CERP

Casting Emission Reduction Program

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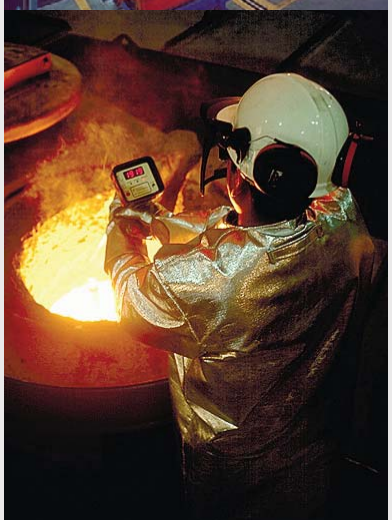

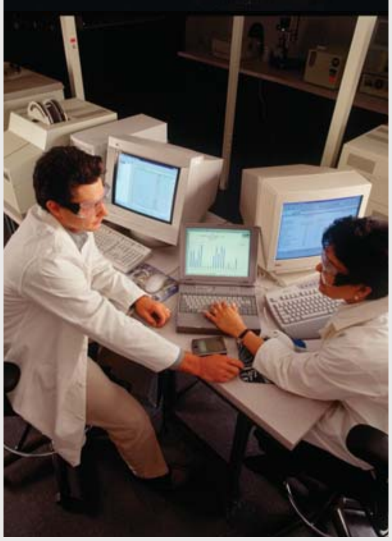

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Optimize Process:

Plasma Treatment Casting Study

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CISA CASTING INDUSTRY SUPPLIERS ASSOCIATION

AFS AMERICAN FOUNDRY SOCIETY

ARMAMENT RESEARCH, DEVELOPMENT & ENGINEERING CENTER PICATINNY, NJ

USCAR UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

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Plasma Treatment Casting Study

1411-132 NA

This report has been reviewed for completeness and accuracy and approved for release by the following:

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EXECUTIVE SUMMARY

An energy committee was formed in 2004 from participating CERP companies and participants. The goal of this committee is to review and evaluate methods and technologies within the foundry industry which could have a positive energy impact and life cycle benefits for the production of metal castings. One of the new manufacturing technologies that has the potential to reduce life cycle costs of foundry operations was developed by Netanya Plasmatec, LTD. The technology is called the Plasma Treatment Casting (PTC) process and works on the principle of applying a plasma arc to increase casting yield and improve the quality of metal castings by controlling the solidification process of the liquid metal.

The PTC process seems to offer the metal casting markets a unique technology that reduces some of the most fundamental problems of the casting industry. These include low casting yield, shrinkage blowholes, porosity, inclusions, segregation, coarse dendrites formation and others, all undesired defects formed during the solidification process. A special plasma generator produces rotating plasma, which is controlled by a patented electrode. The plasma arc stirs the metal during the solidification stage, thereby increasing casting yield and productivity, improving macro and micro structure and mechanical properties.

This report describes application and successful demonstrations of the PTC process. CERP is planning to identify a test foundry in North America that would be interested in having a detailed test done on a production casting. A more scientific study would be completed at the end of that test.

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1.0 INTRODUCTION

1.1. Program Background and Objectives

The Casting Emission Reduction Program (CERP) is a co-operative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). The signers of the CERP Cooperative Research and Development Agreement (CRADA) include: the Environmental Research Consortium (ERC), a partnership of DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation; the U.S. Army Research, Development, and Engineering Command (RDECOM-ARDEC); the American Foundry Society (AFS); and the Casting Industry Suppliers Association (CISA). The US Environmental Protection Agency (US EPA) and the California Air Resources Board (CARB) also have been participants in the CERP program and rely on CERP published reports for regulatory compliance data. All published reports are available on the CERP web site at www.cerp-us.org.

CERP's primary purpose is to evaluate materials, equipment, and processes, quality and energy usage in the production of metal castings. Technikon's facility was designed to evaluate alternate materials and production processes designed to achieve significant air emission reductions. The facility's principal testing arena is designed to measure airborne emissions from individually poured molds. This testing arena facilitates the repeatable collection and evaluation of airborne emissions and associated process data.

1.1.1. Specific Study Objectives

To identify and review new casting technology useful for improving casting quality, reducing energy and materials cost.

The plasmatic PTC process has the potential to significantly reduce costs for high production semi-permanent production facilities. Automotive casting suppliers of aluminum cylinder heads and blocks should be capable of reducing riser size because of the thermal input of the plasma treatment. The objective of this study is to evaluate this process and determine if a detailed test should be scheduled.

