A Shop Floor Approach to Improving Quality in Investment Cast CF8M Components for Biomedical Applications.

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Todays Presentation

- Presentation outline:
  - The Cost of Quality
  - Production KPI on Delivery Vs Product Troubleshooting:
  - Motivation for the Study
  - Innovation arising from different initiatives
  - How do we engage process staff to improve quality?
  - Studies in the causes of Dimensional Variability
  - Study of rework time
  - Acknowledgments

The Cost of Quality

- "Quality" is a measure of excellence or a state of being free from defects, deficiencies, and significant variations, where (high) quality is brought about by the strict and consistent adherence to measurable and verifiable standards to achieve uniformity of output that satisfies specific customer or user requirements.

- The "cost of quality" is actually the cost of poor quality, since non-conforming products increase total product cost and lengthen (delivery) lead-time.

Improve Quality to Reduce Cost

Production KPI on Delivery Vs. Product Troubleshooting:

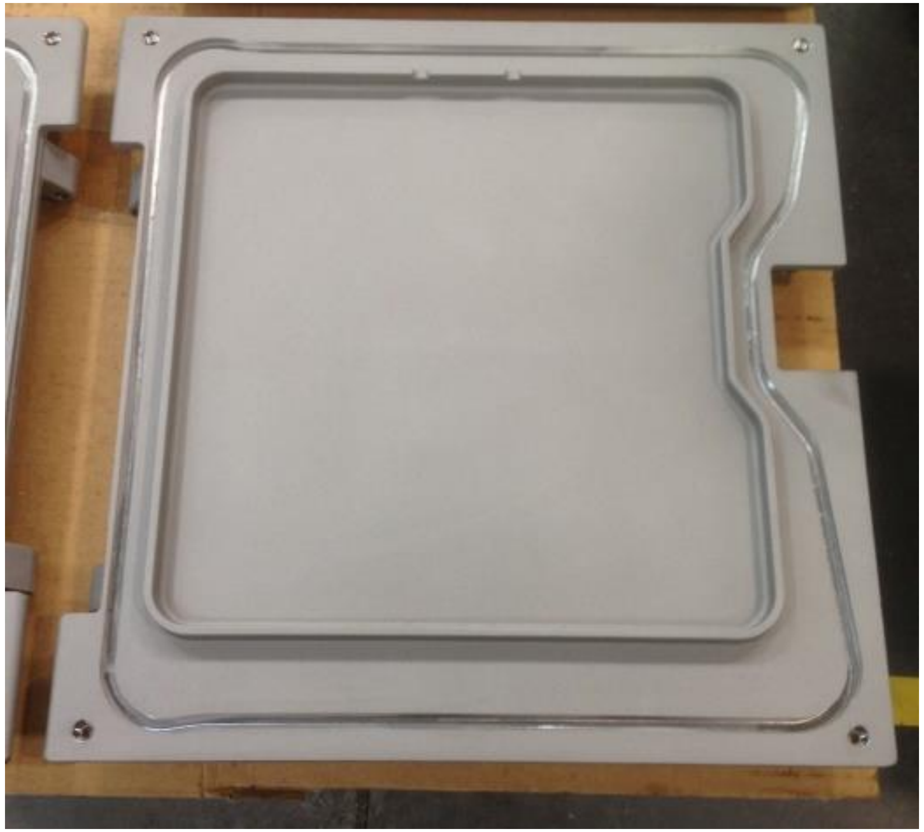
As managers, we often find out after rework / repair has been completed that there is a problem.

This is not cost effective and does not address the quality deficiency.

A problem can escalate rapidly without intervention!

Conducting a quality improvement study while in production is especially challenging.

Biomedical Stainless Steel Castings



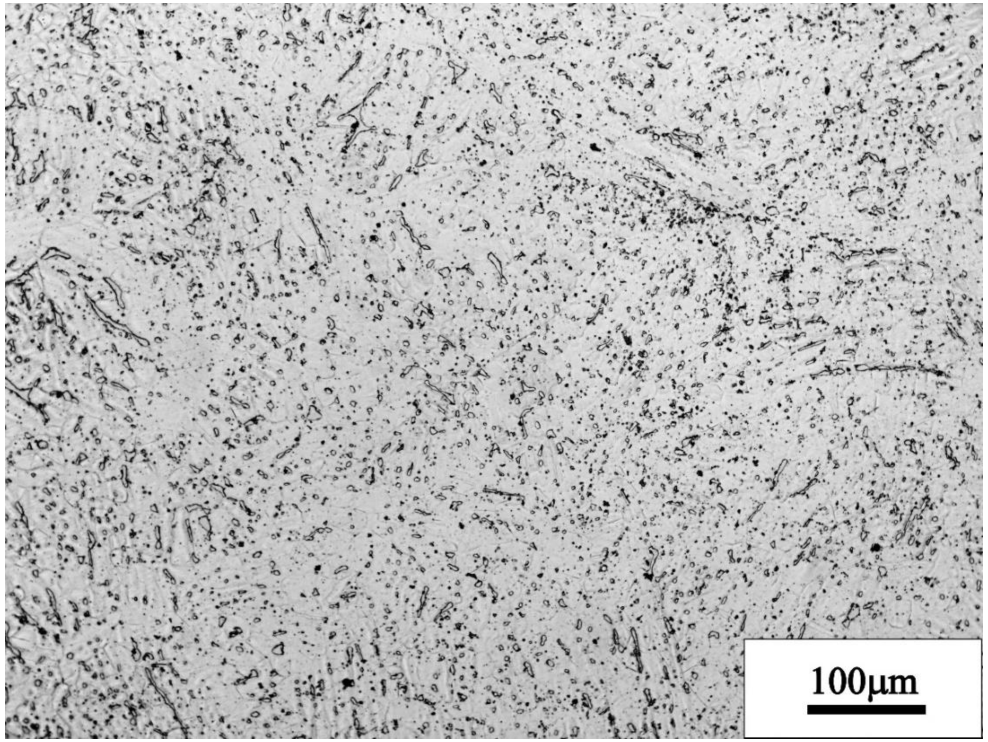
Finished machined part, after pickle and passivation

Stainless Steel Alloy CF8M

Mechanical Property Minimums: Y.S. 207 MPa, UTS 482 MPa, >30%El.

