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CARBIDE ENHANCEMENT AND EXACT GRAPHITE CONTROL IN ICDP ROLLS WITH CALCULATED PROCESS PARAMETERS[1]

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Abstract

Throughout recent years, roll manufacturers have developed different kinds of high performing rolls. For roughing mills and first finishing stands HSS rolls and for the last finishing stands carbide enhanced ICDP rolls. Different types of alloying elements have been chosen and the ratio of carbide forming elements to the carbon content gives a big variety of opportunities. At ESW the world-wide patented VIS grade was developed and there are still enough possibilities for new concepts. ESW has introduced a new system to describe the status of the liquid metal. For all grades with free graphite precipitation it is essential to characterize the nucleation status of the melt. The inoculation is key process to influence the amount and the shape of the free graphite, which will be present in the roll after casting and solidification. Due to the ability to define the graphite content in carbide enhanced ICDP rolls under the normal production process, it is thus possible to produce customer tailored rolls to meet specific rolling mill requirements. In comparison to conventional rolls the variety of graphite content and microstructure is much smaller and can be varied according to the specific mill conditions.
Keywords: Graphite control; Enhanced ICDP; Nucleation of melt; Special carbides.

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1 INTRODUCTION OF A NEW SYSTEM TO CHARACTERIZE MELT

The trials for characterization of a melt started with a very simple system. A small amount of liquid melt was cast into a pot and where a thermocouple was inserted. The cooling curve was recorded and the result of the curve was used to evaluate the liquidus temperature. Beside that, different other samples with triangle shapes were cast and broken, to determine visually the amount of clear chill and the area of slower solidification, with graphite precipitations. Both methods combined with the experience of a melter, lead to a reasonable characterization of the melt. The inoculation was determined according to the experience of the melter. This was basically the only possibility to achieve a certain range for the graphite content in a roll.
This method was possible, as long as the chemical composition did not vary very much and the various ICDP grades were limited in number. The range of roll dimensions was also narrower compared to today. In the late 1980’ies the first system of cooling curve measurement and data processing was invented. The system was based on DOS and could also provide on different areas of the cooling curve, values for the characterization of the nucleation. The supercooling and the amount of recalescence, as well as first derivative of the solidification part of the cooling curve lead to a table of fixed inoculation for different alloys and diameters of a roll. This first system was developed by a small group and unfortunately this company did not exist very long. The decision was then made to introduce a new system, which was already used in many foundries and for that reason gave insurance, that help and support could be available also for the future.

1.1 Thermoanalysis from OCC

The new system was selected based on a few very interesting items:

a) Small size of samples, reduced time for cooling curve
b) Possibility to compare pure material and inoculated material
c) Good reproducibility of the cooling curve
d) Good filling ability of sample
e) Mathematical soft ware for evaluation.

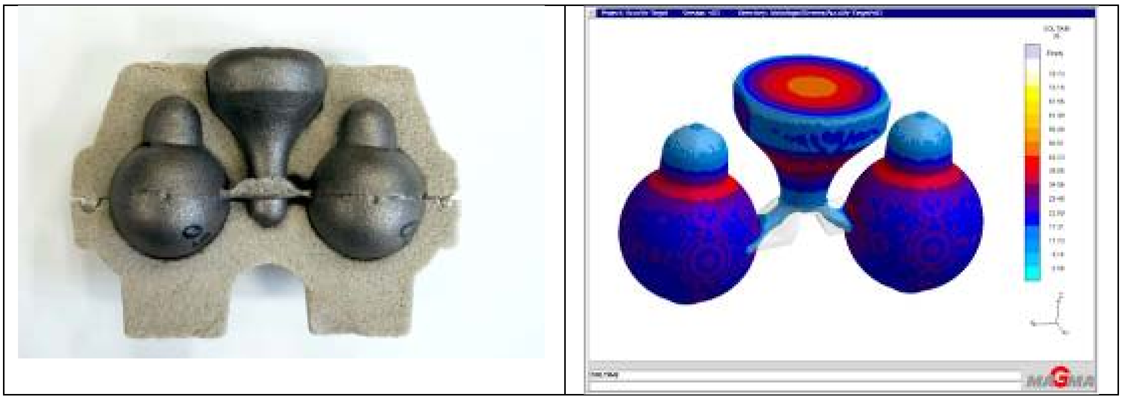

Figure 1. Cast sample and thermal calculation of cooling.

