Time Management at the HKM-Huckingen BOF-Shop

J. Cappel, H.-P. Kaiser, J. Schlüter
Hüttenwerke KRUPP MANNESMANN GmbH, Duisburg, Germany

ABSTRACT/SUMMARY : The Steelplant of HKM in Duisburg-Huckingen is one of the world most demanding plants in terms of coordination of transport activities, because of its wide range in products and steel grades, its customer structure, the lack of space in the plant and related the high concentration of producing facilities in the exisiting building [2] [3]. Therefore, more than ten years ago a scheduling model was introduced, which is the suitable solution to visualize actual and future production conditions in the plant with the goal to optimize the output [1] [2] [4] [7]. The faster growing demands on production quantity and quality in the last years lead to the observation, that the overall scheduling view of the steelplant material flow itself is not sufficient enough for the desired increase in production intensity. For that reason the so called "charge-clocks" were introduced in the bottle neck parts of the plant, which compare the actual time schedule with an optimum one on-line. The compressed and clustered deviations between optimum and real duration are the base for further organisation or investment activities in future.

1. INTRODUCTION

The Hüttenwerke Krupp Mannesmann GmbH (HKM) are an integrated steel works for the production of slabs and round bars for their shareholders Thyssen-Krupp Stahl AG (TKS), Vallourec & Mannesmann Tubes S.A. (VMT) and Mannesmannröhren-Werke AG (MRW) [2] [3] [6]. The uncompromising investment strategy of the last ten years, which enlarged the availability of hot metal, the tightening of logistics in the entire works, and the installation and expansion of the secondary steelmaking facilities in the steelplant, lead to the increase of the works production up to 5.8 mtpy. With the reconstruction of an existing oval-bow-caster for TWIN-slab-casting and the installation of a modern vertical-bending and high-productivity-slab-caster, today it is possible to satisfy customer demands in a wide range of steel-grade and quality requirements [8].

Product Type	Mill Type	Customer	Location	CC#1 	CC#2 	CC#3 	CC#1 	CC#2 
Flat Products and welded Tubes	Hot Rolling Mill	TKS	Bruckhausen			8		
		TKS	Beekerwerth			384		
		TKS	Bochum		323	1.486		
		SZAG	Salzgitter			39		
		HHL	Hohenlimburg	555				
	Plate Mill	TKS	Hüttenheim		485			
		MRW	Mühlheim		702			
		SZAG	Ilsenburg		26			
	Beam Mill	SZAG	Peine		14			
Seamless Tubes, Rings, Structwals and Forgigs	Mandrel Mill	V&M	Mühlheim				296	
		V&M	Saint-Saulve				32	
		V&M	Belo Horizonte				8	
	Push Bench Mill	V&M	Zeithain				150	24
	Piercing Mill	V&M	Düsseldorf-Rath					278
		V&M	Aulnoye					96
		V&M	Deville					26
	Section Mill	HHO	Schwerte				57	
	Planetary Mill	MRW	Eschweiler					69
	Ring Rolling Mill	HRE	Dortmund					31
	Forging Mill	V&R/TKS/MRW	Several Locations					36
Structure of Products shipped in 2002				**555**	**1.550**	**1.917**	**543**	**560**

Fig. 1 : Product and Production Structure

2. PRODUCTION- AND QUALITY STRUCTURE

The semis produced can be devided in slabs for hot and cold rolled coils and sheet, slabs for heavy plates and round bars for seamless pipes and forging pieces **(Fig. 1)**. The slab producing facilities support in total nine hot rolling mills of different type, including three wide hot strip mills, one hot strip mill for medium strip width and four heavy plate mills. The round bars are processed in eight hot rolling tube mills of different type, one heavy section mill and various ring rolling and forging mills.

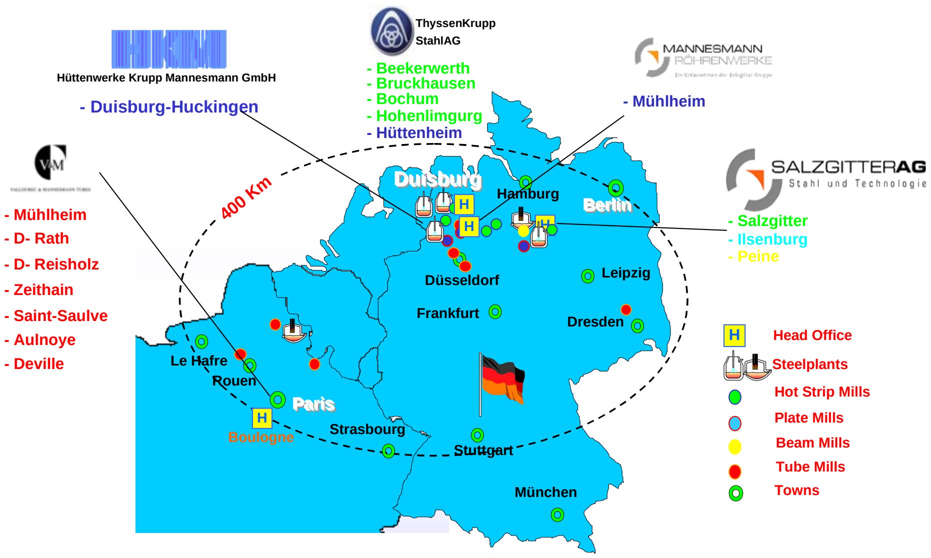

Fig. 2 : Location of HKM and the hot-rolling Mills

The concast products **(Fig. 2)** are carefully inspected due to surface quality requirements and customer service sizing and marking. They are delivered by railway to the rolling mills of TKS, VMT and MRW, which are located within a 400 km radius around the works [2] [6].

