. 2 (a –d) – Effect of sintered density on the UTS, yield strength, elongation, and room temperature impact energy of selected high performance P/M materials.

Photomicrographs illustrating the microstructure of materials MDB (as-sintered) and MDC (sintered and tempered) are presented in Figures 3 and 4. The microstructure of material MDB consists of martensite, some bainite, and divorced pearlite with some areas of very fine unresolved pearlite. Material MDC has a predominantly martensitic microstructure with some bainitic areas.

Future work will evaluate the fatigue performance of the new materials and production trials will be conducted on potential part applications.

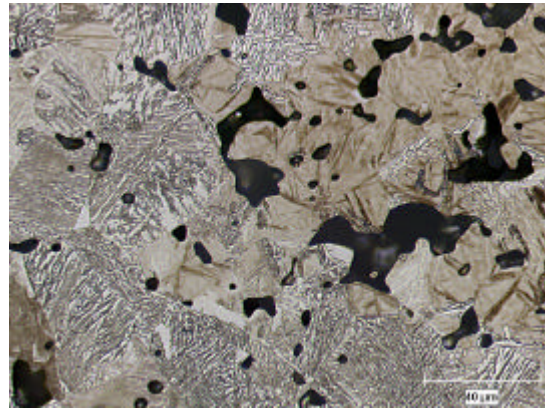


Fig. 3 – Microstructure of material MDB. Etched 2% nital 4% picral. Original magnification 500X.

III. CONCLUSIONS

A number of new ferrous P/M materials have been developed. The mechanical properties that can be developed in compacts made from these new materials

matches the performance characteristics of a number of malleable and ductile cast irons.

Material MDD has better tensile strength than material MDA while exhibiting higher tensile ductility. Material MDB has even higher tensile strength but does so at the expense of some ductility.

The new materials MDB and MDC exhibited an extremely good combination of tensile strength, tensile ductility, and impact energy. The elevated sintering temperature needed for the materials results in microstructures that contain

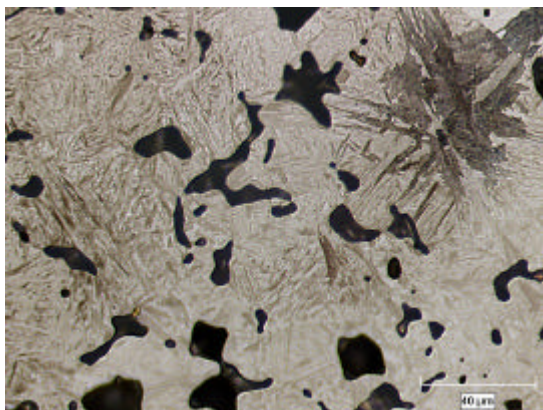


Fig. 4 – Microstructure of material MDC. Etched 2% nital 4% picral. Original magnification 500X.

significant amounts of martensite and the materials are effectively sinter hardened. Work in progress indicates the optimum tempering temperature for material MDC is 245 °C rather than the 190 °C used in the initial program. Tempering at 245 °C resulted in a 14% improvement in yield strength while maintaining an apparent hardness of over 65 HRA. The optimum tempering temperature for material MDB appears to be 300 °C. Tempering at this temperature resulted in an 11% increase in yield strength compared with untempered material.

The new materials, MDA, MDB and MDC, are marketed under the tradenames Ancorloy MDA, Ancorloy MDB, and Ancorloy MDC. Their performance matches many of the characteristics of a number of malleable and ductile cast irons and they should be evaluated with respect to potential applications such as ring gears, pinion gears, and carriers.

IV. REFERENCES

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