Elemental Composition

Carbon:	0.08% Max
Manganese:	1.50% Max
Silicon:	1.50% Max
Phosphorous:	0.040% Max
Sulphur:	0.040% Max
Nickel:	9.00 – 12.00%
Chromium:	18.00 – 21.00%
Molybdenum:	2.00 – 3.00%

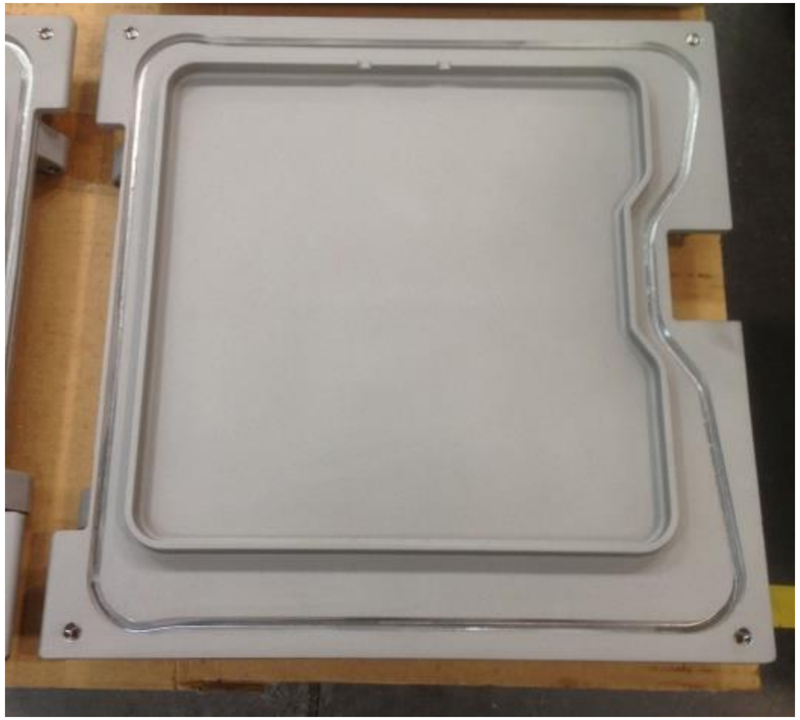


Motivation for the Study

Parts historically had problems associated with rework, straightening and excess welding.

Biomedical products: no porosity allowed on the surface.

