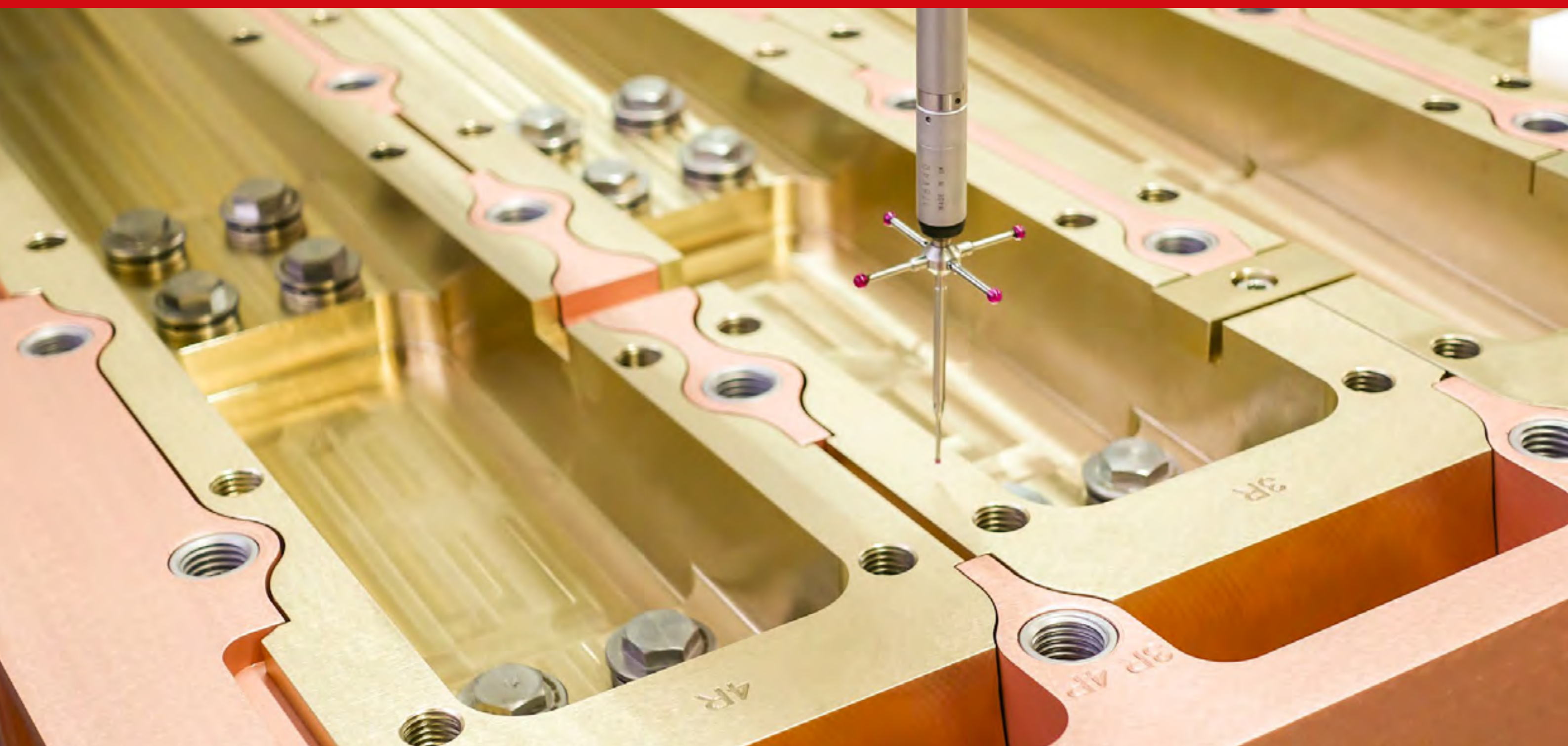
ENGINEERING
COPPER
SOLUTIONS

AMT®

ADVANCED
MOULD
TECHNOLOGY

KME Special Products GmbH & Co. KG
SPECIAL DIVISION
[GB]



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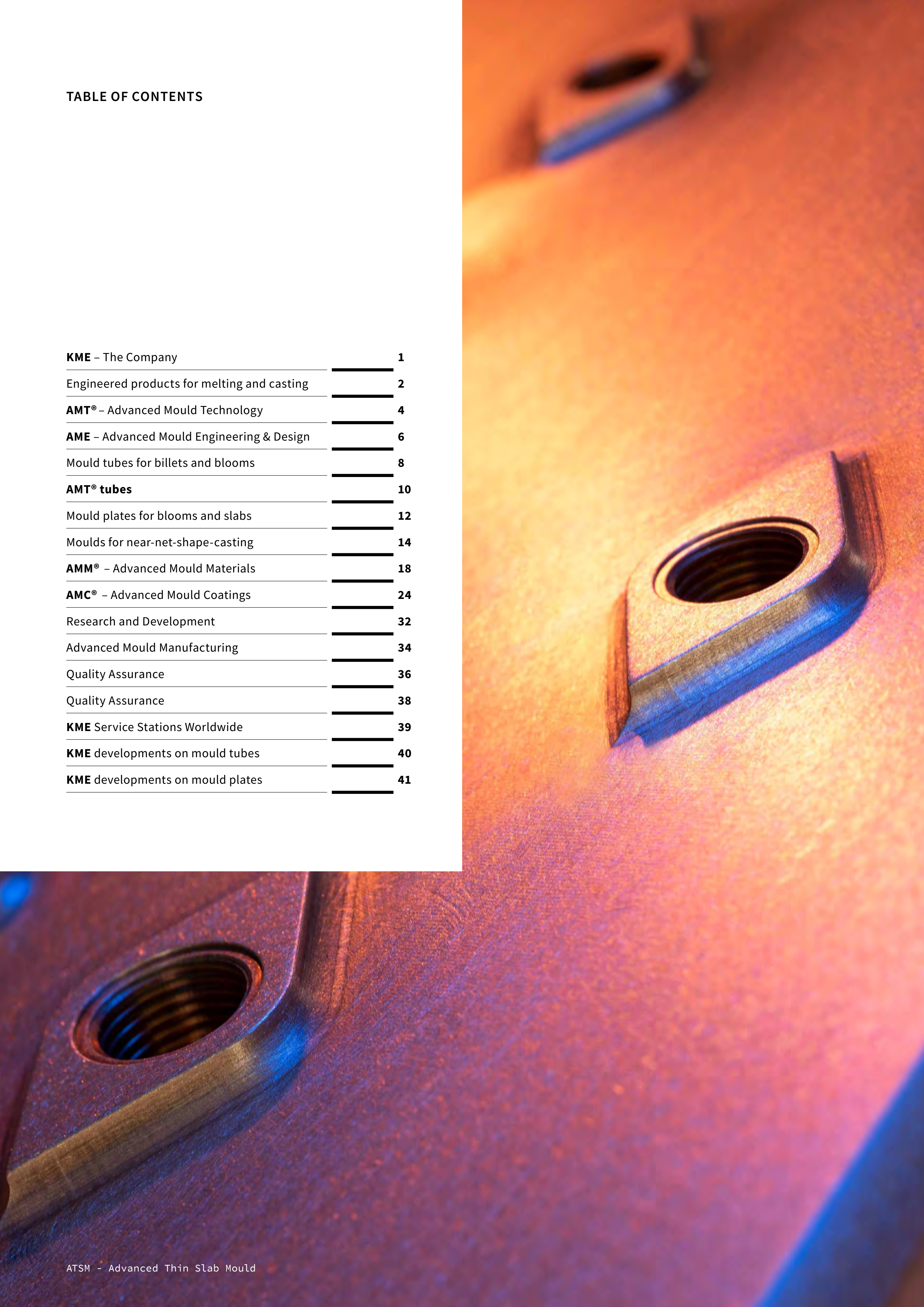


THE COMPANY

KME is one of the world's largest manufacturer of copper and copper alloy products. **KME** manufactures a wide range of semi-finished, finished and special products at locations across Europe, North America and Asia.

KME's corporate goal is to develop and manufacture products that meet customer demands, finding solutions for their specific applications, and providing services as a long-term partner. **KME**'s strategy for accomplishing this goal is based on a highly skilled and experienced workforce. **KME** has the ability to invent and develop new materials and innovative production processes via ongoing advancement and training of our employees and the continual improvement of its engineering capabilities.

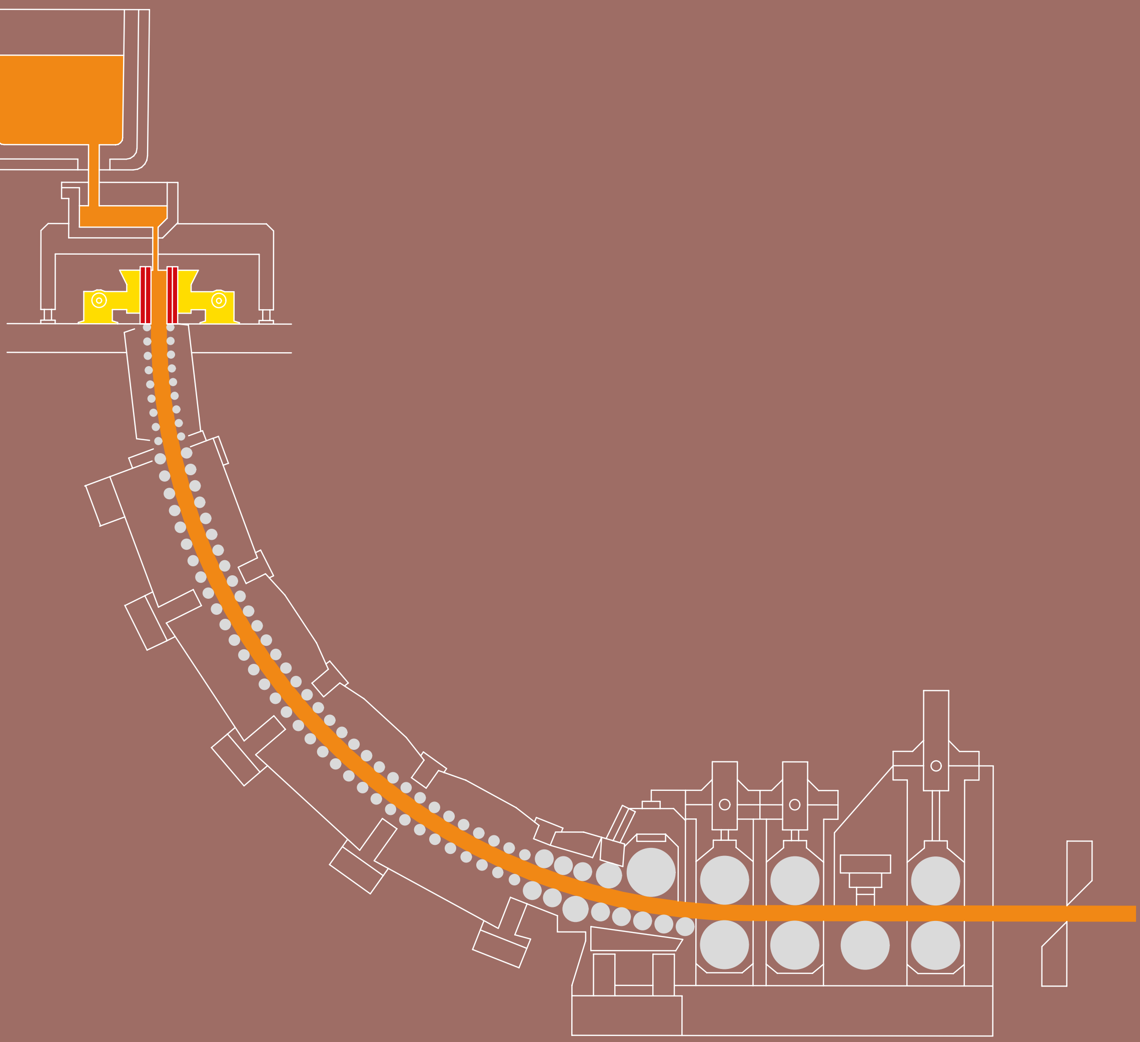
ENGINEERED PRODUCTS FOR MELTING AND CASTING

THE CONTINUOUS CASTING OF STEEL HAS SEEN MAJOR TECHNOLOGICAL IMPROVEMENTS OVER THE PAST DECADES. THIS HAS LED TO CONSIDERABLE INCREASE IN PRODUCTIVITY AND PRODUCT QUALITY NECESSARY TO ENSURE SURVIVAL IN TODAY'S HIGHLY COMPETITIVE ENVIRONMENT. THE ENGINEERED PRODUCTS DIVISION OF KME HAS BEEN INSTRUMENTAL IN ACHIEVING MANY OF THESE PROCESS IMPROVEMENTS.