2.0 SCOPE OF STUDY

Netanya Plasmatec, LTD. has developed a Plasma Treatment Casting (PTC) process that uses a plasma generator to improve the yield and quality of castings by supplying additional heat to the metal in the mold. For aluminum casting, the improved yield has the potential to save energy because the riser size can be reduced by up to 70%.

Additionally, the process is particularly useful for improving the quality of ferrous cast metal ingots, bars, billets, blooms and slabs. Plasmatec's PTC method combines and integrates the following treatment methods to affect the metal during its crystallization in the mold:

- Influence of concentrated energy source
- Intensification of heat exchange in liquid metal
- Controlled heating of the metal in specific ingot regions
- Hot isolation of top portion of the ingot
- Super-position of the electromagnetic fields:
  Longitudinal,
  Transversal and Rotational
- Gas pulsation inside the melted metal
- Nucleation

2.1. Description of the Plasma Treatment Casting System

The PTC process applies a plasma arc during the metals and alloys solidification process. While the metal goes from liquid to solid, the rotating plasma arc moves along a prescribed path defined by a special electrode discharging into the ingot mold as shown in Figure 2-1. In the PTC multi plasma arcs system two or more arcs are operated simultaneously (parallel arcs are on top of the risers as shown in Figure 2-2). The PTC system equipment is displayed in Figure 2-3.

Figure 2-1 PTC Electrode

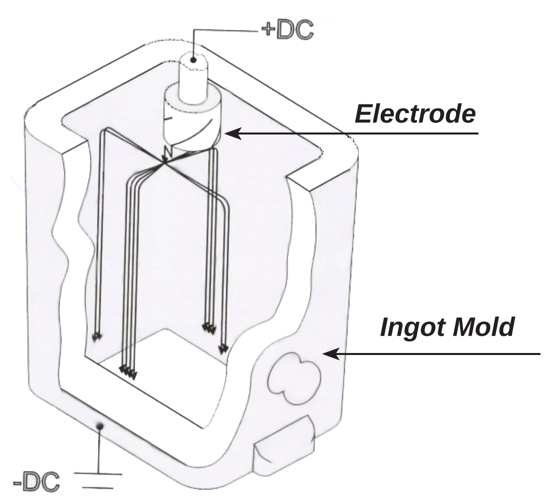


Figure 2-2 PTC Multi Plasma Arc System

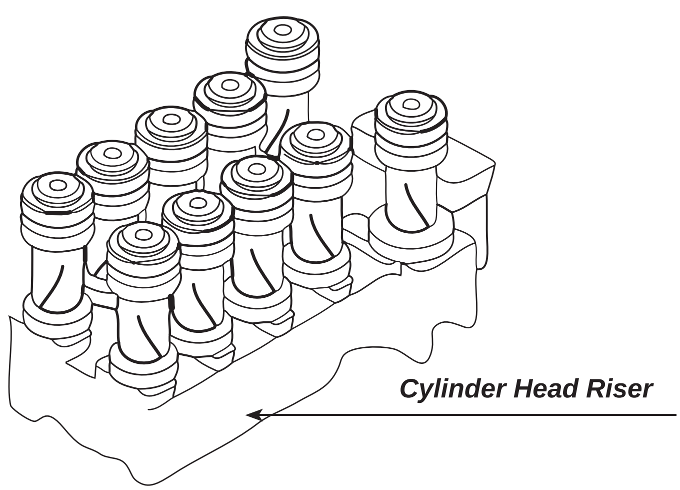
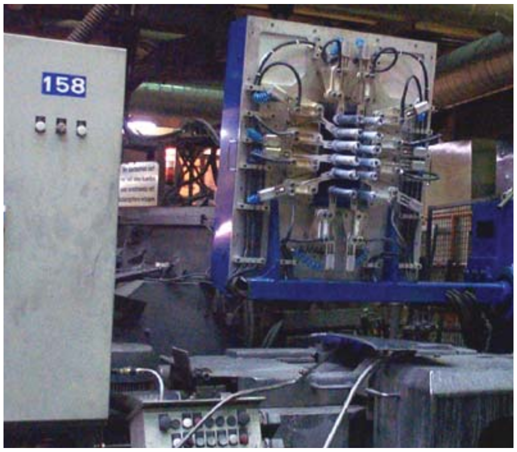
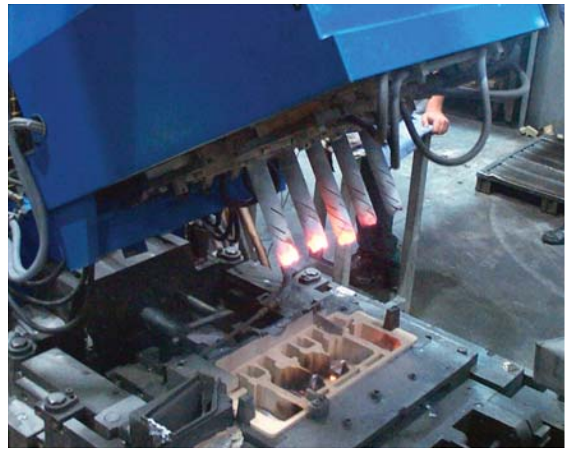


