Bridging the Gap between Refractory Supplier and the Refractory User in the Steel Plant → Real Value-in-Use

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Tata Steel IJmuiden has developed an in-house Value-in-Use model for the steel ladle. This model very efficiently calculates and predicts all the costs and benefits of changes in refractory designs and refractory materials. The model helps to explain in a comprehensive way the financial effects of modifications. The result of applying the model after several years, besides an increased ladle life and capacity as well as enhanced safety with decreased overall refractory costs and energy consumption, is an increased level of acceptance for modifications internally as well as externally.

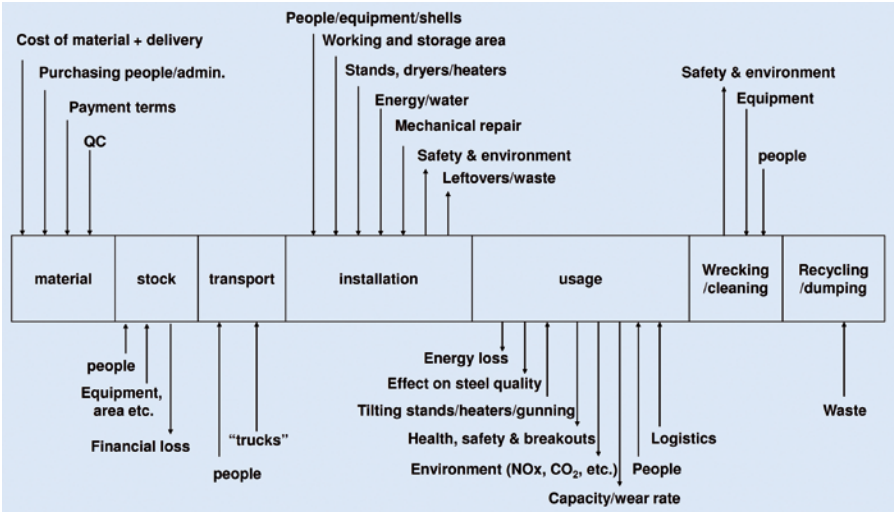

Fig. 1 Different aspects in the refractory lifecycle of the steel ladle influencing the Value-in-Use

Introduction

Tata Steel in IJmuiden produces 7,3 Mt of steel per year. To do this in a successful way, stable and safe production are essential. Consequently the quality of the refractories is key. Tata Steel in IJmuiden has the philosophy that in-depth understanding the performance of refractories is a core competence for producing iron and steel. This translates to having essential refractory knowledge and experience in-house. The focus is not on how to develop, design or produce refractories (because this is typically seen as the core competence of refractory suppliers), but on knowledge of interaction between high-temperature iron and steel processes and refractories, Dutch regulations on health, safety and environment, reliable installations, long-term performance and optimal refractory design and materials choices. Value-in-Use is the essence for this philosophy. Compared to other similar Western-Europe based steel plants, in Tata Steel IJmuiden a large number of people is working on refractory related issues. This can only be done if the benefits of this philosophy are higher than outsourcing or simply refraining from this refractory related work. When only the bare refractory cost per ton of steel is considered, this philosophy won't last for very long.

The concept of Value-in-Use in refractories applications is not new [1, 2]. However both the definitions as well the variables taken into account can be different. In Tata Steel IJmuiden the total lifecycle of the refractories and all the costs and (process) benefits related to refractory choices are considered. In this paper the steel ladle lining is taken as an example.

Life cycle of refractories in the steel ladle

The lifecycle of steel ladle refractories consists of several steps (Fig. 1): buying refractory materials, storage and transport, installation of refractories in the ladle, use of the steel ladle, wrecking and waste removal.

