TLP-17-013 Cooper, Mark

DD13 Piston Rings: Batch Consistency Analysis

Report

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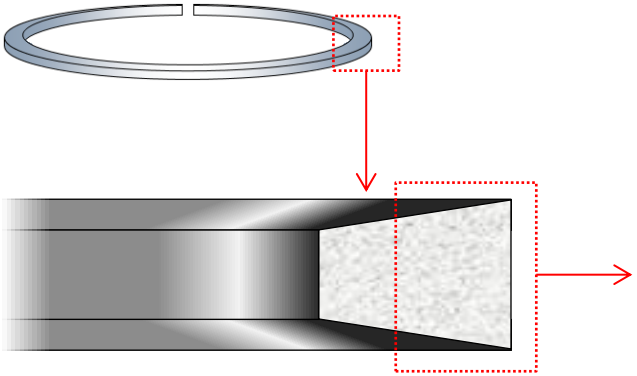
ADDING UP™

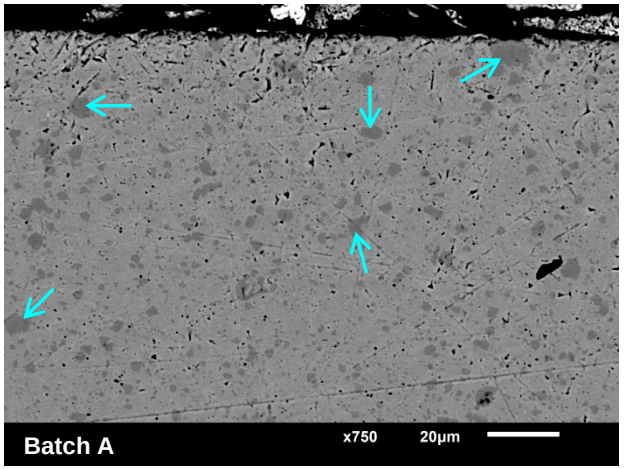
Overview

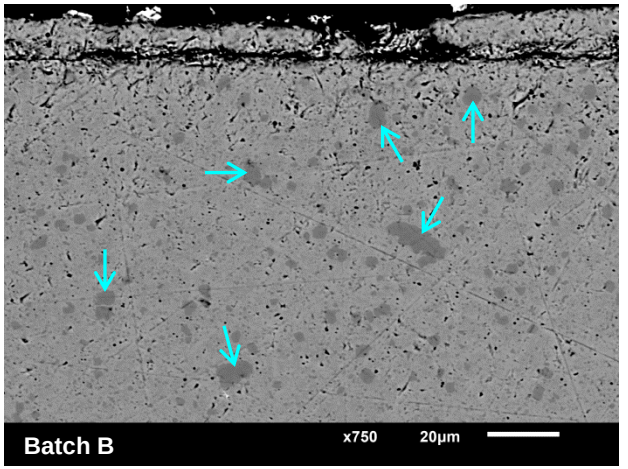
- **Parts Analyzed:**
  - Piston Rings from DD13 Engine
    - Batch A Top Ring
    - Batch B (new batch) Top Ring
    - 2nd and oil control rings from batch A (as there are no batch changes expected for these two rings, these rings are analyzed only for information purposes)
- **Analysis:**
  - Metallurgy: Metallographic microstructure analysis using optical and scanning electron microscopy (SEM)
  - Chemical Composition: Elemental composition analysis using EDS (energy dispersive X-ray spectroscopy) coupled to SEM.
  - Mechanical properties: microhardness measurements

- **Summary of Findings**
  - Both batches of the top rings have the same chemical composition and hardness. Both rings are manufactured using DIN 1.4112 (AISI 440B) stainless steel and are essentially identical.

Top Piston Ring: Batch Comparison







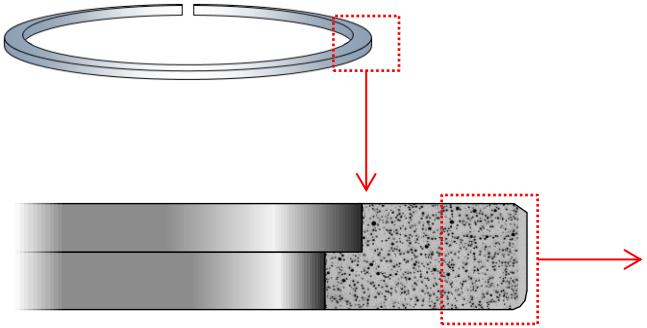
Backscattered electron images of the cross section (magnification x750) of the two top rings analyzed (left: batch A; right: batch B) are shown here. Chromium carbides (small dark areas highlighted by the blue arrows in both images) are present in a matrix of tempered martensite/retained austenite.

