

The Development of a Cast 5% Chromium Back Up Roll

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The increasing demand from flat product rolling mills for improved back up roll performance in terms of absolute wear, wear profile, and value in use, has been met with a new generation of cast steel back up rolls.

Surveys of materials having suitable metallographic properties lead to the selection of 5% chromium tool steel. The problems associated with the adoption of such materials, not usually utilised for such applications, have been overcome. Further development of the alloy system and manufacturing process has led to a reduction in production costs, and therefore selling price enabling the material to be even more attractive in such a competitive marketplace.

Introduction

At the previous Rolls 2000 conference a paper was given by Mr. Stuart Cox entitled "Cast Steel Back Up Rolls". This paper outlined the increasing demands being made of back up rolls in flat product rolling mills, and traced some of the progress that had been made in meeting these demands. It described the types of roll material and the manufacturing processes of the materials currently supplied for such applications. The paper ended on a brief description of the development of materials for enhanced performance based on 5% chromium tool steel.

This paper continues this theme, and describes the development of this most recent step forward in cast roll technology. The particular circumstances that instigated the development work are described. The material selection process is outlined, together with a description of the properties of the material that made it suitable for the application.

Particular manufacturing problems are summarised, and the solutions to those problems are outlined. Details of the ability of the material to perform in the mill to the levels requested by the customer are given.

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Performance Requirements

The Davy Roll Co.Ltd. Gateshead has a close working partnership with Hoogovens Staal B.V. of the Netherlands. In the course of our regular partnership discussions on performance improvements, Hoogovens gave a top priority to extending back up roll campaigns. This had to be achieved without an increase in barrel wear profiles, and indeed a reduction of such was requested.

The Hoogovens mill comprises of 5 roughing stands and a 7 stand finishing train. High chrome iron is used in F1-F4, and Alloy Indefinite Chill in F5-F7. No roll pre-bending or shifting is used. A high control of strip tolerance is maintained by particularly careful control of back up and work roll profiles. No high speed steel work rolls were originally used, but trials are currently progressing with these materials. Hoogovens roll a large proportion of high strength and thin gauge materials, and their reputation for high quality is well known.

Hoogovens had previously used monobloc differentially hardened alloy cast steel at 3% chromium, double poured alloy cast steel, and forged steel back up rolls. Typical performance figures showed at best 75,000 t/mm, with the lowest wear profiles out of the mill being around 0.2 to 0.5 mm for rolls used for 1 week in the most difficult stands, or two weeks in the easier stands. In particular this level of wear made it impossible to extend the campaigns to 2 or 4 weeks, without losing control of strip shape.

Material Selection

With these things in mind Davy Roll began a literature search for materials whose metallographic and physical properties were consistent with the enhanced wear characteristics required, while maintaining the properties that made the standard materials so successful. Of many alloys studied, a highly alloyed tool steel material with 5% chromium was selected as the basis for trials. As well as the expectation of maintaining levels of strength and soundness from the new alloy, the most important feature discovered was that the material could be made to exhibit a pronounced secondary hardening effect. This effect was seen as being particularly useful for this application.

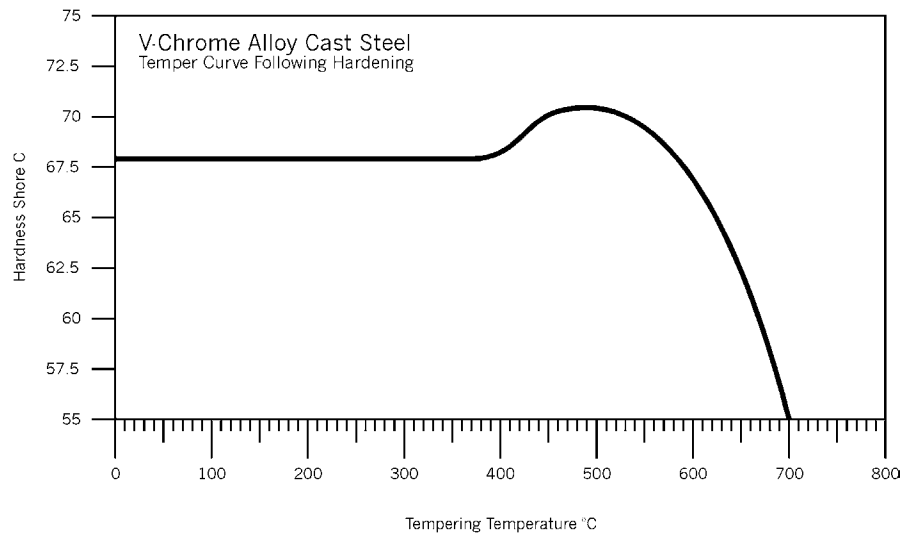
From the results of laboratory scale testing an alloy suitable for full-scale foundry trials was eventually produced.