The advances in casting technology were made possible by the development of high-performance moulds made of copper alloys. KME was involved in these activities right from the very beginning and has continued to set milestones in the development and production of copper moulds for the continuous casting and re-melting of steel and non-ferrous alloys.

The Engineered Products Division was formed as part of a strategic reorganisation, with the aim of providing a flexible solution to market demands and improving the customer orientation of our business. Our customers are manufacturers of steel and non-ferrous metals, casting machine builders and maintenance companies throughout the world.

The division not only serves our customers as a general contractor for the production of mould assemblies, but also as a partner in solving the many technological challanges in the field of continuous casting.



AMT® – ADVANCED MOULD TECHNOLOGY

The performance requirements that have to be met by moulds and mould materials depend on the specific application and the levels of stress involved. These stress levels are mainly predetermined by the machine and casting parameters, which means that many different cast shapes are needed, depending on the type and construction of the mould. When designing a new mould, the correct profile must be chosen in order to achieve high product quality, optimal casting speeds, smooth casting operations and long service life of the moulds.

A good example of this are the requirements placed on modern mould materials for near-net-shape-casting processes which have been developed in recent years. Here, very high casting speeds are achieved and a much higher proportion of the liquid metal must solidify in order to form a sufficiently

stable strand shell. The resulting extreme temperatures demand moulds with higher strength levels. At the same time, a high alternating thermal stress can occur, for example on casting rolls. This wide variety of requirements placed on moulds has to be met by highly developed materials and system expertise.

In order to be able to offer our customers future-oriented solutions for the wide variety of different casting technologies and taking into account the constantly changing requirements on moulds and mould materials, **KME** is conducting research in the following fields of mould technology:

- Mould engineering
- Mould materials
- Mould manufacturing
- Mould coatings

Unlike all other manufacturers, **KME** has all the key technologies for the production of high-performance continuous casting moulds under one roof. This unique combination of expertise, numerical simulation, calculation methods and long-standing experience in the field makes us a highly qualified partner in all mould related questions that arise.

AME – ADVANCED MOULD ENGINEERING & DESIGN

The range of mould materials developed and produced by KME allows appropriate selection of the optimum copper alloy for individual applications. However, in order to achieve high performance, optimum steel quality and a long service life of the moulds, further engineering work is generally necessary – particularly when casting parameters have been changed from the original concept in order to achieve higher casting outputs or produce special types of steel. This is where KME's mould engineering service comes into play, supporting its customers in upgrading continuous casting moulds and optimising system parameters and mould constructions.

Using FEA and CFD to calculate the mould stresses based on 3D CAD modelling allows accurate simulation of the mechanical and thermal stress factors involved in each case. Mould dimensioning, tapering and the specification of cooling conditions are based on the results of these calculations. KME can provide detailed support on the design of new moulds. On request, KME will also do the entire detailed engineering based on the machine builders' design drawings.

DIMENSIONING

When designing a mould for slab, bloom or billet, each case must be considered individually. The main variables that play a role are the construction of the casting machine, the steel grades to be cast, the desired casting speed and the cooling conditions.

MOULD TAPER

The taper is one of the most important parts of the mould design, especially in case of non-adjustable moulds. When specifying the mould taper the steel grade and the casting parameters are the main factors that must be taken into account.

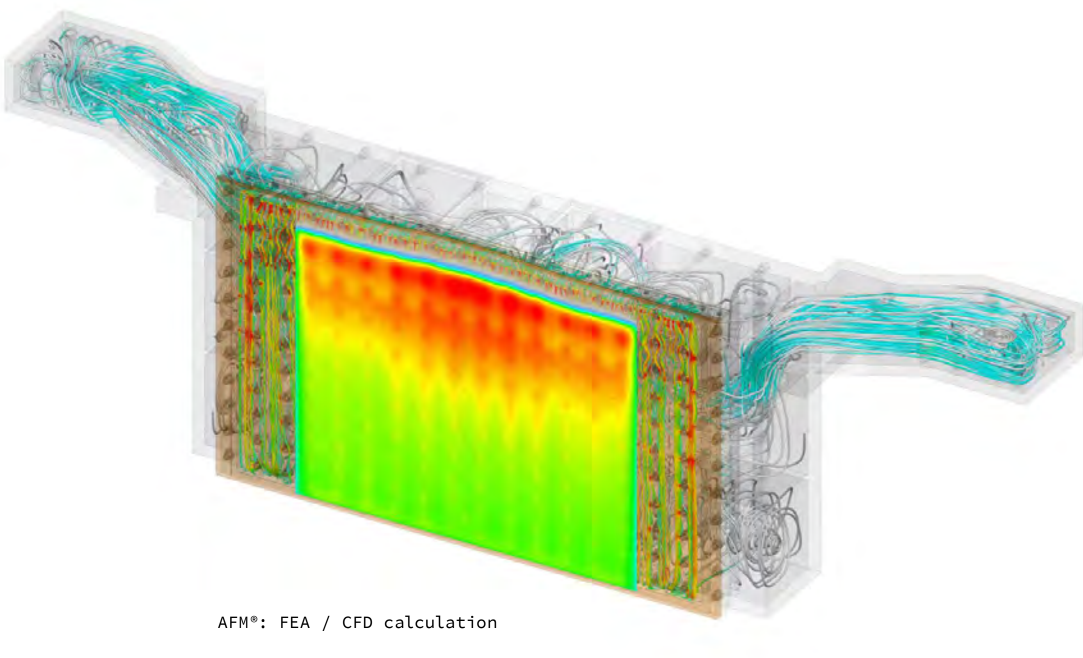
From a theoretical approach, the optimal taper of a mould can only be defined for one steel grade (due to its specific shrinkage behavior) and for one specifically defined casting condition, i.e. superheat of the liquid steel, casting speed, etc.

This means, a taper can always only be a compromise that has to fit for a wider range of casting conditions. Because tailor-made parabolic tapers fulfill this task better, they are nowadays the dominating design, while tubes with linear, double or quadruple tapers are getting less in usage.

COOLING CONDITIONS

Another important factor for designing a mould is the adjustment of cooling conditions and casting parameters in order to ensure good system productivity and product quality.

For this purpose, KME performs CFD (Computational Fluid Dynamics) calculations of the water flow between cold face of the mould and the water box. In combination with the thermal load calculation of the hot-face, this will give a detailed analysis of the thermal and mechanical stresses on the mould during the casting process and will support the optimisation of the design.



AFM®: FEA / CFD calculation

ADVANCED SMART MOULD TECHNOLOGY FOR IMPROVED PERFORMANCE

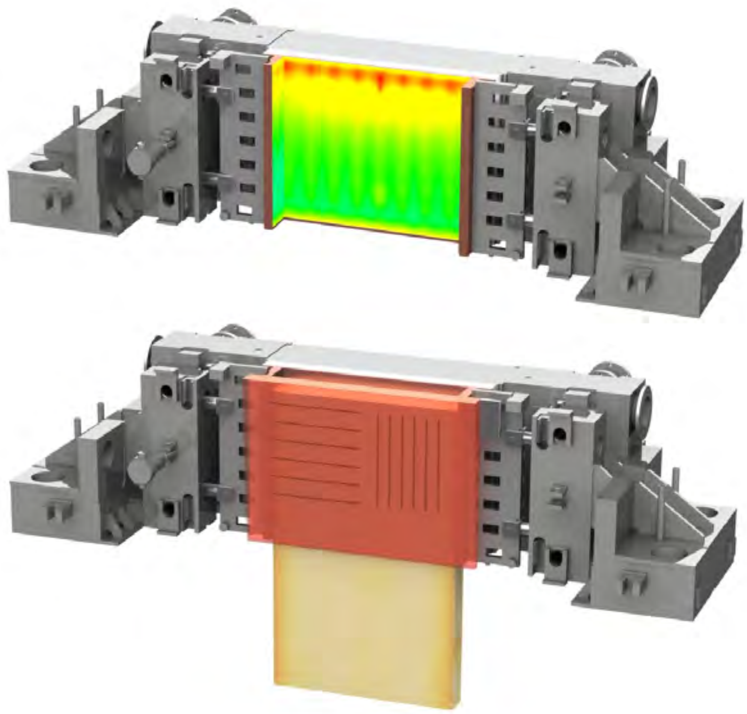
In recent years, significant progress has been made in the development of high tech and automated steel production processes. KME is supporting this effort with the development of our 'Advanced Smart Mould Technology'. This new technology allows for the digitalisation of key mould operating parameters that can then be optimised for improved continuous casting results.

MOULD TEMPERATURE MONITORING

Monitoring the temperatures seen by the copper mould during casting is critical for process control and to understand the dynamic solidification processes during casting. Therefore, robust temperature measurement techniques are a basic requirement for the digitalisation process. KME offers two technologies for temperature measurement and thermal monitoring:

- The application of thermocouples in different designs and arrangements, depending on the type of casting mould.
- The application of fibre optic measuring systems with Bragg elements that offer a substantial improvement in resolution and quality of the temperature information.

KME has the technical know-how as well as experience to select and design these systems. Furthermore, we also have the capability to handle the installation including the very difficult deep-hole drilling (up to 2500 mm depth and 1.2 mm diameter) in both mould plates and mould tubes. Thus, we can offer a complete packaged solution for either of these systems.



Vertical and horizontal temperature monitoring

ADVANCED MOULD ORGANIZER

QR MOULD IDENTIFICATION

KME has developed a new QR-code based system that provides mould identification and tracking. This technology is able to simplify the often-difficult task of determining the specific mould being used in the casting operation and/or maintenance shop. In the future, the QR-code will be linked to various other informations, such as mould geometry, and other product data.