Buying refractory materials

The purchasing price of refractory material will be a function of production costs, overhead costs, profit margin for the supplier and transport costs. Some companies like Tata Steel perform QC testing to ensure a constant and reliable performance of the

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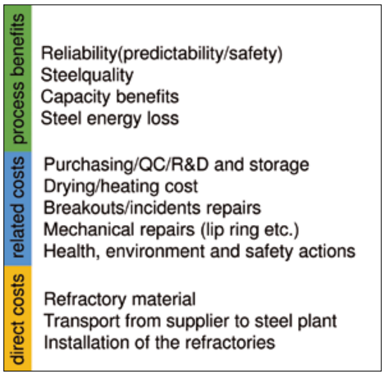

Fig. 2 **Direct (~30 %),refractory related cost (~30 %), and the process benefits influencing the Value-in-Use (~40 %)**

refractories in the steel plant [3]. So besides the direct material cost a number of related costs have to be added, such as costs is related to payment terms. For example: under the assumption of an integrated steel plant using EUR 25 million per year on refractories, a 1 week later payment by the user will save between EUR 25 000–55 000 per year (interest). Payment terms of several months are more or less standard within the steel industry.

Storage and transport

After the refractory material arrives at the site of the steel producer, it will be stored in a warehouse. Besides storage space, equipment like fork-lift trucks, people, administration and transport to the installation areas, the materials in stock have to be financed. When a plant uses EUR 25 million of refractory/a and the material stays in stock for 1 month, the cost to finance (interest) this material will be between EUR 100 000 and EUR 250 000 per year. A solution for a steel producer to reduce this spend can be consignment stock. The advantage for the user is that the risk and cost of the stock is transferred to the supplier. On the other hand it can be expected that at a certain moment this will be reflected in the price of the products.

Installation of refractories in the ladle

To line the steel ladle with refractory materials in the steel ladle, people to install the materials (internal or an external installation company), space and facilities for the workers are required. The ladle needs mechanical repair to the shell and top rings, water/electricity has to be available, cutting machines, etc. Next to this there are costs of drying and heating facilities for the ladles as well as the costs of the energy for drying and heating. The requirement for every aspect is related to the refractories life in the ladle, number of incidents (the worst one: breakouts) and type of refractory materials used e.g. castable versus bricks, high or low conductivity refractories.

Use of the steel ladle

After installing the refractories and heating up of the steel ladle it goes into service. The refractory materials and design have an effect on the energy losses of the liquid steel, availability of the ladle, quality of the steel, on the wear rate of the refractories and therefore on the (average) capacity of the ladle, health, environment and safety issues. Choices in refractory material and/or design can have an enormous effect on process costs and benefits of a steel plant. For example: heating 1 t of liquid steel by 1 °C will cost 4–10 eurocents depending on local energy prices and type of heating. To heat all the steel, for a 3 Mt steel plant with 1 °C, the cost will be between EUR 120 000 –300 000 per year. For large ladles (>300 t) with relatively short turn-around times (1–2 h) and relatively short residence times (2–4 h) calculations, operational experience and benchmark studies show that different choices in refractory design/materials can easily lead to 20 °C difference in liquid steel tapping temperature that can be saved/lost. In case of small ladles with long residence times and long turn-around times this can be much more than 20 °C.

Wrecking and waste removal

After the ladle is used and the refractories are worn, the ladle lining will be wrecked. Specialized machines and people are required to perform this operation. The waste will be recycled, sold (benefit) or dumped (cost). In most cases more than 50 % of the installed refractory material will end up as waste.

Cost and benefits

On being asked on refractory costs, someone involved in refractories will most likely only think about the costs directly related to the material and installation (most of the time referred to as refractory costs per ton of steel). However the above steel ladle lifecycle shows that these "direct costs" are only a part of the total cost. If all other "refractory related costs" are taken into account, the "direct costs" may only be 40–60 % of the total cost.
Besides "direct costs" and "related refractory costs", the choices made in refractories have significant effects on the steel process (average production capacity, liquid steel temperature, safety/number of incidents and steel quality). If these factors are taken into account in a Value-in-Use analysis, the "direct costs" of refractories might be not more than 20–35 % of the total equation (Fig. 2).