Dimensionally accurate to meet customer specifications

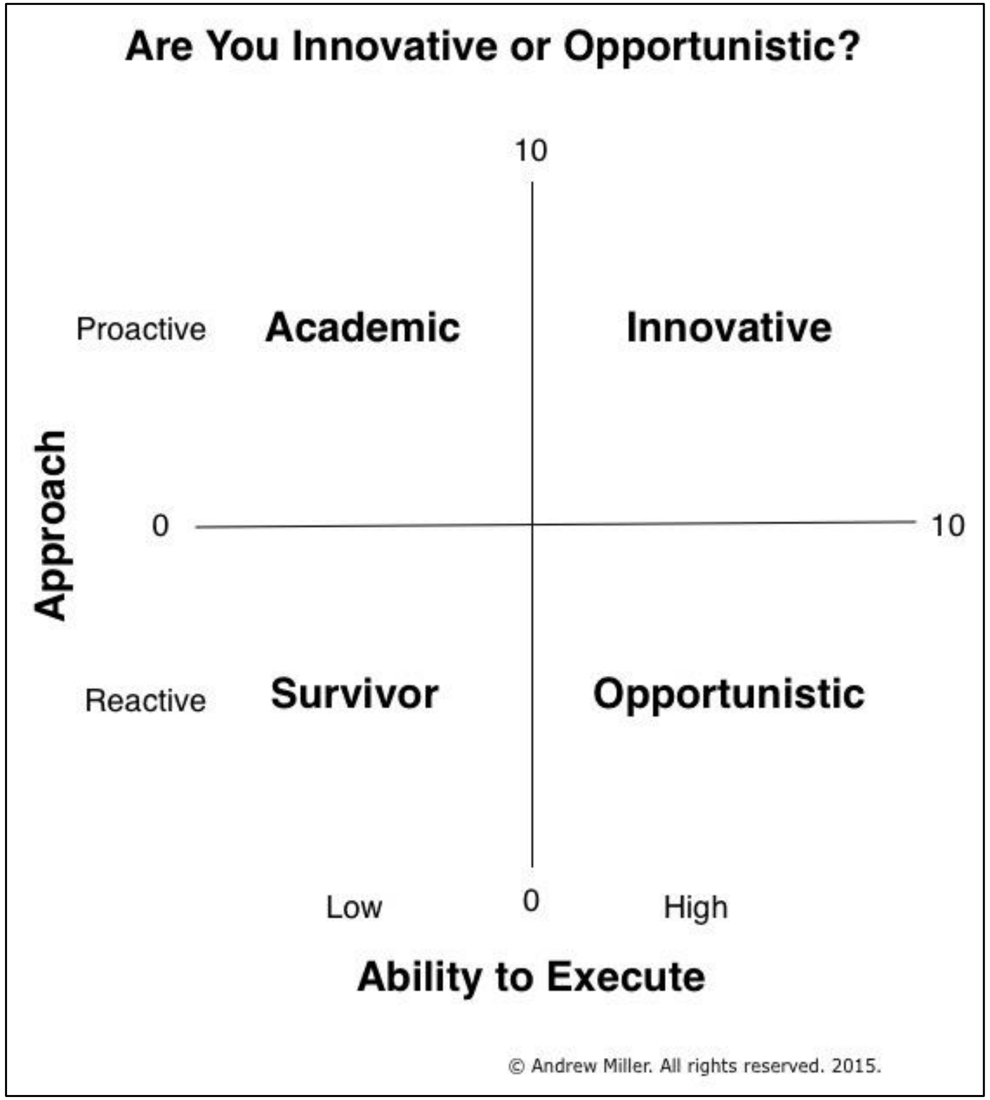


Innovation arising from different initiatives

- Whenever faced with a quality problem, try to resolve the issue & simultaneously reduce cost.
- ($) is going to be spent anyway!

- By:
- Removing process steps.
- Removing components or consumables.
- Make the job easier: reduce labour.

- Planning to fit with production is key.



How do we engage process staff to improve quality?

1. **Teamwork, with managers on the shop floor.**

Examples of the Problem

Customer concern due to bleed out / stain from fine surface porosity: Resulting in excess welding & straightening.

How do we engage process staff to improve quality?

2. Make the job easier: reduce manual processes

Parts historically had a high runout rate

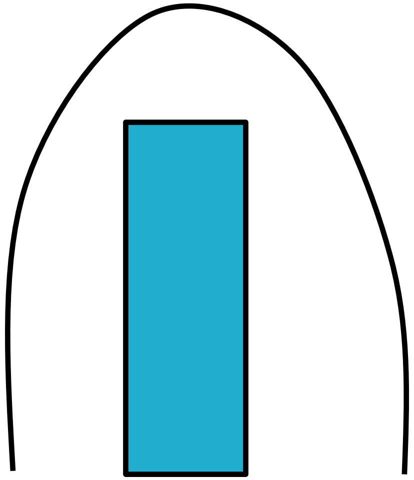
Two runout shells, after cooling, showing the shell splitting associated with the edge.

Make the job easier

Remove Clips, Excessive Patching and Wiring

Establish the root cause

Understanding the geometry of shell building was most important.



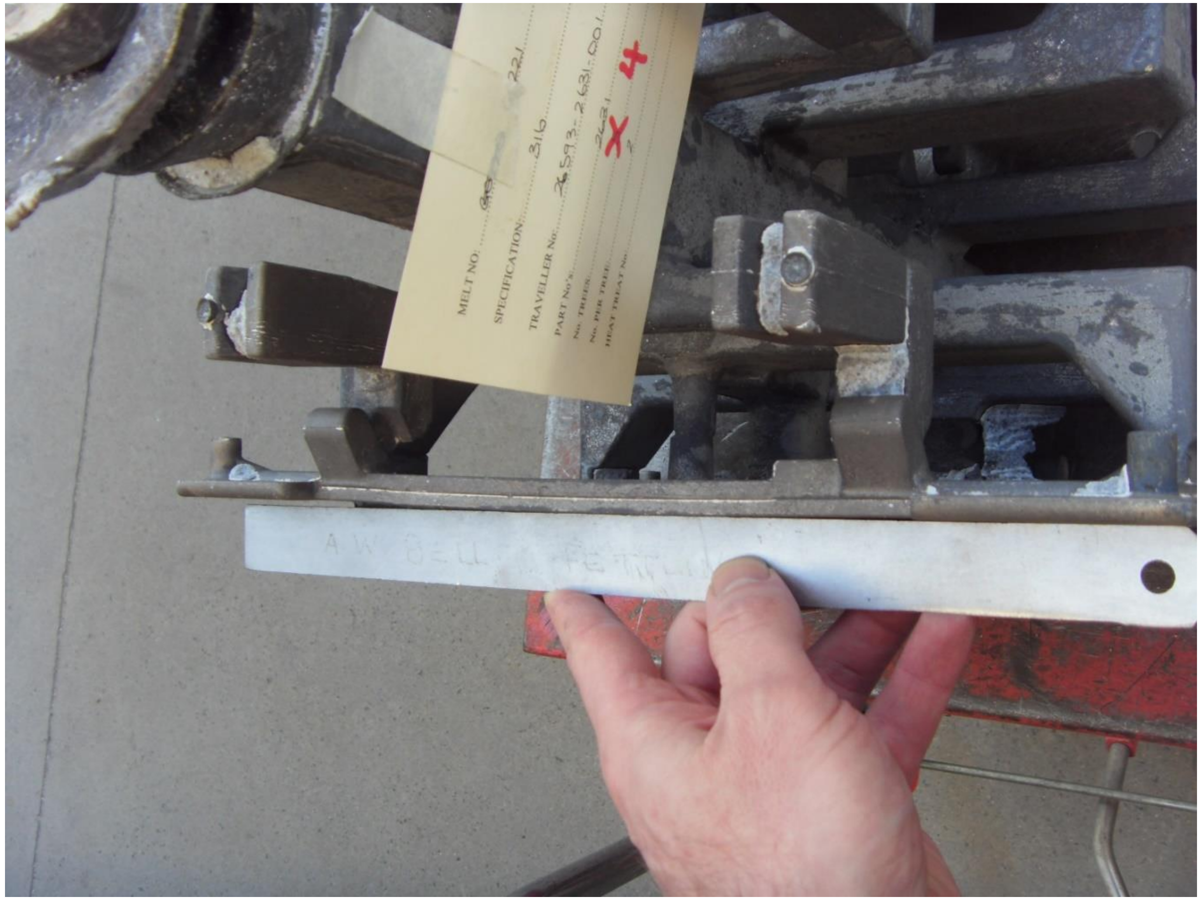
Final configuration: No wire and little to no patching.