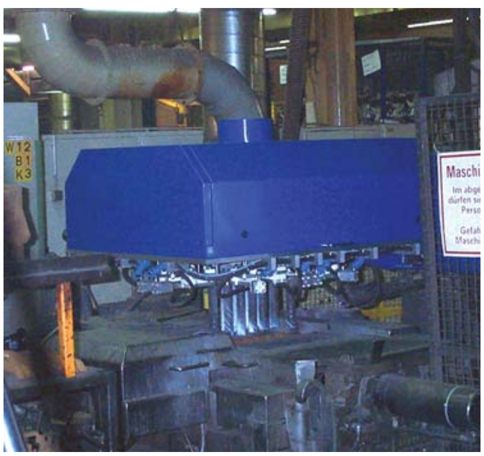
Figure 2-3 Plasma Treatment Equipment Configuration



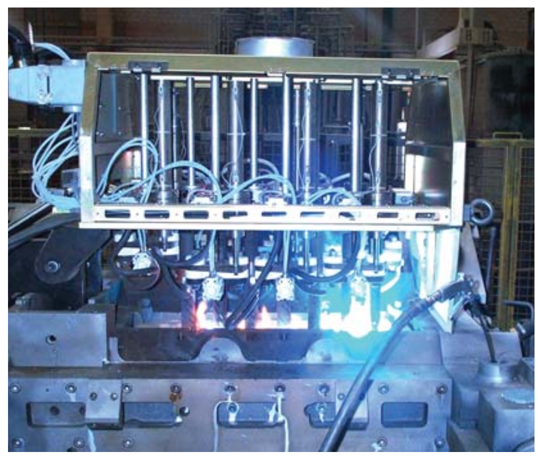
a) Control cabinet and electrode array.



d) Electrode array in open position.



b) Electrod array in closed position.



e) Plasma arc system energized.

c) Close view of plasma arc system while energized.

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3.0 STUDY RESULTS - ANTICIPATED BENEFITS

Preliminary test results indicate several improvements both in aluminum castings and steel ingots as a result of the PTC process. The method is also promising for other metal treatments, including most casting methods such as continuous casting and semi continuous casting. It is anticipated that the PTC process will achieve multiple business advantages over conventional methods by:

- Reducing energy consumption
- Eliminating shrinkage blowhole
- Eliminating internal and external cracks
- Eliminating porosity
- Reducing segregation and grain size
- Structure refinement
- Producing higher quality end products with improved mechanical properties.
- Reducing riser's mass by 80%
- Increasing foundry yield from 50% to 80%
- Reducing foundry sand reclamation by up to 40%
- Increasing casting productivity by at least 20%
- Improving metal feeding
- Finer and more uniform inter-dendrite spacing

Examples of demonstrated improvement are shown in Figures 3-1 to 3-8.

Figure 3-1 PTC Treated and Conventional Microstructure

a) PTC treated - fine eutectic structure.

b) Conventional - course eutectic structure.

Figure 3-1 shows Aluminum (7% Si sand casting microstructure) finer and more uniformed inter-dendrite spacing from PTC process. The PTC induces electric and magnetic fields in the molten metal. The PTC creates changing current density flow in the molten metal. These effects produce very effective stirring which creates shear forces on the growing dendrites in the mushy zone thus breaking them. Each fracture creates new nucleation centers. The outcome of this stirring is smaller and more uniform dendrite arm spacing (DAS) and significant porosity ratio reduction.

