BADISCHE STAHL-ENGINEERING GMBH

Excellence in Steelmaking

Conceptual Basics and Excellence of Maintenance in Minimills

Update of the article originally published in MPT International 5/2008

Maintenance in Minimills is a real challenge.
This is not only because of the extremely rough conditions around the electric arc furnaces, casters and rolling mills but also because of the general goal of every maintenance programme: *„Highest availability of equipment at lowest feasible costs“.*
This means achieving best effectivity *and* best efficiency at the same time. Under Minimill conditions this is a very difficult task.
Considering „normal“ economic conditions, this article discusses the maintenance goal and its implications for Minimills with a focus on productivity, and the possibilities and examples of maintenance optimization measures.

Dirk Riedinger, Senior Manager Consulting
Ralf Hetzel, Senior Manager Consulting
Badische Stahl Engineering GmbH, Kehl, Deutschland
Reiner Hagemann, Superintendent Central Maintenance
Badische Stahlwerke GmbH, Kehl, Deutschland

Figure 1: Conduction of a planned maintenance downtime at the BSW meltshop

Effectivity - the availability goal

Production must go on. But equipment may deteriorate over time due to fouling, wear, corrosion, fatigue, by external damage or by human error. It may fail at different points of its lifetime, e.g. premature, age related (about 10%) and not age related (>80%) [1]. To keep the equipment running the service maintenance has to be performed to restore the initial condition.
Maintenance can follow different - more or less effective - approaches. The pure breakdown (re-active) maintenance approach is the most ineffective one. Only planned (pro-active) maintenance can really be effective.
In contrary to the re-active approach, pro-active activities prevent equipment failures and avoid their consequences. It is evident that to deal with unexpected failures is absolutely unfavourable. However unexpected failures are not 100% avoidable, therefore quick failure finding and elimination are necessary maintenance qualifications.
Pro-active maintenance measures like inspection, service, discard, restoration, function testing and optimization require periodical planned and coordinated maintenance downtimes which have to be carried out systematically to ensure minimal failure rates. Downtimes are also necessary for the production process and can then be used for maintenance activities (e.g. relining, size or pass change).
The application of scheduled downtimes for maintenance is especially important for Minimills because of the extremely rough operating context with liquid steel causing tremendous wear and pollution (dust, scale). The amount of necessary „anti-wear-actions“ (unplanned and/or planned) is large. The impact of equipment loading-roughness on wear is significant. The effectivity required for lowest maintenance delay time is expressed by the maintenance availability goal of this form:

„To carry out the most effective maintenance using planned downtimes resulting in minimal maintenance related delay rates.“

To be able to achieve this goal, the following prerequisites are necessary:

- Qualified maintenance personnel. The maintenance know-how must be within the company. Continuous training is obligatory. Tools for determining qualification levels are job descriptions, qualification / skill matrices and gap analyses (competence model).
- Selective contracting for support, peak demands and specialities.
- Systematic coordination, planning, scheduling and execution of periodical downtimes using a designated planner/coordinator position.
- Close cooperation of maintenance and production. Production personnel (the process owner) have great influence on equipment wear and should be qualified.
- Regular cleaning activities during each downtime.
- Spare parts management providing parts in time and in condition.
- Well equipped workshops and professional tools.
- (Change-)management of documentation, drawings and software.
- Use of a computerized maintenance management system. Maintenance know how must be stored in the system (corporate knowledge), not only in the experts' heads. The system must contain the necessary asset management, reporting and controlling functions.

The organization must provide the structure and the resources to ensure the most effective „concert“ of these prerequisites. Effective maintenance guarantees smooth conduction of all activities in a limited number and duration of downtimes and minimizes delays by quick elimination of equipment failures which interrupt the production process. Problems are *solved*, not only fixed. In the ideal case the maintenance activities would result in undisturbed plant operation until the next planned downtime. Therefore the ideal maintenance availability goal must aim for *zero unplanned* downtimes, i.e. zero maintenance related delay time during *any* production

time. In reality zero maintenance related delay time is not achievable for many different reasons. Still the target must be to minimize the delays.
For clarification: a delay is defined as an interruption of the EAF process (power off and/or standard setup time exceeded) or a stop of rolling (gap time exceeded). The connection of delay times to delay causes is an important factor for process transparency. If delay reasons are not objectively recorded then the time balance will be incorrect and evaluations lead in the wrong direction. The correct and objective recording and analysis of delays and failures is the basis for optimization of equipment and processes and is important because it determines the effectivity level from the delay rates [6]. Therefore the delay recording must provide:

- an automatic delay time recording based on process signals and
- a data base with a delay code system based on the asset structure.