Reduced Labour
Reduced Consumables
Improved Quality
Reduced Rework

Studies in Dimensional Variability

Background:
The shells for the lids had been traditionally sunk into fluidised sand about halfway to stabilise the shell against run-out during casting.

Understanding the need for straightening



Cast parts on tree showing distortion associated with gates and the sharp edges that typically initiated shell cracking.

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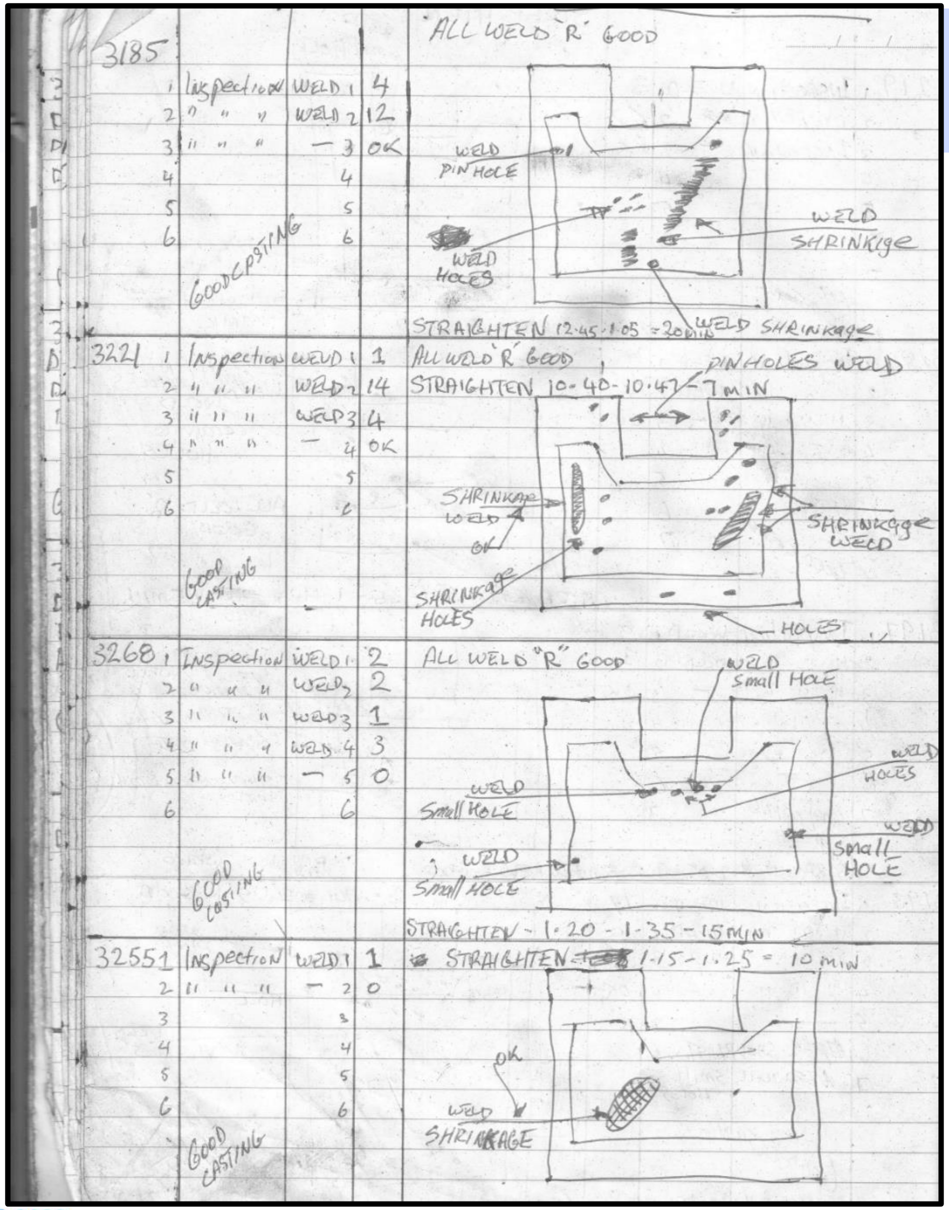
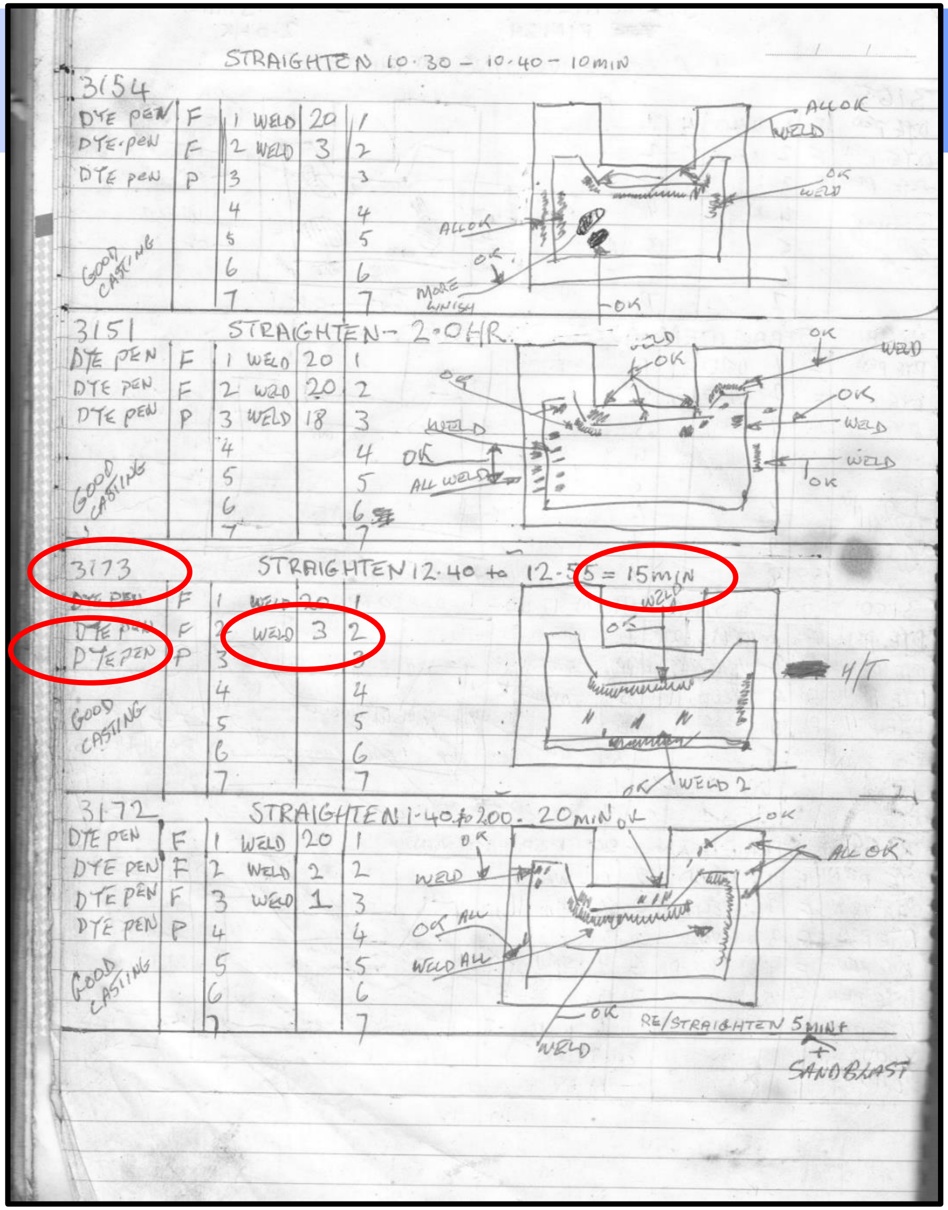
How do we engage our process staff to improve quality?

