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Residual Stress Measurement in Large Grey and Ductile Iron Castings

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Simulation of the casting process has become an increasingly important tool to improve the design of the various cast components in a modern large-bore two-stroke diesel engine and is therefore used extensively in the development and design phase.

In order to better understand the state of residual stresses in our cast components and to compare results from commercial stress simulation software with real life data, residual stress measurements have been performed using the ring-core method.

The results show that the ring-core method is viable and that predictions by the simulation software is relatively close to the measured stress levels and more important, the tendencies and distribution of the stresses correspond very well.

Keywords: *Residual Stress Measurements, Ring-core Method, Cast Iron, Simulation.*

1. Introduction

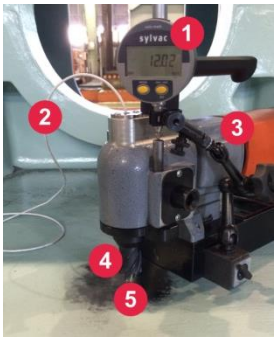
The residual stress measurements have been performed on cylinder frames, as these are a vital component in the two-stroke engine structure and have large variances in section thickness.

In total 32 measurements have been performed on three different cylinder frame castings, additionally, 10 measurements were performed in our laboratory in Copenhagen on a stress relieved grey iron bar subjected to a known load.

The measurements have all been compared to simulations with MAGMASOFT®, using the unified creep material model. It should be noted that for none of the castings on which the measurements have been performed, have we had access to detailed data on the cooling conditions, these are therefore based on qualified guesses.

2. Ring-core method

The method used for the residual stress measurements described in this paper is the ring-core method, in which a strain gauge is fixed to the surface of interest, and a drill (in this case mechanical) is used to remove the material surrounding the strain gauge, and by this relieving the stresses, so that the inverse stress-state is established by the strain gauge.



1. Dial for measuring drilling depth.
2. Wire from the strain gauge going through the drill and connecting to the terminals.
3. Drill with magnetic base.
4. Core drill.
5. Strain gauge.

Fig. 1: Setup for the measurements

3. Measurements

3.1 20 ton grey iron cylinder frame

The measurements were performed on a 6S50MC-C cylinder frame (EN-GJL-250 alloyed with copper) cast by Shanghai Hulin Heavy Industry Co., Ltd. The measurements were performed at the foundry, after cleaning of the casting.

Figure 2 show the results of the measurements performed in the transverse direction compared to the results of the simulation.

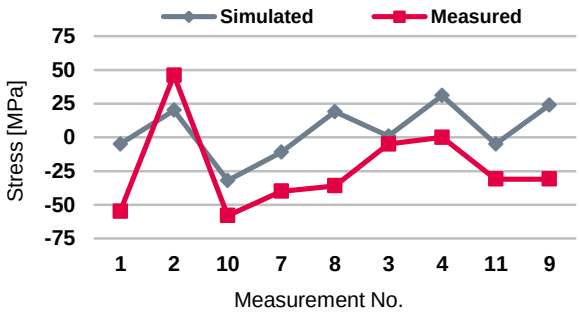


Fig. 2: Transverse results, simulated vs. measured

3.2 10 ton ductile iron cylinder frame

The measurements were performed at Mitsui Engineering & Shipbuilding Co., Ltd., on a ductile iron 3S50MC-C test casting (EN-GJS-500-7) cast by

Mitsui Meehanite Metal Co., Ltd. Sasayama Manufacturing Section.

In total 13 measurements were performed, there were however some problems resulting in unusable results, still 8 reasonably good and stable measurements were performed.

Figure 3 show the results of the remaining measurements, in the longitudinal direction, compared to the results of the simulation.

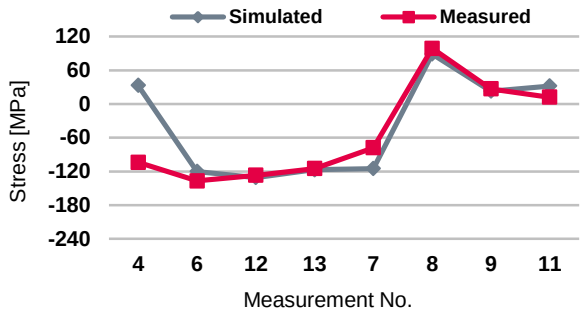


Fig. 3: Longitudinal results, simulated vs. measured

Except for measurement no. 4, the match between the measured and simulated results is exceptionally good.

3.3 Tests on loaded grey iron bar

After the problems experienced during the former measurements, 10 measurements were performed in our laboratory in Copenhagen, on a stress relieved grey iron (EN-GJL-250) bar subjected to a known load, to test different drills and the effects of grinding.

The force was adjusted to ensure a load of 75 MPa in the cross-section of the test bar.

The results from all 9 successful measurements is shown in figure 4. It can be seen that the reproducibility of the measurements is very good.

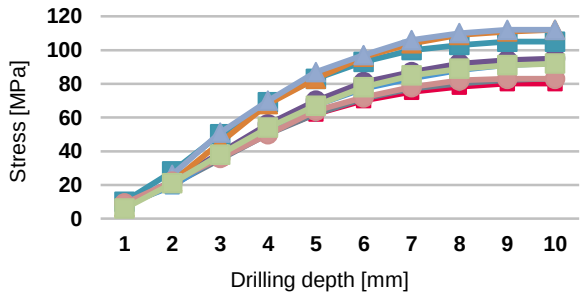


Fig. 4: All measurements

The measurements showing higher than the actual 75 MPa were the measurements on which the bar had been exposed to excessive grinding or on which an unsuitable drill was used.

3.4 25 ton ductile iron cylinder frame

The measurements were again performed at Mitsui Engineering & Shipbuilding Co., Ltd., this time on a ductile iron 6S50ME-B cylinder frame (EN-GJS-500-7) cast by Mitsui Meehanite Metal Co., Ltd. Sasayama Manufacturing Section.

10 measurements were performed, all in a relatively thin (30 mm) section.

The longitudinal results and the results from the simulation can be seen in figure 5, again the tendency of the distribution of stresses in the various points of the cylinder frame matches very well between the simulated and measured results.

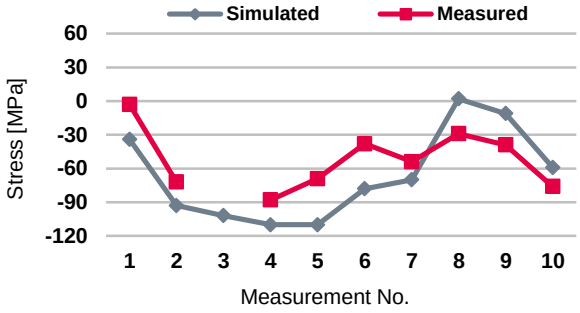


Fig. 5: Longitudinal results, simulated vs. measured

4. Conclusions

After initial problems in performing the measurements, we now belive that we are able to consistently perform good measurements using the ring-core method on grey and ductile iron castings where a relatively large plateau of even stresses is present.

The tests in our laboratory proved that the method gave the expected results and also showed that excessive grinding and/or the state of the drill have an influence on the measured strains.

Generally, and considering our limited knowledge of the shake out procedure and cooling conditions of the castings, the prediction of stresses by MAGMASOFT® has been very good, which has given us increased confidence in using simulation as part of our development and design process.