The delay codes are input by the EAF or rolling mill operator upon automatic system request. A practical availability goal for the electrical delay rate is less than 1% and for the mechanical delay rate less than 2% of gross operation time (gross Tap to Tap time). **Figure 2** provides an overview of present meltshop delay rates generated from the BSE Best Practice data base [5].

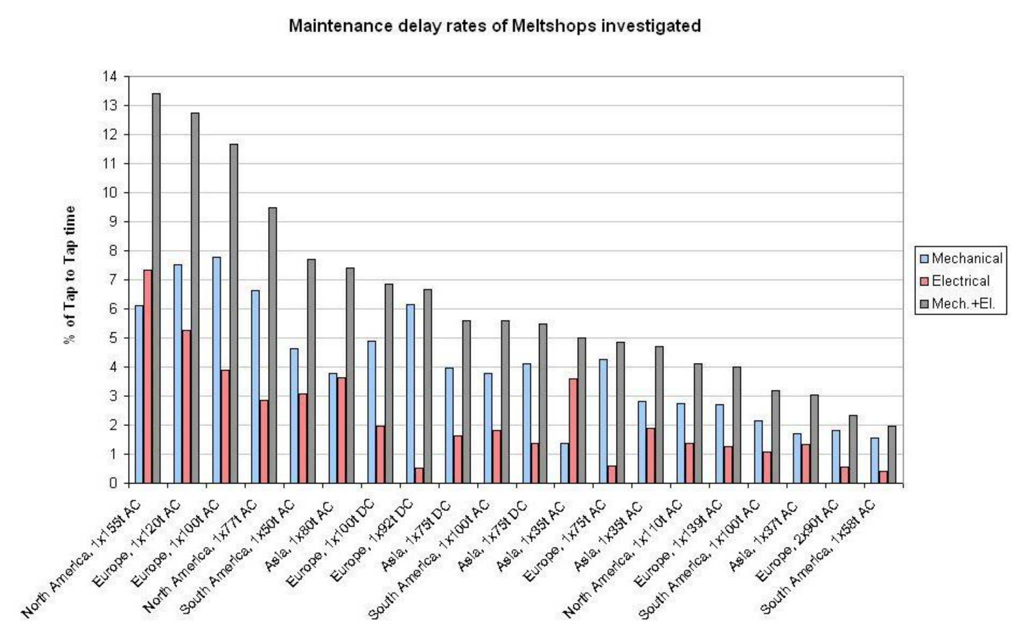


Figure 2: Meltshop delay rates

The range of maintenance related delay rates is large and only 20% of the investigated meltshops come close to the goal. In general a high delay rate always indicates ineffective maintenance. This means that the measures taken do not result in the minimal delay rate for various reasons.

Efficiency - the cost goal

Experience shows that effectivity is the prerequisite for efficiency. Excellent efficiency can only be developed when all maintenance activities are *already* effective. Effective maintenance generates sustainable results and therefore longterm efficiency. But excessive effectivity can be very costly. Consequently effectivity must be „balanced“ to be efficient.
This optimization problem has to be solved in order to achieve efficiency in maintenance:

„To minimize (optimize) all required planned maintenance activities and resources without increasing the established minimal delay rates.“

In other words, to apply only as much (planned) maintenance as absolutely necessary but enough to maintain the high effectivity level (minimal delay rate) that has already been achieved. This is a *complex* and *varying* problem. The efficiency must be monitored and measures readjusted continuously (controlling). The efficiency goal can not be reached by just reducing maintenance activities but only by more sophistication.
To determine the present level of efficiency, a comparison with other plants might be helpful. But benchmarking is difficult to interpret due to different general conditions from plant to plant. As a first iteration Badische Stahlwerke GmbH in Kehl (BSW) has introduced the Meltshop Maintenance Index MMI to determine the position of it’s own direct cost level for the most maintenance intensive area [2]: $MMI = \frac{TDMC \times TOT}{AP^2} \cdot 100\%$,
where TDMC=Total Direct Maintenance Costs, TOT=Total Operation Time (= net Tap to Tap, delay time excluded) [hours], AP=Annual Production [ton_{gp}], **Figure 3**.