MOULD SENSOR

A further development to broaden the KME Advanced Smart Mould Technology is the integration of a special mould sensor that has the ability to communicate data via a 'Bluetooth' interface. This will enable easy access to key operating data such as the mould's time in service, the remaining rework potential, and other information. By using a companion software tool, data from the chip can be evaluated and archived for later analysis.

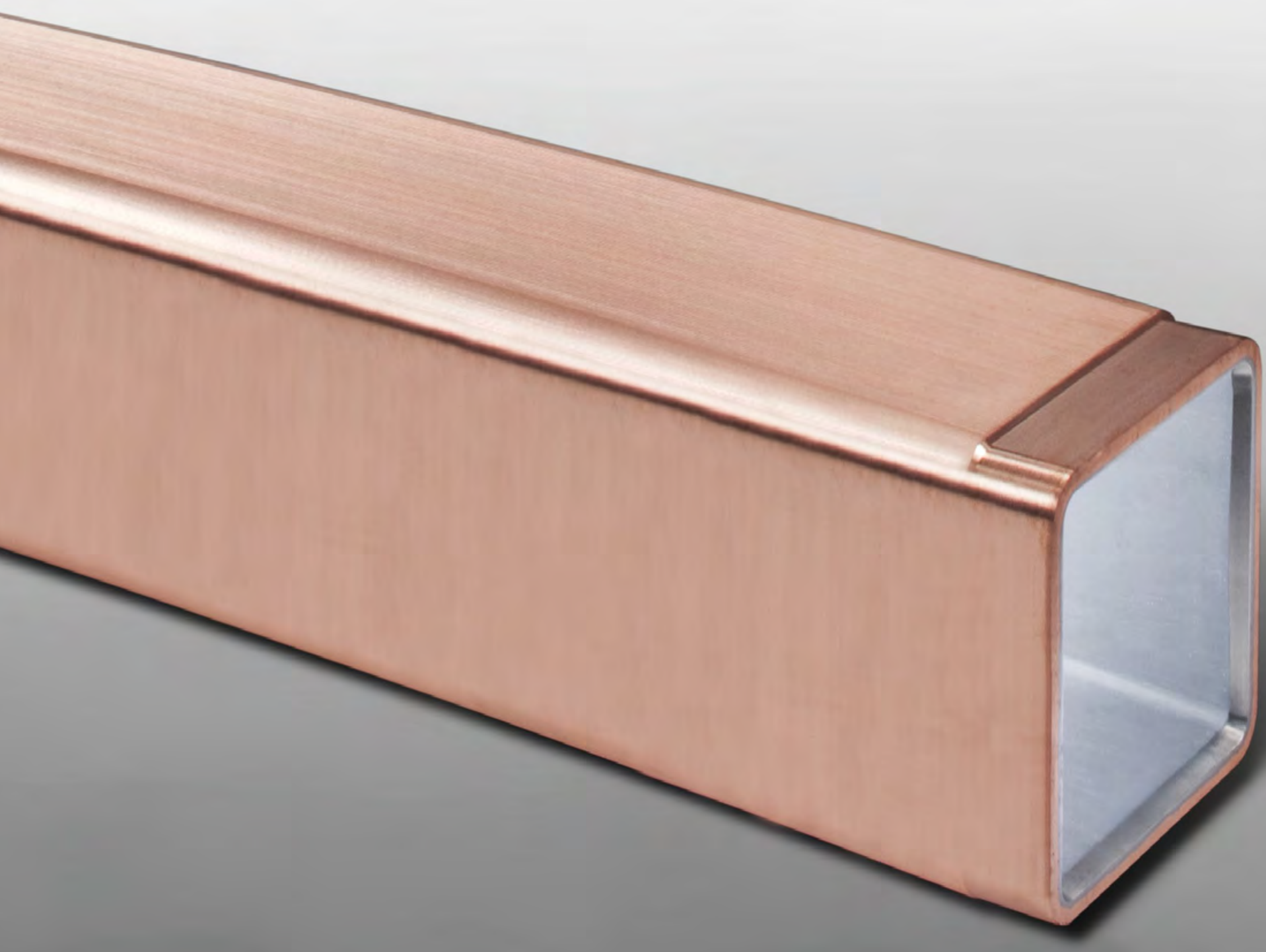
QR Mould Identification

MOULD TUBES FOR BILLETS AND BLOOMS

KME DEVELOPS AND SUPPLIES THE WHOLE RANGE OF MOULD TUBE GEOMETRIES AND DIMENSIONS IN USE TODAY, FROM SMALL RECTANGULAR TUBES RIGHT THROUGH TO LARGE-FORMAT ROUND MOULD TUBES. OUR CUSTOMERS CAN SELECT FROM VARIOUS TAPERS AND SPECIAL INTERNAL GEOMETRIES, SUCH AS AMT®, TEXTURED OR WAVE® SOLUTIONS.

KME MANUFACTURING RANGE FOR MOULD TUBES

Materials	Cu-GS, CuAg-GS ELBRODUR® G, ELBRODUR® GR
Design	– Square, rectangular, polygonal, round, beam-blank – Straight or curved – Outer contour parallel – Internal geometries: parallel, tapered, part-tapered, multi-tapered or parabolic – CONVEX, DIAMOLD® – AMT® – ATM® (KME patent) – WAVE mould tubes (KME patent) – Textured mould tubes
Coatings	– Chrome – Multi-Layer-Coating
Sizes	– no limits
Wall thickness	– no limits – recommended for large sizes max. 30 mm



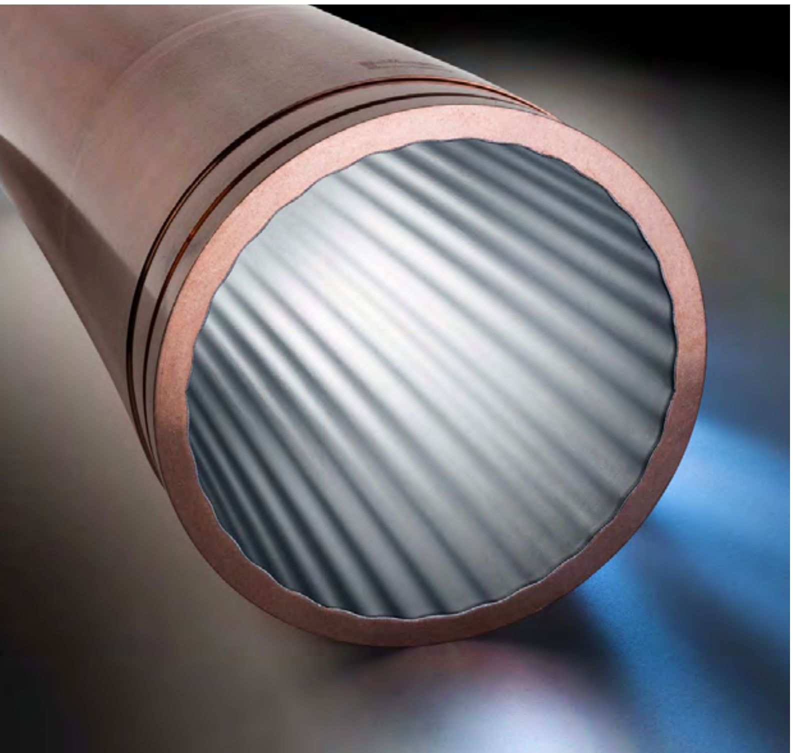
AMT®: Mould tube

WAVE® mould tube

AMT® TUBES

TO OPTIMISE THE CASTING PROCESS AND PRODUCT QUALITY EVEN MORE, **KME** OFFERS INNOVATIVE SOLUTIONS THAT CAN BE COMBINED TO SUIT THE CUSTOMER'S SPECIFIC NEEDS FOR SOLVING METALLURGICAL OR PROCESS-RELATED TECHNICAL PROBLEMS.

Round WAVE® mould tube



WAVE® TUBES

The WAVE® mould has a patented design that superimposes a series of undulations onto the hot-face side of the mould, causing a mirror image to be formed on the billet surface as it begins to solidify. These two surfaces will interlock and the shell will be guided through the length of the mould while restraining any movement from side-to-side.

The mould and shell are thus "coupled" together to such a degree that a more equal heat extraction, and hence uniform shell growth, occurs during this critical time. The result is improved billet shape and internal quality, as well as increased mould life.

This special design is also applicable for round sizes: Round WAVE® tubes.

TEXTURED TUBES

KME has developed a new method for controlling the heat removal in a mould tube. Using a specially developed manufacturing process, a texture can be applied to the casting surface of the mould tubes. This allows the heat transfer to be moderated in specific areas of the mould.

Textured mould tube

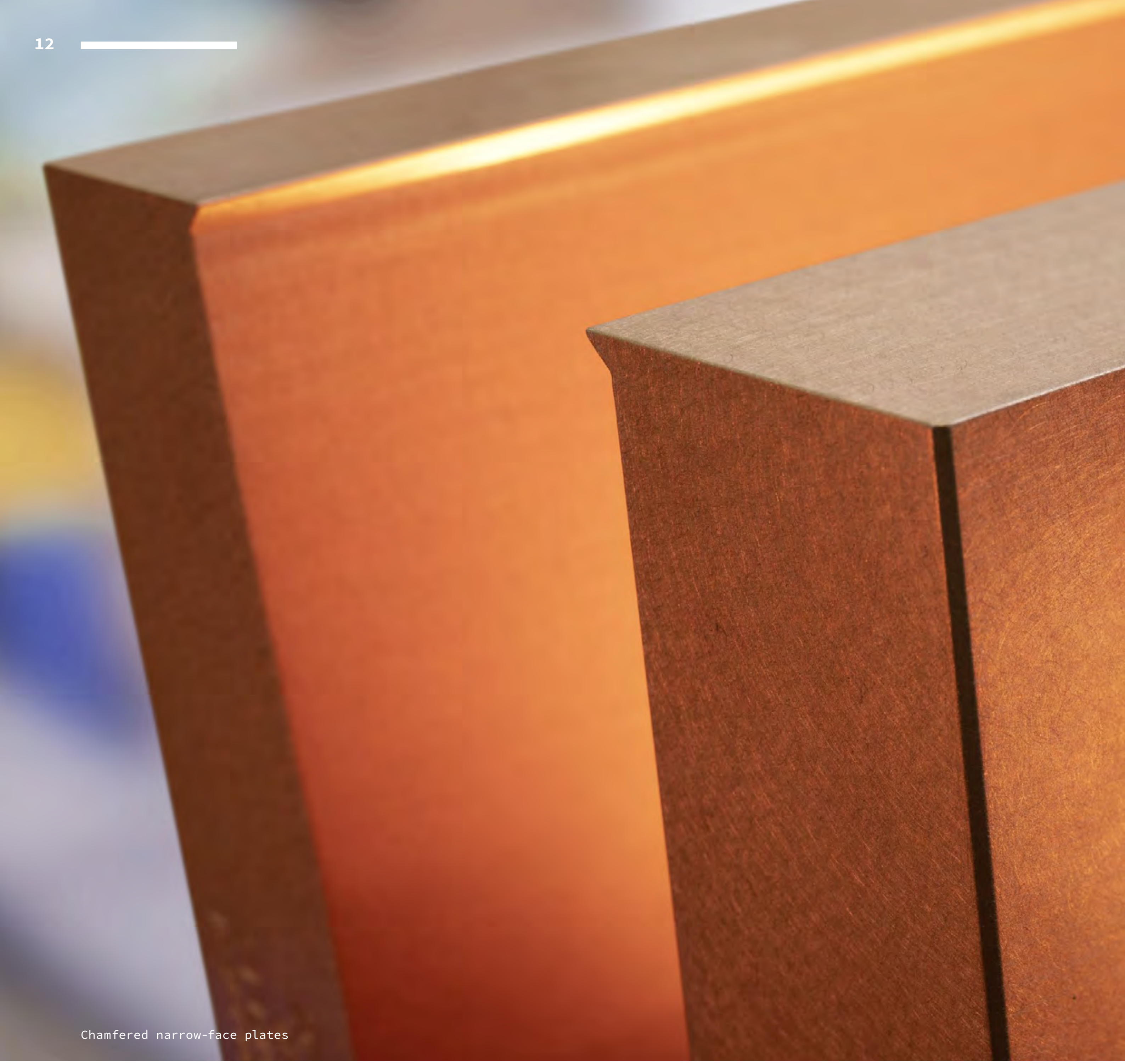
ATM®: Advanced Tube Mould

ATM TUBES

The ATM design is an economical way to replace bloom mould plates by a repairable mould tube design while keeping the existing waterboxes. Corner gap problems are eliminated.

