ADVANCES
IN
ENGINEERING & MANAGEMENT

ADEM 2016

DROBETA TURNU SEVERIN, ROMANIA
November 17-18, 2016

CONFERENCE BOOK OF ABSTRACTS

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Editura UNIVERSITARIA
Craiova 2016

ADVANCES
IN
ENGINEERING & MANAGEMENT

ADEM 2016

Organised by

UNIVERSITY of CRAIOVA

Faculty of Mechanics
Department of Engineering and Management
of Technological Systems

and

DOLJ COUNTY COUNCIL

The organizers thank to:

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Foreword

Welcome to ADEM 2016, the 4th International Conference on *Advances in Engineering and Management* in Drobeta-Turnu Severin, on the 17th - 18th of November 2016!

Organized by the University of Craiova, Faculty of Mechanics, Department of Engineering and Management of Technological Systems, respectively Dolj and Mehedinti Counties, accompanied by industrial companies and sponsors, ADEM 2016 maintains the tradition of the international conferences started in 2010. Our conference continues to highlight the relationship between the fundamental and applied research, respectively the technological transfer in the fields of Advanced Materials and Technologies, Environment Engineering, Naval Engineering and Navigation, Engineering and Management and Modeling and Simulation.

Professor Herbert DANNINGER from the Technological University of Vienna was the guest of honor of ADEM 2016, as the nominated personality for the Doctor Honoris Causa title of the University of Craiova and President of the Scientific Committee of our conference.

Prestigious universities, research institutes and companies from Romania and abroad participated at the ADEM 2016, to share the latest achievements, according to the conference topics:

- Invited papers (5 papers);
- Advanced Materials and Technologies (14 papers);
- Modeling and Simulation (18 papers);
- Environment Engineering (14 papers);
- Naval Engineering and Navigation (10 papers);
- Management and Industrial Engineering (8 papers);

Over 65 participants from 5 countries provided valuable contributions, as oral and poster presentations, with remarkable input for the state-of-the-art in the field of *Advances in Engineering and Management*. The organizers and participants of the ADEM 2016 expressed their expectations to increase the conference impact and recognition at national and international level.

As Chairman of the ADEM 2016 conference, I would like to give my special thanks to the invited speakers and researchers from abroad for their endeavor to participate and disseminate the newest knowledge of their experience. Particular acknowledgements are dedicated to the Scientific Committee, International Advisory Committee and Organizing Committee for their efforts and valuable actions. The organizers express their gratitude to the sponsors for their significant contribution to support our conference.

Drobeta-Turnu Severin, November 2016.

Professor Oana GINGU, University of Craiova, Romania
Chairman of the Organizing Committee of ADEM 2016 Conference

PLENARY SESSION

***Teodor Costescu* Cultural Palace**

***Virgil Ogasanu* Hall**

11^{30}-13^{10}

OXYGEN TRANSFER REACTIONS DURING SINTERING OF FERROUS POWDER COMPACTS

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Abstract. *Powder metallurgy products may be started from powders with widely varying oxygen affinity. Thus the natural oxygen content of the powder compacts also varies in reducibility in the early stages of sintering. Here it is shown that prealloyed powders containing Cr require higher temperatures for oxygen removal than e.g. unalloyed or Ni-Cu alloyed grades. In case of powder mixes of base iron powder with Cr, Mn or Si, oxygen transfer from Fe to the additive powders may occur during heating up to sintering temperature, the "internal getter effect". Finally, there is a similar effect in Cr prealloyed powders in which iron oxides initially present on the powder surfaces are transformed to more stable oxides in a fairly early stage of heating.*

Keywords: *Powder metallurgy, sintered steels, oxygen transfer, reduction*

1. INTRODUCTION

All metal powders that have ever been exposed to air contain some oxygen, and oxidized surfaces can be detrimental by inhibiting sintering. Therefore, removal of oxygen is as essential as is the prevention of further oxygen pickup during sintering. Both measures are particularly critical with PM products containing elements with high oxygen affinity, such as sintered steels alloyed with Cr, Mn and /or Si [1, 2]. Depending on the alloying variant chosen, different aspects have to be considered such as homogeneous or heterogeneous oxygen affinity [3] and the way the oxygen is present [4, 5]. In the present article it is discussed how oxygen can be removed from the powder compact and which reactions may retard the deoxidation processes.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

The starting powders used were water atomized plain iron (ASC100.29) and prealloyed Fe-3%Cr-0.5%Mo (AstaloyCrM), both supplied by Höganäs AB, Sweden. Natural graphite UF4 was added as carbon carrier, and for admixing alloying elements, elemental Cr, Mn and Si powders were used as well as an Fe-Si-Mn masteralloy. The powders were dry mixed and compacted to bars 55 x 10 x 10 mm. Then dilatometry was done with the full size bars using a dilatometer Netzsch 402 with Al2O3 measuring system; a mass spectrometer was coupled to the dilatometer through a capillary coupling, to analyze the gaseous reaction products formed during sintering. The test runs were done in high purity Ar or H2.