The left part of the sample mould, Figure 2, is filled with an inoculant. The result of the two different cooling curves, Figure 3, gives the possibility to analyze the status of the melt and gives advices about the ability to form graphite or not.

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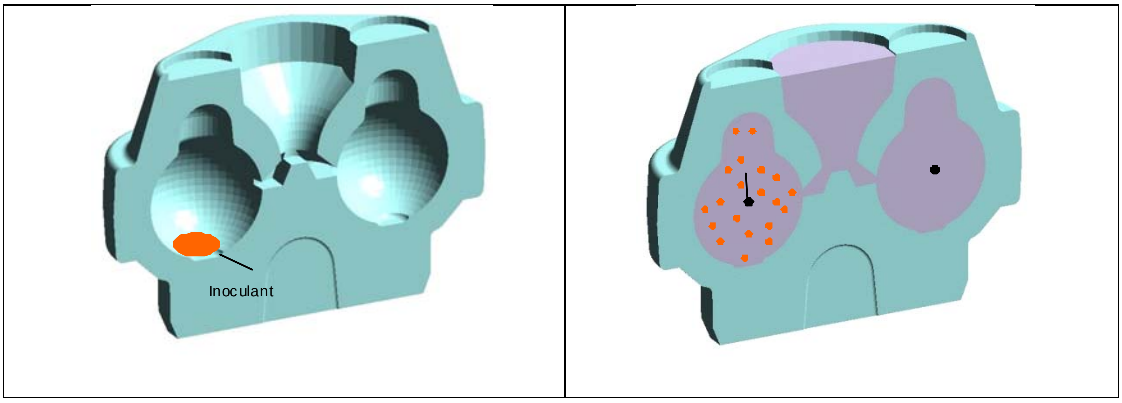

Figure 2. Sample mould and mould filled with metal AccuVo® Cup from OCC.

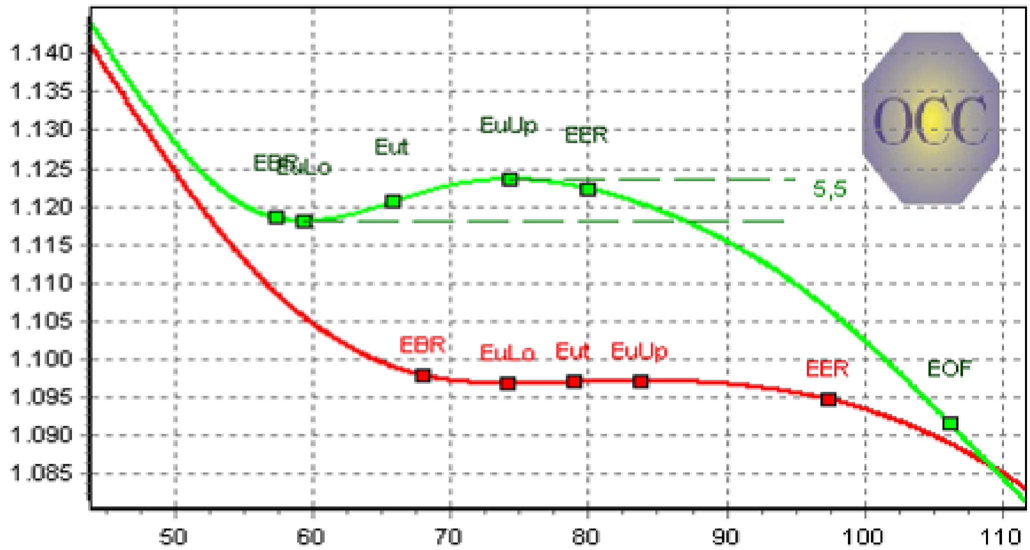

Figure 3. Cooling curves, green: inoculated metal, red: pure metal.

1.2 Data Sampling and Evaluation

After the installation of the new system, more than six months of data collection was done. All recordable data from the melt, the casting and to the results of the metallographic sample analysis were transferred into a database. The comparison between the old system and the new system, figure 4, was made during this time. A control circuit was installed, to get the feedback from both systems. A very large amount of solid samples from the different rolls were taken. It was necessary to get enough statistical data from each material, different sizes of rolls and a high amount of charges, to ensure that the statistical basis was big enough for a reliable evaluation.

1.3 Multiple Linear Regression and Formula Generation

A multiple linear regression method developed by OCC showed as a result, a mathematical formula, which included the most important parameters of the data base. This formula was then tested to determine and predict the inoculation to achieve a certain amount of graphite in a roll.