The MMI shows the relation between effort and output to indicate the level of efficiency. Values close to or less than 5 unit% are considered to be excellent, BSW is currently at 4,1 unit% (November 2009).

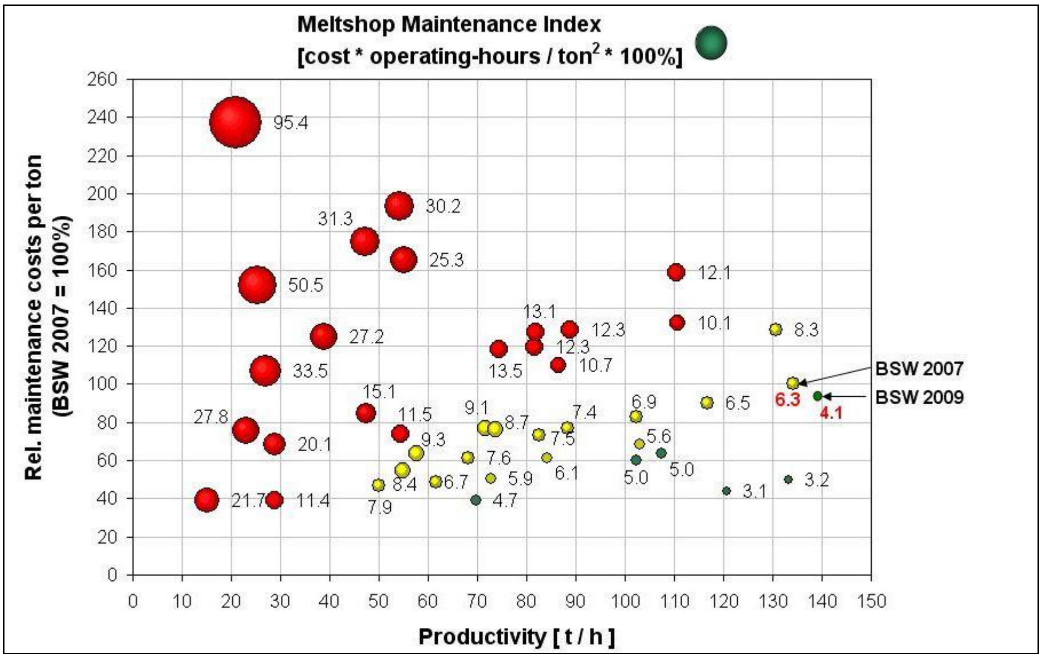


Figure 3: Meltshop Maintenance Index [2], [5]

Reductions of direct costs (and of indirect costs caused by planned downtimes) can be expected by the strategic optimization measures summarized in **Table 1**.

Table 1: Strategic optimization measures

Measure	Constraint
• Periodical analysis and readjustment of maintenance activities per asset.	• Use of an analytic tool like Risk Management or Reliability Centred Maintenance (RCM) to optimize activities.
• Continuous optimization of processes and equipment and it's functions to avoid / minimize wear	• Know How, investments and resources
• Minimization of full scale maintenance downtimes per year (number and duration).	• Improved, not just less activities and resources. The minimal number of full scale down-times is limited by the minimal delay rates aimed for and by the equipment utilization.
• Readjustment of organization and subcontracting.	• Balance between own and contract manpower, core competences inhouse, balance between pool and shift manpower.
• Optimization of the spare parts stock, risk management.	• Critical spare parts available inhouse

In general pure breakdown maintenance is the most expensive one. Whether a time based exchange of parts regardless of condition or the condition based maintenance (inspection, monitoring) is advantageous depends on the ability to predict functional failures and on the cost effectivity. For some equipment it is possible to apply the run-to-failure-strategy when it is cost effective and there are no failure consequences. The RCM systematic determines the optimal maintenance strategy for each equipment [3].
Maintenance can only restore the initial condition of a piece of equipment. When equipment is causing high delay rates then redesign may be necessary. To find the optimal equipment for the given working conditions is a core competence of maintenance and has a high cost saving / efficiency improvement potential especially in Minimills.