The ATM design optimises the mould cooling over the entire surface area of the mould by using a uniform water gap cooling type, while reducing the internal stress in the copper due to the special low-stress bolting technology.

Furthermore the design offers more stability to the mould wall compared to conventional tube designs and is therefore favourable for large sections.



Chamfered narrow-face plates

KME has developed various technology packages for the continued development of the moulds used in the casting of bloom and slab shapes. Based on a precise analysis of the cooling water flow and the load on the moulds arising from the process, an improvement in the service life can often be achieved through local optimisation of the cooling geometry.

Also completely new designs for cooling improvements were established in recent years, such as optimised-deep-drilled plates, chamfered narrow-faces with special edge cooling and ASM mould plates.

ASM MOULD PLATES

KME engineers have developed ASM (Advanced Slab Mould) technology to optimise the cooling of standard mould plates by converting the slot cooling design into a uniform water gap cooling type.

By using filler- or adapter plates in conjunction with the patented AFM® mounting, it is possible to reduce the working load on the moulds and to improve casting efficiency and strand quality with adjusted cooling water flow especially for curved mould plates. A significant advantage of the ASM technology is that existing moulds can be converted without requiring high investment.

REDUCED HEAT DISSIPATION

For the casting of steel grades that are prone to cracking, **KME** offers materials with reduced thermal conductivity as well as solutions with textured hot-faces for mould plates to achieve a reduced heat transfer in the mould.

KME's strength in technical design together with our available materials and coatings, enables us to develop tailor-made solutions for each customer as required.

MOULD PLATES FOR BLOOMS AND SLABS

THE DESIGN AND MANUFACTURE OF MOULD PLATES FOR BLOOM AND SLAB CASTING MACHINES, WHETHER FURNISHED WITH COOLING SLOTS OR DEEP-HOLE DRILLS, IS A MAJOR PART OF **KME**'S PRODUCT RANGE FOR THESE APPLICATIONS, **KME** DELIVERS A COMPREHENSIVE SELECTION OF MOULD MATERIALS AND COATINGS.

Broad face plate with improved meniscus cooling

MANUFACTURING RANGE FOR MOULD PLATES

Materials	CuAg-GS/NS, ELBRODUR® H, ELBRODUR® G/GP/GP-NS/GR, ELBRODUR® NIB
Plate design	– Cooling slots or cooling drills or water gap cooling type – Casting surfaces straight or machined to casting radius
Coatings	– Nickel – Nickel + chrome – Nickel alloy – Nickel alloy + chrome – Metal-Ceramic
Sizes	– Practically no limits

MOULDS FOR NEAR-NET-SHAPE-CASTING

TUBES, PLATES AND ROLLS

New continuous casting systems must guarantee high productivity, ensure good product quality and drastically reduces the specific energy consumption from raw material to finished product. These goals are being pursued with the development and introduction of near-net-shape-casting processes. **KME** played a decisive role in the development of these technologies by developing materials, optimising geometry and cooling and adapting the coating for the moulds. By engineering new mould concepts such as the Advanced Funnel Mould (AFM®) and the Advanced Beam blank Mould (ABBM), **KME** continues to set milestones in the development of moulds for near-net-shape-casting technology.

MOULDS FOR BEAM-BLANK CASTING

A multi-part plate mould or a mould tube can be chosen for beam-blank casting. Plate constructions give a greater degree of freedom when specifying the mould taper and coating, whereas tubes make it possible to use casting oils. Repair techniques for both types of moulds are available at **KME**.

ABBM – ADVANCED BEAM BLANK MOULD

The **KME** Advanced Beam Blank Mould is an innovative development in mould technology for beam-blanks. The combination of a thin-walled copper plate with a water gap cooling type and a support plate permits the separation of functions in this mould type. For the first time, it is now possible to use thin-walled copper plates for optimised heat dissipation without losing any of the maintenance-friendly qualities of plate construction.

MOULD PLATES FOR THIN SLAB CASTING

The casting of thin slabs is the most common method of near-net-shape technology used today. The mould takes on particular importance for the performance of the system. Due to the changed surface/volume ratio in this method, about 50 % of the slab thickness solidifies in the mould, compared with 10 % in conventional slabs. This means that large amounts of heat have to be removed by the mould and the copper is subject to extreme thermal stresses. **KME**'s development of new materials and the in-house production are decisive advantages that can be utilised here. Today, KME manufactures CSP®, ISP® , ESP®, fTSC® and DUE® mould plates for thin slab casting.

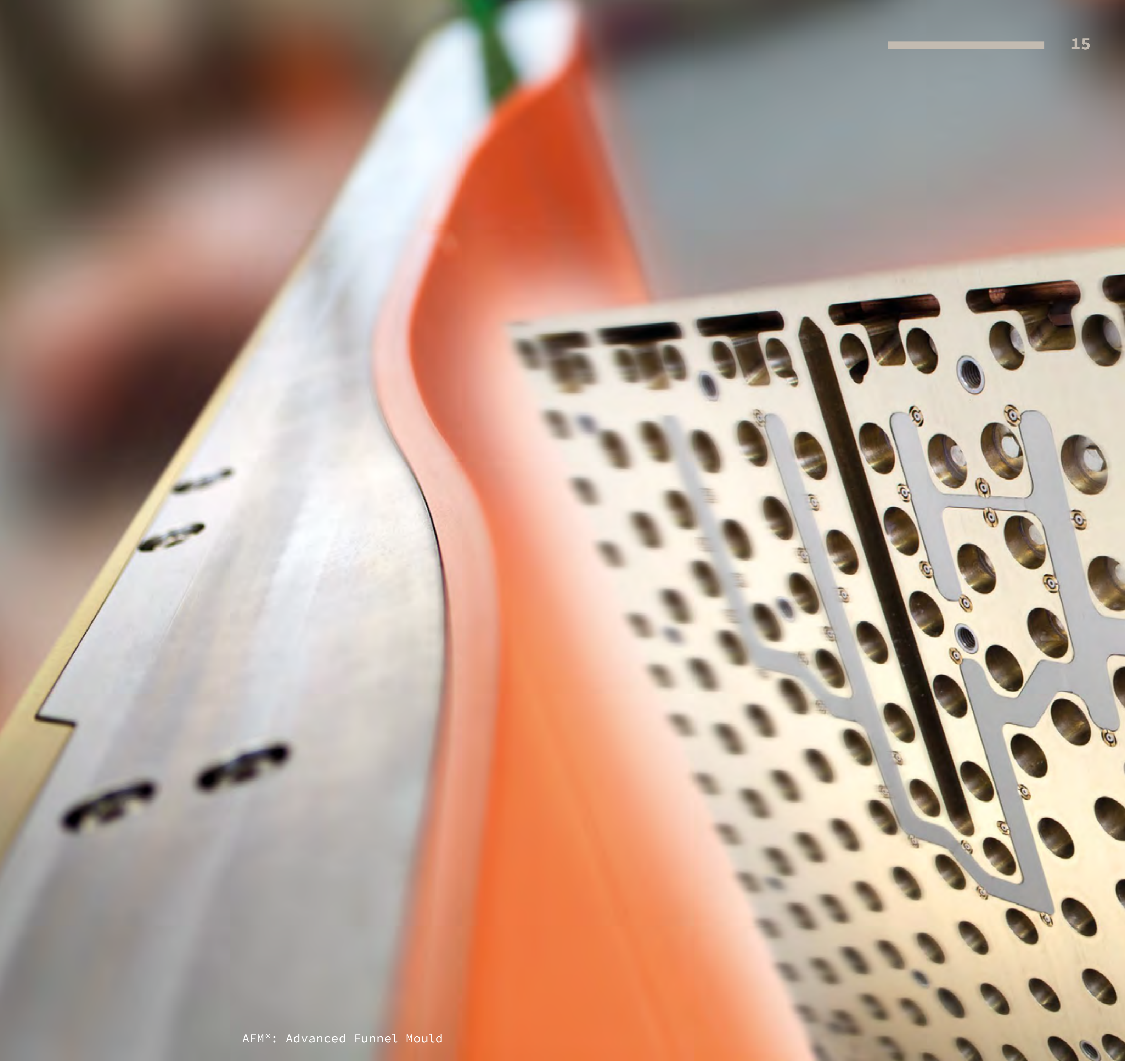
AFM® – ADVANCED FUNNEL MOULD

KME has engineered the innovative Advanced Funnel Mould (AFM®), which consists of a thin-walled copper plate and an adapter plate.

The thin copper plate allows high heat transfer rates, which is a basic requirement for improved casting efficiency. In addition, the thickness of the mould plate is adapted to the specfic heat load in different areas of the mould. Combined with the water gap cooling design this results in homogeneous surface temperatures for uniform melting of the casting flux, and thus improved slab surface quality.

A patented connection to the adapter plate allows a controlled heat expansion of the copper plate during casting, in order to reduce the operating stresses in the copper plates.

The adapter plate makes it possible to fit the mould to an existing water box without additional changes.


AFM®: Advanced Funnel Mould

ATSM – ADVANCED THIN SLAB MOULD

The ATSM Mould is **KME**'s newest design upgrade for thin slab caster. Like the AFM®- and ABBM-mould the ATSM-mould is compatible with existing water boxes. It consists of an improved copper plate design (Patent Applied) with broad cooling fields for a homogenous cooling and an innovative anti-bulging system (Patent Applied) to counteract meniscus bulging.

As additional feature for easy maintenance the ATSM design uses a few swivelling filler plates instead of numerous filler bars as used at the standard designs.

With this feature the ATSM offers maintenance-friendly access to the water-cooled copper surfaces for easy inspection and cleaning.