Slabs for Plates	
Line Pipes	Micro-alloyed Steels
Shipbuilding	Boiler Steels

Rounds for seamless Tubes, semifinished Forgings, Longproducts	
OCTG Grades	Roller Bearing Steels
Carbon Steels	Boiler Tubes
Automotive Tubes	Structurals

Slabs for hot Strip	
Coils and Sheet	Tinplate
Structural Steel	Heat-treatable Steels

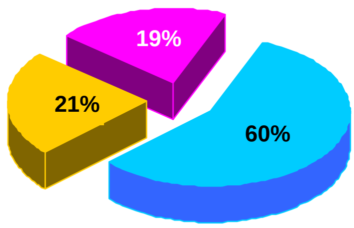

Fig. 3 : Quality Structure

In the case of flat products the quality program **(Fig. 3)** includes all grades starting from non alloyed IF-steel up to high tensile strength grades for sour-gas service. The quality program for the round bars spreads from non alloyed quality steel grades up to high alloyed steel grades for boiler tubes or roller bearings [3] [8]. The analysis of the share of single steel grades in the steel plant program structure, as it is shown in **Fig. 4** for the slab casters and for the dimension allocation at the round casters, demonstrates the variety of the program structure in 2002. The biggest portion of a singular steel grade type is below 10 % of the entire slab production. In the case of the round bar production this portion is even smaller. In total 730 different steel grades were produced and shipped as slabs in 2002, and 291 steel grades as round bars. The extensive product range is a strategic chance and at the same time the main operational problem of the steel plant in Huckingen. On the one hand the simultaneous presence in both, the flat and the long product market, ensures - even during reduced demand periods - an satisfactory capacitiy utilisation of the works. On the other hand the melt shop is equipped with secondary metallurgy devices, which were originally designed for the production of slabs for heavy plates in tubular applications and round bars. Today also slabs for for highest requirements of hot and cold rolled coils and sheet have to be produced in the same facilities.

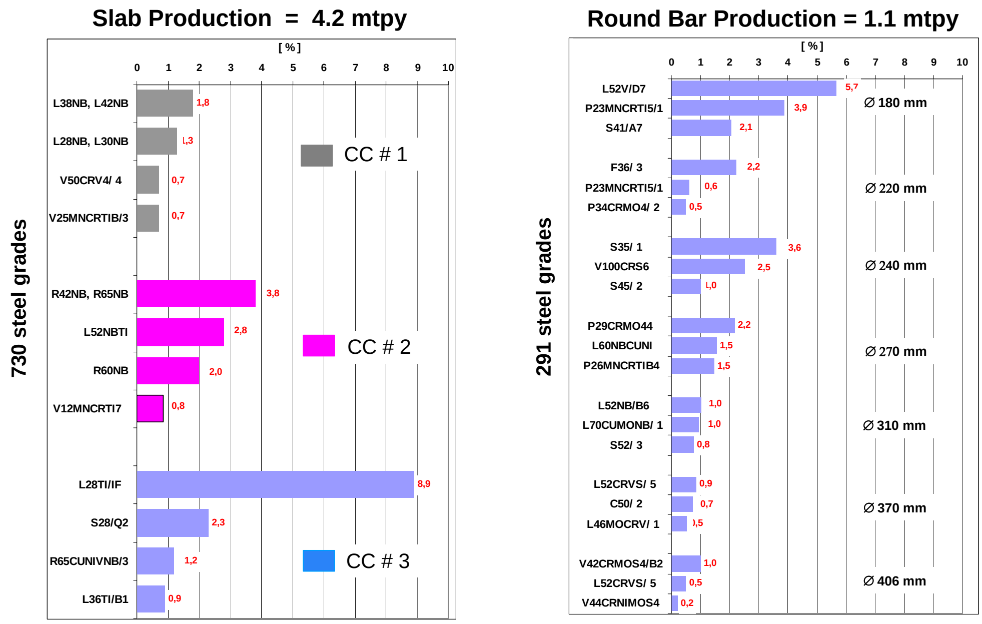

Fig. 4 : Program Structure

3. PRODUCTION FACILITIES

The implementation of this complex product structure in just one steel plant needs a high sophisticated plant and process technology as well as detailed logistic strategies **(Fig. 5)** [6]. Therefore the plant is equipped with a twin-hot metal-desulfurisation unit, two change-vessel BOF's, three argon-bubbling stations and two twin-vessel vacuum-tank-degassing units.

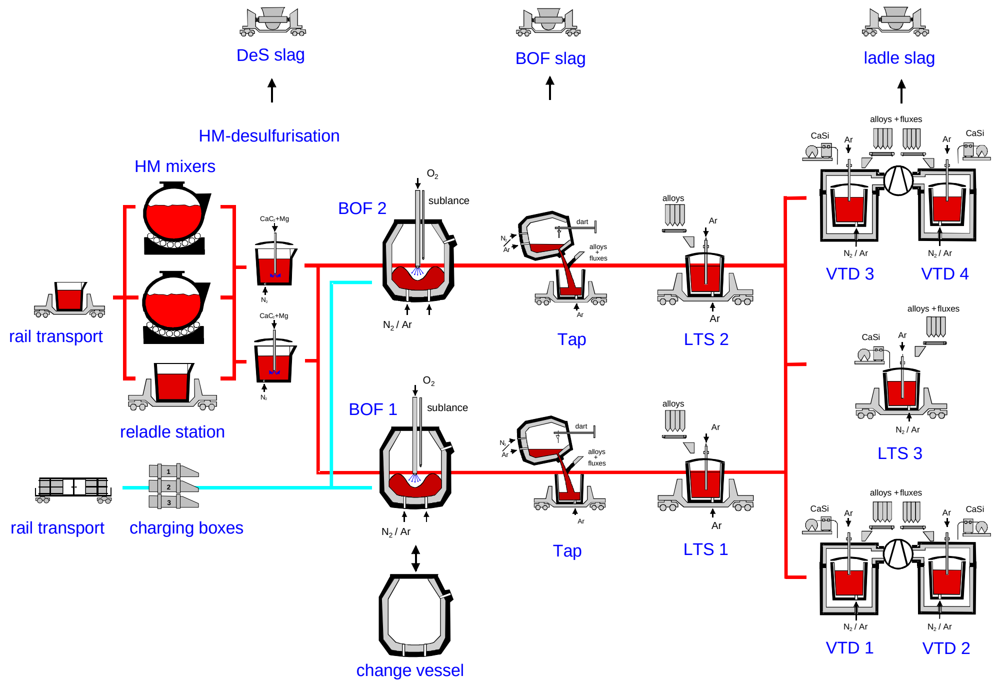

Fig. 5 : Layout of the Steel Making Facilities

The continous casting department consists of five CC-machines with a total of eleven strands for round bars and eight strands for slab casting **(Fig. 6)** [2] [3] [6].