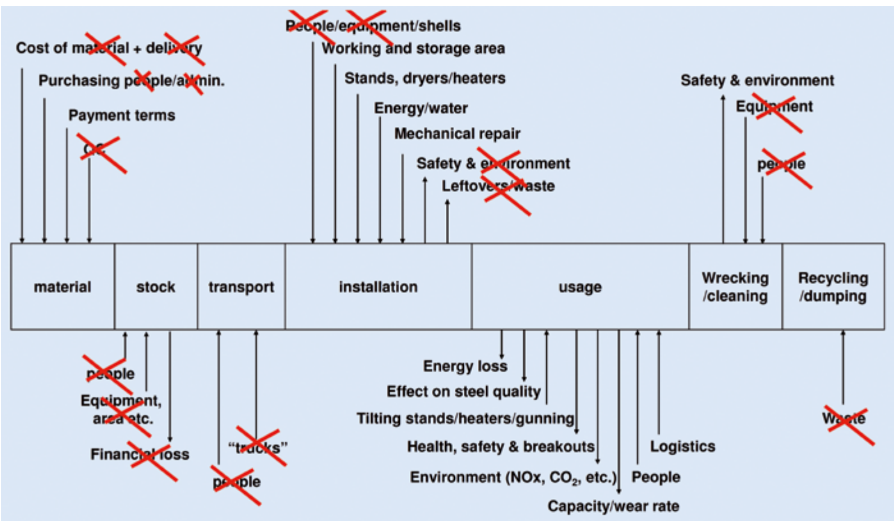

Fig. 3 **Example of full service, transfer of responsibilities from steel plant to refractory supplier**

Cost focus

From the above life cycle of refractories it can be seen that quite a lot of variables can be optimised to get the best Value-in-Use out of refractories. It is very tempting to see Value-in-Use as lowering the refractory cost per ton of steel. This is one of the risks when considering full service contracts. In the most extreme version, material supply, logistics, stock keeping, installation, wrecking and waste removal are all outsourced (Fig. 3). There are positive as well as negative aspects of a full service contract compared to in-house handling by the steel producer (Fig. 4).

Full service contracts based on cost per ton of steel remove a considerable amount of the hidden cost at the steel plant, make negotiations about contracts much more simple and above that, very importantly, reduce refractory cost automatically during a steel crisis or low steel production periods. Generally at the initiation of such a contract major cost savings can be achieved. However the longer such a contract is in place the less knowledge the steel producer will have about the different cost aspects of the refractory life cycle. Consequently during negotiations the supplier's prices cannot be verified and the value of the contract can only be based on offers from different suppliers. Changing from one supplier to another may pose significant risks to steel production, quality and safety. One of the main issues is, the suppliers need to have deep knowledge about the benefits of possible improvements to realize the best Value-in-Use for their customers. Improvements in cost savings can easily be shared, but how to handle improved steel quality benefits, lower steel temperature losses, higher capacity, especially if the refractory costs per se for these benefits are increasing? If the supplier knows the value of these benefits it will disturb the balance during negotiations between supplier and user even further. What if the wear of refractories is increasing, the wear pattern changes or there is a breakout: how do you split the cost or who will picks up the bill? In that respect an interesting difference between steel plants with full service contracts and steel plants without, is the perception of how many of the refractory related steel production problems are really caused by the refractories (and are therefore the responsibility of the supplier). According to steel plants with full service contracts, 40 % of problems in the steel plant related to refractories are caused by the material quality, whereas in steel plants without service contracts less than 20 % of the problems are seen as caused by the refractory materials [4].

Full Service	In house
Lower and less hidden "refractory related service" cost	Knowledge and experience available to reduce refractory related production risks like breakouts, healt and safety issues and to value the contract offers.
Less sensitive to crisis/lower production (knowledge, materials and installation is outsourced)	Focus on midterm (and long term) VIU developments lowering the overall steel production costs
Easy cost control Easy focus on lowering the refractory costs per ton of steel	Easy Value-in Use developments
More knowledge at the refractory supplier about user's production process	In house knowledge about the risks, process wear interactions, possible value creation options
Quicker introduction of new developments (only for the contract refractory owner)	Choice of the developments of all available suppliers
Change from "in house" to "full service" → relatively easy and a lot of short term savings	Change from "full service" to "in house" → difficult, long time to build up knowledge, high costs
Refractory related problems caused by the supplier = 40% [4]	Refractory related problems caused by the supplier = less than 20% [4]

Fig. 4 Advantages of full service contract compared with in-house refractory knowledge for the steel producer

A significant advantage for the steel plant of having in-house control on the refractories is the possibility to develop good Value-in-Use options and the possibility to choose the best refractory options from several suppliers, combining their development strengths. To do this in an effective way, a proper tool for analysing Value-in-Use is of vital importance.

