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Subject : Production of ULC-/IF-Steel Grades in VTD- and RH- based Process Routes

Influence of the Continuous Casting Machine Type on IF-Steel Cleanliness

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SUMMARY

The production of IF-steel-grades for highest demands on surface quality is standardized today in different process-routes equivalent to the metallurgical equipment of the steel plants. In secondary metallurgy the type of degassing unit determines the metallurgical way. In RH-based-process-routes the objective of the treatment is to adjust the analysis without any slag-metal-reactions. In VTD-based-process-routes the intensive slag-metal-reaction is one of the main targets of the treatment. Accordingly different is the type of deoxidation product of both routes. In the RH-route coral-like alumina inclusions are typical. In the VTD-route globular calcium-aluminates are dominating. During casting significant differences in cleanliness between vertical-bending, bow-type and low-head machines are visibly worked out by metallographic investigations. It has to be recognized, that although separation of no metallic inclusions and bubbles is much better in an VB caster, than in other machine types, sometimes surface defects on cold rolled strip are detected, especially on strips for use in highest surface demands. Since not the statistic number of inclusions, but the presence of non workable, globular calcium aluminates is used as a quality judgement in the case of these products, the VTD-based has to be modified in this direction. The objective is to modify the metallurgical way in respect to adapt the inclusion type of a RH-based process route.

INTRODUCTION

The Hüttenwerke KRUPP MANNESMANN GmbH is an integrated steel works for the production of semi finished products, which is producing slabs for Thyssen Krupp Stahl AG (TKS) and Mannesmannröhren-Werke AG (MRW) and rounds for Vallourec & Mannesmann Tubes (VMT). The company was founded in 1990 as a joint venture of Mannesmannröhren-Werke AG and the former KRUPP Stahl AG on the Huckingen site. The shares of the company today are owned by TKS (50 %), MRW (20 %) and VMT (30 %).

In 2001 the production reached 5.138 million mtpy for the first time, which is a portion of 11 % of the steel production in Germany, **Figure 1**. With this production HKM raised to the second rank in Germanys steel industry. The production target for 2002 is roughly 5.628 million mtpy. With the 2001 production sales accumulated to 1.2 billion €/Year. The number of employees ist at a level of 3.525 which is equal to a productivity of 0.98 h/mt. The works is situated in the western part of Germany in the south of the city Duisburg, which is among the world’s most important steel making location with an overall production of nearly 18 million mtpy

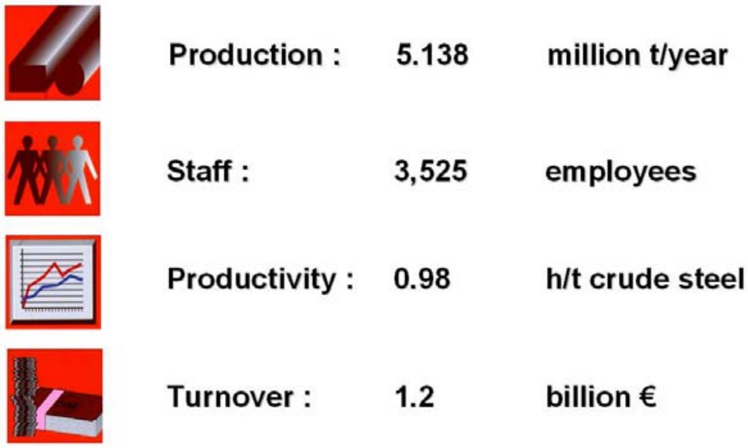

Figure 1 : HKM 2001 at a glance

PLANT AND PRODUCT CONFIGURATION

Since the foundation of HKM in 1990 the works, which traditionally was concentrated on the making, shaping and treating of steel grades for line pipe and seamless tubes and pipes, was enlarged with an investment capital of almost 400 million € to an overall crude steel capacitiy of 6.0 million mtpy within a decade. Also the equipment was modified and optimised for the demands of the production of slabs for hot and cold rolled coils and sheet.

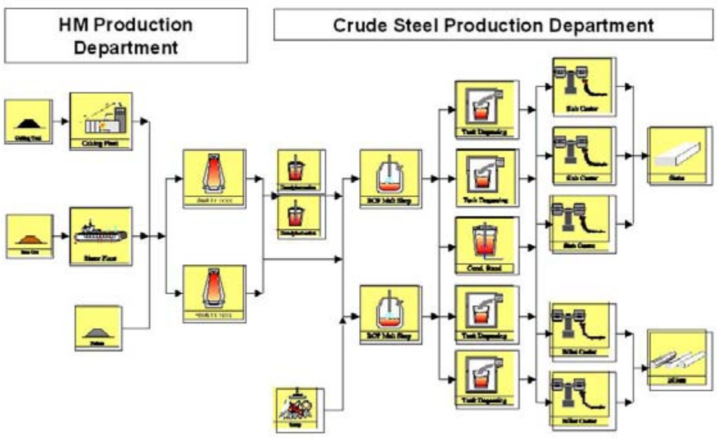

Figure 2 : Production equipment of HKM

Today HKM achieves its targets by using a metallurgical coke oven plant, a sintering plant, two medium size blast furnaces and one oxygen steel making shop containing two BOF-vessels, secondary metallurgy facilities and five continuous casting machines, **Figure 2**.

The semis produced are continuously cast slabs and rounds. They are taken to the rolling mills at other nearby locations of the shareholders TKS, MRW and VMT. The production program, **Figure 3**, is comprised small and wide continuous cast slabs for hot and cold rolled strip (approximately 57 %), continuously casted slabs for the production of heavy plate (approximately 22 %, including HSLA- and

HIC-resistant steels : approximately 7 %) and conticast rounds for seamless tubes (including OCTG), forging grades, special sections, structural hollows (MSH) and Roller bearing steel (21 %).