	Casting Machines					production	number of heats	number of sequences	number of pieces
		Nr.	Strands	Type	Width	[t]	[n]	[n]	[n]
Slabs		CC# 1	2 x 2	Oval Bow	350 650	611.044	2.323	952	61.573
		CC# 2	2 x 1	Oval Bow	800 2100	1.585.133	5.944	1.157	61.143
		CC# 3	2 x 1	Vertical Bending	800 2100	1.956.963	7.243	1.415	81.727
Round Bars		CC# 1	6 x 1	Bow	180 220 240	535.174	1.959	669	197.529
		CC# 2	5 x 1	Bow	240 270 310 370 400	607.867	2.263	743	145.658

Fig. 6 : Layout of the Continuous-Casting Machine

One slab-caster is desinged for TWIN-slab-casting as well. In the finishing areas various cutting facilities for longitudinal and transversal cutting are installed. The simultaneous availabilty of the torch cutting and the cold sawing technology guarantees optimum fixing conditions in hot and cold physical shape. Various cooling process requirements for the different steel grades produced, give rise to fast and slow cooling conditions, which have to be guaranteed by wide and high cooling beds. The overview of the material flow in **Fig. 7** shows, that the heats coming from the BOF's have to be distributed to the left and the right into the secondary metallurgy devices and afterwards to the slab- and round casting departments [1] [2] [4] [7]. The ladle treatment stations, the casters and the tundish preperation areas are located in just one central steel plant hall.

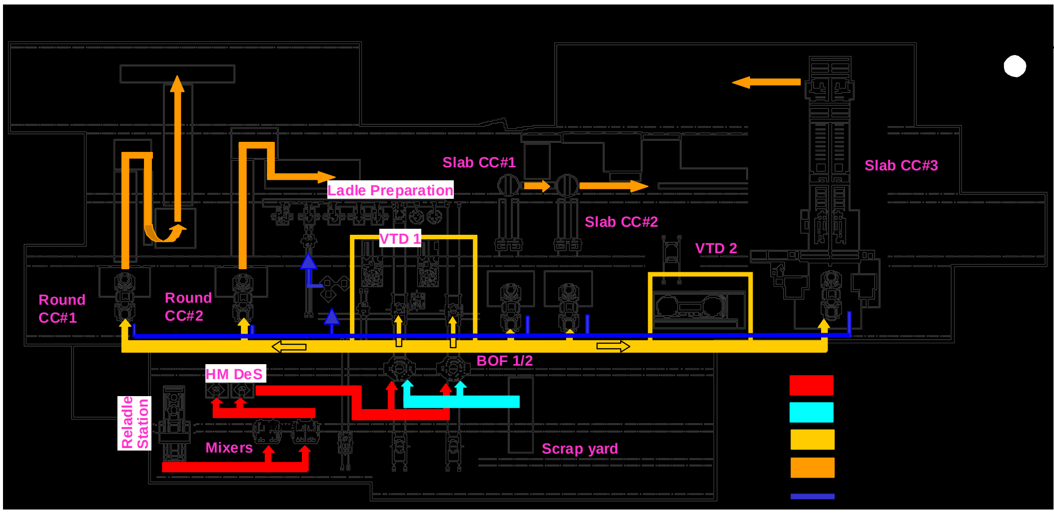

Fig. 7 : Material Flow in the Steel Plant

As far as the empty ladle cycle has to be managed in the same hall on the same crane rail, the resulting transport activities are complex and interpendence hindrance is unavoidable, as it is shown in **Fig. 8** for a high productivity day of 68 heats. All transport activities have to be coordinated with priority to the fast casting slab machines in sequence casting.