Figure 3-2 shows the reduction of risers mass by 70% by reducing risers from 19 kg to 6 kg

Figure 3-2 Riser Mass Comparison on Cylinder Head

a) Without PTC process

a) With PTC process

and reducing total casting weight from 39 kg to 26 kg on aluminum cylinder head. Figure 3-3 shows a saving of 17kg of the riser's mass, casting 37kg instead of 54kg for the same net product.

Figure 3-3 Volume Savings of Riser Mass in an Aluminum Cylinder Head

Figure 3-4 Weight Savings of Riser Mass in an Aluminum Cylinder Head

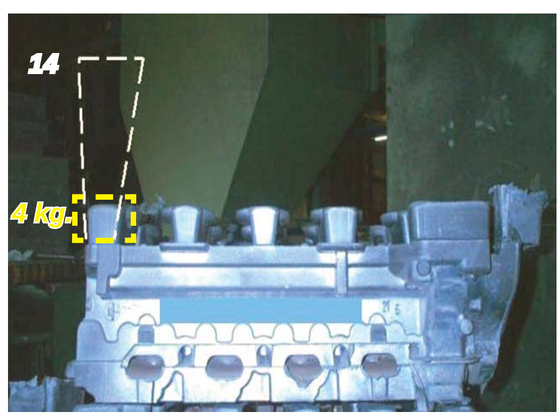
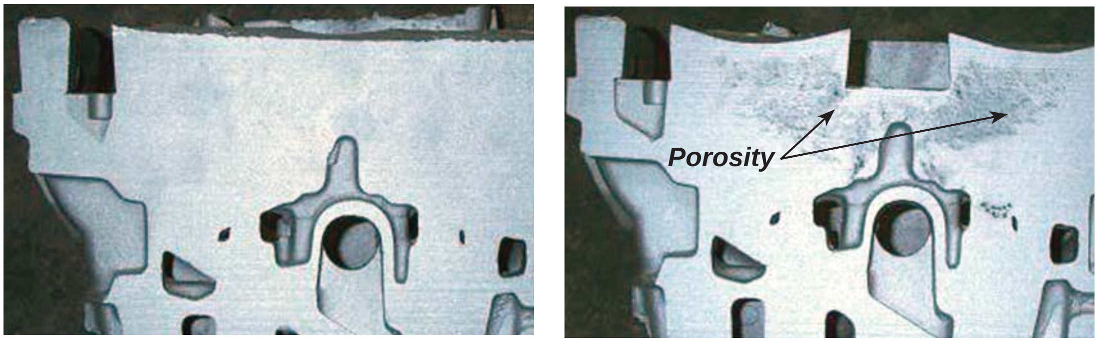


Figure 3-4 shows a reduction of the riser's mass from 14kg to 4kg with the PTC process.

Figure 3-5 Comparison of Porosity of Treated and Untreated Castings



a) Section of cylinder head treated with the PTC process.

b) Section of cylinder head not treated with the PTC process.

Figure 3-5 shows a comparison of porosity of treated and untreated castings.

Figure 3-6 shows a casting using 37 kg instead of 54 kg for the same net product: saving 17 kg of the riser's mass.

Figure 3-7 shows a reduction of the riser's mass by 17 kg.