Product Type	Mill Type	Customer	Location	Slab Casting CC#1	Slab Casting CC#2	Slab Casting CC#3	Round Casting CC#1	Round Casting CC#2
Flat Products	Hot Rolling Mills	TKS	Bruckhausen					
		TKS	Beekerwerth			20		
		TKS	Bochum		51	126		
		SZAG	Salzgitter		3	3		
		HHL	Hohenlimburg	50				
	Plate Mills	TKS	Hüttenheim		57			
		MRW	Mühlheim		32			
		SZAG	Ilsenburg			6		
	Beam Mills	SZAG	Peine			1		
Long Products	Mandrel Mills	V&M	Mühlheim				31	
		V&M	Saint-Saulve					3
	Push Bench Mills	V&M	Zeithain					15
	Assel Mills	V&M	Montbard					1
	Piercing Mills	V&M	Düsseldorf-Rath				23	
		V&M	Aulnoye					6
		V&M	Deville					1
	Pilger Mills	V&M	Düsseldorf-Rath					
	Erhardt Mills	V&M	Düsseldorf-Reisholz					
	Section Mills	TKS	HHL-Schwerte					5
	Ring Rolling Mills	TKS	Hoesch-Rothe-Erde					2
	Forging Mills	several						9
Structure of Products shipped in March 2002				50	143	156	54	42

Figure 3 : Product structure of HKM

This variety of steel grades, products and customers demands a high degree of flexibility in the metallurgical process routes, **Figure 4**. Liquid steel comes from two top-blown oxygen converters. Production downtimes for vessel relining is minimised by utilising a vessel changing system. Comprehensive secondary equipment is installed between the the converters and the continuous casting machines [3], [4], [5], [6], comprised of the stations which are mentioned below and which can be combined as may be required from case to case, namely :

- Alloy and slag forming agent addition to the converter tapping stream
- Slag retaining systems (Mannesmann-dart plus IR-camera system)
- Steel stirring stations in the tracking of the steel transfer cars, and
- Vacuum tank degassing facilities including alloy- and slag forming agent feeding systems for bulk and wire based materials.

The Steel, when treatment is finished, is poured into a total of five contionuous casting machines. Two machines with a total of 11 strands produce rounds in sizes of 180 mm to 406 mm. These conticasters are of 10.5 m radius circular arc casters. Special casting techniques are optimised tundishes and the use of narrow submerged nozzles of only 22 mm to 35 mm outlet size.

Slabs are cast today in three machines. CC#1 is a rebuilt low-head caster with a 5-m-main radius, equipped with a movable TWIN-divider. On this caster a monthly production of 50.000 mtpm is realised for the support of a medium-wide-hot strip mill of TKS in Hohenlimbug. CC#2 is the other low-head caster with a 5-m-radius. The average monthly production is roughly 150.000 mtpm. The machine supplies mainly the heavy plate mills of our customers with microalloyed grades in the peri-tectical carbon range.

The tundishes of both machines have a capacity of 45 tons and are equipped with with double inlet chambers to avoid slag overflow infuence at the casting start of a ladle. Both machines are taped with a static soft reduction zone. Slab conticaster No. 2 disserves special mention, as it is a dry caster, which means it has no secondary spray water cooling system. The dry conticasting technology is a Huckingen steelworks development and allows the production of microalloyed and preitectic slabs without any surface cracks [7], [8]. The main production facility of the CC-Department today is the slab caster CC#3, which is in operation since Dec. 2000. The monthly production capacity is of some 250.000 mtpm, which is almost 50 % of the BOF and Secondary Metallurgy capacity. The Caster layout is of the vertical-bending-type, with a 2,86 m vertical reck. The main machine radius is a 9.125 m circular arc. This machine was especially designed for the casting of low carbon steel grades.

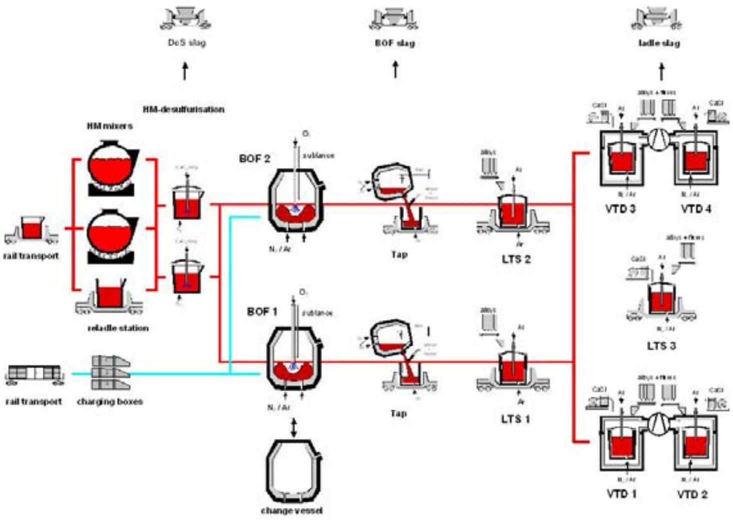

Figure 4 : Equipment of the HKM Steelplant

The wide program range is a strategic chance and the main production problem at the same time as well. On the one hand, the simultaneous presence in both on the flats and the longs markets even during reduced demand periods ensures satifactory capacity utilisation of the works. On the other hand, the steel plant is equipped with secondary metallurgical and continuous casting facilities, which were exept of CC#3 originally designed for the production of rounds and slabs for heavy plate rolling only. Today, the same steel plant equipment, of course upgraded and extended over the years, is used more than 50 % for producing sheet steel grades. Their quality requirements differ fundamentally from those for heavy plate or reound cast billets. This difference and its influence on the production route of an IF-steel grade is explained below.

PRODUCTION OF IF-STEEL GRADES

IF steels are chiefly used for the manufacture of car body parts [11]. The cleanliness of the steel is increasingly important as very high demands are made on the surface condition of the sheets. In addition the necessity for lower fuel consumption is always combined with intensive demand in lower weight of the automobiles, which is related with strong requirements for lower strip thickness at remaining or higher strength characteristics. The strength properties are attainable within close tolerances by a selective tuning of the steel analysis in respect of the elements C, N, Si, P, Mn, Cu,Cr, Ni and Mo. Principally the elements are at given influence on the strength exchangeable. Taken this dependence into account, the cold rolling mills are judging their strength properties not only by steel analysis but by tensile and yield strength investigations and comparative judgement. The best practise in terms of tensile strength on the European market is today at a level of 140 N/mm^2.