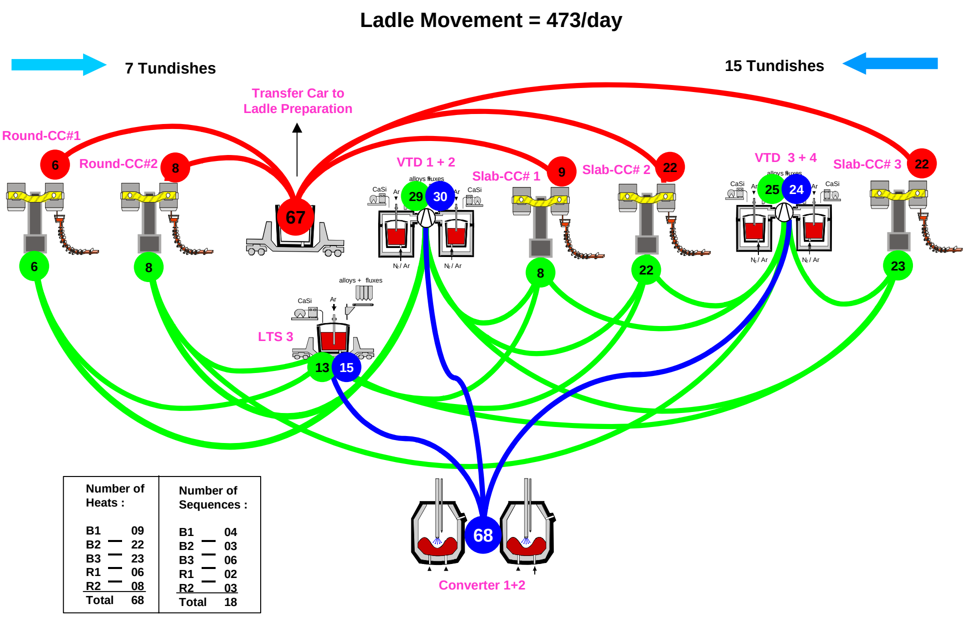

Fig. 8 : Transport Activities in the Steel Plant

Regarding these requirements the logistic challenge of the steel plant management is described sufficiently. In the casting and finishing departments additionally the high number of pieces to be handled, has to be taken in account. It is remarkable, that the number of round bar pieces with about 350.000 pieces/Y is much higher than the number of slab pieces with only 210.000 pieces/y. ISO-Quality-based inspections ensure, that quality deviation caused by the casting process and reported by the casting control measurements are indentified and assigned to their position in the finished strand. This is especially necessary for the detection of the mixing areas in combination casts of different steel grade analysis.

4. PROGRAM REQUIREMENTS

Due to the customer requirements **(Fig. 9)** and the processing equipment installed in the plant, different metallurgical routes for the production of the steel grades are carried out. The metallurgical route of a single steel grade, starting from hot metal-desulfurisation to the cast, are derivied already in the stage of order processing regulated by customer anlysis requirements and other characteristic quality informations.

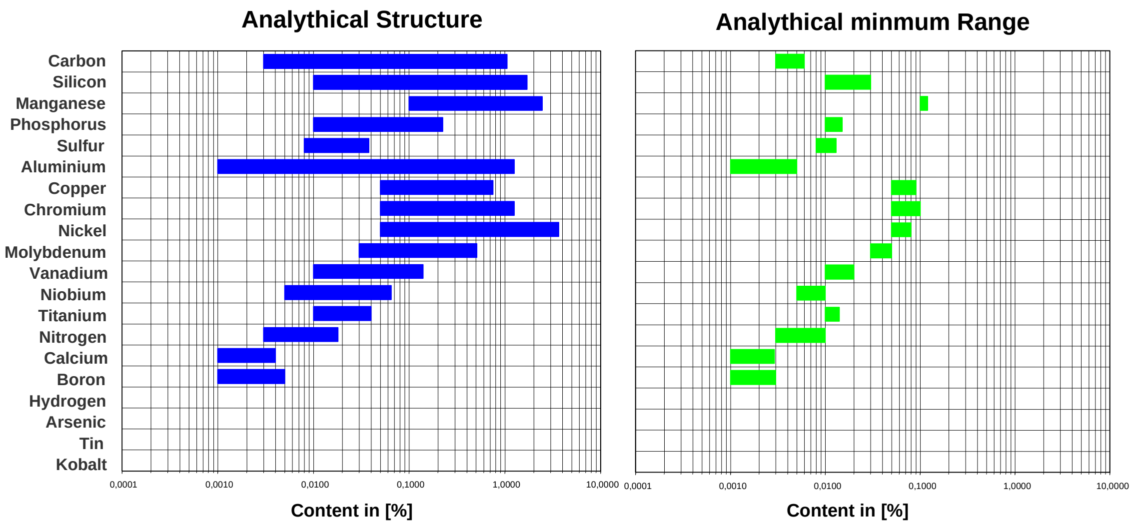

Fig. 9 : Analytic Requirements of the Steel Grades

Further processing steps and the final application of the steel product is of exceptional importance for the determination of the production route. In the last decade the customer requirements have increased in a way, that contradictionary demands have to be met by intellegent metallurgical combination of treatment steps (for example : meeting a regulated nitrogen content of more than 100 ppm and simultaneously limiting the hydrogen content down to 3.5 ppm or limiting the nitrogen content of the melts below 60 ppm and meeting an regulated sulfur content, and so on). On top limitations of tramp elements and of deoxidation agents in a program structure with both, limited and regulated alloy contents lead to limitation in production felxibility, because all grades have to be produced in the same steel ladles. I.e. the steel grade which has been produced in the cycle before has to be mentioned for the choose of the ladle in the actual cycle.

5. PRODUCTION CONTROL BY DISPO

The variety of steel grades produced in the plant require different treatment steps and treatment intensities, which cause a range between 1:4 in processing time in the secondary metallurgy and in the casting departments **(Fig. 10)** [1] [4]. The casting time is only dependent on slab width and casting speed. In secondary metallurgy time utilisation is influenced basically by the requirement of vacuum treatment, because vacuum treatment is an additional step in the sequence of allying and homogenisation work to be done. The wide range in processing time and waiting periods caused by crane transport activities against the molten steel flow (for example empty ladle transports) has to be taken in account for the temperature adjustment of the heats during their way to the casting facilities. Due to the fact that there is no additional electric or chemical heating unit installed in the plant, tapping temperature is rather high compared to the losses during ladle treatment. Therefore moderate cooling by sorted scrap is used in the different stages of treatment and in consideration of the quality requirements. Nevertheless today the rate of liquid steel returns and the superheat in the tundish has not reached an opimum level.