3. Give staff a means to provide feedback on the product they are working on as part of continuous improvement.

Weld Repair of Biomedical Products is Expensive!





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Some staff keep excellent notes.

Understanding the problem

Low alloy and high alloy expected to be similar in investment castings.

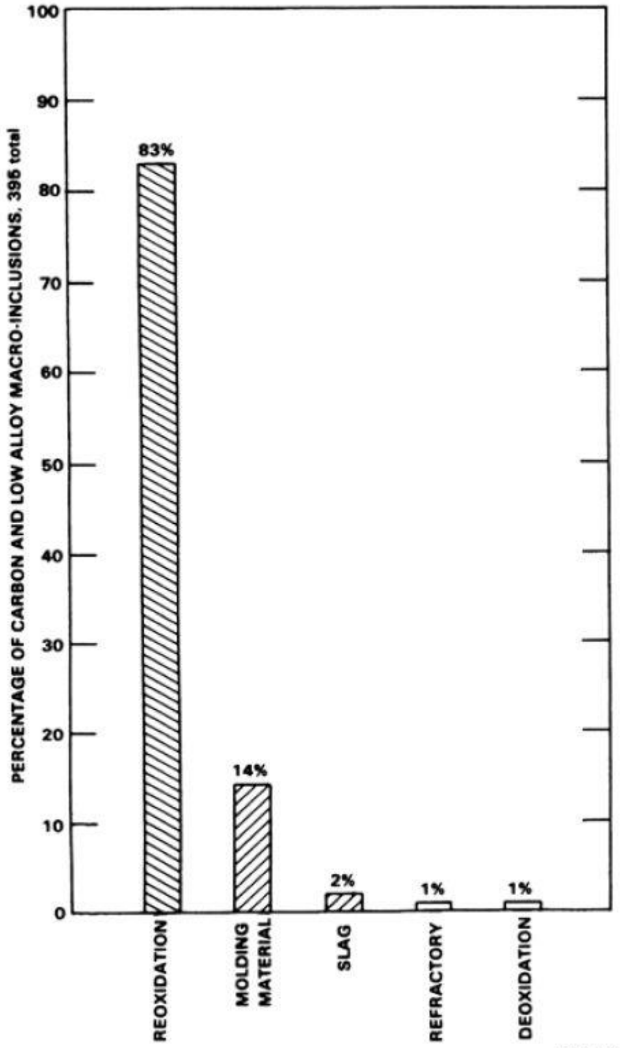


Fig. 1. Distribution of macroinclusion sources in carbon and low alloy steel castings

Monroe and Blair, 2005, WFO

Sources of Oxides

Table I. Sources of oxide macroinclusions by source of oxygen.