The Huckingen steelworks had not produced sheet steel grades, including ULC- and IF-grades, until HKM was founded [1], [2], [3]. Then production routes were developed to enable the steel plant facilities, originally oriented to enable the heavy plate sector, to manufacture sheet rolling semis of the highest quality standard. Because it was common knowledge, that spray water caused defects on the slab surface were no risk, one action taken in this connection was, for instance, the conversion of one of the oval-bow-type casters from dry to secondary spray water cooling. It was clear in liquid metallurgy that the installation of vacuum tank degassing facilities would lead to an operating method entirely different from that of other steel plants, a method in which slag metallurgy is predominant. This difference has always been considered an advantage in metallurgy evaluation as it is able to decisively influence the castability and the inclusion morphology of the steel. A process route has been developed over the years, as can be seen in **Figure 5**.

The process route stations are hot metal desulfurisation → converter vessels → vacuum treatment → steel conditioning [3], [4], [5]. The melt is tapped unkilled and is moved to a vacuum facility for decarburisation. After about 12 minutes of decarburisation under ultra-low vacuum conditions, deoxidising aluminium and slaf forming agents are added at the same time. This method produces a homogeneous liquid calcium alumina slag that is best suitable for adsorbing deoxidation products.

The secondary metallurgy is completed by guaranteeing various standards in the casting metallurgy, such as :

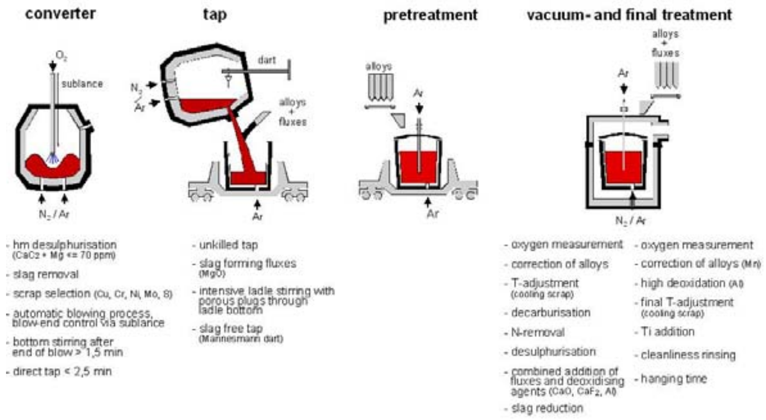

Figure 5 : Process Route of IF-Steel

- Diverting the slide gate sand when opening the ladle outlet
- Use of basic tundish covering compounds
- Casting from dual chamber tundishes
- Casting through submerged nozzles equipped with downward ports
- Casting with the use of electromagnetic slag detectors at the ladle outlet
- Casting with a constant speed of 1.1 m/minute

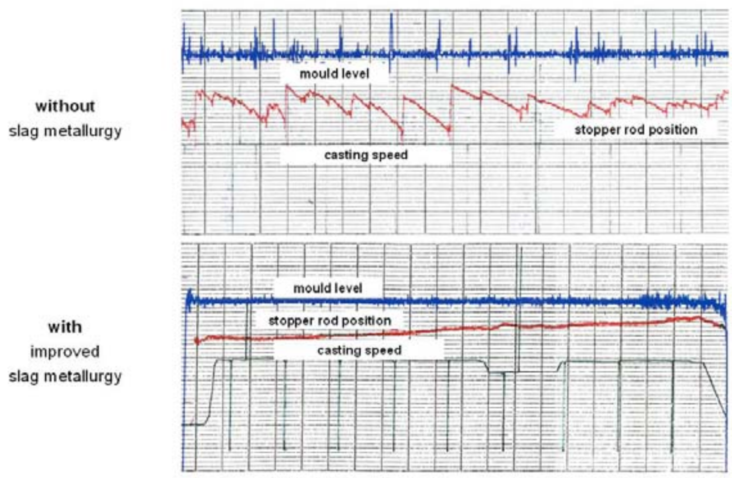

Figure 6 : Castability of IF-Steel

Figure 6 is an illustration of the effects of these metallurgical measures on the castability of the steels using a 4-ladle sequence as a typical example. It can be seen in the illustration, that mould level control is possible within close tolerances and the progression of stopper plot curve reveals an even tendency of erosion. This is the typical casting progression of a calcium treated melt. The calcium dissolved in the steel reacts with the alumina particles that float in the melt to form liquid calcium aluminates, which are almost completely separable in the tundish and on the steel level in the mould. Although IF-Steel is generally not treated with metallic-Calcium, this phenomena leads to the assumption that the effect is caused by the modified and optimised slag forming and deoxidation practise of the process route. The improvement in castability has reproducible positive effects on the Sequence length and the yield in the tundish.

Figure 7 shows the cleanliness results of randomly selected surf board samples from IF-Steel. Indications are between 217 and 573. In spite of the adoption of all measures used for HIC resistant grade metallurgy and casting, the result is clearly poorer in the case of the IF-steels. The probable cause is an increased tendency from secondary alumina and poorer non-metallic oxide separation. Such oxides are the cause of shells and blisters chiefly in sheet manufacture.

In order to improve the rejection statistics in the rolling-mills, a test program in which selected customer orders were produced under continuous monitoring was agreed. The objective of the tests was that of correlating the defects resulting in rejection with characteristic occurrences during steelmaking and continuous casting. The inspection results of the cold rolled strip were recorded by steel plant staff on special record forms and compared with casting progressions and melt data. **Figure 8** typically illustrates the findings from eight coils which had been made from one IF-steel casting sequence. The red and the green colour distinguish between failed material and material that was

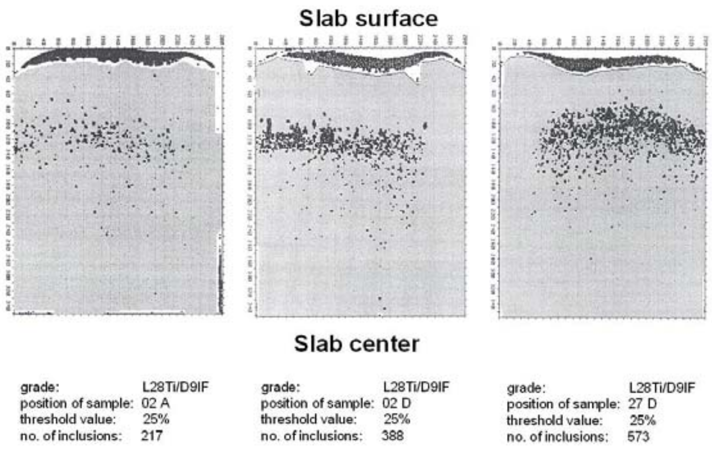

Figure 7 : MIDAS-Results of IF-Steel

released for the customer. The faulty areas were marked on the strip for ease of identification.

