# Influence of Alloying, Inoculation and Preconditioning on Grey Iron for Automotive Industry

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**ABSTRACT**

Engine designers look for solutions where they can design more efficient engines with more horse power / kg of engine. To achieve this it is needed to increase pressure and temperature inside engines which lead to requirements for higher strength materials.

After having done literature study, it seemed to be interesting to compare grey iron grades produced by the use of chromium as the main strengthening element to a grey iron grade where vanadium is used as the main strengthening element.

The effect of preconditioning on mechanical properties, chill and thermal analyses were examined for two grey iron grades for automotive castings. The experiments were performed in lab scale using 300 kg electrical induction furnace. A total of 6 different inoculants were tested in base iron with and without preconditioning.

The results showed that the preconditioning reduced the spread in results and gave more homogeneous properties in the iron samples. It also showed that the preconditioning reduced the chill tendency which indicates that improved machinablity can be expected. The iron grade based on Cr as strengthening element gave considerably less chill compared to the vanadium alloyed iron.

## TRIAL SETUP

The trial was set up as a lab. trial where a 300 kg capacity induction furnace was used for melting. 6 different inoculants were tested in both preconditioned and not preconditioned condition. Preconditioning was done by adding 0.1% of Preseed™ preconditioner with the charge in the furnace. The inoculation was done by adding 0.2% of inoculant into the pouring ladle, pour the iron over and hold for 1 minute before casting the different samples.

Each inoculation combination was done with two repetitions as shown in Table-1 for overview.

To evaluate the trials the following samples were taken for each trial; 4 QuiK-Cup® for thermal analyses, 2 tensile bars for tensile and hardness measurements and 1 chill wedge.

ATAS® thermal analysis system was used with 3 PCs and 5 QuiK-Cup® stands with 4 holders on each. This gave totally a logging capacity of 20 samples simultaneously, as shown in Fig. 1.

**Table-1 : Trial Setup**

| Variables | Levels | Inoculation | levels |
|---|---|---|---|
| Precondition | 0 0,1% | | 2 |
| Cr | 0 < 0.3% | | 2 |
| Vanadium | 0 < 0.1% | | 2 |
| Inoculation | | 6 different x 2 | 6 x 2 |
| | | Total Runs | 96 |
| | | Total Heats, Chem Based | 4 |

Chemical analysis during the trial was done using an Arc Sparc Optical Emission Spectrometer (Arc SparOES). C and S analyses were made using combustion analysis. The C and Si concentrations were also estimated using QuiK-

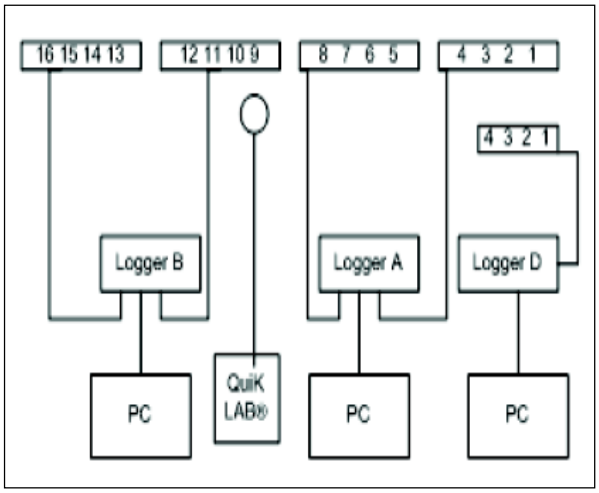


Fig. 1: Connections between PCs, loggers and QuiK-Cup® stands.

Lab® thermal analysis. The final analyses of the iron were performed on selected QuiK-Lab® thermal analysis cups using XRF.

The Chemical composition is given in Table-2.

**Table-2 : Main Elements in Weight %**

| | C | Si | Cr | V |
|---|---|---|---|---|
| Cr grade | 3.3-3.5 | 1.6-1.7 * | < 0.3 | |
| Vanadium grade | 3.3-3.5 | 1.6-1.7 * | | < 0.1 |

* For charge 1, Cr grade with preconditioning, the silicon content was approximately 2.5%

There was a deviation from the target analyses in the first melt due to too high silicon content in the charge.

Unfortunately, this deviation will have an influence on the mechanical properties and will e.g. give lower tensile strength due to higher carbon equivalent in melt 1 compared to the others. However, since it was made quite a high number of parallels it is believed that relatively the differences between the inoculants should be correct.