Traditional cast steel back up rolls use an alloy with a carbon content around 0.4%. Such alloys typically show no primary alloy carbides in their microstructure. The simplest method therefore to improve wear properties would be by increasing this carbon content and so develop a proportion of primary alloy carbides in the structure. However it was already appreciated that higher carbon alloys with their resulting primary carbides were not desirable, as the reduction in strength that results could not be tolerated due to the exacting strength requirements of a back up roll application. This is particularly true in terms of fatigue strength, as back up rolls are probably the only rolls that have lives long enough, at stresses high enough, to make fatigue resistance a consideration. It was also very important to maintain the excellent spalling resistance shown by the traditional 3% chromium material.

However it was the presence of alloy carbides in the microstructure that was seen as being the very requirement to produce the enhanced wear properties desired. The fact that this tool steel alloy with a similar low carbon content to the traditional material shows no primary carbides as cast, but develops significant amounts of hard carbides during the latter stages of heat treatment made it a very attractive proposition.

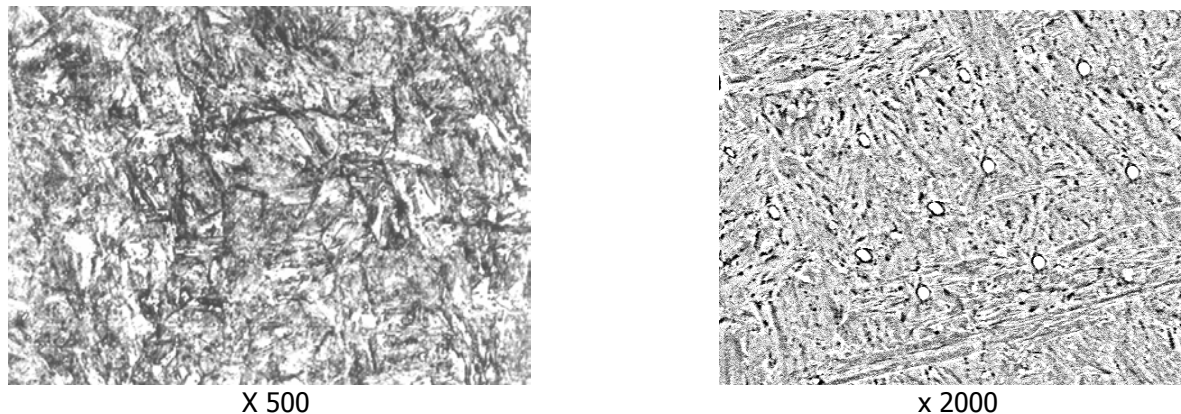
The secondary hardening effect occurs as a result of the precipitation of very fine complex alloy carbides during the tempering phase of heat treatment, which follows the differential hardening process that is applied to the working surface of the roll barrel. The rate and size of the deposition is dependent on the tempering temperature, as well as the time at temperature. The Tempering temperature is therefore selected to produce an optimum precipitate size, and a final hardness of 65/70 Shore C. Figure 1. Illustrates the temper curve that is produced.

Figure 1.



These complex precipitates are shown by microprobe analysis to consist of MC type carbides. They have a spheroidal morphology and an average diameter of 2 – 20 microns. Micrographs of the structure at x500 and x2000 are indicated in Figure 2 below.

Figure 2.