Copper sleeves for thin strip casting

MANUFACTURING RANGE FOR NEAR-NET-SHAPE MOULDS

TYPE OF MOULD	FORM	MATERIALS	DESIGN	SIZES	COATINGS
Thin slab	Plates	CuAg-NS ELBRODUR® H ELBRODUR® G/GP/GP-NS ELBRODUR® NIB	– With cooling slots or drilled cooling channels – Casting surfaces with special contours for casting thin slabs – Straight or machined in accordance with casting radius CSP®, ISP®, ESP®, fTSC®, DUE®, AFM®, ATSM	Practically no limits	Nickel Nickel alloy Metal-Ceramic Cobalt alloy
Beam-blank	Tubes	CuAg-GS ELBRODUR® G	– External contour parallel – Internal geometries: parallel, part-tapered, multi-tapered, or parabolic, and with special internal contours for casting beam-blanks with additional cooling channels	Up to 450 mm square; Larger sizes upon request	Chrome
	Plates	CuAg-GS/NS ELBRODUR® G/GP/GP-NS	– With cooling slots or drilled cooling channels ABBM	Practically no limits	Nickel Nickel + chrome Nickel alloy + chrome Cobalt alloy + Cr
Thin strip	Casting rolls	ELBRODUR® G/GP ELBRODUR® NIB ELBRODUR® B 95/B 95S	– Cooling system in the shape of slots or drilled channels, depending on overall design	Practically no limits	Upon request

MOULDS FOR THIN STRIP CASTING

As early as 1891, Sir Henry Bessemer drafted the principle of a casting machine in which the molten steel was supposed to solidify directly into steel strips between two casting rolls. Just over a hundred years later, his idea has become reality.

As a result of the unusually high surface/volume fractions that prevail in strip casting, great amounts of heat have to be conducted away by the casting rolls. **KME** can meet the extremely high demands on materials and the manufacturing precision required for all the various strip casting machines in use around the world. Customerspecific adaptations of the material characteristics to the cooling conditions and to the load situation are an important key to the successful development of the technology.

Since **KME** controls all stages along the entire process chain, it is possible for us to deliver specific engineered solutions for each individual customer and hence support start-up and production process.

KME manufactures according to OEM drawing and specification, including steel shafts, if requested for “ready to use” state.

Copper sleeves for thin strip casting

AMM® – Advanced Mould Materials

MATERIAL SCIENCES AND THE DEVELOPMENT OF COPPER ALLOY SYSTEMS HAVE FOR MANY YEARS REPRESENTED AN IMPORTANT AREA FOR KME AS THE LEADING MANUFACTURER OF COPPER PRODUCTS. A MAJOR PART OF **KME**'S EFFORTS IN THESE FIELDS IS DEDICATED TO THE DEVELOPMENT OF COPPER ALLOY SYSTEMS FOR CONTINUOUS CASTING MOULDS. THEREFORE, DEPENDING ON THE APPLICATION AND THE RANGE OF PROPERTIES REQUIRED, THE MOULD MATERIAL CAN BE ADJUSTED USING SPECIALLY TAILORED ALLOYS.

CU-GS
DHP copper was developed as a standard material for mould tubes under normal service conditions at temperatures in the meniscus area of up to about 300 °C. The material displays excellent heat and creep resistance at high temperatures and its workability is good.

CUAG-GS/NS
Copper-silver alloys (CuAg) are used in applications in which higher thermal stresses and wall temperatures occur. CuAg alloys have a higher thermal conductivity, which means that the temperatures in the mould can be kept on lower levels. In addition, they have higher temperature resistance to softening than DHP-Cu.

ELBRODUR® H
ELBRODUR® H is a newly developed advanced material based on approved ELBRODUR® G alloy. This material is designed to bridge the gap between the highly conductive copper silver alloys and the creep resisting, precipitation hardened alloys like ELBRODUR® G. The material was developed for the application with net-shape-casting operations.

ELBRODUR® G
ELBRODUR® G is an age hardenable CuCrZr alloy which has excellent mechanical properties, both at room and higher temperatures. High heat conductivity, a very high softening temperature, high creep resistance and high resistance to alternating thermal stresses are exceptional properties that set this alloy apart from the copper alloys previously presented. The good combination of properties achieved in this material is made possible by the use of alloying elements and a special thermo-mechanical treatment (see Fig. 4).

ELBRODUR® GP
ELBRODUR® GP is an advanced material developed on the basis of the approved ELBRODUR® G. It has been possible to further improve this material’s properties through careful tuning of the chemistry and process control during manufacture.

ELBRODUR® GP-NS
ELBRODUR® GP-NS is an advanced material developed on the basis of the approved ELBRODUR® GP, but with a higher strength level. It was developed for near-net-shape-casting applications, such as beam-blank and thin slab moulds.

ELBRODUR® GR

The ELBRODUR® GR alloy is based on the material ELBRODUR® G and has been specially developed for moulds that work with electromagnetic stirring coils. The precisely controlled reduction of the electrical conductivity of this alloy, while maintaining the mechanical properties, ensures that the electromagnetic losses in the mould wall are kept to a minimum and no additional output is required from the coils. As a result of these special properties, there is no need to reduce the mould wall thickness. At the same time, sufficient strength of the mould is achieved.

ELBRODUR® B 95

This is a high-alloyed age hardenable CuCoBe based material which has medium conductivity, along with very good elevated temperature strength. This material is suitable for very special applications requiring reduced cooling, such as casting rolls.

ELBRODUR® NIB

This is a material based on CuNiBe. It has been developed specifically for use in moulds for near-net-shape-casting and other moulds that need to withstand particularly high stresses.

Its outstanding characteristics are high strength along with medium conductivity. Importantly, it has a special resistance to cracking when exposed to thermal stresses caused by large temperature fluctuations in the mould wall.

Different mould tube designs made of different copper alloys.

PERFORMANCE REQUIREMENTS FOR COPPER MATERIALS

MOULD FUNCTION, TYPE OF EXPOSURE	PROPERTIES REQUIRED
Handling; assembly/disassembly	High basic hardness and strength
Transfer of superheat and heat loss of solidification	High thermal conductivity
High wall temperatures	Retention of high strength at the relevant operating temperatures
Mechanical stresses at high temperatures	High resistance to creep
Heavily fluctuating thermal stresses (fluctuating meniscus level)	High resistance to fatigue and cracking
Strand/mould friction	High hardness and resistance to wear
Screening in electromagnetic stirring systems	Reduced electrical conductivity

Fig. 1
Recrystallisation/softening behaviour of KME mould materials versus standard copper (ETP Cu)

- E-Cu (ETP Cu)
- Cu-GS
- CuAg-GS/NS
- ELBRODUR® H
- ELBRODUR® G/GP/GP-NS
- ELBRODUR® B 95/NIB

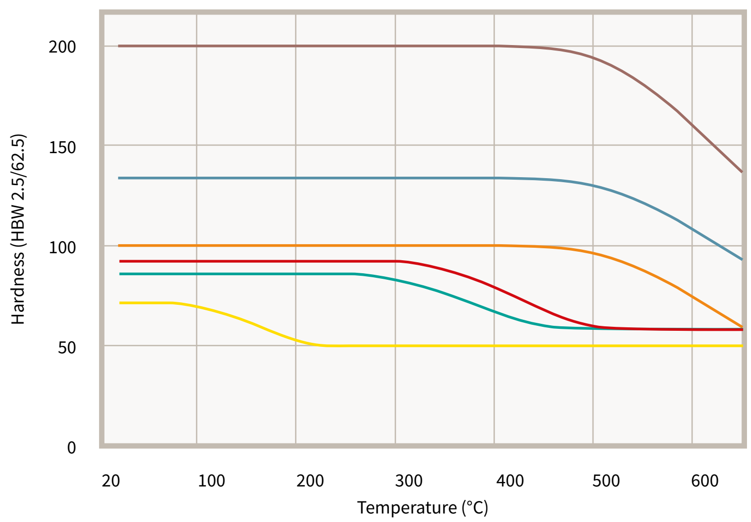


Fig. 2
Creep characteristics of mould materials
(temperature 200 °C/392 °F, stress 150 MPa)