The combined effectivity and efficiency goal

Availability and cost goal are not independent of each other. One influences the other. Effectivity minimizes delays and thus also indirect costs. The resources used for being effective are constrained by the direct costs, thus by the efficiency goal. The combined availability and cost goal becomes:

„To carry out the most effective maintenance using a minimum of planned downtimes and resources resulting in minimal maintenance related delay rates.“

To achieve this goal, first the position of the present maintenance according to **Figure 4** must be determined.

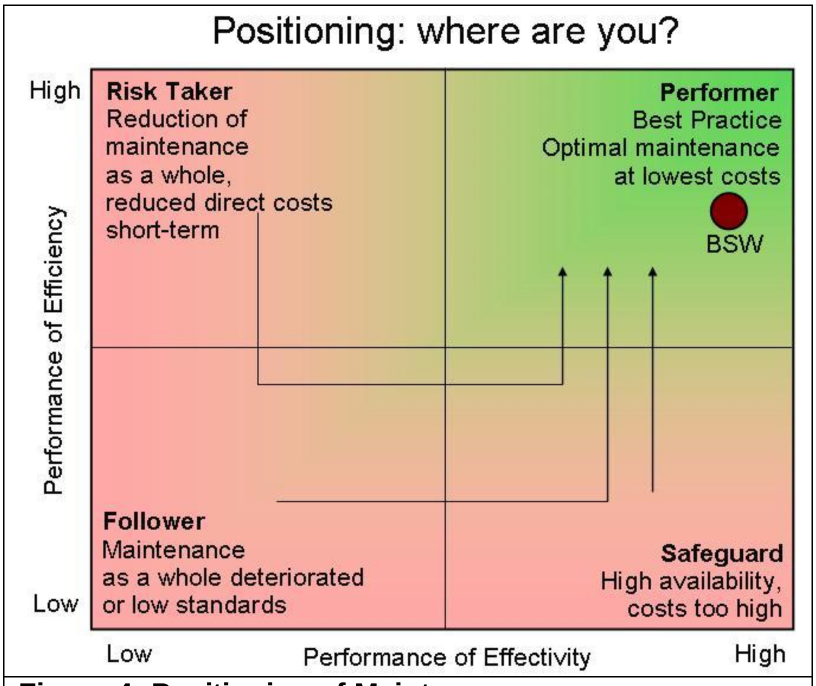


Figure 4: Positioning of Maintenance

Effectivity can be determined relatively simple by the delay rates. The determination of efficiency is much more subtle and requires continuous monitoring and controlling.
If the position is at a low effectivity (delay rates too high) then actions have to be taken to establish effectivity. Investments will be necessary and efficiency may suffer. This is indicated by the lines of development in figure 4.
Still with every improvement of effectivity the efficiency level has to be checked and improved if necessary. Thus cost transparency is obligatory. Maintenance expenditures are usually planned by use of the bottom-up versus the top-down budgeting. If the budgets are satisfied then maintenance has accomplished the efficiency goal.
The general optimization strategy is: „First do the right things (be effective), then do the things right (be efficient).“
BSW has in place a very effective maintenance programme for many years, the delay rates are very small. **Figure 5** displays the historical development of the meltshop delay rates (% of gross operation time or gross tap to tap time). The delay rates are constantly small. As the production output increased from 1,733 Mio tons in 2000 to 2,213 Mio tons in 2008 and the delay rate remained approx. constant during that time, the absolute delay time per heat must have decreased in principle. Constant delay rates mean constant yearly delay time when yearly production time is constant (not regarding fluctuations).