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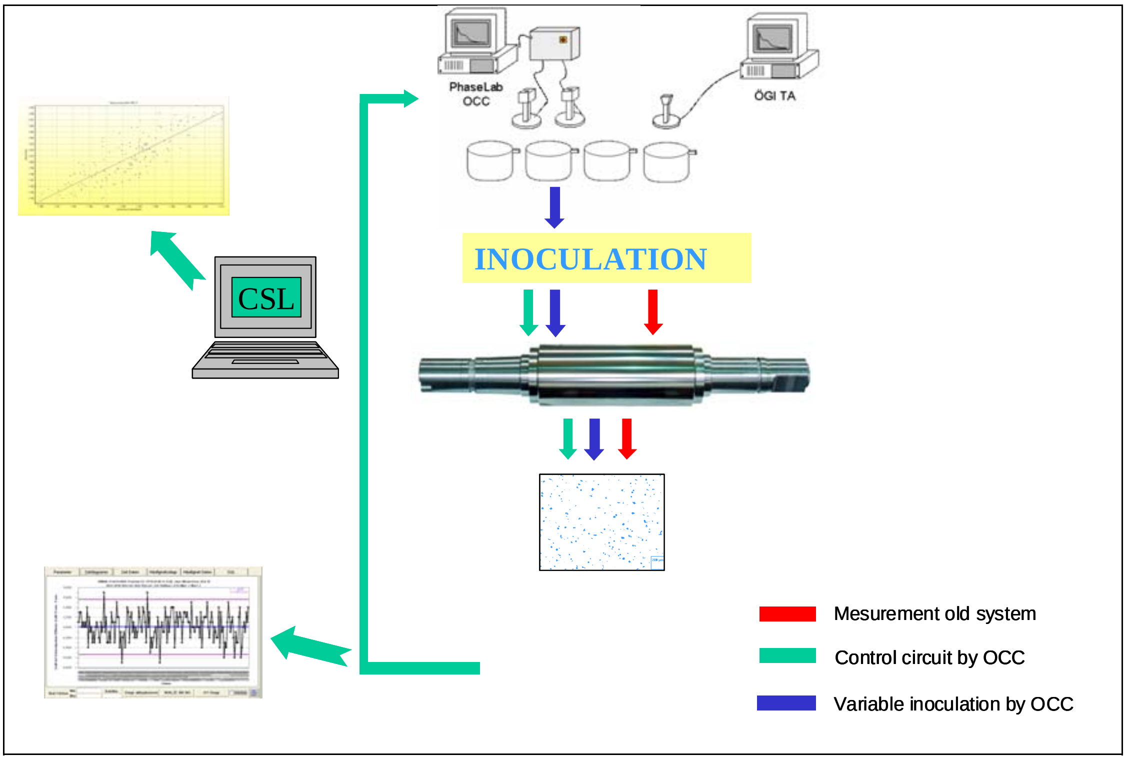

Figure 4. Control circuit, old system, new system and SPC from database.

The method was introduced and supervised the next months, to make the final adjustments. Nowadays, the formula is implemented in the production process. For each and every customer we have now a tailored table, were we have fixed the required graphite content. According to the material used and the size of the roll, the last sample before the casting is analyzed and the formula is predicting the correct amount of inoculant, to achieve the expected graphite content.
Combined with the results of the roll performance in the mill, it is now possible to further improve the inoculation strategy, or to decide to change over to the next higher or lower internal grade of the enhanced ICDP grade, to fulfil the special needs of every customer.

2 DEVELOPMENT OF A NEW TYPE OF ENHANCED ICDP

The past has shown that the conventional ICDP is losing market share year by year. The mills are being continuously upgraded and the testing facilities in the roll shops are nowadays having the possibility to find out most of the defective areas of a roll. This in turns leads to more and more usage of enhanced carbide ICDP rolls. The performance of these rolls is much higher compared to conventional ICDP. The safety in operation is guaranteed by the roll shop testing facilities.

2.1 Comparison of ICDP and Enhanced ICDP Rolls Such as VIS

The biggest difference between the enhanced ICDP and the conventional one is the hardness penetration. The conventional ICDP normally has a higher hardness drop, figure 5, than the enhanced ICDP. The hardness drop leads to bad surface aspect of the roll during the lifetime and more roll changes are then needed.