Figure 3-6 Casting Showing Less Usage of Material

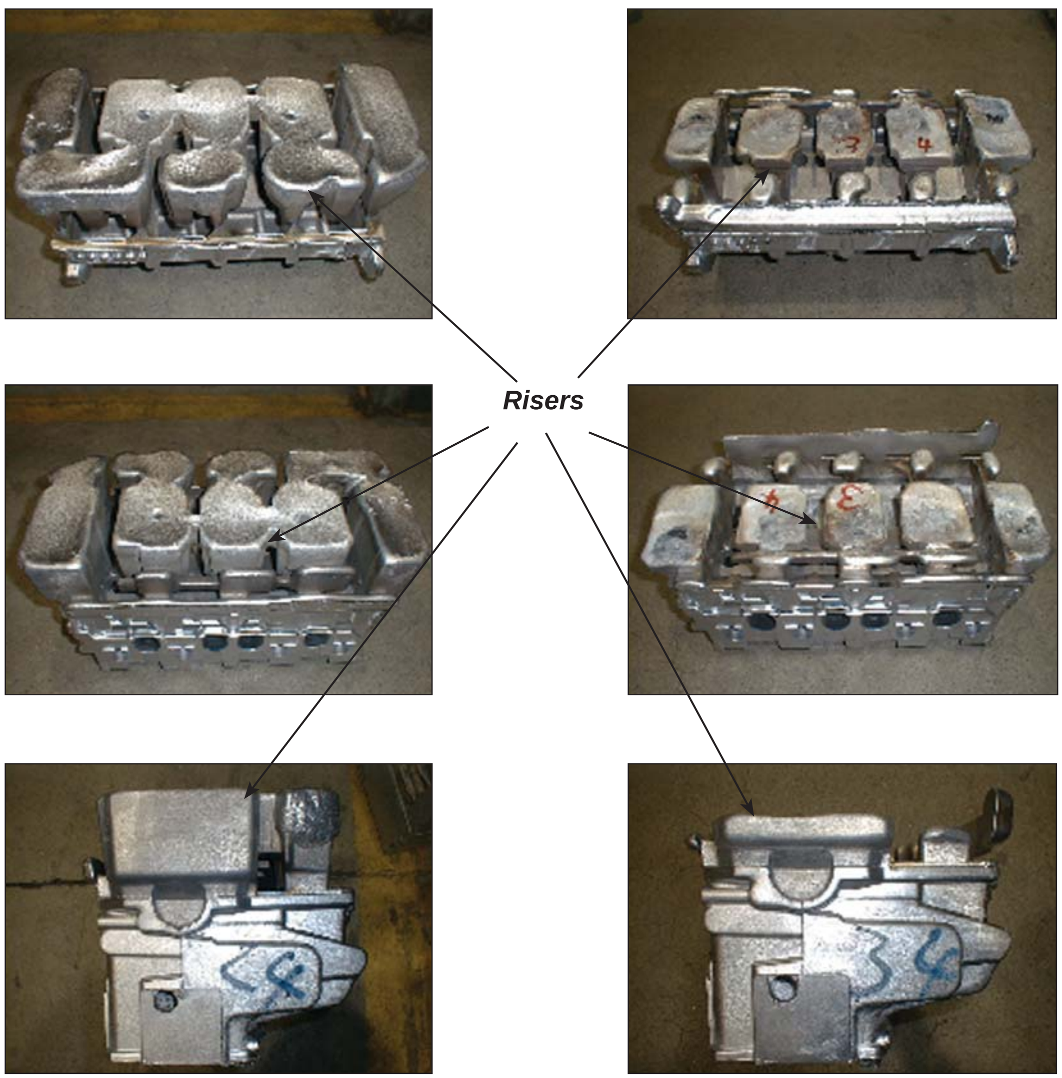
Figure 3-7 Comparison Reduction of Riser Mass in Aluminum Block Casting

a) Conventional process using 54 kg. of aluminum.

b) PTC process using 37 kg. of aluminum.

Figure 3-8 shows casting 20 kg instead of 31 kg for the same net product: saving 11 kg of the riser's mass.

Figure 3-8 Comparison of Conventional and PTC Process Riser Mass Reduction



Conventional casting process standard riser size.

Plasma treatment casting process reduced riser size.

4.0 DISCUSSION OF STUDY RESULTS

Preliminary test results done by Netanya in Europe, indicate several improvements both in aluminum castings and steel ingots as a result of the PTC process. The method is also promising for other metal treatments, including most casting methods such as lost foam casting, continuous casting and semi continuous casting. It is anticipated that the PTC process will achieve multiple business advantages over conventional methods by:

- Reducing energy consumption
- Eliminating shrinkage blowholes
- Eliminating internal and external cracks
- Eliminating porosity
- Reducing segregation and grain size
- Structure refinement
- Producing higher quality end products with improved mechanical properties.

To test these processes Technikon, LLC tentatively plans future research. The results of that testing will determine if the capabilities of the PTC process meet the energy reduction and process improvement goals. The results of this test will be written into a technical report and the information shared with the industry.

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APPENDIX A ACRONYMS AND ABBREVIATIONS

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Acronyms and Abbreviations

AFS	American Foundry Society
CARB	California Air Resources Board
CERP	Casting Emission Reduction Program
CISA	Casting Industry Suppliers Association
CRADA	Cooperative Research and Development Agreement
DAS	dendrite arm spacing
DC	direct current
kg	kilograms
PTC	plasma treatment casting
US EPA	United States Environmental Protection Agency
USCAR	United States Council for Automotive Research
WBS	Work Breakdown Structure