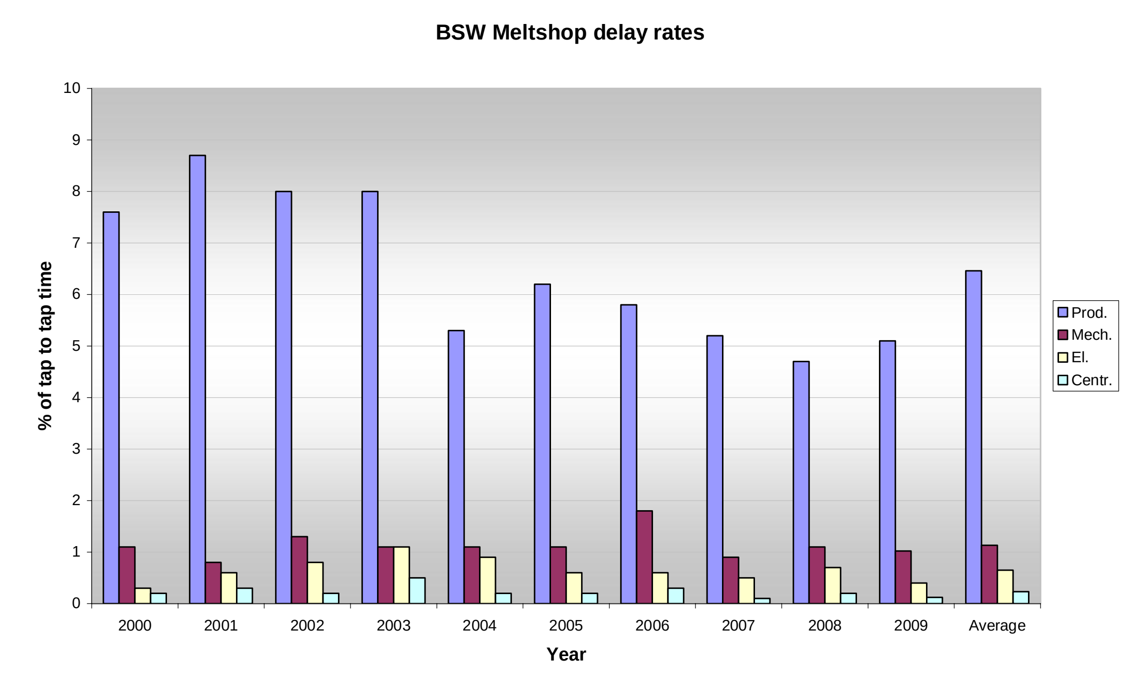


Figure 5: BSW meltshop delay rates since 2000

Keeping the yearly delay time constant while increasing production output (more heats per year with less delay time each) is only possible at a higher maintenance effort. BSW adopted an extensive preventive maintenance approach.
In 2006 a project for the implementation of the above mentioned optimization measures was started because it was noticed that – although the yearly production output increased – the specific maintenance costs (Euro per ton) were slowly increasing instead of being at least constant. This meant an overproportional increase of absolute maintenance costs to keep the delay rates constantly low. This fact induced considerable potentials for cost savings, the maintenance approach had to be optimized and put at a new level to be efficient. The launched optimization and restructuring program „MCM“ (Maintenance Cost Management) achieved savings of about 8Mio Euro to date, **Figure 6**. This is an excellent result because though costs were reduced by about 20% in total (considering a cost growth rate for personnel, material and increased production output) the delay rate is still constantly low.