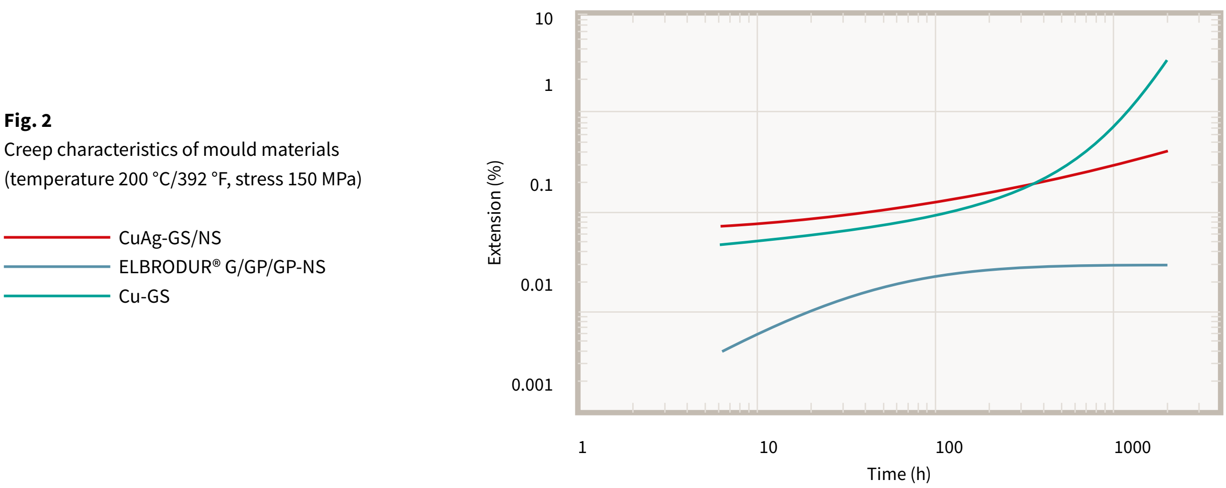


Fig. 3
Hardness and electrical conductivity of KME mould materials

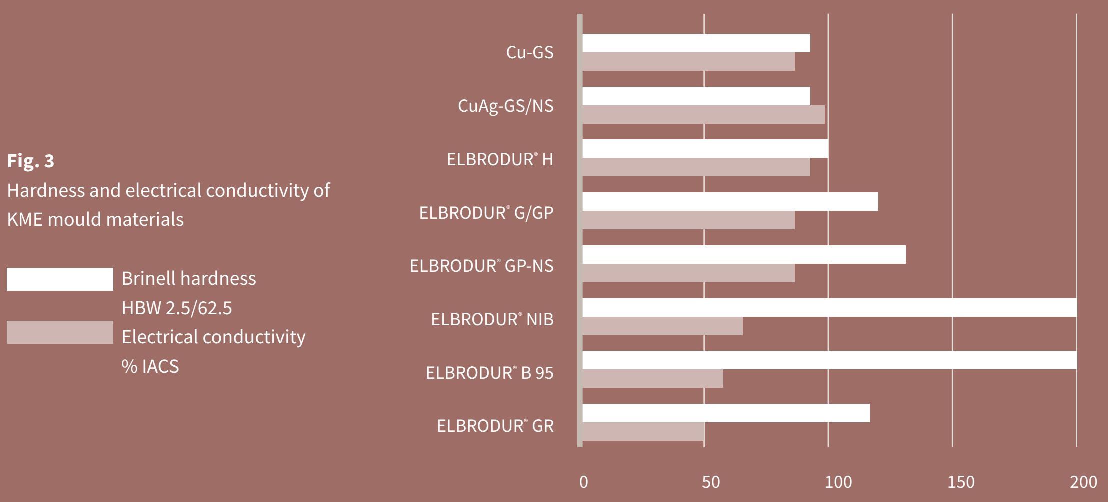
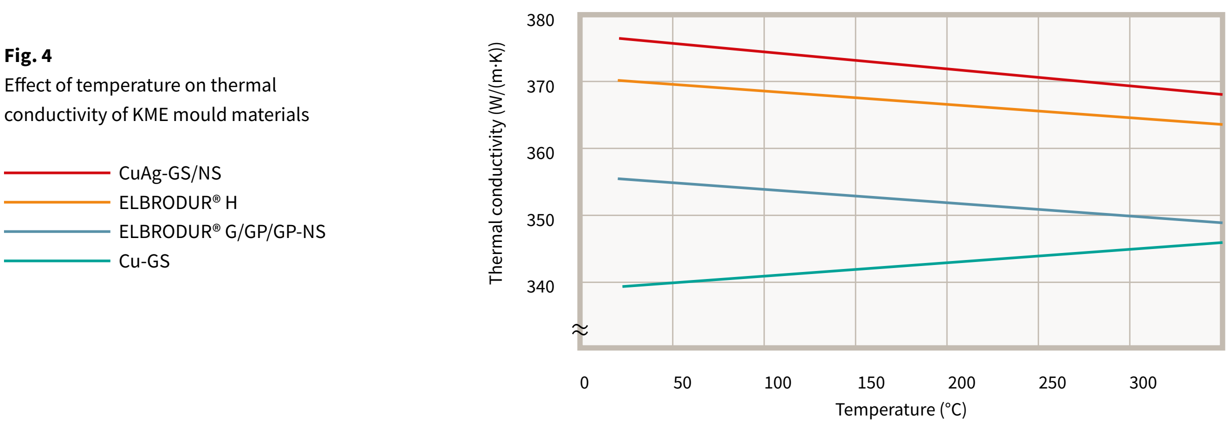


Fig. 4
Effect of temperature on thermal conductivity of KME mould materials



WAVE® mould tube with flat top design

AMM® – Advanced Mould Materials

TABLE 1: KME MATERIALS FOR MOULD TUBES

MATERIAL PROPERTIES*	TEMPERATURE		UNITS	Cu-GS	CuAg-GS	ELBRODUR® G	ELBRODUR® GR 50
Chemical composition (without copper)			%	0.03 P	0.09 Ag	0.65 Cr	0.65 Cr
					0.006 P	0.1 Zr	0.1 Zr
							1.5 others
Physical Properties	°C	°F					
Electrical conductivity	20	68	S·m/mm²	48	55	50	29
			% IACS	83	95	86	50
Thermal conductivity	20	68	W/(m·K)	340	377	355	205
Coefficient of thermal expansion	20–300	68–572	10^{-6}/K	17.7	17.7	18	18
Recrystallisation temperature	-	-	°C	350	370	(800)	(800)
Softening temperature**	-	-	°C			580	580
Modulus of elasticity	20	68	10^3 MPa	120	125	128	128
Mechanical Properties	°C	°F					
0.2 % Proof stress $R_{p\,0.2}$	20	68	MPa	290	290	360	350
	200	392		260	260	335	330
	350	662		(215)	(215)	295	300
	500	932		(20)	(20)	(185)	(210)
Tensile strength R_m	20	68	MPa	310	310	430	420
	200	392		265	265	400	390
	350	662		(220)	(220)	340	330
	500	932		(80)	(80)	(210)	(230)
Elongation A_5	20	68	%	16	16	19	20
	200	392		14	14	18	18
	350	662		(12)	(12)	19	16
	500	932		(70)	(70)	(20)	(17)
Hardness HBW 2.5/62.5	20	68		95	95	130	130

Units: 1 MPa = 1 N/mm² = 0.102 kgf/mm² = 0.145 ksi; 1 W/(m·K) = 2.388 · 10^3 cal/(cm·s·°C)

* Values may change with varying thermal and mechanical treatment due to geometry and manufacturing procedure

** Measurement according to DIN ISO 5182

( ) Values may change due to restricted reproducibility of measurement

Copper mould plate

TABLE 2: **KME MATERIALS FOR MOULD PLATES, BLOCK MOULDS AND CASTING ROLLS**

TEMPERATURE		UNITS	CuAg-GS	CuAg-NS	ELBRODUR® H	ELBRODUR® G/GP	ELBRODUR® GP-NS	ELBRODUR® B95	ELBRODUR® B95S	ELBRODUR® NIB	ELBRODUR® GR 50
		%	0.09 Ag	0.1 Ag	0.1 Zr	0.65 Cr	0.65 Cr	1.0 Co	1.4 Co	1.5 Ni	0.65 Cr
			0.006 P	0.004 P	Ag	0.1 Zr	0.1 Zr	0.1 Be	0.3 Be	0.2 Be	0.1 Zr < 1.5 others
°C	°F										
20	68	$S \cdot m/mm^2$	54	57	54	48	49	35	31	40	29
		% IACS	93	98	93	83	84	60	54	69	50
20	68	W/(m·K)	377	385	370	350	350	240	220	290	205
20–300	68–572	$10^{-6}/K$	17.7	17.7	17.7	18	18	18	18	18	18
-	-	°C	370	350	(700)	(800)	(800)	(800)	(800)	(800)	(800)
-	-	°C			530	580	580	590	590	590	580
20	68	10^3 MPa	125	125	125	128	128	128	128	128	128
°C	°F										
20	68	MPa	275	285	270	285/330	370	490	610	510	275
200	392		245	255	240	260/290	330	450	580	500	250
350	662		(200)	(200)	230	230/255	300	430	540	470	220
500	932		(20)	(20)	(190)	(200/220)	(245)	(400)	(450)	(420)	(180)
20	68	MPa	280	290	310	410/420	430	630	720	630	400
200	392		250	250	265	350/365	370	570	670	570	340
350	662		(210)	(210)	240	295/310	325	500	600	510	290
500	932		(80)	(80)	(195)	(230/250)	(255)	(440)	(500)	(430)	(215)
20	68	%	16	17	21	25/22	19	13	10	12	26
200	392		14	15	19	24/20	16	11	7	10	23
350	662		(12)	(12)	17	22/19	16	(5)	(3)	(4)	21
500	932		(70)	(70)	(16)	(22/19)	(16)	(3)	(2)	(3)	(21)
20	68		90	90	100	120/130	135	200	235	200	120

Units: 1 MPa = 1 N/mm^2 = 0.102 kgf/mm^2 = 0.145 ksi; 1 W/(m·K) = 2.388 · 10^3 cal/(cm·s·°C)

* Values may change with varying thermal and mechanical treatment due to geometry and manufacturing procedure

** Measurement according to DIN ISO 5182

( ) Values may change due to restricted reproducibility of measurement

1) Hardness HBW: 2.5 /187.5 for ELBRODUR® B95 and ELBRODUR® NIB

AMM®
Advanced Mould Materials

NOWADAYS THE MAJORITY OF ALL COPPER MOULDS AROUND THE WORLD ARE HOT-FACE COATED – TO EITHER PROTECT THE COPPER AGAINST ABRASIVE WEAR OR DIFFUSION OF HARMFUL ELEMENTS OR – TO PROTECT THE SURFACE QUALITY OF THE CAST PRODUCT AGAINST COPPER PICK-UP (STAR CRACKS). KME HAS DEVELOPED DIFFERENT ADVANCED MOULD COATINGS TO SERVE THESE SPECIAL NEEDS.

Step coated narrow-face copper plate

Copper materials have a relatively low hardness and thus low resistance to abrasive wear. For this reason, a high degree of wear can occur, mainly in the lower part of the mould. The main object of coating mould tubes and plates is to increase the service life of the mould, as well as an improvement in the product quality. **KME** has come up with future-oriented solutions by further developing and by using new coatings and coating-systems. New wear-protection layers and coating techniques are also being investigated in our laboratories.

COATING OF MOULD TUBES

The small size billet moulds, are particularly susceptible to wear. The hard chrome coating AMC-HC 90 on the inside mould surfaces provides effective anti-wear protection which results in a substantial gain in mould lifetime.

AMC-ML

In casting operations, mould tubes are exposed to an extreme varity of operational loads. In addition to a high thermal and high abrasive load, the steel melt often also introduces tramp elements into the process which cause a chemically induced damage. Such tramp elements like zinc or sulphur often originate from the steel scrap.

The formation of cracks and as a result a spalling of the coating in the meniscus level are typical damage patterns which necessitates a replacement of the mould tube.

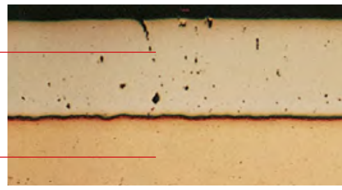
As a countermeasure **KME** has developed the multi layer AMC-ML coating to provide effective protection of the mould tube against the combined chemical, thermal and mechanical loads.

COATING DAMAGE FROM ZINC

Zinc from the steel melt can initiate a specific failure mechanism in connection with chrome coatings. Vaporising zinc mainly from scrap makes its way to the copper surface by diffusing into the micro cracks which are always present in hard chrome. High mould temperatures encourage the diffusion, so that the problem mainly occurs in the mould meniscus area, especially if cooling conditions are unfavourable.
The copper reacts with the zinc forming brittle, and "bulky", intermetallic phases of brass which result is premature chrome chipping.

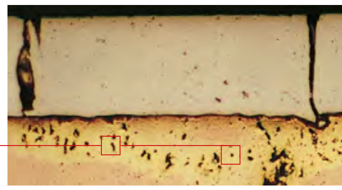
Chrome

Copper



Original chrome coating (cross section)

Alpha/beta phases of brass



First damage stage

Gamma phase of brass

Final failure stage: chrome layer flakes off

EFFECT OF NICKEL THICKNESS ON HEAT TRANSFER AND WALL TEMPERATURE

Calculation based on constant coefficients of heat transfer; heat flux approx. 1.8 MW/m^2.

Material: CuAg (DPS-Cu)	**Ni coating** mm	**Δ T wall** °C	**Δ heat transfer** %
Wall thickness: 35 mm	0.7	+ 11	- 0.9
	1	+ 15	- 1.3
	2	+ 30	- 2.6
	3	+ 45	- 3.8

COATING OF MOULD PLATES

When it comes to coatings for mould plates, a distinction has to be drawn between

- coatings for metallurgical protection to improve the surface quality of the cast strand (e. g. prevention of star cracks), and
- anti-wear coatings to improve resistance to abrasion.

Depending on the distinction and the overall conditions at the plant the casting surfaces of the mould plates are either full-face coated or only partially with nickel, nickel alloys or special ceramic coatings. Also multi-layer coatings are possible.

COATINGS FOR SLAB PROTECTION

When casting certain steel grades the surface quality of the cast strand can become impaired by copper particles picked up from the mould wall (especially in the lower part of a mould) which can lead to the development of star cracks. To avoid this defect, the mould plates of slab casters used for the production of these sensitive steel grades are protected with a nickel or nickel-alloy coating.

ANTI-WEAR COATINGS

Considering the lower thermal conductivity of coating materials a decision for the right coating geometry has to be made.