Figure 9 shows the comparison of this results with the related casting report of a three melt sequence. It appears that the rejections cannot be predicted by evaluating the casting log. Contrary to expectations, no preponderance can be noticed even in the transition zone between two successive melts. When comparing the default pattern of the strips of Figure 9 with the casting

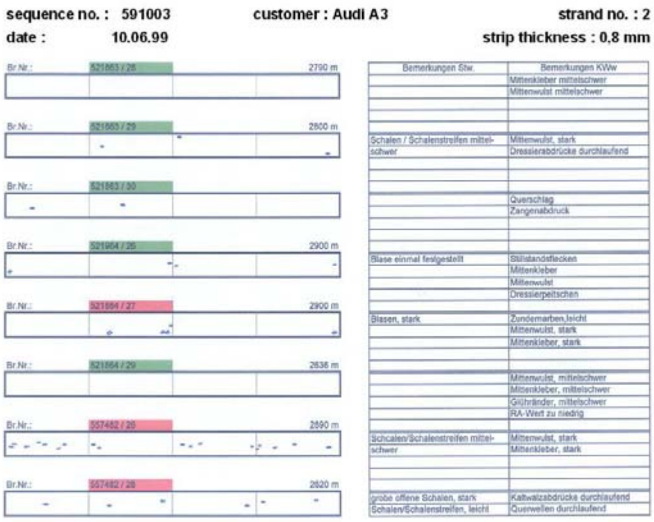

Figure 8 : Cold-rolled-Strip-Inspection Results of IF-Steel

progression shown in Figure 10 we see that our present insight does not allow us to find any correlation between the sporadic occurrence of shells over a strip length of more than 2700 m and events in the casting progression of the associated slab of 10 m length. It is even more difficult to draw conclusions from the melt data, because a melt is subdivided into not less than 8 slabs. Experience does indicate that irregularities during casting may result in a greater proneness to rejection at the rolling mill, but on the other hand a completely normal casting report is no guarantee of a low rejection rate in the rolling-mill. Nevertheless, achieving uniform casting progressions reduces the total rate of defects.

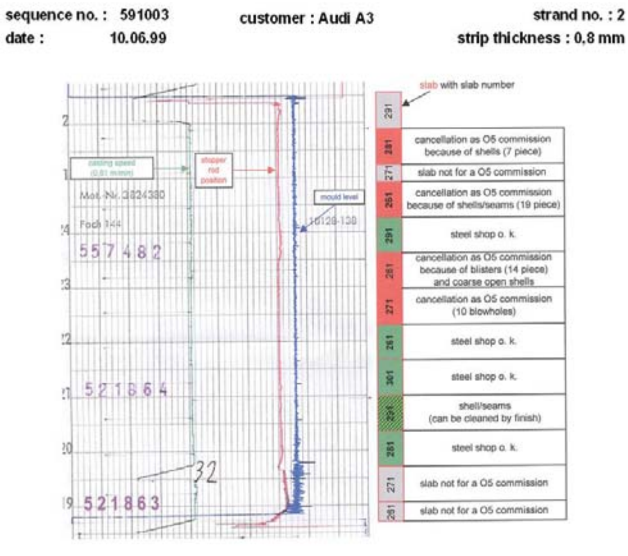

Figure 9 : Comparison of Castability and Cold-Rolled-Strip-Inspection Results of IF-Steel

Caused by this results HKM was not allowed to release IF-Steel in the channels of highest demands on surface quality. At least the strategic reflection at TKS about concentration of the crude steel production in the Rhein-region together with the innovative installation of a thin-slab-casting and -rolling plant at the Duisburg Bruckhausen works, lead to the necessity to increase also the production capacity of conventional casted slabs in Duisburg. Since HKM was, starting in 1998 with the installation of a second twin-vessel-tank-degassing plant, very well prepared to produce a high amount of vacuum treated steel, it was obvious to replace one of the existing low-head-casters with limited capacity by a vertical-bending caster with a sufficient capacity of 2.5 mtpy. Based on the successful experience of the rebuildt of the bow-type-caster in the TKS-Bruckhausen-works to a vertical-bending-caster, it was quite assumable that the oxide cleanliness of the steel is positively influenced by the vertical reck, as shown in, **Figure 10**.

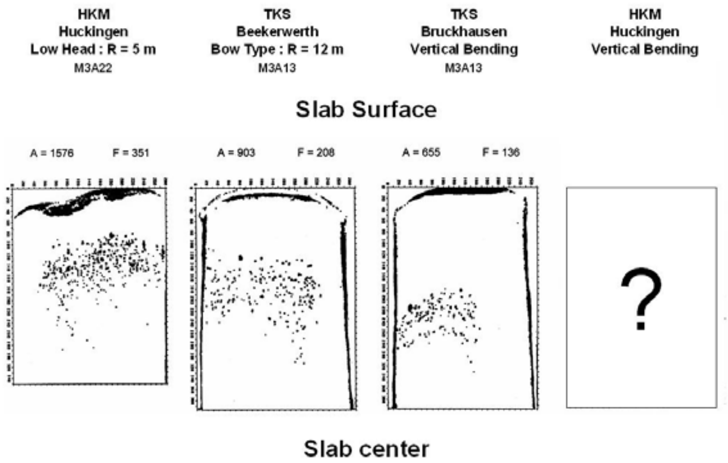

Figure 10 : MIDAS-Results of different Casting Machine Types

The Figure demonstrates, that the cleanliness of a comparable steel grade is improved by increasing the machine radius and the installation of vertical reck. Furthermore it is obvious, that the depth of the inclusion band is moved visible from the sub-surface to the centre of the slab. For these state of the art findings it was decided to install a new vertical-bending-caster in the HKM-steelplant. The caster was designed for a monthly capacity of 250.000 tpm and had to be installed during the full operation of the existing plant. The Main constructional features of the machine are shown in **Figure 11** as a comparison of the existing low-head machine and the new vertical-bending-machine.