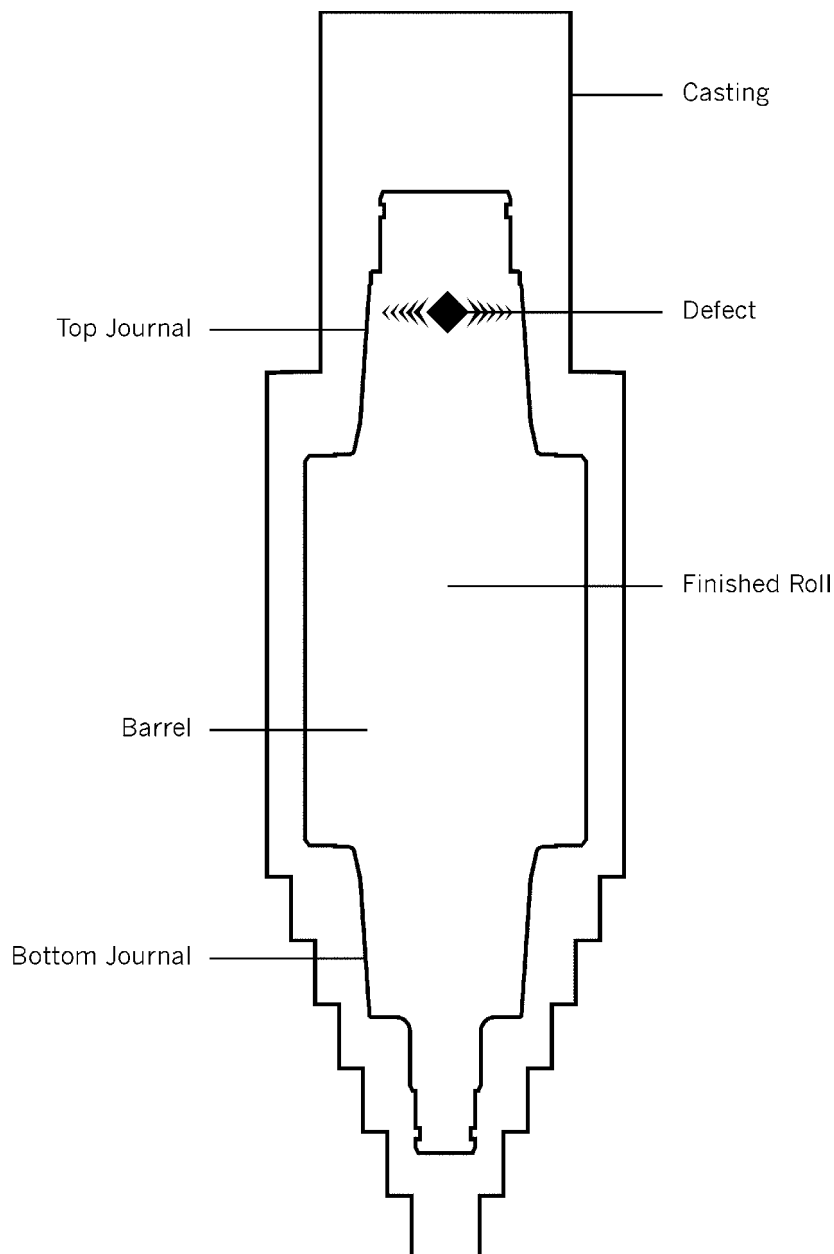


This morphology and size means that the carbides have little effect on the strength of the material, as would be experienced if large carbides were produced, and so the levels of strength and spall resistance typical of the standard alloys are maintained. The remaining matrix consists of tempered acicular products – similar to that of standard differentially hardened materials. The journal and axis being kept at sub-critical temperatures during barrel hardening, experience no such effect, and so maintain a soft, strong, ductile character.

Production Problems

As this alloy had originally been developed for use as an air-hardening, hot work steel for tools and dies, it was somewhat of a step to attempt to make 80 tonne monobloc castings with it. Laboratory scale castings and heat treatments were successful in obtaining the properties that were required. It was assumed that in terms of solidification, the material would behave in a manner similar to that of the standard 3% chromium alloy. However actual casts showed an area towards the top end of the casting, in the middle of the top journal that gave strong ultra-sonic indications. The location of this area in relation to the casting and to the finished roll is illustrated in Figure 3 below.

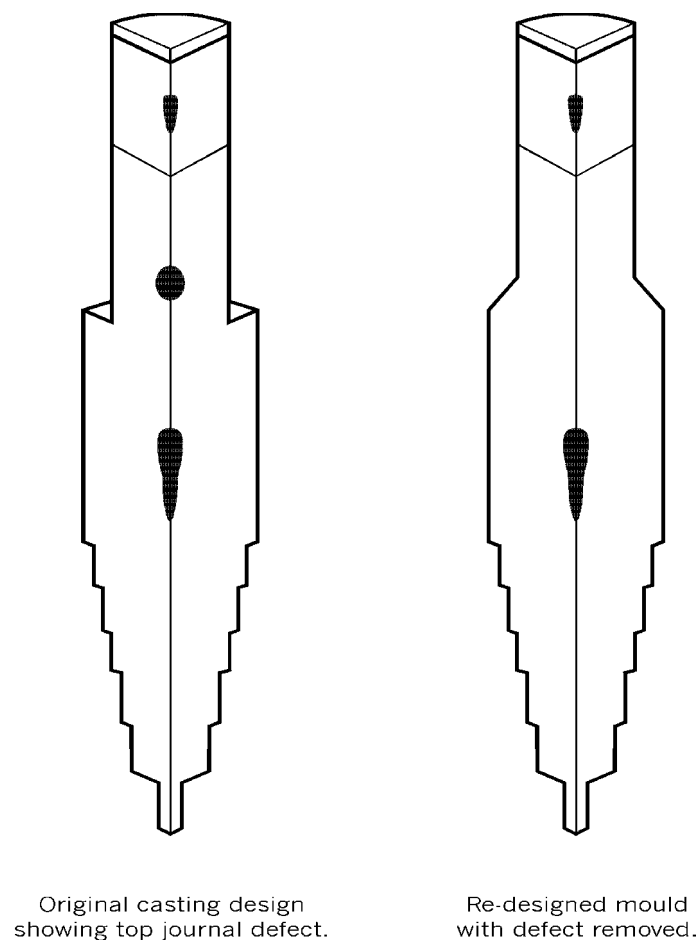
Figure 3.