As a result of the associated reduction in mould heat transfer, and because of the resultant higher wall temperatures which affect nickel adherence to the copper, thick nickel coatings have a major impact on the operational handling and relevant casting parameters. This puts definite limits on the maximum allowable nickel thickness in the meniscus area.

The table shows the effect of nickel plating thickness on heat transfer and wall temperature From the point of view of caster operation, a reduction of approx. 3.8 % in heat transfer with 3 mm nickel on the copper is not significant, but the accompanying 45°C increase in wall temperature causes considerable stresses in the nickel due to the difference in coefficients of thermal expansion of the two metals.

Due to that hairline cracks may develop in the nickel at the mould meniscus and can propagate into the copper. For this reason undue coating thickness should be avoided, especially in the meniscus area.

Nickel alloys, like **KME**’s AMC-HN 40 or AMC-HWR are an interesting alternative to pure nickel layers. As a result of their greater hardness, they have good anti-wear properties with slightly lower thermal conductivity.

For the reasons outlined above, tapered nickel (alloy) coatings that are approx. 1.0 mm thick at the top and approximately 3.0 mm thick at the bottom end, or 2 – 6 mm thick partial coatings on the lower half of mould plates, represent optimal solutions with respect to both metallurgical and cost requirements.

Center Divider with coating on hot-face

For adjustable slab and bloom moulds, friction between the surfaces of the wide-face coppers and the edges of the narrow-face coppers leads to wear and the localised development of deep scores and scratches.

Here, the rate of wear can be reduced considerably by coating the edges of the adjustable narrow-face plates, which slide on the inside (hot-face) of the wide-face coppers, with a material that has greater hardness.

Deep-drilled narrow-face plate for thin slab mould
with coating on hot-face and edges

Deep-drilled narrow-face plates for thin slab mould
with coating on hot-face and edges

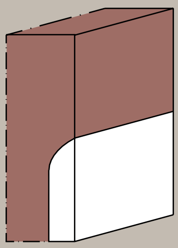
Beside the nickel and nickel-alloy coatings, **KME** can also supply metal-ceramic coatings (AMC-HF). The high hardness of such coatings makes it possible to achieve considerable improvements in the lifetime, especially of narrow-face plates.

It can be seen that very complex interrelationships have to be taken into account when selecting a suitable coating and layer thickness. Recommendations can therefore only ever be made in relation to specific system and casting parameters. Close consultation between the system operator and the mould supplier is necessary to ensure that the appropriate coating systems are selected.

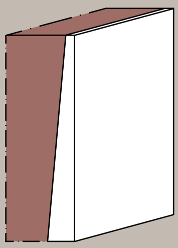
The selection of coating may furthermore depend on what possibilities exist in terms of mould maintenance and available re-coating services.

AFM® – Advanced Funnel Mould:
thin-walled copper plate + adapter plate

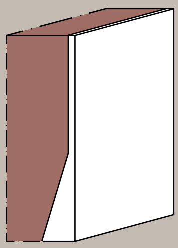
COATINGS FOR PLATES



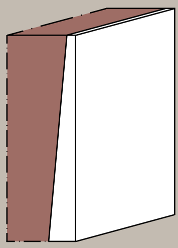
2.0-6.0 mm HN 20
or 2.0-3.0 mm HN 40 / HWR



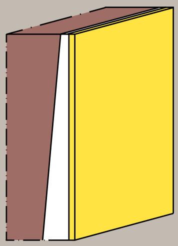
1.0-3.0 mm HN 20
or 1.0-2.0 mm HN 40 / HWR



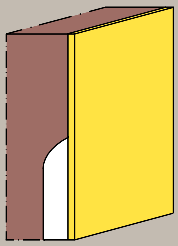
0.3 mm + 3 mm
HN 20 / HN 40 / HWR



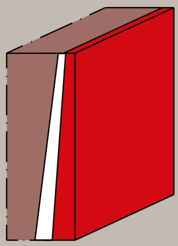
1.0-3.0 mm HN 50



1.0-3.0 mm HN 20 / HN 40 / HWR
+ 0.025-0.05 mm HC 90



2.0-6.0 mm HN 20
+ 0.025-0.05 mm HC 90

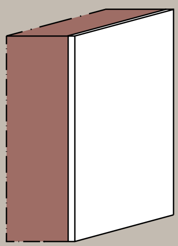


0.1–0.6 mm HF 120

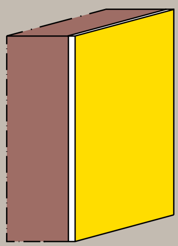
AMC – Advanced Mould Coatings – hardness, thermal conductivity and thickness range

MATERIAL	Hardness HV	Thermal conductivity W/(m·K)	Thickness range mm
AMC HN 20	220	90	2–6
AMC-HWR	240	80	2–3
AMC-HN 40	400	80	2–3
AMC-HN 50	500	80	2–3
AMC HF 120	1200	30	0.1–0.6
AMC-HC 90	900	70	0.05–0.12
AMC-ML Multi Layer	220/900	90/70	> 0.5

COATINGS FOR TUBES

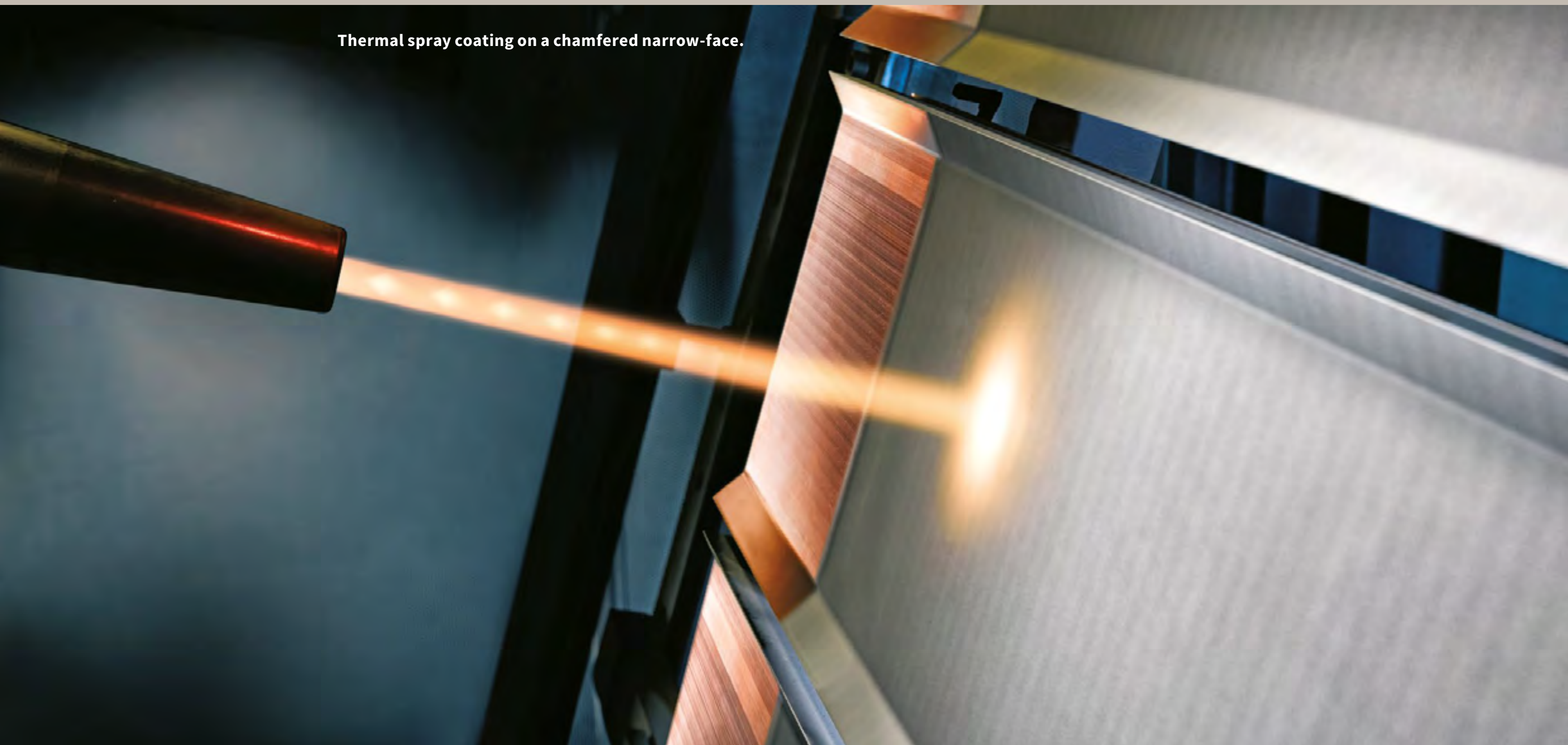


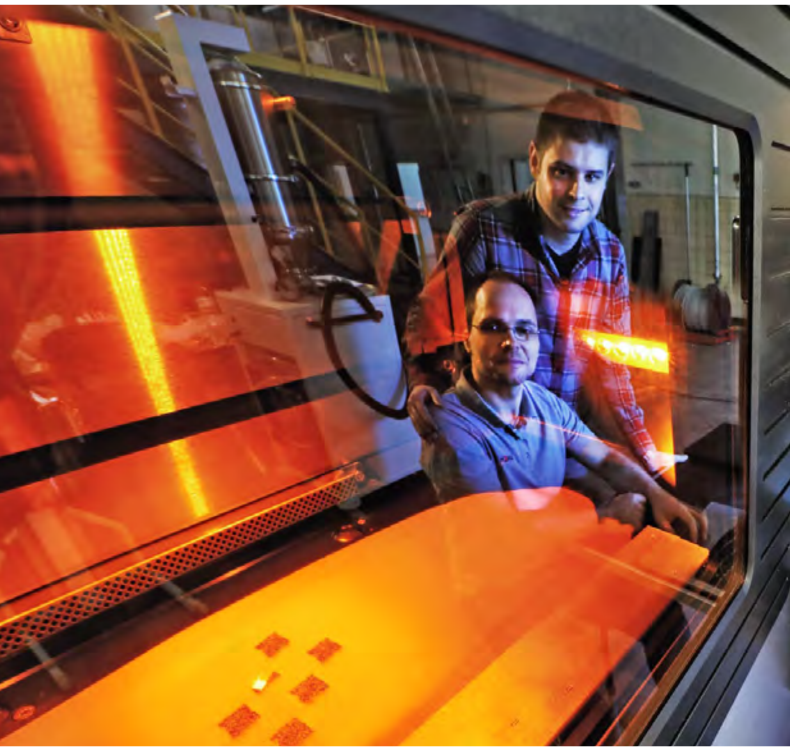
0.08 mm-0.12 mm HC 90



0.1 mm ML

Thermal spray coating on a chamfered narrow-face.





RESEARCH AND DEVELOPMENT

THE AIM OF OUR WORK IS TO CONSTANTLY IMPROVE OUR PRODUCTS FOR THE BENEFIT OF OUR CUSTOMERS. TO THIS END, **KME** CONTINUOUSLY WORKS ON NEW MATERIALS AND MATERIAL PROCESSING TECHNIQUES. FOR THE DEVELOPMENT OF MOULDS, WE CAN DRAW ON THE CORE COMPETENCE AND KNOWLEDGE OF THE ENTIRE GROUP. THE R & D DEPARTMENTS OF THE GROUP ARE POSITIONED TO COVER THE ENTIRE SPECTRUM OF TASKS FROM THE DEVELOPMENT OF NEW MOULD MATERIALS TO THE SUPPORT OF THE APPLICATION OF THE NEW PRODUCTS.