Main content of active elements in the different tested inoculants was:

Zr in inoculants Nos. 1, 3 and 4

Sr in inoculants Nos. 2, 3 and 6

RE in inoculant No. 5.

## RESULTS

### Thermal Analyses

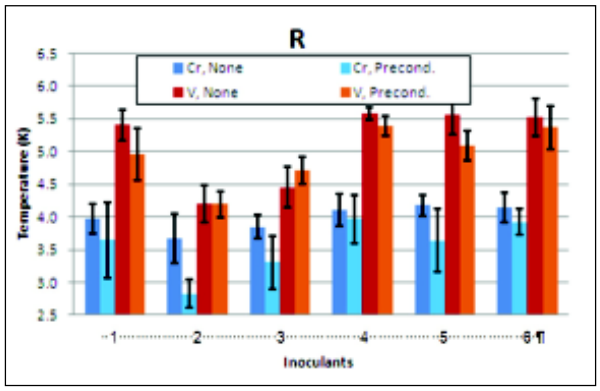


Fig. 2 : Average recalescence with standard deviation for the different inoculants.

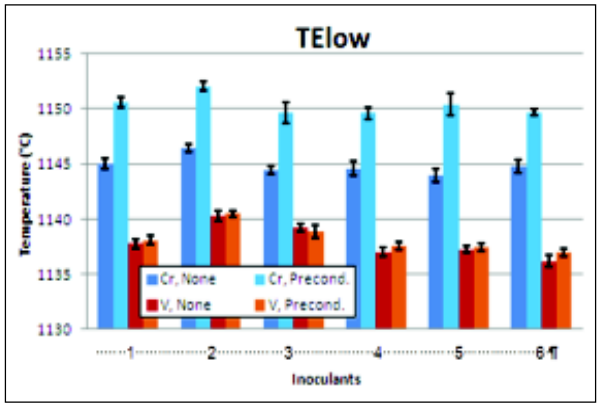


Fig. 3 : Average low eutectic temperature with standard deviation for the different inoculants.

For recalescence both grades show the overall best result with inoculant 2, the poorest with inoculant 4 and inoculant 6. Cr grade benefits from preconditioning while the vanadium grade shows less response to preconditioning in the thermal analyses, as seen in Fig. 2.

For the low eutectic temperature again the thermal analyses indicates that inoculant 2 performs best for both grades. The Cr grade benefited from preconditioning while the vanadium grade showed less response to preconditioning as seen in Fig. 3.

### Mechanical Testing

Figure 4 gives a general overview. It shows that the ultimate tensile strength is higher for the vanadium alloyed grade. However for the first set of trials, the Cr grade with preconditioning, the Si-content was far too