For the construction of the caster an amibitious scedule was worked out. From the date of commis-sioning to the SMS-Demag AG on September 10th 1999 the steps basic engineering, detail, engineering, manufacturing, foundation, mounting, cold and hot function test work were conducted within the limitation of the schedule, **Figure 12**. Therefore the first heat was produced in the **new world record** time of 15 month. The start up period of the caster was synchronized, as planned, with the necessary relining of BF B, which is one of two blast furnaces operated by the works. With this meeting of the targets the production losses caused by the necessary shut down of caster CC#1 for the converting of auxiliary supporting systems could be minimised. The start-up of the caster

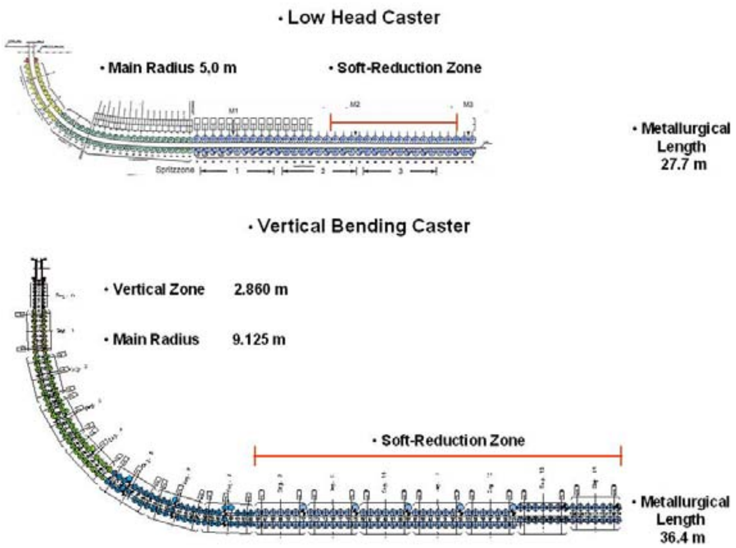

Figure 11 : Comparison of the Constructional Features of the Low-Head and the Vertical-Bending Caster at HKM

was within the targets too, so that 200.000 tpm was reached only three month after commissioning the machine. The reason that it was not possible since yet to demonstrate the ability to produce the desired amount of 250.000 tpm is a general change in the HKM production program. Caused by the the shut down of the Dortmund steel works of TKS it was necessary to switch the production of the TKS-Hohenlimburg middle-width-hot-strip-mill from Dortmund to Duisburg. In the original plan it was manifested, that the requirements of small width slabs for this mill should be operated by slitting slabs from the VB-caster in Huckingen. As far, as it was from the point of target costs and quality demands more useful to cast with a nature slab corner, it was decided to rebuilt the shut down caster CC#1 to a TWIN-casting machine, by seperating the two existing strands with a changeable width TWIN-mould. For that reason nearly 60.000 tpm were switched from CC#3 to CC#1.

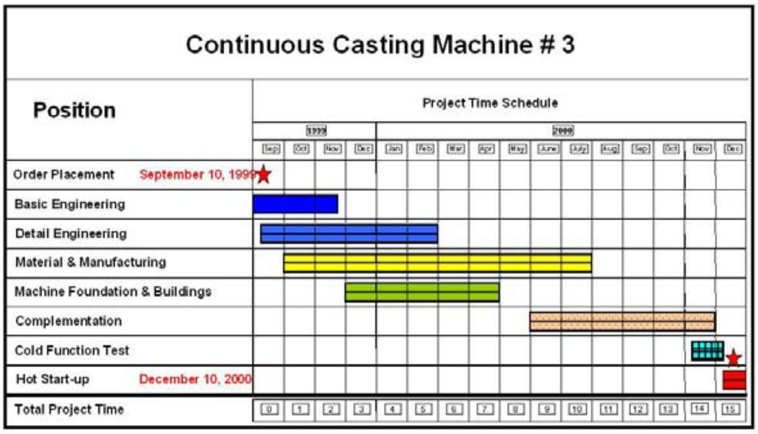

Figure 12 : Installation Scedule of CC#3 at HKM

Quality Results

After the start up of the the VB-machine in cooperation with the TKS-rolling-mills a industrial scale trial was iniciated, in which targets the suitability of the new machine for the production of ULC-/IF-steel grades was investigated. As mentioned above, special selected customer orders were taken and followed from the steel plant to the inspection line of the cold-rolling-mills. With this prodedure it was possible to identify the results of the rolling mills in respect of the corresponding melting and casting conditions. These trials were accompanied by extensive metallografic investigations. The results were within the limits expected. The slabs of the new VB-machine showed an visible improved progress in slab cleanliness. The MIDAS results, as shown in **Figure 13** compared to other constructional layouts show, that :

1. the number of indications could be significantly lowered by 2/3 of the initial level and
2. the depth of the inclusion band is visibly moved into the slab centre.

The statistical evaluation of the examined MIDAS samples so far support these qualitative commitments. The mean-values of both caster-types significantly shows the advantage of the vertical-bending-principle, **Figure 14, left hand**. The VB-type caster lowers the number of defects to a 25-% level of the initial amount at a low-head-caster. The metallurgical treatment is the same in both production conditions. **Figure 14, right hand** shows clearly the doubling of the surface distance of the inclusion band in both casting principles.

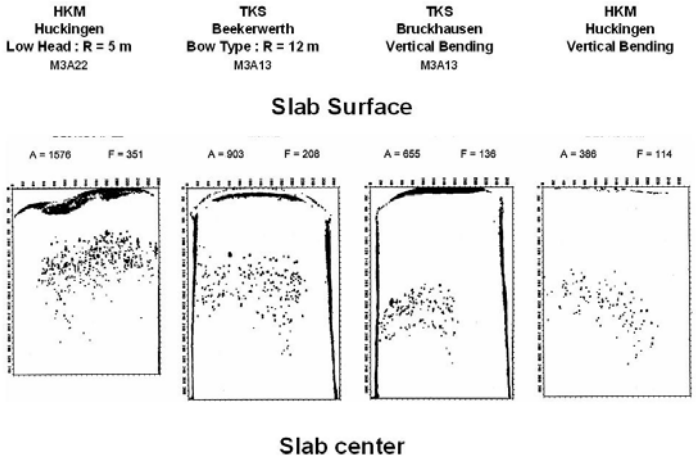

Figure 13 : MIDAS-Results of different Casting Machine Types

As far as the surf board is equivalent to a 9 time deformation of the slab-sample, the depth of the inclusion band increased from 10 to 20 millimeters distance from the slab surface.