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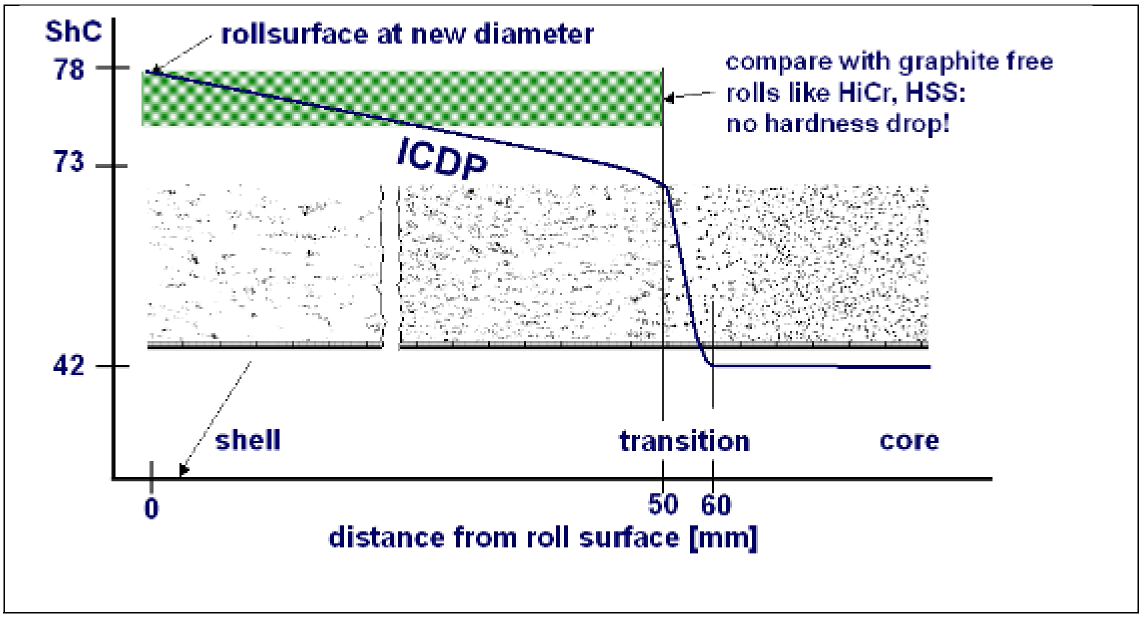

Figure 5. Hardness penetration of conventional ICDP.

Especially in single stand application as Steckel mills and Plate Mills, the invention of enhanced ICDP made a major step forward. Also in the HSM application the roll changes are going down and since new mills have the chance to use rolls with different sizes in all their stands, the flexibility increased and higher performing rolls could be used longer. The weakest part in the chain dominates the roll change and the output of the mill.

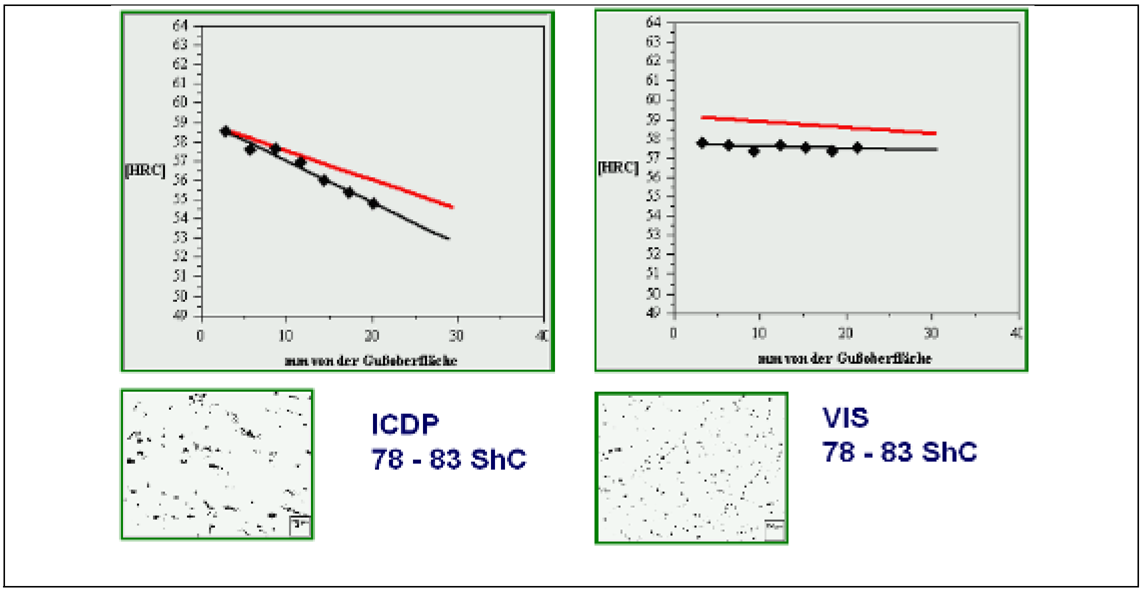

Figure 6. Hardness penetration of enhanced ICDP = VIS.