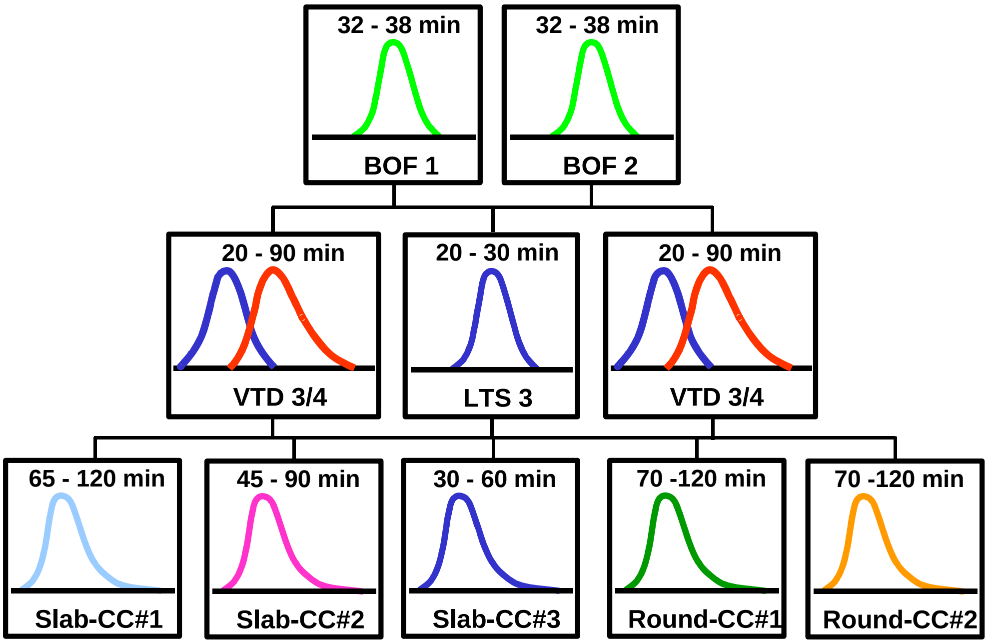

Fig. 10 : Distribution of Treatment Time

For the control of the complex processing steps and to improve the temperature adjustment in the plant, a scheduling system **(Fig. 11)** was introduced already ten years ago, at the foundation of HKM, which guarantees an permanently optimised time management in the steel plant, beginning from the hot metal desulfurisation to the end of the cast [2] [7].

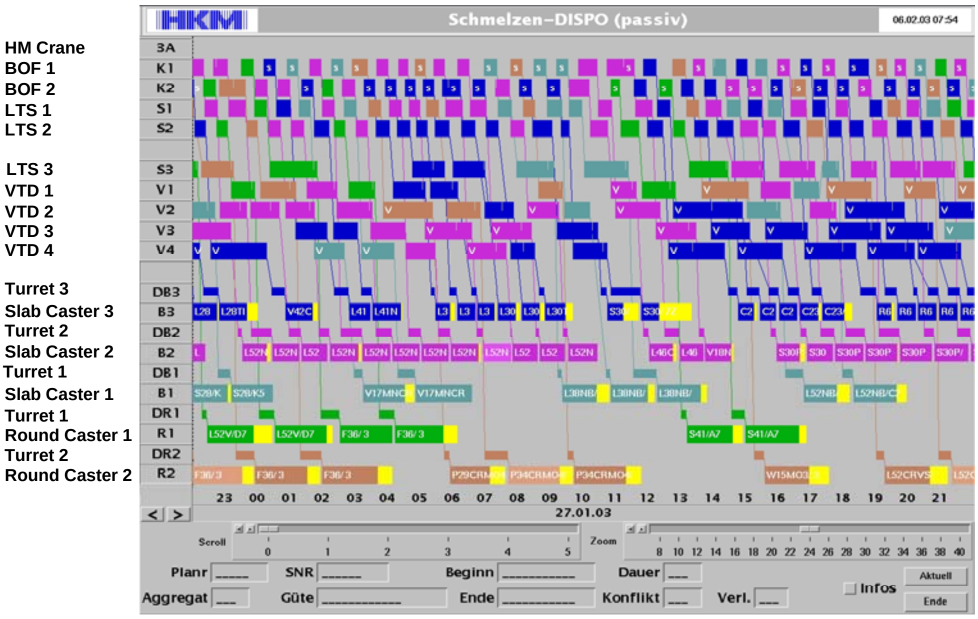

Fig. 11 : DISPO-Schedule

The Dispo-system calculates and shows the processing of the actual und future heats on their way through the steelplant. In the design-phase of the model a combination between computer based calculation and manual operation of the system was choosed deliberate. This model strategy has improved since today in comparative tests of fully automated versions of the Dispo-System. Dispo is operated manually from a central control room in the casting hall of the plant. In this control room all important informations for the plant performance are accumulated on-line, by radiotelephony or telephon. In consideration of this strategy also unimportant seeming details are registrated and can be taken into account in the fast changing priorities of the steel plant production. The success of the combined model strategy between automatic calculation and manual control can be measured by the fact, that at least the installation of an metallurgist as production-supervisor was introduced successfully. The supervisor is controlling the scheduling strategies and is acting in approval with the Dispo-operators to stream the operation.

For further improvement of the works production, sattelite systems were developed, to support the central unit with accurate and detail information needed to operate the optimisation algorythm of Dispo **(Fig. 12)** [1] [2] [4] [7]. The satellites are in use for the scrap- and hot-metal-supply, the piloting of the casting hall cranes, the monitoring of the ladle-cycle in the plant and the maintenance-management in the plant. Another completation of the central Dispo unit is the scheduling system for the slab finishing department, which is under construction now. Recently with the Dispo-model and its satellites the complex logistics in the steelplant are controled by an integrated planning instrument. The Dispo installalation guarantees an measureable increase in production output of 10-15 %, compared to conventional expert operation.