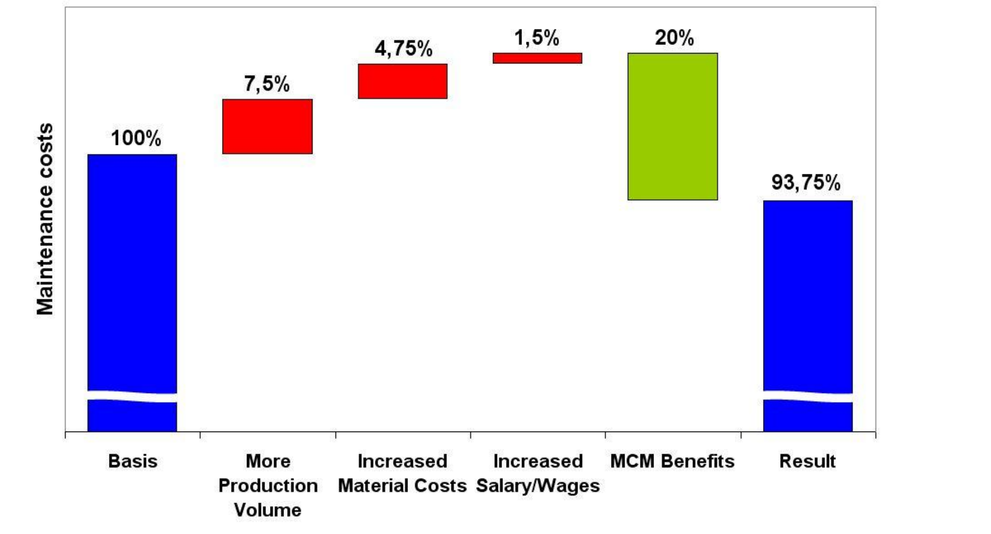


Figure 6: Consolidated cost savings of BSW’s 3 years MCM program

Experiences in meltshops worldwide

The financial crisis that started end of 2008 demands for cost reductions in steel industry more than ever. It is clear that when production is reduced to e.g. 50% due to market reasons, also maintenance activities must be reduced accordingly. But this paper is meant to discuss maintenance under „normal“ conditions. So the following explanations must be understood accordingly.

Cost savings are easily done in maintenance simply by reducing activities and resources. This approach apparently saves direct costs in the short term but totally neglects the effect on indirect costs (unplanned losses of production output) which will further increase as an increasing number of equipment failures will be causing delays. It is therefore not sustainable at all in the medium term.

The connection of direct and indirect costs can be described by a U-tube filled with a liquid and both sides being functionally related in a nonlinear way [4], **Figure 7**.

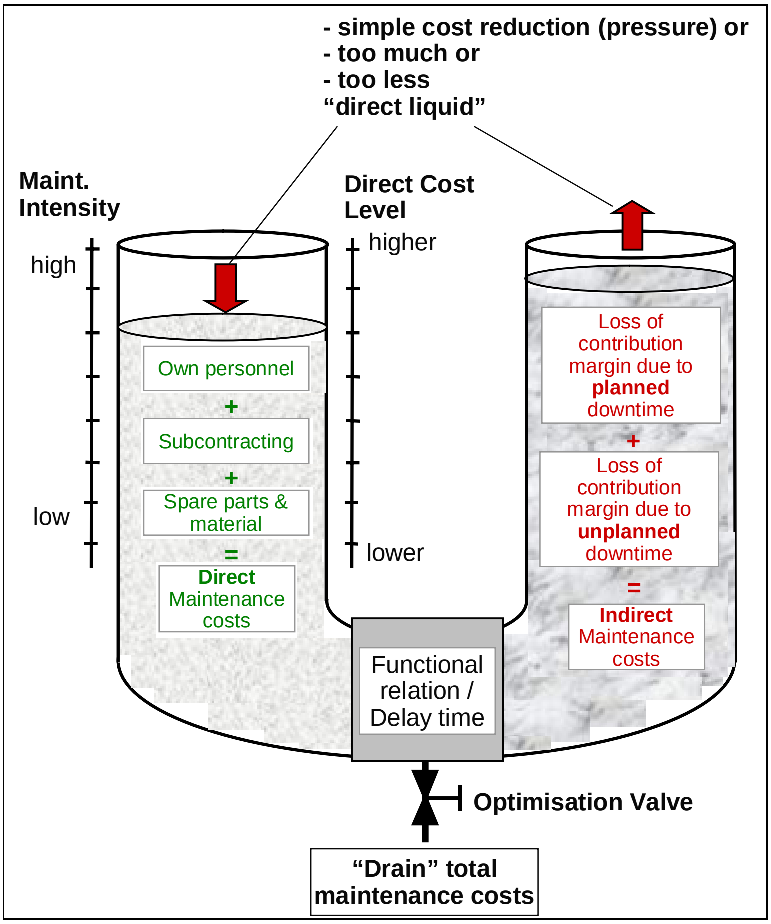


Figure 7: Relation of direct and indirect maintenance costs [4]

Pressure on one side increases the level on the other side. By draining the U-tube, the total level can be decreased (optimization).

