Improving steel quality and decreasing production cost and carbon footprint through raw material management

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ABSTRACT

A thorough raw material selection and blending is essential for achieving a high quality melt at a minimum cost. Residual material from previous production constitute a large part of the material input and a practice where residuals from one steel type is used for producing the same steel type often lead to big stocks of internal scrap. The value of internal scrap is high due to its known alloy content and can, if used optimally, reduce overall production costs

Global Warming has put the emissions of CO2 as a main focus point in product ecology. The choice of alloy source and electricity (if possible) is vital for reducing the carbon footprint for stainless steel.

This paper discusses possible ways to decrease the capital bound in stock for a stainless steel foundry. Ways to improve quality control of scrap are outlined in order to be able to buy cheaper scrap and reduce the fraction of alloying elements coming from primary alloys.

Keywords: Steel, Raw Material, Scrap, Ferro Alloy, Quality, Cost, Optimization, Carbon Footprint

INTRODUCTION

Raw material optimization for steelmaking using the Simplex method is an established technology in stainless steel plants. In foundries and low alloy steel production it is less often used for a number of reasons for example:

- The potential has so far been too small to make it worth while
- The quality of the raw material varies and is to some extent unknown to the personnel
- Software has been complicated and expensive

Increasing prices for raw materials has however made it important for procurement departments to try to find cheaper material without putting the product quality at risk and for the logistics department to decrease the amount of raw materials in stock.

Furthermore an increased consumer interest in product ecology and the products Carbon Footprint makes it even more important to get as much as possible of the alloy content from alloyed scrap instead of virgin ferro alloys.

This study has been performed with data from the steel foundry Österby Gjuteri AB in Sweden. In the year studied 27 different steel grades were produced. In general internally recycled sprues, runners and scrap of the same steel grade is used for new melts.

With an improved calculation support all internally recycled raw materials could potentially be used in the production of all steel grades, resulting in lower overall stock levels and improved ROCE. Improved calculation methods could also lead to better utilization of the alloy content of scrap, reduce the need for pure alloys and reduce the overall production cost, mainly for raw materials. As a consequence of using smaller quantities of pure alloys the carbon footprint of the target product will also be reduced.

This study aims to quantify the above gains by comparing a loading practice similar to the one used at Österby Gjuteri, i.e. loading same type internal scrap only, with a calculated optimal loading practice. For the calculations the software system RAWMATMIX®, developed by Kobolde & Partners AB has been used.

BASIC DATA ABOUT CURRENT PRODUCTION

The model steel foundry used in calculations produces approximately 1500 tonnes of high alloy steel per annum, divided between 27 different steel grades. Internally recycled metals are valued based on their alloy content.

At the time of the study the inventory of raw materials was as follows:

- Internal scrap – 150 tonnes
- Externally bought scrap – 124 tonnes
- Alloys, metals and reduction agents – 23 tonnes
- Value of inventory – 23% of material value for annual production

Of the 27 steel grades the six grades with largest volume of production account for 80% of total output in a year.

Production volumes for each steel grade are shown in figure 1.

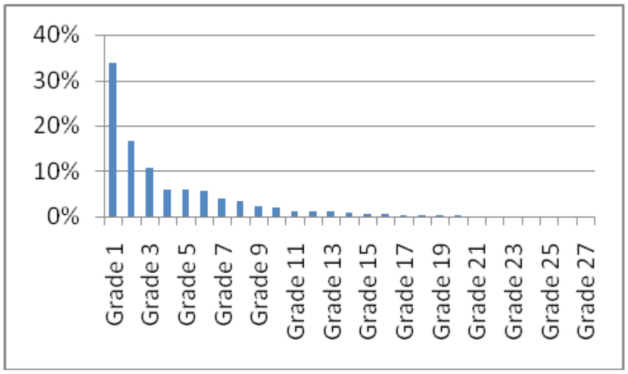

Figure 1. Annual manufacturing of steel grades as percentage of total tonnage

METHODOLOGY

The calculation tool used for this study, RAWMATMIX®, is a commercially available scrap optimization software available over the Internet.

MATHEMATICAL OPTIMIZATION MODEL

The model used by the RAWMATMIX® [2]software calculates the cheapest possible way to combine different type of scraps and alloys that meet the requirement of the steel grade.