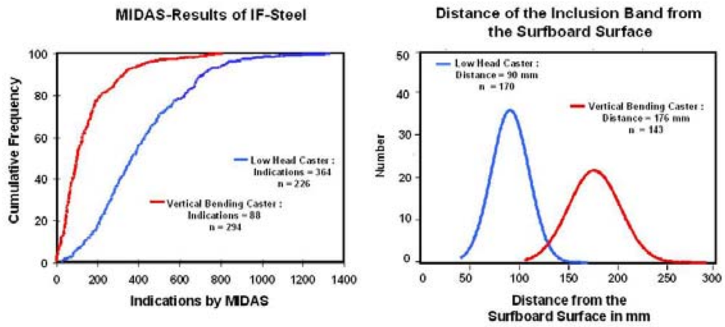

Figure 14 : Statistical evaluation of MIDAS-results at different casting machine types

This result could be adapted 1:1 to the rejection rates of the cold-rolling mills, which improved to a visilble lower level in comparison to the results of the low-head machine used before, **Figure 15**. Since surface-quality-results and internal-crack-introducing with the reported steel grades did not change negatively, TKS gave a general approval to the production of ULC-/IF-steel-grades for highest surface demands.

Sometimes even today surface defects are detected on rolle coils, but in almost all cases the strip can be repaired by cuttting and welding and will be released in the customers specification. It is noticeable that pencil pipe defects/blisters were not detected any more since the introduction of the VB-caster. Our interpretation ois that although casting speed and the correlated argon flow through the stopper rod has increased by almost

50 %, the separation of the bubbles (and non-metallic particles with the bubbles) is visible more effective than in the bow-type or low-head machine. With this knowledge it is possible to avoid clogging in SEN entry, the shaft and on the ports nearly completely by increasing the argon amount in the steel flow. In respect to this effect we changed the regulation system of the argon support system from flow guidance to pressure guidance.

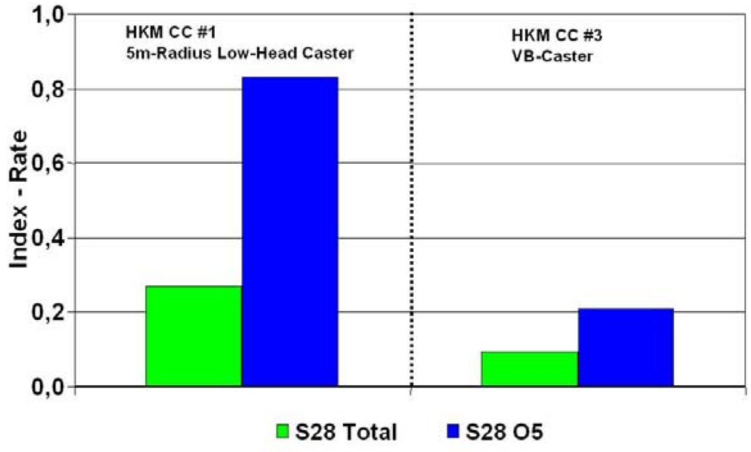

Figure 15 : Development of the rejection rate of cold-rolled-strip

OUTLOOK

Although the introduction of the VB-caster at HKM was successful, a few problems concerning IF-steel-production have to be solved in the future :

Figure 16 shows MIDAS-results of an IF-steel-grade and an sour-gas-service-steel grade (HIC) in comparison. The difference in cleanliness is obvious and the HIC-grade shows only 1/2[f] to 1/3[rd] of the defect level of the IF-grade. This difference was obtained at the low-head machine as well, only on a higher level and has remained although we tried hardly to adapt the sufficient steps of metallurgy from the HIC-route to the IF-route as far as even possible. It seems, that the late strong deoxidation in the ladle and the lack of other reoxidation protection alloys (like C, Si, and Mn) in the case of the IF-grade have an significant influence on cleanliness.

Figure 17 shows another phenomena, which is accompanied with the VB-caster type typically and was not noticed at the low-head machine before. In the centre specimen of the the slab in addition to the inclusion band someone always will find subsurface macro-inclusion, which might be the reason for remaining defects in the coil surface. In some bibliography the positive influence of EMS in the mould on this type of defect is reported. Other specialists are pointing out the influence of the SEN-design in this context.

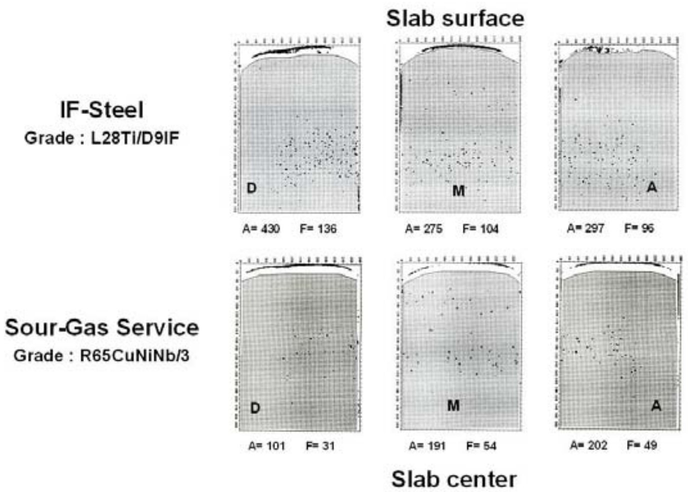

Figure 16 : MIDAS-Results of different Steel Types at a Vertical-Bending Caster in comparison