Once maintenance has been cut down, it is very difficult to rebuild it. The following shortcomings are typical:

- Deterioration of equipment
- Loss of qualified personnel and competence
- Non-availability of required spare parts

The most severe problem is to get back the qualified personnel and to rebuild the necessary know-how and experiences (long learning curve). Well qualified own personnel not only main-

tains - like subcontractors - but optimize procedures, equipment and functions. This makes the difference. The motivation of people is another important factor. Are they committed and feel ownership or do they do the required minimum? The difference in the results is gigantic. It is the task of management to care for motivation and commitment. This is a key for success. Of given resources 80% of success is related to the human factors in maintenance and those between maintenance and production.
If maintenance has deteriorated, the vicious circle of firefighting starts: one problem is fixed (not solved) while the next pops up. At the same time planning and proactive measures are reduced because resources are limited. The result is more firefighting. At this stage only investments will help, a short term positive result can not be expected. Improvements must be implemented step by step.
Another situation generating severe trouble for maintenance can be encountered sometimes with major investments (capital projects), when the maintenance know how is not sufficiently considered in the specifications set up by the capital projects department (insufficient cooperation). Typical problems are:

- Diversification of equipment instead of standardization (e.g. uniformity of PLC systems).
- Equipment and installations not appropriate for the conditions onsite.
- Correction work during commissioning and start-up phase with the associated costs and delay times.

Maintenance has developed certain equipment standards over the years and has learned from experience. These standards guarantee low delay times. If the standards are not observed from the beginning when setting up new installations then trouble and additional costs are very likely. A general rule is that new equipment cannot be purchased just by price comparison. The technical solution is more important. Many projects are paid twice, at purchase and then for corrective work at and after start-up and for insufficient availability.
Some exemplary cases from practice will illustrate other typical maintenance problems encountered during many consulting projects executed by BSE worldwide.

Case 1
Extensive outsourcing of personnel. Expected result: less costs for own personnel. Long term result: contract costs higher than costs for own personnel, less commitment and motivation, lost competence. Deterioration towards breakdown maintenance with high delay rates and according costs.
Case 2
Deterioration of spare parts stock due to lack of responsible personnel and investment. Result: the spares on stock are not in the right condition, not complete, not available, obsolete, cannot be found. „We don't know what we have“. Lack of knowledge as to which parts are critical. Downtimes are prolonged by missing or non-usable parts. Very expensive emergency purchases.
Case 3
Strong restriction of planned maintenance downtimes without analysis. Delay times are subtracted from planned downtimes. Result: time for necessary proactive measures insufficient, high delay rate and corresponding costs. Maintenance personnel are frustrated as they are held responsible for the delays and at the same time are not allowed to carry out appropriate planned maintenance.
Case 4
Insufficient cleaning activities on meltshop charging cranes. The conductive dust cumulates on the cranes and enters the electrical installations. The dust is partly aggressive (lime) causing skin burnings. The working conditions during operation (troubleshooting) are extreme (heat, noise, dust). High availability of the cranes (especially with old technology like slip ring motors and contactor logic) can only be guaranteed with sufficient downtimes and regular cleaning activities.

Case 5
Insufficient workshops. Workshops in open areas under the furnace platform close to the slag pit. No air conditioning. Dust cumulates everywhere. Professional tools are hardly available. Good working results can not be expected, the reliability of the performed work on e.g. bearings or sealings is highly questionable.

Case 6
Insufficient drawing and documentation (change-)management. Many drawings are obsolete or incomplete. The consequences are prolonged troubleshooting (electric) and problems with manufacturing or purchasing of required mechanical spare parts. Without proper documentation management no professional maintenance work is possible.

Conclusion

Due to the financial crisis steel industry is in a very difficult situation presently, so is maintenance. This paper describes the importancy of maintenance under „normal“ economic conditions and that it is possible to increase efficiency without increasing the delay rate (compromizing effectivity). Optimal maintenance definitely increases competitiveness. It is maintenance that keeps production running. Despite the critical situation of steel industry the aim should be to optimize maintenance, not only to minimize it. Once economy picks up again it will be necessary to have an optimal maintenance working.
The roadmap indicated in **Figure 8** shows how BSE analyzes and optimizes maintenance based on long experience within the steel industry worldwide and practice at Badische Stahlwerke GmbH (BSW), Germany.