A. REOXIDATION - reaction of liquid metal with oxygen

SOURCES	MECHANISM OF FORMATION	PREVENTION
1. Air	· liquid steel reacts quickly during pouring with air as a function of surface area exposed and time of exposure.	· must minimize exposure to air by fast pouring, ladle alignment low to mold, compact pouring streams.
2. Refractories	· moisture or poor refractories can be reduced by deoxidizers in steel.	· must use dry, high quality refractories · must recondition ladles to remove slag and metal attack and expose good refractory · patching must be dry and good quality.
3. Slag	· furnace slags high in FeO can contribute to reoxidation slags and are especially harmful if left on refractories in ladle in spout or bottom pour area.	· must not pour slag into casting · must clean slag out of ladle between uses.
4. Mold	· mold binders high in moisture or other oxidizing components can contribute to reoxidation.	· use organic additives or organic binders to produce a more reducing atmosphere.

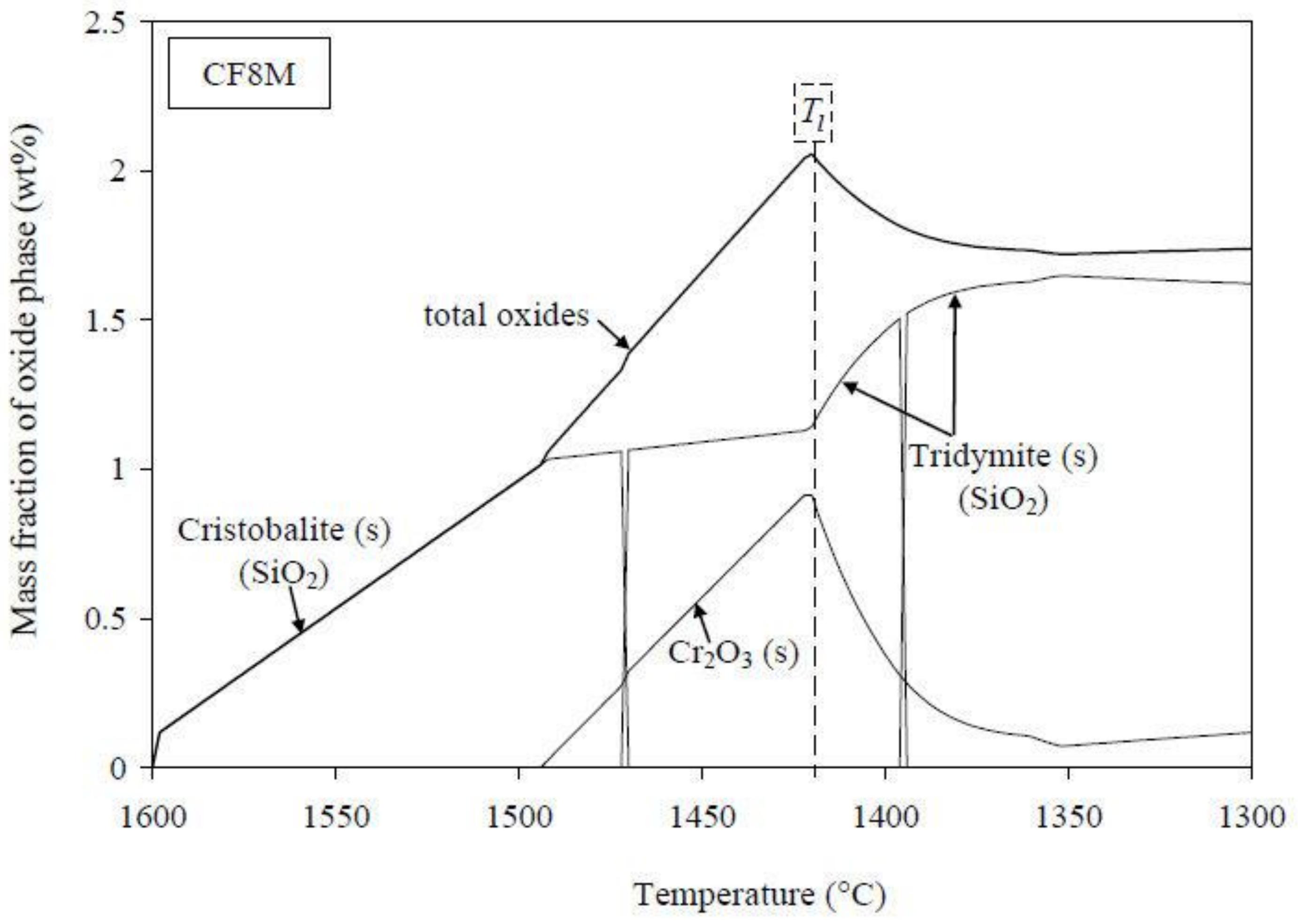
B. ENTRAPMENT - capture of an existing oxide in liquid metal

SOURCES	MECHANISM OF CAPTURE	PREVENTION
1. Slag	-slags high in FeO are very fluid and apt to be entrapped in pouring.	· avoid large amounts of furnace slag, clean old slag from ladle pouring areas, avoid mixing acid and basic slags.
2. Refractories	· metal can attack binder areas of refractory and allow erosion.	· use good refractories resistant to metal attack and erosion, especially in the area of pouring.
3. Mold	· scabbing or erosion can lead to trapped sand or mold wash.	· use a proper sand mix and gating design to prevent scabbing and erosion.