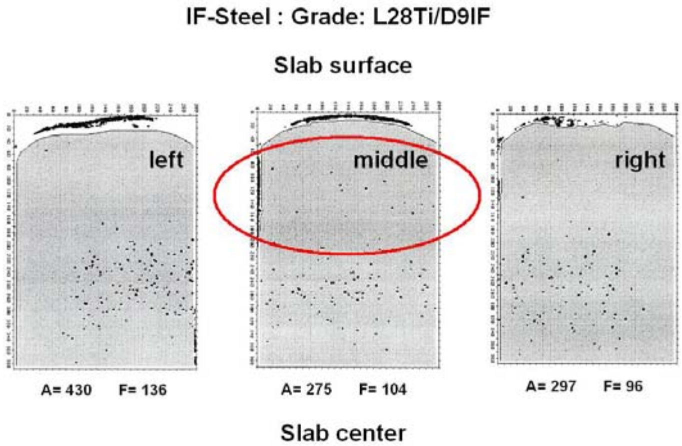

Figure 17 : Subsurface Inclusions at the Slab-Centre

Figure 18 demonstrates another still remaining problem in the IF-VTD-process route. Although cleanliness of the steel is improved noticeably, surface effects, detected by the so calle Ericcson deep drawing test often shows big, not workable, globular macro-inclusions of the calcium-alumina-type. Since more the detection of this inclusion type, than the statistic number of defects in total is an indication for the quality of products for highest surface demands, the qualification of the VTD-based process route is still doubted. This type of inclusion is typical for the intensive slag metallurgy practised in the VTD-process at the HKM steel plant. That these nometallic micro-particles are not separated in the ladle or the tundish on their way to the mould and are coagulation products of the casting turbulence in the mould is one of the possible explanations of their occurance in the slab product, **Figure 18 left hand**. Since these particles are not workable during strip hot and cold rolling, surface defects are more probable than in the case of alumina inclusions. This type, Figure 19 right hand, is crushed and stretched during rolling and remains in the strip body without damaging the surface. Alumina type inclusions are typically for the RH-based process route used in the steel plants of most of our competitors. Consequently we have to improve the metallurgical target of our VTD-process route with the objective to produce alumina-type inclusions. Castability seems controllable since the VB-caster allows to intensify the argon bubbling at the stopper rod. In addition the demands on the production low tensile strength products with lowest contents of Carbon, Silicon, Phosphorus an Chromium are leading inevitable to a change in the classic VTD-process to a route without the participation of the ladle slag. The results of introducing this type of metallurgy in a VTD-based steel-plant will be content of an future presentation.

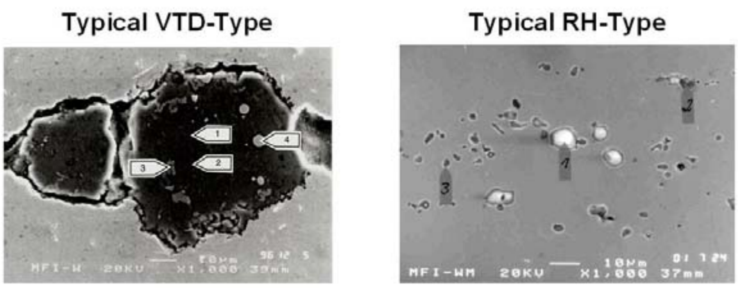

Figure 18 : Inclusion Types of VTD- and RH-based Process Routes

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Figure ..... : Steelplant locations in Germany

	Company	Location	Share Holders	Internet Adress	Year of Con-struction	Capacity	Furnaces Type	Furnaces No.	Furnaces Tap Weight	Production 1999	Employees 1999	Sales 1999
					[Year]	[Mt/y]	[-]	[1]	[t/Heat]	[Mt/y]	[1]	[MDM/y]
BOF-Steelplants	Thyssen Krupp Stahl	DU-Beekerwerth DU-Bruckhausen	TKS	www.thyssen-krupp-stahl.de	1992 1998	5.800 5.200	TBM TBM	3 2	265 380	5.570 4.141	23.025	9.600
	Salzgitter	Salzgitter	Salzgitter AG	www.salzgitter-ag.de	2000	4.200	LD-BS	3	210	4.725	6.935	2.696
	Hüttenwerke Krupp-Mannesmann	DU-Huckingen	TKS/MRW	www.hkm.de	1982	5.400	LD-BS	2	285	4.542	3.244	1.800
	Stahlwerke Bremen	Bremen	ARBED/SIDMAR	www.arbed.lu	2000	3.800	LD-BS	2	305	2.742	4.810	1.757
	Saarstahl	Völklingen	Dillinger Hütte	www.saarstahl.de	1982	2.800	LD	3	180	2.360	4.993	1.577
	ISPAT Stahlwerk Ruhrort	DU-Ruhrort	ISPAT	www.ispat.com	1994	2.400	LD-BS	2	140	1.287	899	621
	EKO Stahl	Eisenhüttenstadt	USINOR/COCKERILL	www.eko-stahl.de	1990	2.200	LD-BS	2	235	2.250	2.800	1.490
	Dillinger Hütte	Dillingen	Saarstahl AG	www.dillinger.de	2001	2.000	LD-BS	2	185	1.784	5.111	1.839
	NMH Neue Maxhütte Stahlwerk	Sulzbach-Rosenberg			1977	480	K-OBM	2	65	394	850	
EAF-Steelplants	Badische Stahlwerke	Kehl	BSE	www.BSW-kehl.de	1991	1.550	ELO/DC	2	80	1.550		
	ISPAT Hamburger Stahlwerke	Hamburg	ISPAT	www.ispat.com	2001	1.000	ELO/DC	1	133	1.000	630	501
	Saarschmiede	Völklingen	Dillinger Hütte	www.saarstahl.de	1990	1.000	ELO/DC	1	125	in Numbers of BOF included		
	Stahlwerk Thüringen	Unterwellenborn	ARBED	www.stahlwerk-thueringen.de	1995	1.000	ELO/AC	1	120	905	645	
	B.E.S. Brandenburger E-Stahlwerke	Brandenburg	RIVA ACCIAIO	www.rivagroup.com	1994	900	ELO/DC	2	150	900	751	
	H.E.S. Henningsdorfer E-Stahlwerke	Henningsdorf	RIVA ACCIAIO	www.rivagroup.com	1994	900	ELO/DC	2	70	900	634	
	Lech-Stahlwerke	Herbertshofen	Max Aicher	www.lech-stahlwerke.de	1998	800	ELO/DC	2	70	933	738	
	Salzgitter	Peine	Salzgitter AG	www.salzgitter-ag.de	1997	750	ELO/AC	1	100	in Numbers of BOF included		
	Krupp Edelstahlprofile	Siegen	TKS	www.edelstahlprofil.de	1992	720	ELO/DC	1	140	300	1.310	434
	Georgsmarienhütte	Osnabrück	GMH	www.georgmarienhuette.de	1994	600	ELO/AC	1	127	574	1.250	417
	Benteler	Lingen	Benteler AG	www.benteler.de	1998	550	ELO/DC	1	85	439	15.746	4.888
	Edelstahl Witten-Krefeld	Witten	TKS	www.edelstahl-witten-krefeld.de	1981	550	ELO/DC	1	130	408	2.370	850
	ESF Elbe-Stahlwerk Feralpi	Riesa	Gruppe FERALPI	www.feralpi.it	1994	500	ELO/DC	1	70	500		
	Edelstahlwerke Buderus	Wetzlar	Buderus AG	www.buderus.de	1985	400	ELO/DC	1	100	386	1.395	546
	BGH Edelstahl	Freithal/Siegen	Boschgotthardshütte	www.bgh.de	2001	300	ELO/DC	2	45/27	300	650	
	Stahlwerk Bous	Bous/Saar	GMH	www.stahlwerk-bous.de	1994	300	ELO/DC	1	70	300		
	Moselstahlwerk	Trier			1984	270	ELO/DC	1	45	270		
	Gröditzer Stahlwerke	Gröditz	GMH	www.stahl-groeditz.de	1992	100	ELO/DC	1	35	100		
RSH	Krupp Thyssen Nirosta	Bochum/Krefeld	TKS	www.nirosta.de	1996	790	ELO/UHP AOD/KCB-S	2 2	150/80 80/80	1.222	4.000	