The model is based on linear optimization like most optimization programs, and includes a metallurgical module that calculates how the elements distribute between slag and metal. For instance some of the charged chromium and most of silicon will be oxidized by oxygen in the atmosphere or by injected oxygen, deepening on EAF operations. Or on the contrary, e.g. if nickel oxide is added it will probably be reduced by other elements with higher affinity toward oxygen.

The model can also be restricted not to take too much of certain qualities, so that the charge has a good mix of dense scrap like ingots that take long time to melt in the EAF and voluminous scrap like turnings that would result in too many scrap baskets to be loaded for a single charge. The model always suggests the cheapest way (can be proven mathematically) to load the charges based on these restrictions.

ASSUMPTIONS / METHODS USED

Raw material inventory values were chosen from a random one-off point in time. Annual production tonnage and mix of steel grades was based on actual production figures during one year. The inventory value of materials used in calculations was based on Österby inventory figures.

In the calculations of manufacturing cost only the variable costs like material, additives and electricity have been used. Evaluation was done on the melting operation only. The value of annual production was based on the material value of the semi finished product after the removal of sprues, runners etc.

In the grade x to grade x calculations, RAWMATMIX® was instructed to favor raw material from the same steel grade as the steel grade produced.
In the optimized case RAWMATMIX® was allowed to choose and combine any feasible material available in stock.

RESULTS

REDUCTION OF INVENTORY

The chosen loading practice means that steel grades that are infrequently produced risk building up excess inventory. This is in fact the case and figure 2 shows that the more infrequent steel grades all show high inventory levels with grade 17 being the worst example. The most frequently produced steel grades however, show very low inventory levels as could be expected.

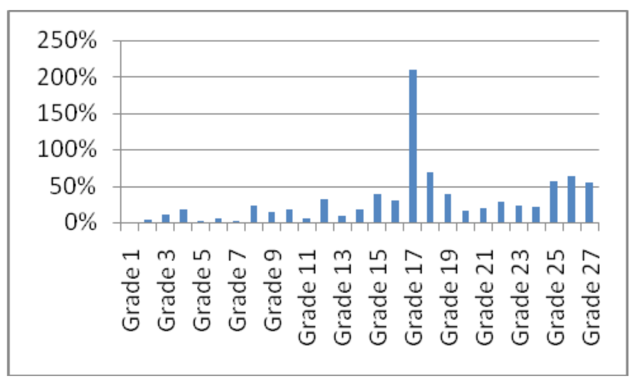

Figure 2. Inventory levels before optimization for internally recycled raw materials as a percentage of annual production for each steel grade

An optimized raw material management will deplete the excess inventory of internal raw materials and lower total inventory levels. In the case studied the quantity of internal raw materials (returns and internal scrap) will go down from 150 to 58 tonnes, a reduction by 61%. The reduction by value is 50%.

The optimization will lead to a slight increase in the inventory of externally bought scrap, alloys and metals. In spite of this the total inventory level will be reduced by 48% by value.

REDUCTION OF MANUFACTURING COST AND CARBON FOOTPRINT

An optimal use of raw materials will also lower total manufacturing cost. The source of this saving is mainly the fact that the alloy content in scrap, and in particular returns and internal scrap where the analysis is well known, is utilized to the full. The amount of pure alloys and metals can then be kept to a minimum.

The results for the six largest steel grades in our study are shown in table 1.

By implementing a strategic raw material purchase planning, using RAWMATMIX® as a continuous optimizing tool, manufacturing costs and inventory can be kept low. Better utilizing alloy elements in the scrap will decrease the use of more expensive pure alloys and metals in the melting operation. As a consequence the carbon footprint of the end product will be reduced as recycled scrap has a much lower carbon footprint for the same amount of alloy elements than for virgin material.

Table 1. Reduction in manufacturing cost for most common steel grades

	Grade 1	**Grade 2**	**Grade 3**	**Grade 4**	**Grade 5**	**Grade 6**
Grade x to grade x only (€/kg)	2.02	2.49	1.02	3.07	0.94	1.77
Optimized solution (€/kg)	1.83	2.06	0.97	2.96	0.94	1.41
Cost Saving	-9%	-17%	-5%	-4%	0%	-20%

FINANCIAL ASPECTS

The most common key ratio for measuring the efficiency of a business is return on capital employed or ROCE. The ratio is popular because it is affected both by the margin, i.e. sales minus costs, and by the capital needed to perform the business. As we have seen in this study an improved raw material management can positively affect both parameters.