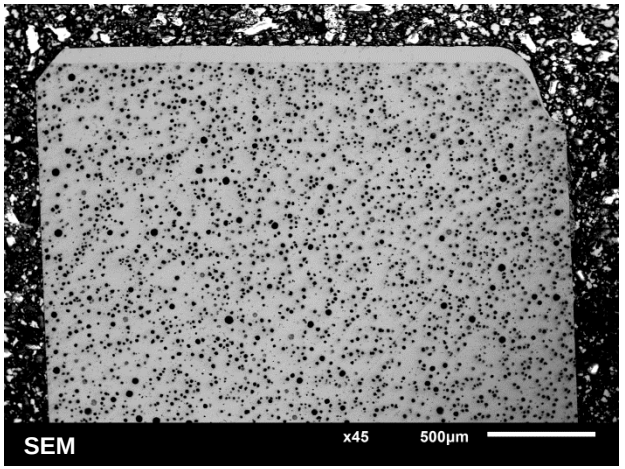
- The cross sections of the top piston ring from both batches A and B were analyzed for chemical composition (using EDS) and metallography. Both piston rings were found to be plain faced rings (i.e. there is no ring face coating present). The EDS data as well the SEM micrographs of the microstructure (see images above) for both rings indicates that both rings are manufactured from a martensitic chromium steel. The average elemental composition of the alloy is as follows (per EDS analysis):

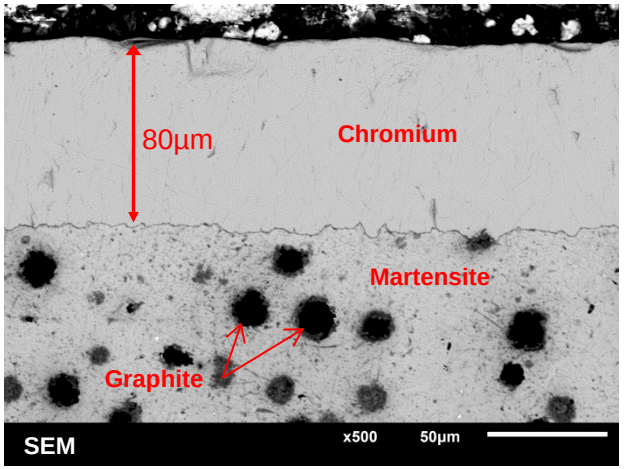
Element	**C**	**Si**	**V**	**Cr**	**Mn**	**Fe**	**Mo**
wt%	<1	0.5	0.1	17-18	Trc.	Bal.	1-1.2

- The hardness of the alloy for both rings was measured in the range of HV400 to HV450 using microhardness tester.
- Based on chemical composition and microstructure as well as the measured hardness, it very likely that the steel used to manufactured this ring is DIN 1.4112 (AISI 440B) stainless steel.

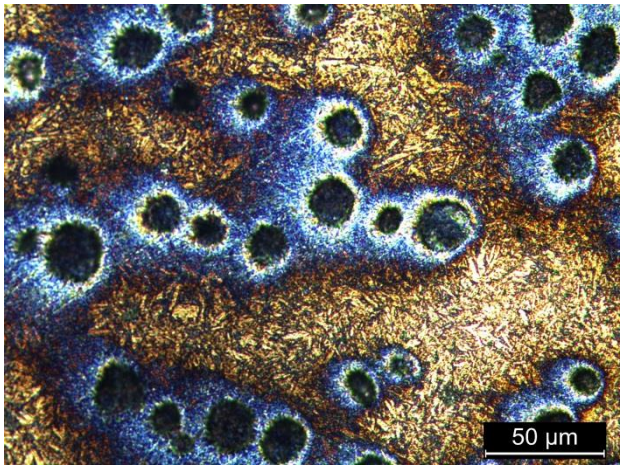
2nd Piston Ring: Metallurgy and Construction