Table ..... : Steelplant locations in Germany

Slabs for Plates	
Line Pipe (including HIC)	Micro-alloyed (HSLA)
Shipbuilding	Boiler Steels

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

Slabs for hot and cold rolled Strip	
Hot rolled Coils and Sheet	Cold Rolled Coils and Sheet
Pickled and Oiled Coils	Tinplate
Galvanized and Galvanealed	Dual Phase and Trip Steels

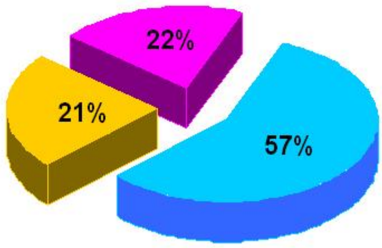

Figure ….. : Quality Structure of the HKM products

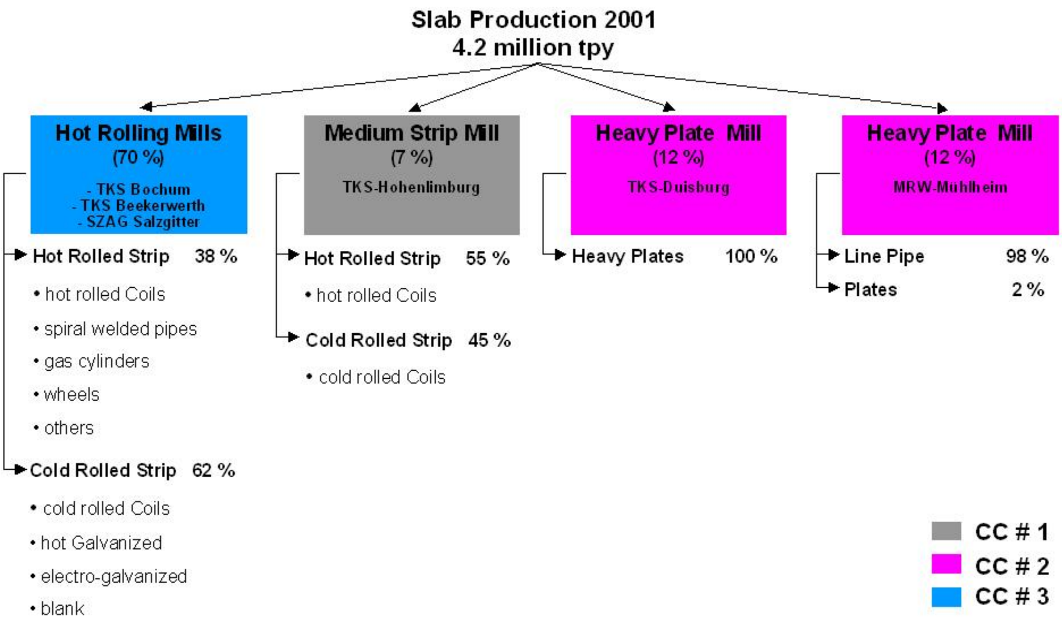

Figure ….. : Customer structure of HKM

CC#3 : Basic Construction Data

Ladle Capacity	280 to
No. of Strands	2
Slab Thickness	260 mm
Slab Width	850 mm - 2100 mm
Slab Length	5.500 mm - 10.000mm
Production Capacity	250.000 to/m - 3.000.000 to/y
Machine Type	Vertical-Bending
Vertical Part Length	2.86 m
Tundish Capacity	65 to
Mold Length	900 mm
Main Radius	9.125 m
Metall. Machine Length	36.4 m
Secondary Cooling System	Air-Mist-Cooling

Product	Chemistry
ULC/IF	= 80 ppm C
LC	< 900 ppm C
Peritectic Grades	800 - 1300ppm C
Micro-Alloyed Grades	V, Nb, Mo, Ti-leg.
Welded Pipes	400 - 800 ppm C
Structural Steel	St 37 - St 52
Carbon Steel	> 2000 ppm C

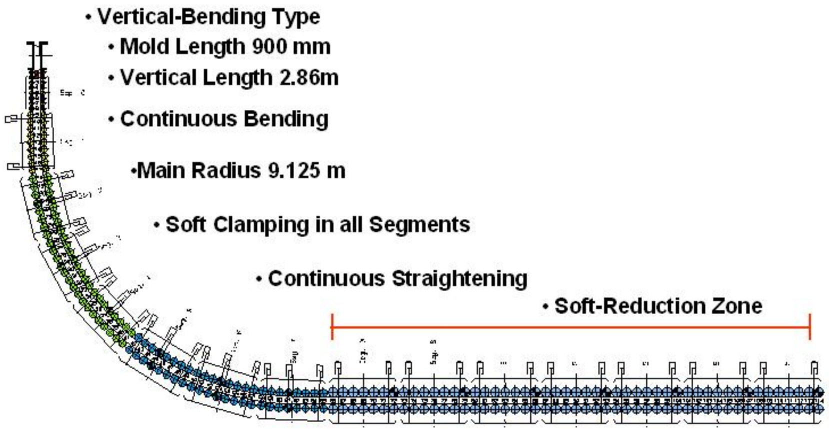

Figure ..... : Constructional Features of VB Caster CC#3