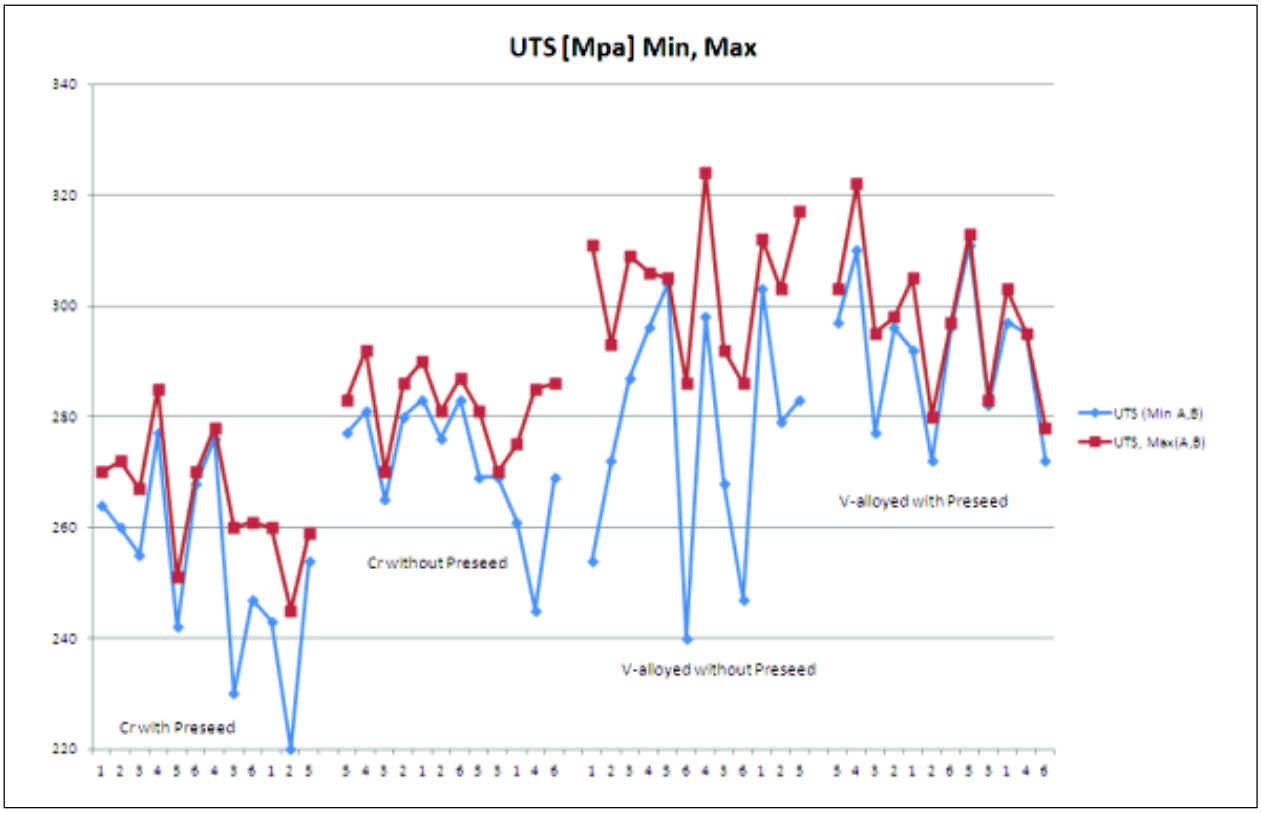


Fig. 4 : Ultimate Tensile Strength (UTS) for all trials, two tensile bars per trial.