Beside the hardness, also the graphite content and the graphite shape of the enhanced ICDP gives a much better surface compared to the conventional ICDP. The round shaped graphite particles are smaller and the wear (abrasion) becomes different. The flaky type of graphite in the conventional ICDP gives a much rougher surface, Figure 7, after a campaign. The reason is, the graphite is breaking out of the surface and the holes are bigger, than the holes from round shape graphite particles.

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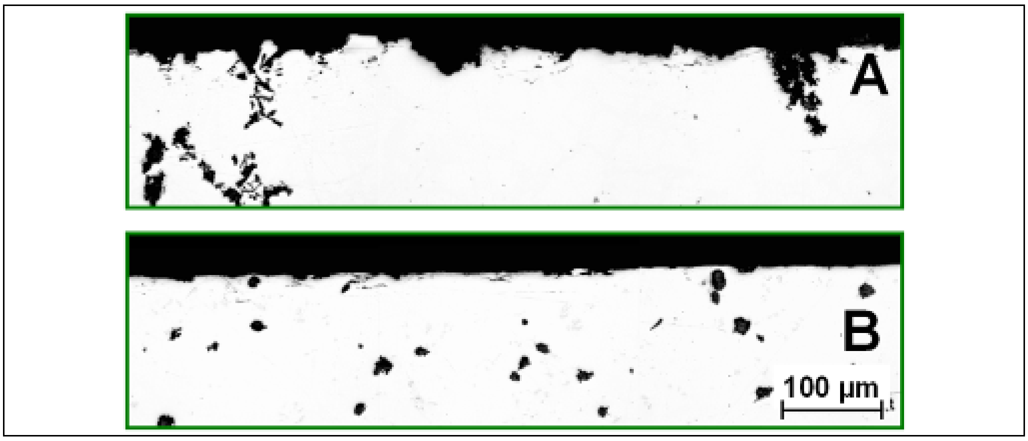

Figure 7. Surface after exposure: A conventional ICDP, B enhanced ICDP VIS.

2.3 Latest Development Of Vis Type Called Vanis

In the last recent years a continuous improvement of VIS types has been made. On the market the 4th and 5th generation have been introduced. Since we have the possibility to determine and predict the graphite content much more precise, we could again go a step ahead. The leading force in the improvement was the calculation of the carbide equivalent CE.

$$CE = 2 * \%Cr + 5 * \%W + 10 * \%Mo + 40 * \%Nb + 70 * \%V$$

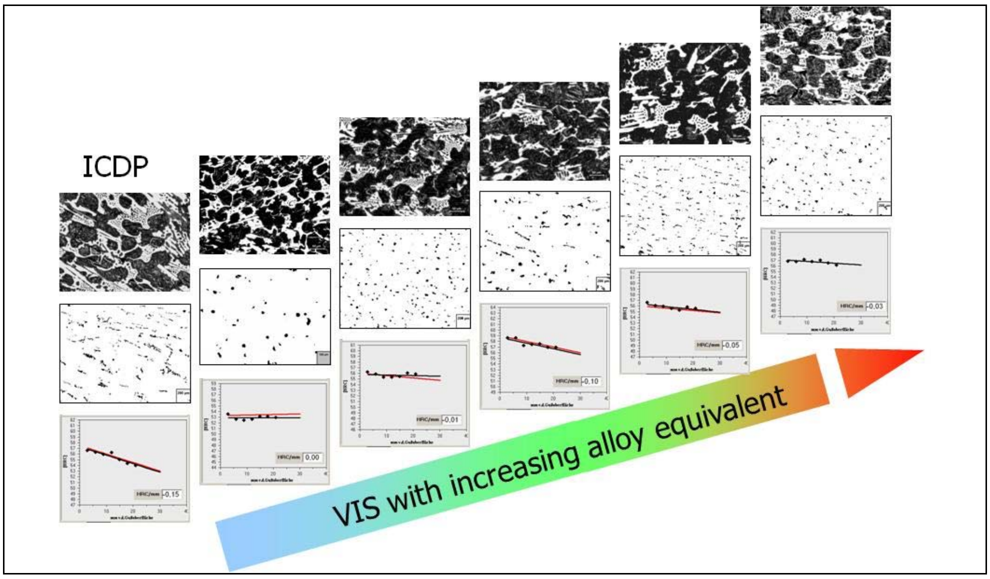

Figure 8. Steps of VIS generations with increasing CE.