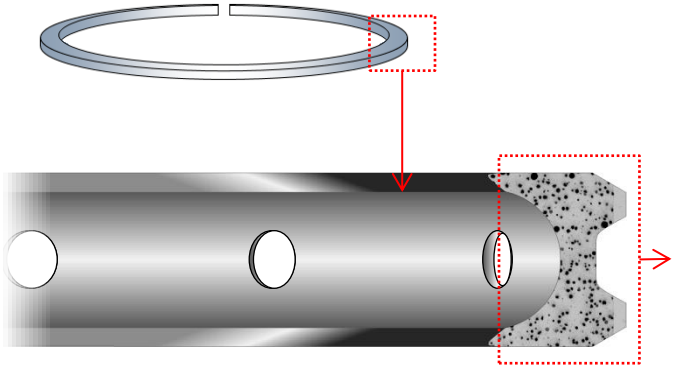


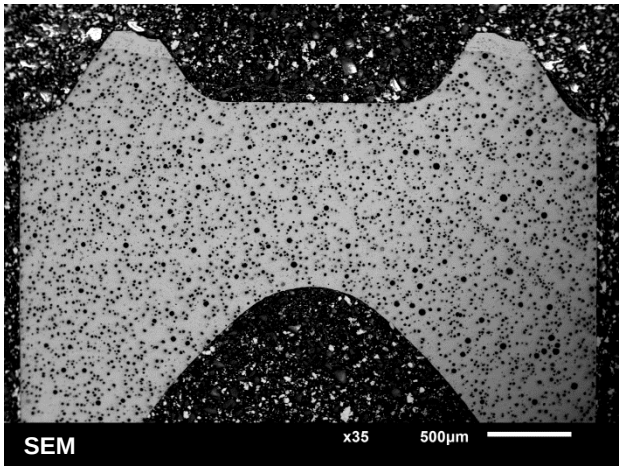


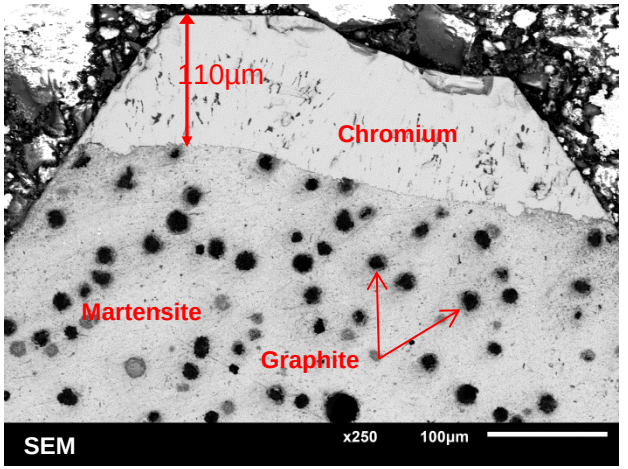
- The second ring in this engine is a rather conventional nodular cast iron ring with an 80µm-thick chrome face. The hardness of the chromium face coating is about HV800-900 while the bulk of the ring (nodular cast iron) consists of a nodular (spherical) graphite in a martensitic matrix with a hardness of HV320-380.
- Images:
  - Top Left: Low magnification (x45) SEM micrograph of the cross section of the 2nd ring showing the location of the chromium coating on the face of the ring.
  - Top Right: x500 magnification SEM micrograph of the cross section of the 2nd ring near the surface showing the bulk and coating microstructures.
  - Bottom: Optical micrograph of the microstructure of the nodular cast iron of the 2nd ring showing the graphite nodules enveloped in free-ferrite within a martensitic matrix.



Oil Control Ring: Metallurgy and Construction







- Similar to the second ring, the control ring is also a nodular cast iron ring with two 110µm-thick chrome faces. The hardness of the chromium face coating is about HV800-900 while the bulk of the ring (nodular cast iron) consists of a nodular (spherical) graphite in a martensitic matrix with a hardness of HV320-380.
- Images:
  - Top Left: Low magnification (x35) SEM micrograph of the cross section of the oil control ring showing the location of the chromium coating on the face of the ring.
  - Top Right: x250 magnification SEM micrograph of the cross section of the oil control ring near the surface showing the bulk and coating microstructures.
  - Bottom: Optical micrograph of the microstructure of the nodular cast iron of the oil control ring showing the graphite nodules enveloped in free-ferrite within a martensitic matrix.