There are various different intermediate constructions possible between full service contracts where everything is outsourced and doing everything in-house by the steel producer. For every application and situation the benefits and disadvantages have to be considered. A good overview of the different options is given by T. Vert [5].

Cooperation between steel producer and refractory supplier

Whatever philosophy is used, good communication and cooperation between refractory user and suppliers is key. It often occurs that suppliers don't feel appreciated for their developments, services, advice and efforts [4, 6]. This has much to do with a difference in perceived value of the solution, offer or trial. To get the best effect the quality of the solution should be high, but the level of acceptance by the steel plant also needs to be high (Fig. 5). Both, supplier and user, may not be realistic about the value of the solution. To come to an agreement it is necessary to uncover the real value/performance. But to determine the real value is a serious problem with refractories in the steel industry. One of the reasons is that wear of refractories is difficult to analyse because of the enormous number of process variables that influence the wear rate [7]. There is still quite a number of hurdles to be taken before this will improve [7]. Even if there is an agreement between the supplier and the user about the technical performance result (wear related), there

Effect = Quality x Acceptance

Quality =
- Real performance of the refractory solution
- Real Value in Use
- Real service and support level
- Real potential of the refractory proposal

Acceptance =
- Perceived performance of the refractory solution
- Perceived Value in Use
- Perceived service and support level
- Interaction refractory supplier and steel plant
- Perceived potential of the refractory proposal

Fig. 5 E = Q × A, how to realize the optimum effect in the steel plant

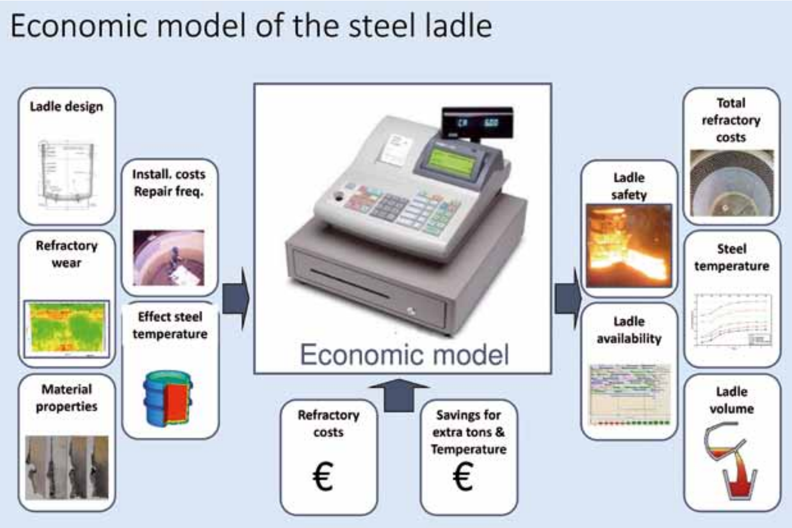

Fig. 6 A schematic presentation of the in-house developed Value-in-Use steel ladle refractory model of Tata Steel in IJmuiden

can be a completely different view on the Value-in-Use result. When is a trial technically successful and when is it considered to be successful in terms of Value-in-Use?