In a number of castings it was found that this area also contained a planar defect or "clink", which lead to scrapping of the casting. This occurred either after the first homogenising annealing treatment, or even after the hardening and tempering treatment. Examination of the defect area showed micro-porosity and segregation, which produced a weak region in the centre of the section. The thermal stresses generated during the course of production when experienced in this area, lead to the internal rupture detected by ultra-sonic testing. It was decided that finite difference computer modelling was required to help address this unacceptable situation.

Modelling of the casting using the known physical properties of a 3% chromium alloy showed no defects in the area found in practice. Therefore the next step was to attempt to determine the physical properties of the new alloy. Some properties were available in literature, but as modifications had been made to the original tool steel described in the literature, these were obviously questionable. The determination of the various properties that are required for successful modelling can be both very costly and very time consuming. Therefore small-scale casts were carried out that included high accuracy thermocouples embedded throughout the casting and mould. This produced extensive, accurate cooling curve data for a known system. Using the known physical properties of the mould materials, modelling was then carried out to simulate the same cooling curves as produced in practice. The physical properties of the alloy thus "back calculated" were used in full-scale models. These models showed no feeding defects, but significant levels of micro porosity and segregation in the area under question, as predicted using the Niyama equation. Alterations to the modelled profile were now made until the area of porosity was removed. Figure 4 illustrates the finite difference modelling results with and without the defect.

Figure 4.



Application of the same profile changes to actual castings gave the result of there being no ultrasonically detectable defects in the critical area and no internal ruptures at any stage of the process.

Roll Performance

Laboratory work had led to the selection of a material whose properties seemed ideal for the application from theoretical considerations. However the success of the rolls could obviously only be determined from results of rolls in the mill. These results were found to be very successful.

The first roll supplied has now rolled over 7.5 million tonnes, and to date we have now delivered 24 of these rolls to Hoogovens. Overall performance is currently at an average of around 150,000 tonnes per mm, but most importantly, wear profiles on rolls out of the mill are measuring between 0 and 0.05 mm, after 1 and 2 week campaigns. Typical actual wear profiles are shown for both a pair of standard 3% chrome alloy cast steel after 70,000 tonnes rolled and for a pair of what we now designate V-CHROME alloy cast steel rolls after 138,000 tonnes are given in Figure 5 below.

Figure 5.

3% Chrome ACS



V-Chrome ACS



This excellent achievement of such a flat wear profile means that even after double the normal rolling campaign for a given stand, the rolls do not lose shape, and therefore no unacceptable strip thickness variation is produced. Additionally large cost reductions are made from reduced down times, and reduced roll dressing requirements. The roll shop has found that no specialised grinding equipment has been necessary for dressing between campaigns, and no additional NDT is necessary. The levels of work hardening produced after rolling have been found to be comparable to that of previous materials. This has meant that there is no extra risk of failure due to any barrel surface cracking and spalling and that therefore this is not a limiting factor on the campaign lengths achievable.

Hoogovens are still developing the other mill controls and set up parameters to more fully utilise the potential of these rolls, and expect even higher tonnes per mm figures, with all finishing stands being able to roll for either 2 or 4 week campaigns.

The gradual absorption of development costs, better understanding and therefore better control of the manufacturing process, and other improvements to the method of production have led to internal production cost reductions. These reductions have been able to be passed on to the customer making the roll an even more attractive proposition in a very competitive marketplace.

Conclusion

In a world of ever-increasing demand from flat product rolling mills for improved roll performance, particularly in terms of value in use, a new generation of cast steel back up roll has been successfully developed to meet these requirements.

Acknowledgements

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