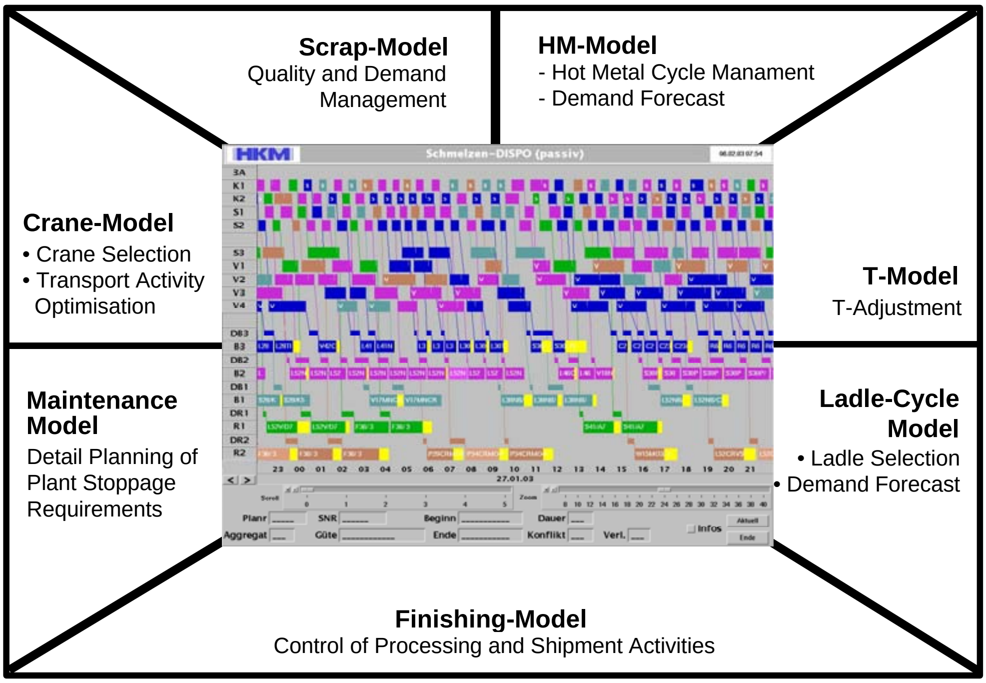

Fig. 12 : DISPO, an integrated Control System

6. PRODUCTIVITY INCREASE

In the last years the introduction of Dispo was one of the major steps, which lead to an continuous progress in production output as well, as in quality assurance. Since 1997 bottle neck parts in the plant were consequently eliminated by investment projects to reach the long term productivity target of 6.0 mtpy shipped products,. Of course improvement and development of product quality aspects were always an aquivalent target of the investment activities. **Fig. 13** shows the portion of the steel plant activities, done within the increase of the works performance in the last five years, sorted by the year of comissioning. The table shows, that more than 50 % of the total investment was used for the enlargement of the steelplant, where the installation of a TWIN-VTD in 1998 and of a new VB-casting machine in 2000 were the main subjects. Compared to these projects, the capital needed to increase the tap-weight of the heats, coming from 238.0 tons liquid/heat up to 282.5 tons liquid/heat, which is an 44.5 tons liquid/heat or 18,7 % increase since 1994, was a rather moderate value. The major investment activities to reach this operation level in average production condition, were an reinforcement of the trunnion ring and the tilting devices at the BOF's, an reinforcement of all crane beams in the hot metal and the casting hall and the replacement of the ladle fleet in the hot metal and liquid steel department.

Investment	**million €**	**start-up**
Extension of Slab Caster #2	4	10 / 1997
Relade Station for Hot Metal	3	01 / 1998
Reinforcement of BOF for 275 t	3	06 / 1998
New Steel Ladles for 275 t Tap Weight	10	06 / 1998
Capacity Increase of Finishing Yards	13	06 / 1999
Vacuum Twin-Tank-Degasser #2	39	09 / 1998
Adaption of Steam Supply etc.	2	05 / 2000
Central Control Room for BOF-Shop	4	12 / 2000
New Sab Caster #3	81	12 / 2000
Replacement of Ladle Tilters	3	12 / 2000
Additional Slag Dumping Area	1	06 / 2001
New Ladle Crane BS6L	2	06 / 2001
Grand Total	**165**	

Fig. 13 : Investment Activities in the Steel Plant for 6.0 mtpy

In the hot metal department the major investment project of the last five years was the relining and volume enlarging of blast furnace B in 2000. The theoretical increase in production capacity of hot metal and shipped steel products is shown in **Fig.14**.

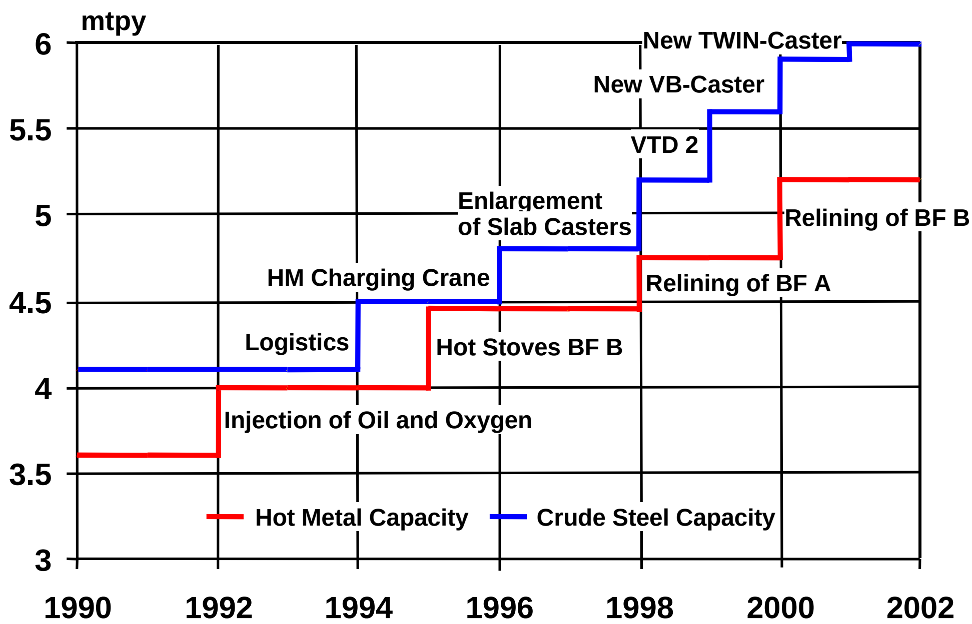

Fig. 14 : Development of Crude Steel and Hot Metal Capacity

The fast increasing demands on productivity and production quality made clear, that Dispo with its overall view on the production flow would not successfully increase the production frequency in the desired speed, described above. In respect to this analysis an so called „charge-clock“ was designed and installed in the bottle-neck part of the steel plant, the BOF-shop **(Fig. 15)**.