Proper gating and filtering can help reduce oxide macroinclusion.

Svoboda, 1987

Oxide inclusions may be particularly problematical



(a) Temperature range: 1600 to 1300 °C.

Experimental Program

a) Baseline condition (1000°C shell temperature and sunk into fluidized beds).
b) Fast melting and limited de-slagging, all other conditions the same.
c) Shell temperature reduced by 50°C, sunk into fluidized beds.
d) Shell temperature reduced by 50°C, cast on raised beds.
e) 1000°C shell, cast on raised beds, with filters used in the pouring cup.

In total, 36 parts were cast in the evaluation.

Aftercast staff asked to record data including a rating of quality (1-10).
(e.g. time of rework, location, number of welds, straightening time.)

Some Important Initial Results

Initially;

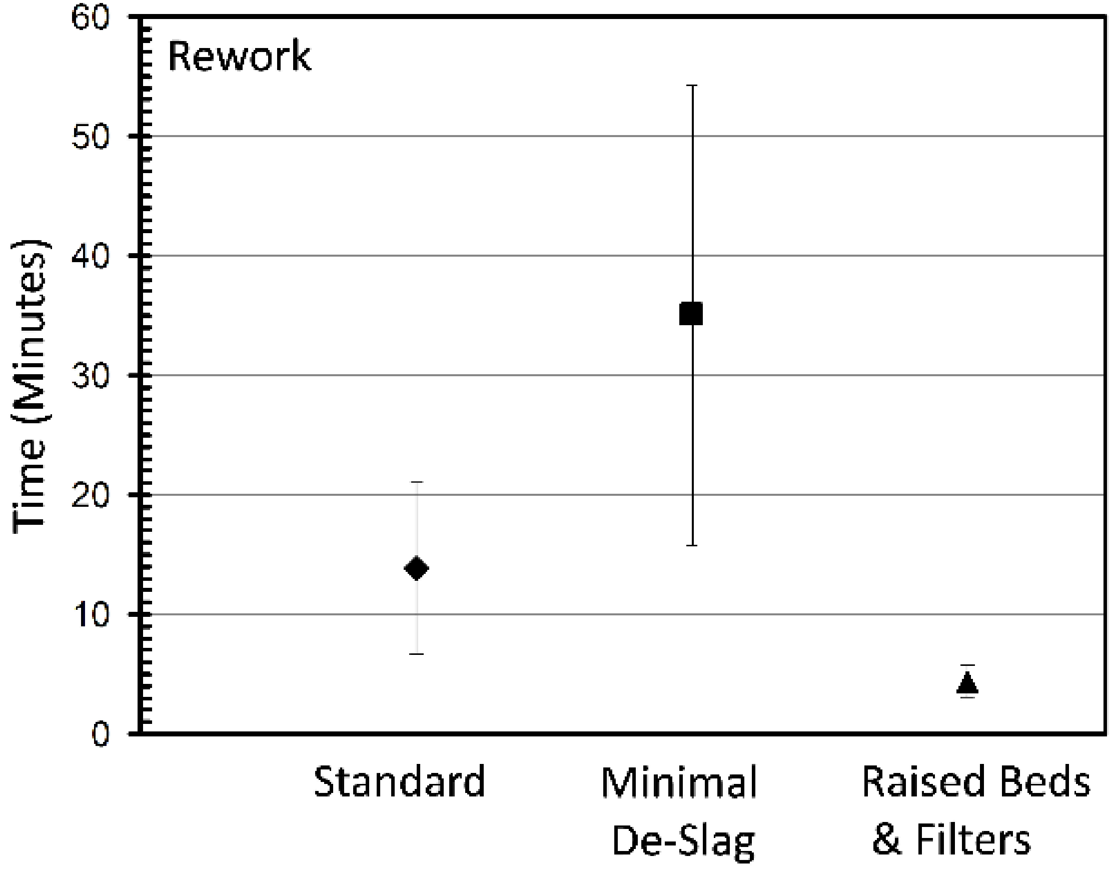
One part bent by operator handling during cutoff
3 parts scrap due to shell inclusions;

Not worked on further (11% rejects already!)