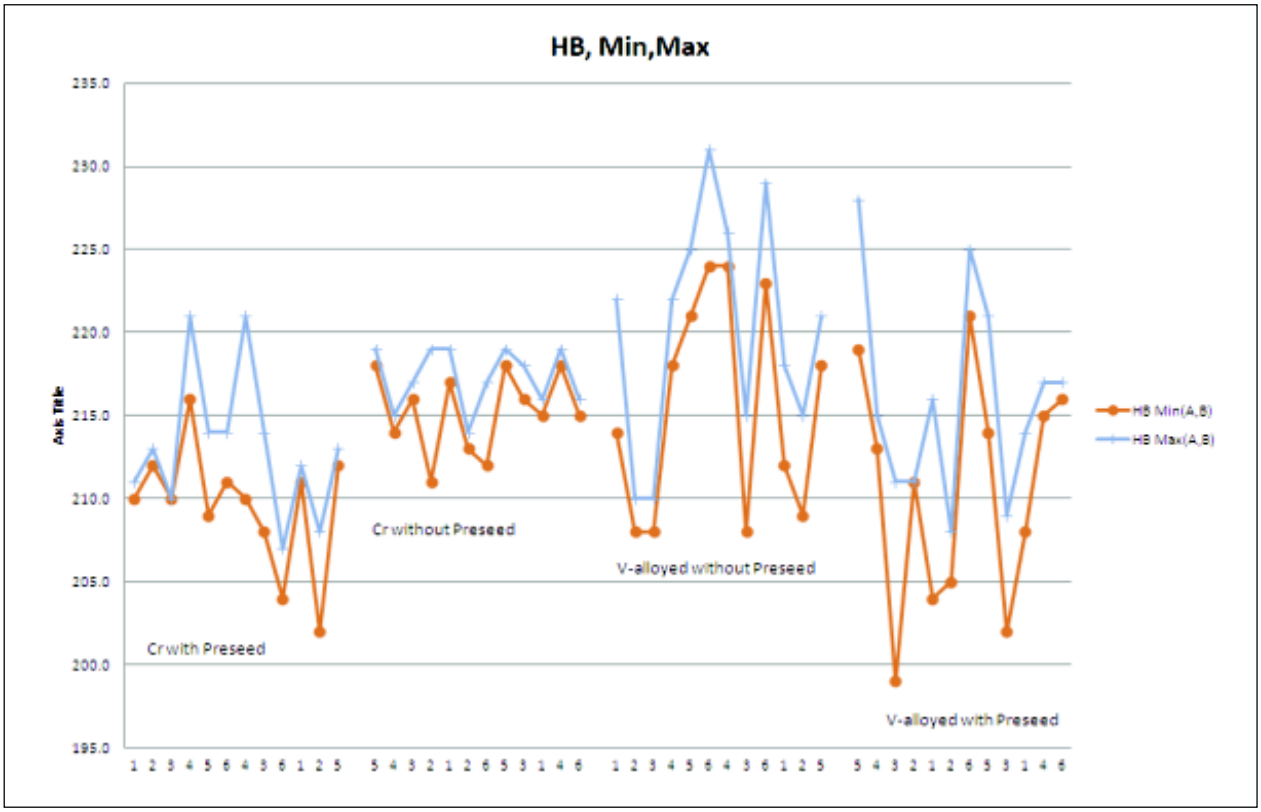


Fig. 5: Brinell Hardness (HB) for all samples.

high and this is the main reason for the low UTS for this series. For the vanadium grade the results show that there is considerably less variation between the two parallel tensile bars in the preconditioned samples compared to the not preconditioned ones.

The hardness measurements are done with one measurement on each tensile bar after performing the tensile tests. The results show that the Cr grades without preconditioning have the highest and most consistent hardness. The vanadium grades have the greatest spread in hardness results. The results are seen in Fig. 5.

### Chill Wedge Measurements

The chill wedge measurements are done manually by the use of electronic vernier callipers on both half's of the broken chill wedges giving 2 measurements per chill wedge. For both the Cr grade and the vanadium grade the chill in both not inoculated and inoculated samples are reduced in the preconditioned iron compared to the not preconditioned iron. The chill is significantly higher in the vanadium grade compared to the Cr grade in all the samples. The results are seen in Figs. 6 and 7.

## RESULTS AND DISCUSSION

### Thermal Analysis

For the Cr grade iron as well as for the vanadium grade iron, the overall best results are with inoculant 2. Preconditioning has a significant and positive effect for the Cr grade.

### Mechanical Testing

Due to the difference in carbon equivalent between the melts it is hard to compare them directly. Most pronounced effect of the preconditioning on the mechanical properties is that it has reduced the differences between the parallel tensile bars in the vanadium grade considerably.

For the Cr alloy there are very small differences between the various inoculants for the not preconditioned iron, while for the preconditioned iron, iron inoculated by