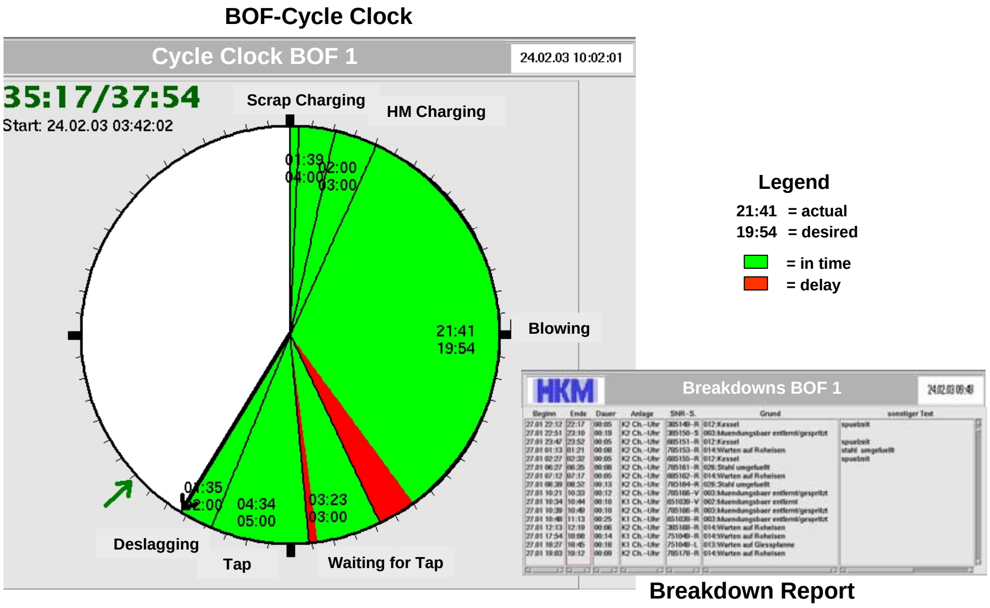

Fig. 15 : BOF-Cycle-Clock

This control instrument devides the converter cycle in characteristic steps, which are compared and reported to an idealised cycle automatically. The system gives an on-line feed-back of the personal influence on the entire plant success to the operators. Basing on the on-line deviation comments of the operators, statistical analysis of differences to the assumed idealised operation conditions can be used as helpful informations for further investment activities. With the installation of the “charge-clocks” in the BOF-shop, it was pointed out, that today not the converter cycle itself, but the management of the scrap- and hot-metal supply and the manipulation of the hot metal ladles and the scrap-chutes and additionally the comlex logistic cycle of the charging hall are responsible for delays and capacity losses in the BOF-shop. In respect to this analysis all control rooms at the scrap- and hot metal supply areas were completed with similar „charge-clocks“ to guarantee the tuning of the Dispo-required converter rhythm. Another conclusion from the “charge-clock” analysis was, that scheduling of the converter preparing periods, like tap-hole change, mouth-cleaning and others is useful for the caster utilisation and the plant output as well. It can be summarised, that with the “charge-clocks“ on the same time hidden reserves and obvious bottle necks can be pointed out and mobilized.

7. OPERATION RESULTS

Dispo and its sattelites are an intergrated productivity factor in the steel plant of HKM today. By taking in account, that the productivity of the whole integrated steel works HKM is based on only two operating BOF’s, it is obvious, that today sprint-periods, in the way of make up for delays are seldom during common operation. Nevertheless the steelplant output, based on Dispo, will be measured by comparison to a production period, free of utilisation problems at the hot metal-department and free of big steelplant breakdowns as well. **Fig. 16** shows the monthly accumulated shift-tapped-heat-frequence in the first quarter of 2003 compared to the annual results of 2002.