3. RESULTS AND DISCUSSIONS

Test runs done in parallel with Fe-0.5%C and Fe-Cr-Mo-0.5%C showed (Fig.1) that in Ar atmosphere, oxygen removal occurs at significantly higher temperatures in the prealloyed steel than in the plain Fe-C grade. In both cases, 2 pronounced reduction maxima, indicated by peaks of m28 (CO) and m44 (CO2) are discernible, but for Fe-C these emerge at about 800 and 1100°C, respectively, and for Fe-Cr-Mo-C at 1000 and 1250°C. This agrees well with the stability of the oxides as indicated in Richardson-Ellingham diagrams. Therefore, while for Fe-C oxygen removal occurs

more or less automatically when sintering in standard belt furnaces at 1120-1150°C, for sintering of Cr prealloyed steels higher temperature are required to ensure sufficient deoxidation, i.e. oxygen transfer to the external atmosphere.

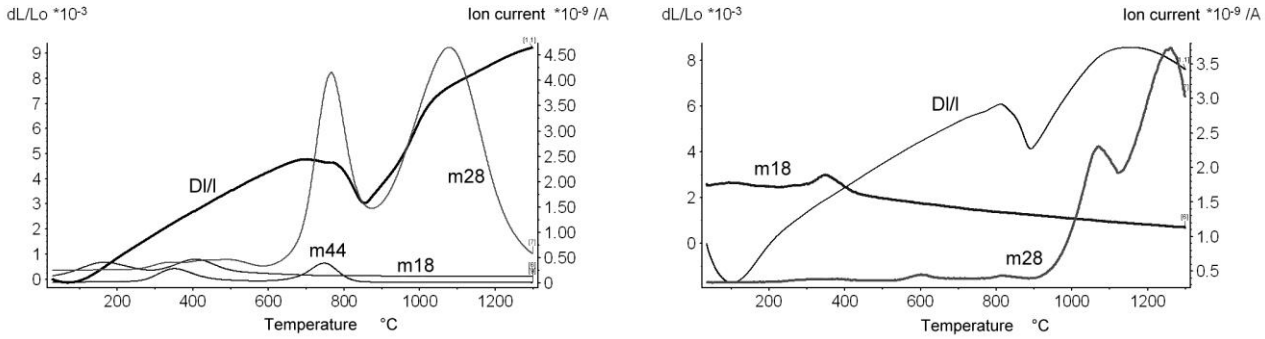

Fig.1a: Fe-0.5%C *Fig.2b: Fe-3%Cr-0.5%Mo-0.5%C*

Fig.1: m28 MS signals for sintering of Fe-C and Fe-Cr-Mo-C, respectively. Dilatometer, 10 K/min, argon

As an alternative to prealloying, also mixing of elemental powders can be done, e.g. adding Cr, Mn or Si to a base plain iron powder. This however means heterogeneous oxygen affinity within the powder compact. The consequence for sintering is that the oxygen present on the base iron surfaces is reduced at fairly moderate temperatures, but the gaseous compounds formed, e.g. CO, CO_2 and, if sintering in H_2, H_2O, react rapidly with alloy element particles in the vicinity, oxidizing them ("internal getter effect"). The reduction of the Fe surfaces is hardly visible externally but the reduction peaks are shifted to much higher temperatures, those required for reduction of the alloy elements. This phenomenon is depicted in Fig.2, with Si as example for an alloy element with high oxygen affinity. A similar redistribution of oxygen can even occur in prealloyed powders during heating: while the surfaces are initially covered with iron oxides, during heating these are transformed to more stable types, which are more difficult to reduce.

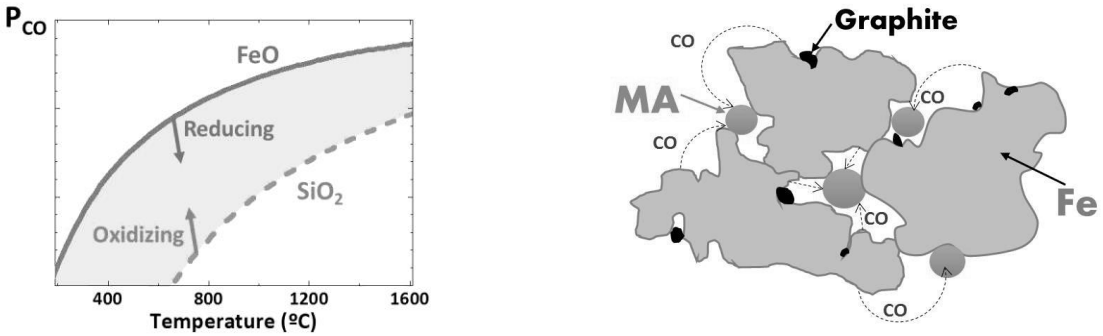

Fig.2: "internal getter effect": oxygen transfer from base iron powder to the alloy element particles (schematic)

4. CONCLUSIONS

It has been shown that in addition to removal of oxygen from powder compacts in the early stages of sintering, also redistribution processes, "internal getter effects" may occur. One of these is the transfer of oxygen from the base iron powder to the alloy element particles through the gas phase; the other is transformation of the surface oxides from iron oxide to more complex ones. In both cases the net result is a shifting of the deoxidation processes to higher temperatures.

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