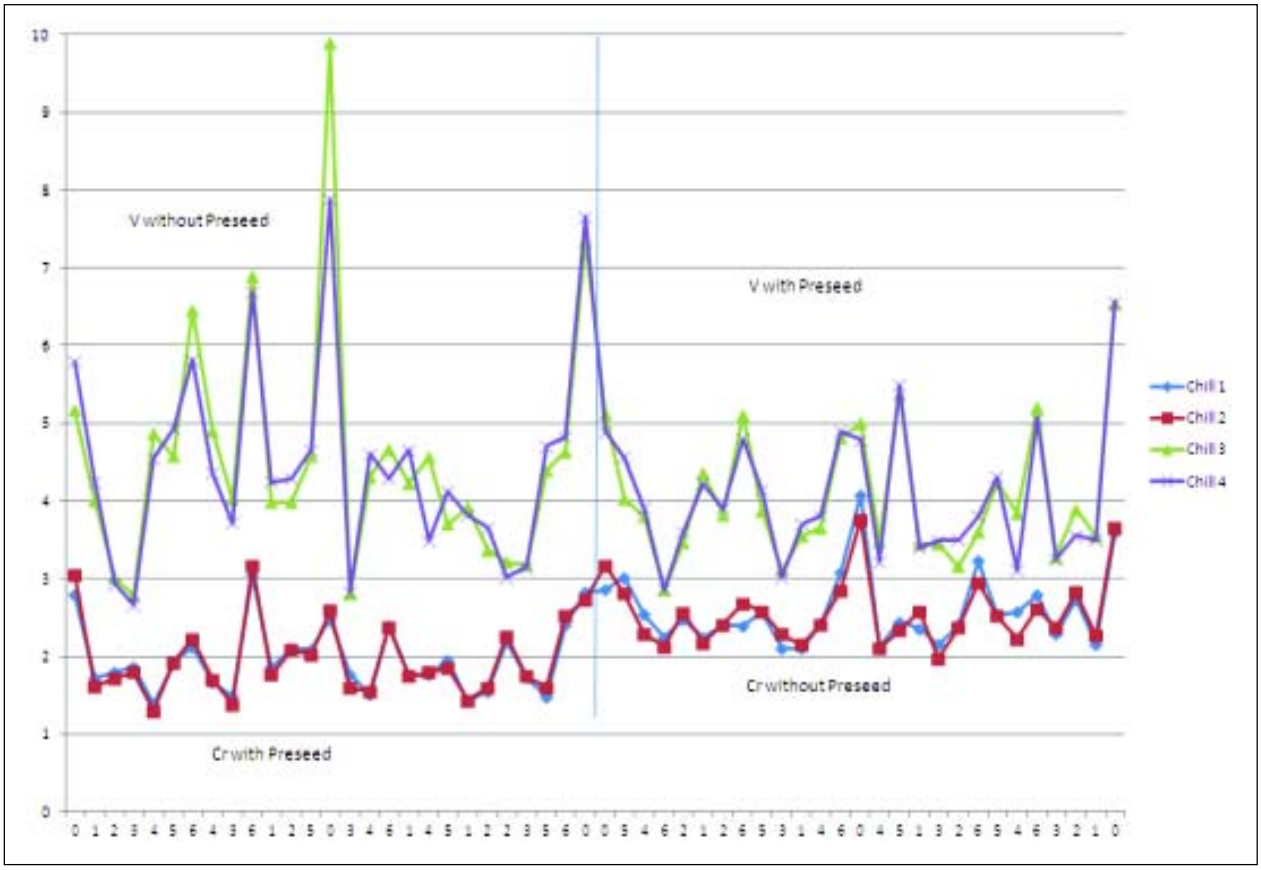


Fig. 6 : Chill wedge measurements for all the trials, two measurements per chill wedge.


Fig. 7 : Chill wedges from trials without preconditioning for the different inoculants, first and last chill wedge is uninoculated samples. The upper one is the Cr grade while the lower one is the vanadium grade

inoculant 4 has both the highest tensile strength and the highest hardness.

For the vanadium grade with no preconditioning, inoculant 6 had the lowest tensile strength and the highest hardness. High content of cementite is most likely the reason for this. Samples inoculated by inoculant 4 and inoculant 5 have the highest tensile strength for both preconditioned and not preconditioned iron. Except for the samples inoculated by inoculant 6 they also have the highest hardness. Inoculant 2 that performed best according the thermal analyses did not stand out as better or worse than the other inoculants regarding mechanical properties in these trials.

## Chill Wedge Measurements

The vanadium grade iron had considerably more chill compared to the Cr grade iron for both preconditioned and not preconditioned samples. The preconditioning by Preseed™ preconditioner reduced chill significantly both for Cr and vanadium grades iron, except for vanadium grade inoculated by inoculants 1, 2 and 3. For both grades and both preconditioned and not preconditioned iron, samples inoculated by the use of inoculant 6 had the highest content of carbide. For the Cr grade, inoculants 3, 4 and 5 give the lowest chill for both preconditioned and not preconditioned iron. For the vanadium grade inoculant 3 performed best both in not preconditioned and in preconditioned iron, however the preconditioning did not improve the performance of inoculants 3, 2 or 5. The preconditioning had significant effect on reducing chill when inoculants 4 or 6 were used.

## CONCLUSIONS

There seems to be little correlation between the thermal and the mechanical test or chill results. The thermal analyses indicated that inoculant 2 performed best for both Cr and vanadium grades, while this was not confirmed by the mechanical or chill results. In none of those tests, inoculant 2 stood out as the best inoculant.

For the vanadium grade there is a very good correlation between chill and hardness results, however this correlation is not found for the Cr grade.

From the test performed the following conclusions can be drawn:

(i) The vanadium alloyed grade gives in general considerably more chill than the Cr alloyed grade.

(ii) Preconditioning by the use of Preseed™ preconditioner reduces the carbide formation.

(iii) Preconditioning by the use of Preseed™ preconditioner reduces the spread in results and gives more homogeneous properties.

(iv) Inoculant 4, which is a Zr containing inoculants, is the inoculant that in combination with Preseed™ preconditioner gives the highest tensile strength combined with the lowest chill. ■