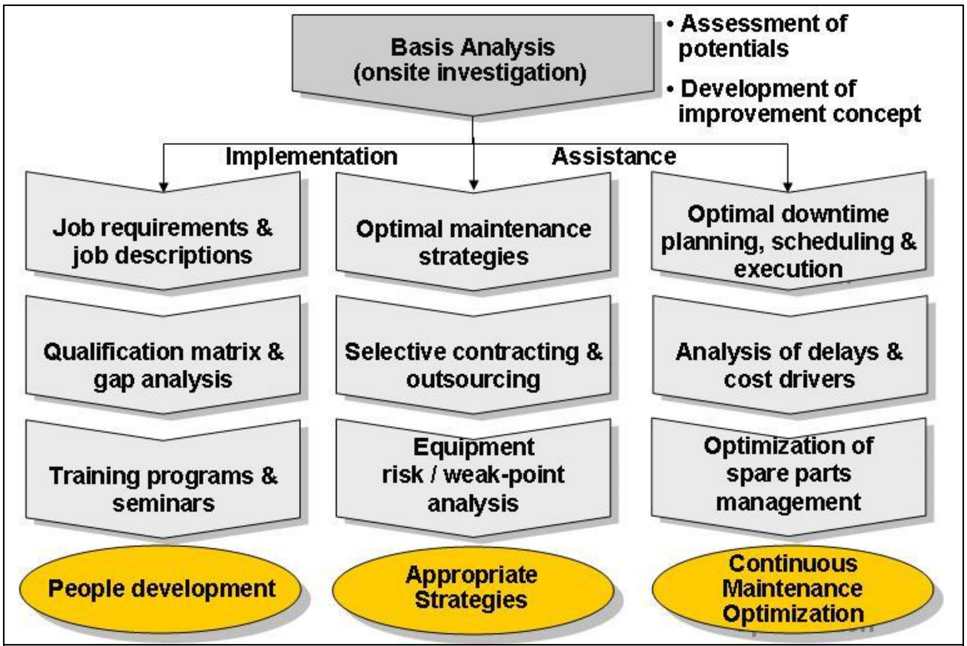


Figure 8: BSE Maintenance Package

References

[1] Narayan: „Risk and reliability strategies for optimizing performance“, Industrial Press, 2004

[2] Dr. Fleischer, Greinacher, Hamy, Ridder: „Maintenance at Minimills – Effective but also Efficient?“, Iron and Steel Technology, February 2008

[3] Bloom: „Reliability Centered Maintenance – Implementation made simple“, McGraw-Hill, 2006

[4] van den Heuvel: „Life cycle management – neue kurzlebige Managementmethode oder nachhaltiges Erfolgsrezept?“, Stahl und Eisen 127 (2007) No. 3

[5] BSE Best Practice Data Base

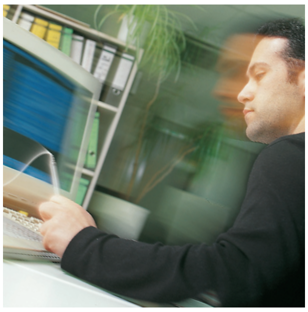
[6] Riedinger, Dr. Opfermann, Vogel: „The time balance of the electric arc furnace“, MPT International 1/2009

BSE: the Steelmaking Excellence Network.

Kehl/Rhine, Germany: aerial view on one of the world's most successful EAF steel plants.

BSE is at the center of a worldwide active partnership that is driven by a common goal: to help steelmakers all around the globe in doing their good job even better. From raw material procurement to product portfolio and market analysis, from staff and management training and consulting to the most advanced EAF steel production soft- and hardware – the BSE Competence Network covers it all. Find out for yourself what BSE can do for YOUR excellence in steelmaking!

- **BSE consulting and training**
- **BSE concepts for chemical energy input**
- **BSE measurement and control solutions**
- **EAF, LF and CCM modernisation by BSE**
- **BSE environmental services**



Badische Stahl-Engineering GmbH

Robert-Koch-Straße 13
D-77694 Kehl/Germany
Phone (+49) 78 51/877-0
Fax (+49) 78 51/877-133
eMail info@bse-kehl.de
www.bse-kehl.de

1811 Sardis Road North, Suite 204
Charlotte, N. C. 28270 USA
Phone (+1) 704/553-15 82
Fax (+1) 704/553-23 17
eMail info@bse-america.com
www.bse-america.com

BSE
BADISCHE STAHL-ENGINEERING GMBH

Excellence in Steelmaking