Example

Let's assume we have a one shot ladle (wear lining in the bottom, wall and slagline are replaced at the same time). The slagline life is 60 % of the time limiting the life of the ladle. To improve the average life the slagline brick is replaced with a 50 % more expensive quality with a significantly higher thermal conductivity. After several successful trials (increase in life) this solution becomes the standard. The wear in the slagline is reduced and the ladle is now taken out on other areas. At first sight it looks positive, the life goes up and in most cases this will compensate for the higher refractory cost of the slagline (refractory cost in the ladle per ton of steel is reduced = positive). However the energy losses of the liquid steel will increase because of the higher thermal conductivity of the refractory material (= negative). More volume will be created in the ladle at the end of the campaign because of more wear in wall and bottom (= positive). Less volume will be created in the slagline (lower wear rate = negative). Lower wear of the slagline starts in the beginning of the campaign, thus the capacity will increase slower than in the old situation (= negative). The overall average capacity of the above ladle might increase or decrease. In case of a decrease in capacity this can reduce the Value-in-Use significantly. The higher energy losses and the (negative) effect on capacity have to be compared with the savings in refractory costs. As can be seen from this example this can be extremely difficult to calculate. This can result in numerous discussions between supplier and user afterwards. It would be much better and less frustrating if beforehand it is clear under which circumstances a trial is considered to be successful. This would reduce a lot of internal steel plant discussions such as: "Should a trial be done?", "What are the risks?", "What are the potential benefits?", "How do we choose between offers from several suppliers?" It would give good guidelines to a supplier of what is expected and will deliver a clear yes or no after a trial.

Value-in-Use model

From the above example it becomes clear that analysing the real Value-in-Use afterwards without a proper tool is already extremely difficult and would take at least several days of work. To solve this problem Tata Steel IJmuiden has developed an in-house Economical steel ladle model (Fig. 6). The model uses an approach similar to the training model used at the VDEh training "refractory technology – applications and wear mechanism"[8]. Every year people from the steel and refractory industry are trained with an interactive economical steel model to look in a different (non-technical) way at refractories. The model in IJmuiden is more sophisticated and accurate and has the possibility to vary far more variables. It takes all the "direct costs", most of the "related costs" and "process benefits" into account (currently 70–80 % of all the items related to the refractory lifecycle is in the model). It is able to handle changes in design and materials, it takes into account real wear rates (based on wear rates analysis per ladle, area and quality of refractory material measured with a laser scanner) [7], heating costs, installation costs etc. The effect of changes on the liquid steel energy loss is calculated in a separate Finite Element Model. The financial benefits of lower heat loss and higher average capacity/efficiency are added to the model. These benefits can change from year to year, depending on the economic situation. It depends on raw material prices (ore, cokes, scrap etc.), selling prices of the steel, order book, economic outlook, availability of other equipment, steel portfolio etc.

The model calculates the change in real Value-in-Use benefits in absolute EUR million, but also shows the different individual effects. This last feature is important to understand the effects and acceptation of the results. It makes the discussion easier and more to the point. If, for instance, a change in refractories would cost EUR 300 000 more on a yearly basis and would save EUR 400 000 in capacity per year, would this be worthwhile doing? The answer to this question may depend largely upon the economic situation. If one has to pay EUR 300 000 more on refractories, but it will get EUR 2 million in capacity or energy benefits in return the decision is more clear.

Benefits of Value-in-Use model

The model in the current format took around 4 years of development and is still being improved on a regular basis by adding more refractory related variables to the model. Such a complicated and reliable model could only be developed because detailed in-house knowledge about the steel process, refractories and refractory wear, benefits, other related cost, modeling, and statistics is available within Tata Steel IJmuiden. It was complicated and it took a long time but the benefits are already significant:

- Less trials. Different proposals are analysed beforehand with the model. Together with the available refractory knowledge and experience and depending on the expected benefits only, the most promising trials are selected. This combined approach also resulted in an improved success rate of trials.

- Streamlining of the developments for the ladle. It helps to analyse where improvements based on the latest refractory development available on the market are possible and what the potential saving could be. Based on this, there are strategic discussions/investigations with several suppliers which will lead to additional significant Value-in-Use improvements in the next 2–4 years.
- Significant time savings in internal decision making before and after trials
- Increased life of the ladle
- Lower refractory cost per ton of steel, even though in certain areas the refractory materials as such are significantly more expensive than before
- Increased capacity of the ladle
- Lower liquid steel heat loss
- Increased safety.