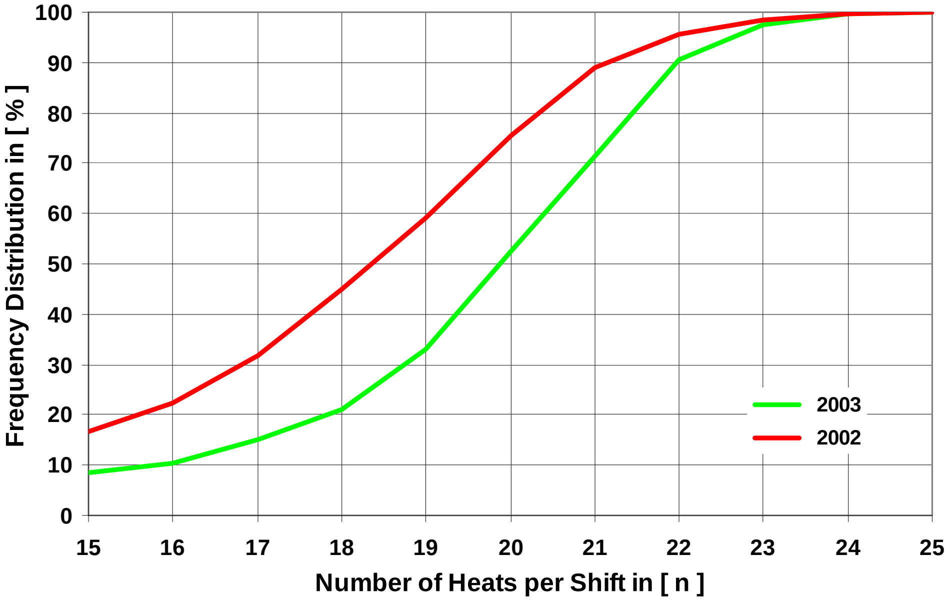

Fig. 16 : Operation Results

The effect of the logistic improvement steps of the last year is pointed out clearly by the graph. The difference appears in the portion of shifts below 15 heats, as well as in the average and the portion of shifts over 22 heats. In 2002 an exceptional break-down frequency stressed the production result of the steelplant. Therefore the lower part of the frequency distribution in **Fig. 16** demonstrates an successful improvement of the break-down-management. The upper part of the frequency distribution is an synonym for a better utilisation of the sprinting-capability. The difference can be quantified to more than 2 heats/shift in the lower part of the distribution and at least to 1 heat/shift in the upper part of the distribution. This observation correlates with an increase in productivity of more than 150 heats/month in the first quarter of 2003. This increase was generated by working with one planned monthly repair shift, one vessel change at BOF's and the various break downs, characteristic for hot cycle operation plants all over the world.

Empty Ladle Cycle :

⇨ Increase in Steel Production
⇨ Higher Transport Frequency in the Casting Hall
⇨ Longer Manipulation Time for Ladles after Finishing Cast
⇨ More Steel Rests and Slag Glaze in the Ladles
⇨ More Temperature Losses in the Ladles
⇨ Less Preperation Time for the Ladles

Solution : New Transfer Car, Slag Pit and Manipulation Crane for the Cycle

Slag Pot Cycle :

⇨ Increase in Steel Production
⇨ Higher Slag Amount at Converters and Casters
⇨ More Slag Pots in the Cycle
⇨ More Transport Capacitiy by Cranes, Slag-Pot-Manipulating Waggons, Locomotives and Manipulating Capacity at the Pits is required

Solution : More Slag Pots, Higher Locomotive Capacity, Improvement of Pit Handling

Fig. 17 : Remaining Problems and their Solutions

By using the deviation information coming from the reports of the Dispo-sattelites new bottlenecks are pointed out during production optimisation. Naturally these focal points are today moving from the raw material support of the primary processes to the secondary preparation problems of the production units installed in the plant. The solution of this problems will be re-dressed with priority in 2003 **(Fig. 17)**.

8. CONCLUSION

Scheduling systems today are of common use in the age of modern communication by computer technique. While production forecast in former times was a question of expert knowlegde, the use of common, understandable systems is a consequence of the permanent increasing productivity demands of the new century. Today the intensity of information, taken into account for meeting the productivity and quality goals as well, is much higher than the capability of single experts with long term experience in the plant. By recognizing this fact, the introduction of scheduling systems is obvious for high-productivity plants. Those systems, today, concentrate additionally the peripheral activities in a steelplant like scrap-, and hot-metal supply as well, as the ladle- or crane-cycle. Furthermore the latest activities were the introduction of "charge-clocks", which give an permanent comparison between an idealised and the real bottle neck operation in the plant. The "charge-clocks" allow the operator an on-line feed-back of its individual influence on the production of the steelplant. In addition the statistical deviation analysis, based on the on-line operation results, are collected and summarised in the plant computer system and are developed to bottle-neck elimination organisation- and investment actions. The use of all Dispo-system components lead to an productivity increase at the HKM-Steelworks up to a monthly average of 20 heats per shift, with a tap-weight level of 282.5 t/heat, which increased the plant output up to 5.6 million tons of concast products per year.

REFERENCE

1. Bernatzki, K.-P.; Fengler, D.; Kaiser, H.-P.; Lanzer, W. :
   „Disposition und Zeitwirtschaft im Stahlwerk Huckingen unter Einsatz von Fuzzy-Technologie"
   Stahl und Eisen 114 (1994), Nr. 5, S. 89 - 95
2. Käding, G. :
   „Hüttenwerke KRUPP-MANNESMANN GmbH"
   Stahl und Eisen 117 (1997), Nr. 2, S. 39 – 42
3. Wiemer, H.-E.; Cappel, J.; Klärner, A.; Pfeiffer, A.; Wünnenberg, K. :
   „Metallurgische Prozeßtechnik in einem Stahlwerk mit breitem Erzeugungsprogramm„
   Stahl und Eisen 117 (1997), Nr. 3, S. 85 – 90
4. Kaiser, H.-P.; Müller, N.; Urban, W.:
   „Qualitätsführung bei der Einsatzstoffbereitstellung für den Blasprozeß„
   Stahl und Eisen 119 (1999), Nr. 8, S. 79 – 83
5. Bannenberg, N.; Bruckhaus, R.; Kaiser, H.P.; Schütz, C.-H.:
   „Metallurgische Verfahrensentwicklung für die Erzeugung hochwertiger Stahlsorten"
   Paper presented at the anual meeting Stahl 2000, Düsseldorf, Germany, November 16, 2000
6. Cappel, J.; Kaiser, H.-P.; Schlüter, J. :
   „Anforderungen an den Reinheitsgrad von Sauergas- und IF-Stahl und Veränderungen in der metallurgischen Verfahrens-technik"
   Asia Steel International Conference – 2000, Beijing, China, September 26-29, 2000
7. Arnold, H.; Bernatzki, K.-P.; Ehrenberg, F.; Fengler, D.; Limbeck, W. :
   „Integration operativer Dispositionssysteme in einem Hüttenwerk"
   Stahl und Eisen 121 (2001), Nr. 4, S. 55 - 60
8. Anton, O.; Ehrenberg, J.; Kaiser, H.-P.; Kemper, G.; Liebisch, K.-O. :
   „The new continuous slab caster of Hüttenwerke Krupp Mannesmann GmbH"
   Paper presented at the anual meeting Stahl 2001, Düsseldorf, Germany, November 15, 2001