The first VIS types have been in the range of CE 40 till 120, Figure 8. The VANIS has a CE far over 200. The graphite shape is totally round and the graphite amount has to be achieved by strict following the calculated inoculation. The amount and the distribution of graphite are very homogenous. In addition the amount of graphite particles per square mm is much higher in VANIS compared to the last generations.
The microstructure is dominated by a very special equilibrium of special carbides and carbide precipitations in connection to the graphite particles. The graphite is the

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guarantee for the good behaviour in the mill. The microstructure is having the basics in the near of a HSS.

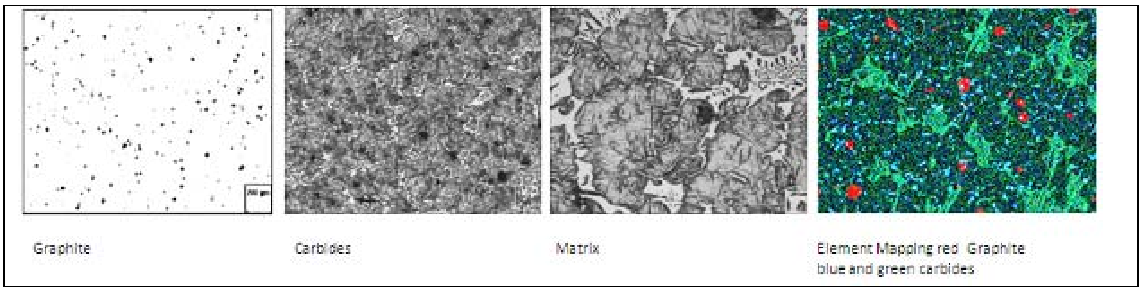

Figure 9. Graphite and microstructure of Vanis.

2.4 Results of Vanis in the Mill

Due to the new morphology of the microstructure and the new formation of the graphite, the performance in the mill is much better than the earlier VIS types. The Figure 10 shows the performance results in the last finishing stands of a 6 stand HSM.

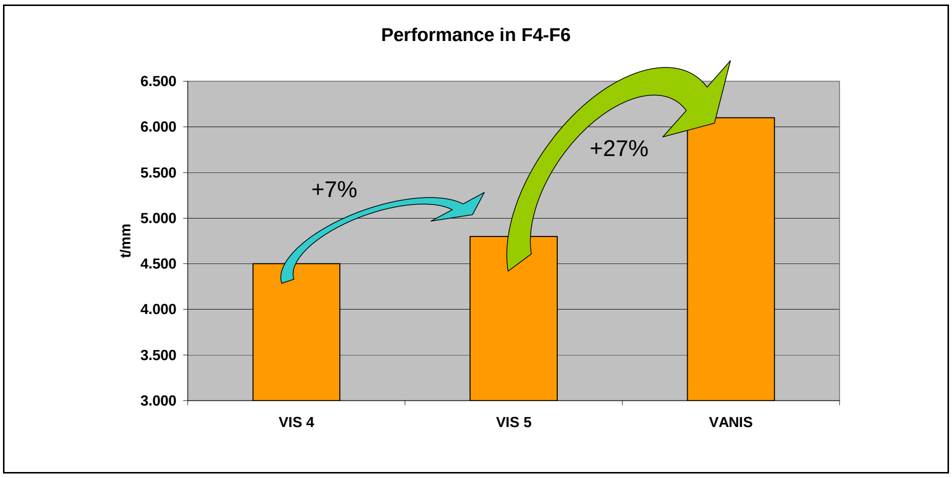

Figure 10. Performance results.

3 CONCLUSION

A new method of testing the behaviour liquid metals in combination with a prediction formula has opened the possibility to design rolls for a variety of different purposes. The use of the internal data filing and the results of the external performance figures is the way for a continuous roll material improvement.

The new grade VANIS is for the moment the leading material in the area of enhanced ICDP from ESW.