There are still many improvements to be made in the model and with the model more savings will be realized in the coming years. Even more improvements can be made if this model can be combined with an improved wear analysis [7].

The model already helps in the discussion with suppliers. It does not mean that the supplier will always agree or will be happy, but the situation is more explanatory and upfront chances for success are more clear.

Philosophy effect on Value-in-Use

As discussed, Tata Steel in IJmuiden has the philosophy to focus on Value-in-Use. This philosophy means an investment in the future. Wouldn't a full service philosophy have been more beneficial? In Fig. 7 the effects of the two philosophies are schematically given. If 3–4 years ago it had been decided to go for a full service (refractory cost per ton of steel) contract for the steel ladle, many "refractory related costs" could have been eliminated quickly (purchasing, people, QC, R&D, etc.). Also the following years further improvements could have been realized by the supplier especially within the "direct costs". However slowly the expertise in the steel plant will decrease resulting in less negotiation power. Even more

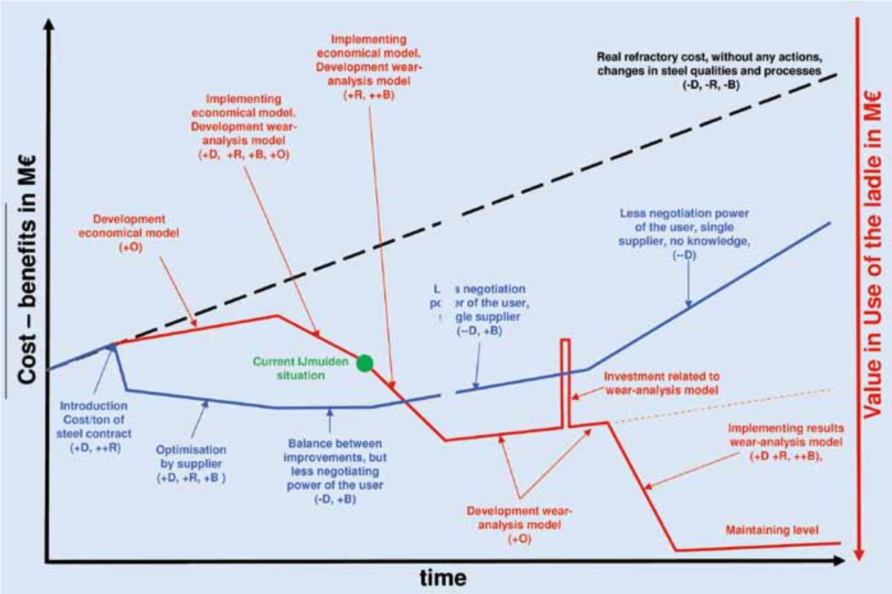

Fig. 7 **Philosophy strategies for the steel ladle: red line = philosophy of Tata Steel IJmuiden, blue line = full service philosophy; D = direct refractory cost, R = refractory related cost, B = process related benefits, O = other improvements; ++ = high positive effect on VIU, + = positive impact on VIU, – = negative impact on VIU, — = very negative impact on VIU (VIU = Value-in-Use)**

important: With decreasing knowledge it becomes more difficult to determine possibilities for process related benefits. With a continuously changing steel production process the Value-in-Use of the used refractories will decrease quickly. Fig. 7 shows that the choice of Tata Steel IJmuiden has resulted in higher cost (lower Value-in-Use) in the last few years compared with the choice to go to a full service contract. Since the developed economic steel ladle model is actively used considerable value and lower costs have been realized. More value is expected especially in the area of process benefits. Another advantage of the economic model is that also in the future with changing steel processes the optimal situation can be analysed very quickly and therefor maintaining the Value-in-Use at a higher level.

Summary

The economic model for the steel ladle in IJmuiden adds significant Value-in-Use to the steel plant. This model could only be developed because of the in-house knowledge about refractories and steel production. Besides the financial calculations of the benefits, it also helps to explain and predict decisions on performance and trials. It quantifies the real Value-in-Use of refractory solutions and therefore it is a powerful tool to bridge the gap between supplier and user.

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