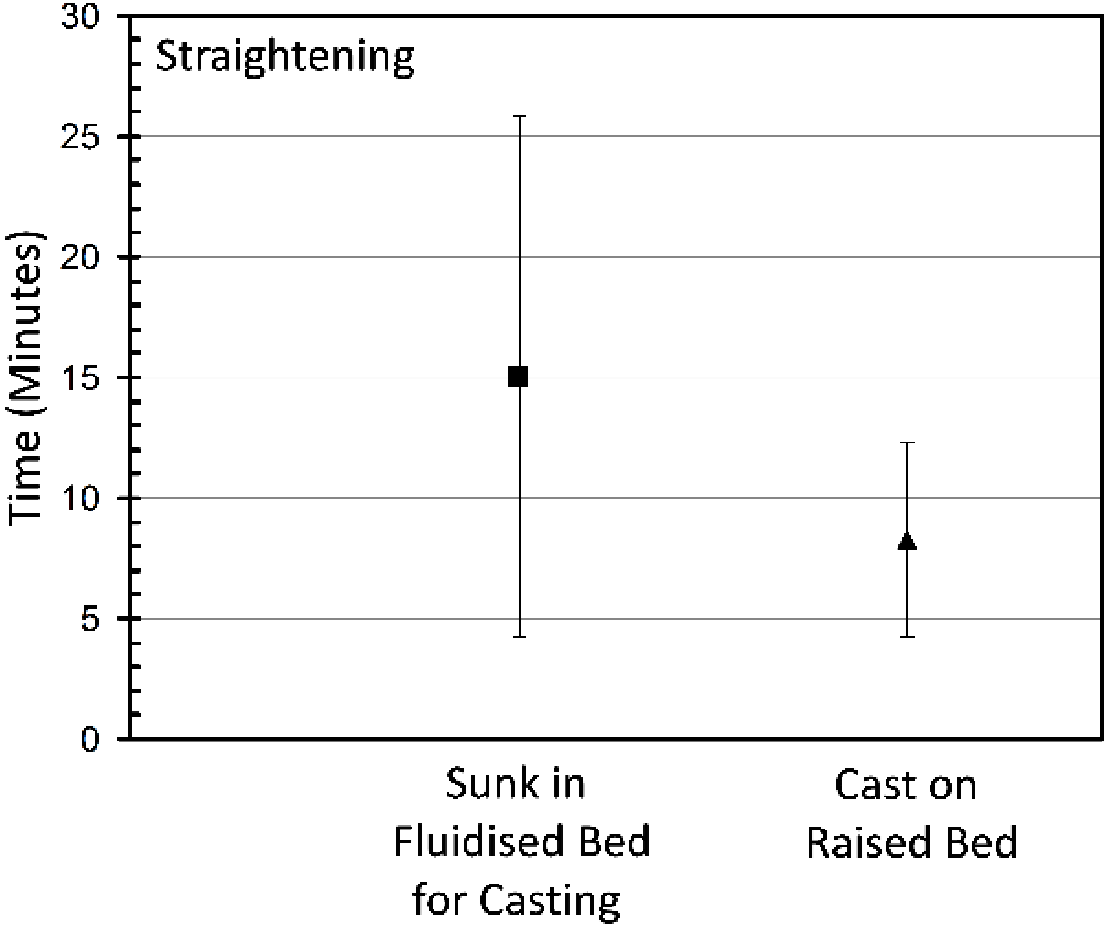
(Working with the operators on loading for cutoff & Address prime coat spall)

Rework Study

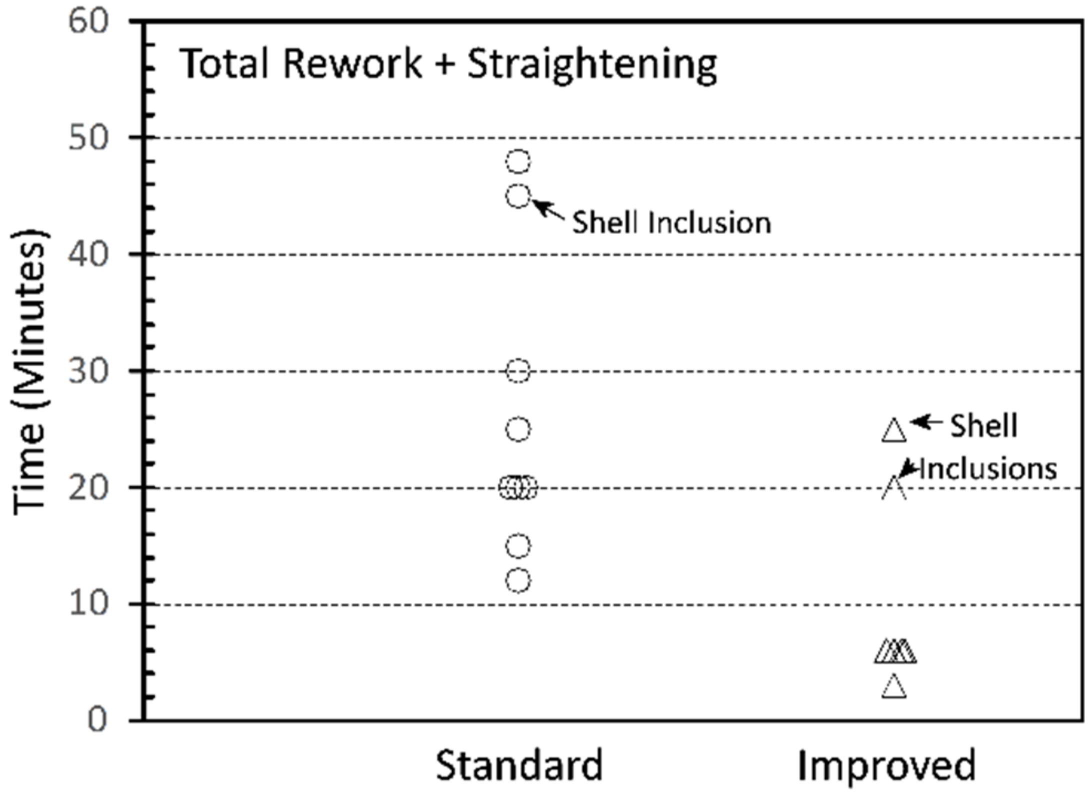
Average rework time per part and variability related to experiment a),b)&e).



Experiments c) and d)



The total time of rework and straightening combined comparing the standard method (experiment (a)) with the improved method (experiment (e)).



Standard = sunk in fluidized beds

Improved = cast on raised beds, with filters

Conclusions

1. Quality of the prime coat was not optimal.

2. Excessive time was spent in straightening due to the use of fluidized beds in casting contributing to distortion.

3. Re-oxidation and entrainment defects resulted in significant weld repair.

4. Weld repair caused distortion and increased straightening time.

5. The flow on effect of the program of work was beneficial across multiple product lines.

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