The effect on ROCE from lower raw material inventory will depend both on the proportion of total capital employed that consists of the raw material value. This can vary significantly depending on the age of the plant and several other factors. Figure 3 describes the improvement in ROCE that will be achieved given different levels of raw material inventory as a percentage of total capital employed.

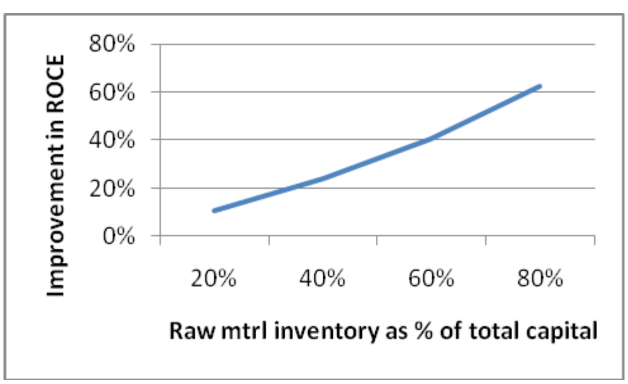

Figure 3.Improvement in ROCE depending on raw material inventory's portion of total capital employed

The lowering of raw material costs affects the total margin and therefore also ROCE. The effect will depend on the proportion of total costs that are raw material costs and on the pre-optimization margin. Figure 4 describes how ROCE is improved based on these inputs.

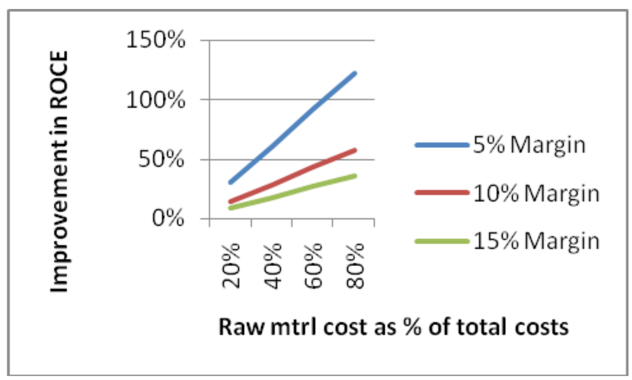

Figure 4. Improvement in ROCE depending on raw material cost's portion of total costs and pre-optimization margin

CONCLUSIONS

For the type of production done at the foundry studied, significant gains can be made financially and environmentally.

By more powerful calculation support excess inventory of internal scrap can be eliminated and inventory levels for these raw materials can be reduced by 61% by weight or 50% by value. Annual inventory turnover improves from 4.3 to 9.5 and the number of inventory days of supply improves from 53 to 24 days. To support production some additional external scrap and alloys need to be added to inventory but total raw material inventory cost can still be reduced by 48%. All else equal this will result in an improvement in ROCE by 92%.

Comparing a loading practice where returns and internal scrap is only used to produce steel of the same grade with a calculation supported loading practice of loading all materials for all grades yields a significant improvement in manufacturing cost and carbon footprint. For the six most important steel grades the cost saving is on average 10% (ranging from 0% to 20%).

Table 2. Summary of the results

	Result
Inventory of returns and internal scrap (by weight)	-61%
Inventory of returns and internal scrap (by value)	-50%
Total inventory (by value)	-48%
Inventory turns increased from 4,3 to 9,5	+5,2
Inventory days of supply	-29 days
Manufacturing cost (average)	-8%
Total improvement in ROCE	Significant

New Technology like hand held analyzing instruments makes scrap sorting easier. Other improvements that may facilitate raw material management are enhancements of site specific ERP-systems to track the internal scrap supply promptly and increased scrap sorting facilities at the scrap suppliers' sites.

It is the authors' opinion that we in the coming years will see an increased interest in raw material management and charge optimization with tools like Rawmatmix®. This will however only be successful if management is prepared to make the efforts to further develop their business processes and make the necessary investments in internal systems and personnel skills.

ACKNOWLEDGEMENT

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REFERENCES

1. RAWMATMIX® on line documentation and reference list 2011.