Material analysis in the central lab

Investigation of additive manufacturing technologies

Casting trial in the lab foundry

In the development of new materials, new compositions are tested and familiar ones further developed. The R & D department for materials development solves both tasks. Here, mould materials used throughout the world today were developed at the beginning of the 1960s – such as ELBRODUR® G (CuCrZr) and others.

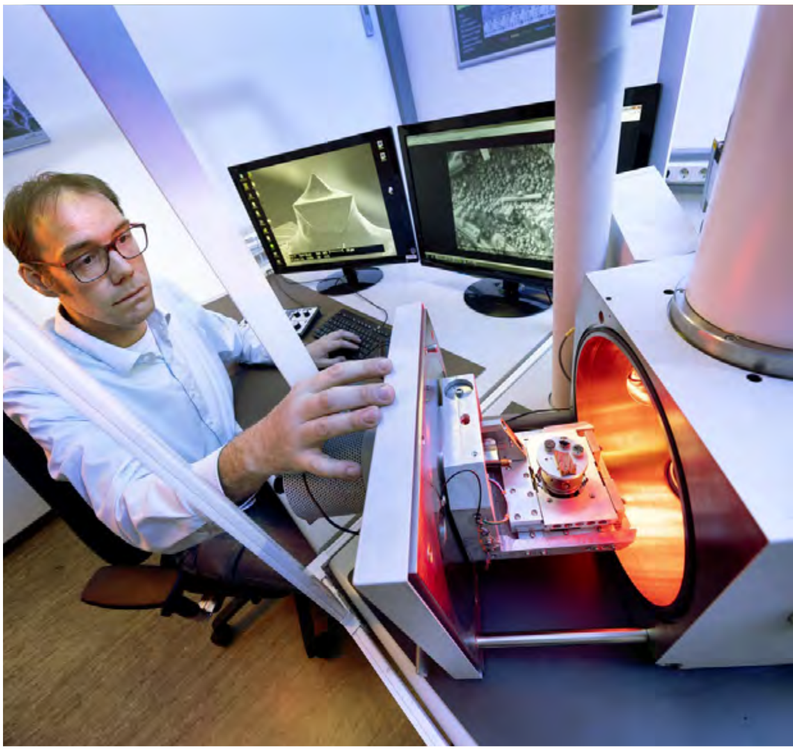
KME's laboratory's melting and casting facilities are capable of casting blocks weighing 3,500 kg which can be further processed at the production facilities. This means that new materials can be tested on industrial scale in short time and optimal production parameters can be determined in advance. A rolling mill and a press, together with annealing and salt-bath furnaces, are used for thermo-mechanical treatments within the department.

The development of materials is supported by the full range of chemical analysis (S-OES, XRF, ICP, F-AAS, etc.), including metallography, and by SEM electron microscopes, including EDX analysis systems. In the area of coatings, a galvanic laboratory was set up to facilitate their development. The technological laboratories for physics and mechanics are equipped with all of the necessary devices for testing and determination of material properties. This includes tests on creep, relaxation, softening, fatigue resistance, etc.

Destructive tests provide additional data, making it possible to investigate customer-specific conditions on particular stresses such as thermal/chemical problems in the meniscus area with softening and high temperature corrosion, deformation due to insufficient cooling or wear in the bottom/edge area.

R & D is also concerned with assessment of relevant new manufacturing technologies such as additive manufacturing, joining technologies and coating processes. In many cases, these processes can be investigated directly on-site at the Technology Centre and tested for applicability in the manufacture of moulds.

Today, basic laboratory research is supplemented by development work for the customer, focusing on improved productivity together with high reliability and service life in specific industrial applications. Thus, the primary aim of all development activities carried out by KME is to provide technical support to customers on how to optimise their facilities, processes and products.



Chemical analysis

Investigations with the scanning electron microscope

Preparation for metallographic examination

ADVANCED MOULD MANUFAC- TURING

ANOTHER MAJOR ELEMENT OF INTEGRATED MOULD TECHNOLOGY IS **KME**'S COMPREHENSIVE PRODUCTION KNOWLEDGE. STARTING WITH MATERIAL DEVELOPMENT, THROUGH THE ENTIRE PROCESS CHAIN FROM MELTING TO CASTING AND ALL THE WAY TO THE FINAL QUALITY CONTROL, KME USES ITS VAST EXPERIENCE TO SUPPLY SUPERIOR MANUFACTURED MOULD PRODUCTS.

MELTING AND CASTING

KME's copper and copper alloys are produced on state-of-the-art melting and casting facilities. High purity cathodic copper is mainly used for producing the mould materials and the composition of the melt is monitored by appropriate analysis systems.

Billets and slabs can be cast on different casting machines in different geometries to ensure that the dimensions of the starting size offers favourable conditions for the downstream production.

FORMING

KME has access to both hot and cold rolling mills for forming the materials as well heavy –duty systems for extrusion, forging and ring rolling and heat treatment too. Special procedures and process sequences developed by KME ensure the manufacturing of complex geometries and dimensions, while maintaining the highest levels of quality.

MACHINING

Modern, precise CNC machine tools are available for machining of moulds. CAD/CAM-Systems for the design, manufacturing and quality control allow the manufacturing workpiece surfaces with extremely tight tolerances.

RESEARCH & DEVELOPMENT

ENGINEERING

MELTING

CASTING

Tube	
Hot extrusion	
Drawing	
Cold forming	
Machining	
Plating	
Quality control	
FINAL PRODUCT – TUBE	

Plate	
Hot rolling	Hot forging
Cold rolling	Cold forging
Machining	
Plating	
Quality control	
FINAL PRODUCT – PLATE	


KME
KME Germany
Osnabrück Germany
Dept.: Engineered Products

QUALITY ASSURANCE

THE USE OF HIGH-QUALITY PRODUCTS IS ABSOLUTELY IMPERATIVE FOR THE SAFE OPERATION OF CONTINUOUS CASTING FACILITIES. IN ORDER TO ENSURE THIS, KME HAS ALL PRODUCTION AND BUSINESS PROCESSES CERTIFIED TO DIN ISO 9001.

THIS TOTAL IN-HOUSE CAPABILITY GIVES KME THE START-TO-FINISH CONTROL NEEDED TO PURSUE ITS BUSINESS PHILOSOPHY ON ALL LEVELS INVOLVED AND THROUGH ALL STAGES OF PRODUCTION.

SERVICE FOR MAINTENANCE AND RE-COATING

MOULD ASSEMBLIES

From the smallest size billet mould to remotely adjustable slab moulds – KME builds and assembles all types of casting moulds complete with their complex drive and control systems.

Here, too, the uncompromising quality standards of KME are ensured through in-process quality control at all stages of a project, no matter whether it is a one-off job or the manufacture and assembly of a whole series of moulds. These services for maintenance and re-coating are for customer's requirements on a worldwide basis.

REPAIR OF MOULD TUBES

As a matter of basic principle, mould tubes are designed as expendable items. Yet, in certain cases it may be economically worthwhile for a client to have his large-section mould tubes reworked.

REPAIR OF MOULD PLATES

KME's maintenance and repair services for mould plates include the proper remachining as well as repair of stud-welded moulds and possible re-coating of the copper, plus a complete overhaul of the entire mould assembly, if needed.

In the case of a complete mould overhaul, the mould will be dismantled and all its mechanical and supporting parts will be inspected and, if necessary, renewed. Like KME's newly built moulds, the reassembled unit complete with the remachined copper – or with new copper, if necessary – will undergo a complete operational check.

KME SERVICE STATIONS WORLDWIDE

KME Moulds Service Spain *Poligono Industrial "El Campillo"*
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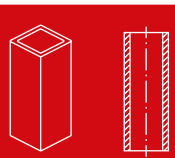
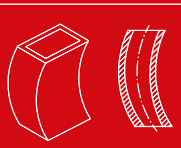
KME DEVELOPMENTS ON MOULD TUBES

1960
Manufacture of the first copper mould tubes for continuous casting of steel
Size range 80-120 mm



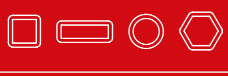
Straight   Inside parallel uncoated

1963-1965
Development of a special manufacturing process to ensure a reproducible quality
regarding
– high dimensional stability
– close tolerances

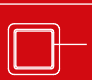


Curved   Inside tapered

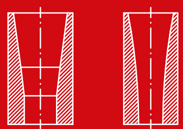
– Broadened size range
– All shapes



1965/66
Development and use
of Cr-plated mould tubes

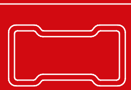


From 1980
Improvement of mould tube geometry to meet high-standard market requirements
– set up individual taper
– modification of corner radii
– modification of wall thicknesses
– closer tolerances



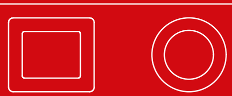
Double/ triple taper   Parabolic taper

1982
Supply of first mould tubes
with beam-blank moulds



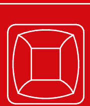
Curved tapered Cr-plated

1986/95
Supply of world's largest mould tubes
Square
Round

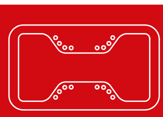


Size
360 x 320 mm   ø 600 mm

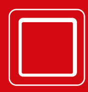
1994/95
Supply of mould tubes with special geometries for high speed billet casting
– CCT®-Mould
– AMT®-Mould
– DIAMOLD®



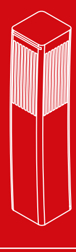
1998/2001/2002
Gun-drilled beam-blank moulds



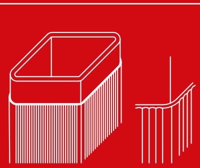
2001
Development of improved
chrome coating



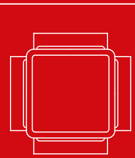
2006
Development of homogenous
cooling mould tubes



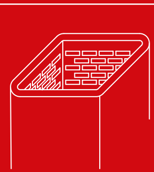
2008
Development of the AHE
Advanced High Efficiency Mould Tube



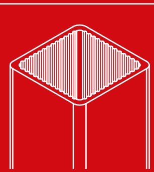
2009
Development of the
ATM Advanced Tube Mould



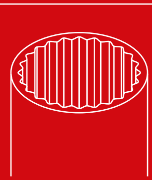
2010
Development of the
Textured Mould Tube



2012
WAVE®

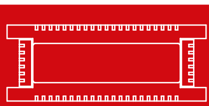


2018
Round WAVE®



KME DEVELOPMENTS ON MOULD PLATES

1964
Start of manufacture and reconditioning of complete non-adjustable slab moulds

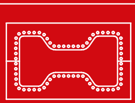


Size 200 x 1700 mm

1966/70
Development and use of the special alloys of CuAg and Elbrodur® G

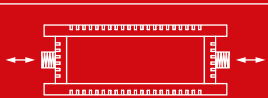
Extreme dimensional stability i.e. resistance to deformations through
– high thermal conductivity
– excellent high temperature strength
– high creep resistance

1968
Supply of the first beam-blank moulds 2-piece design



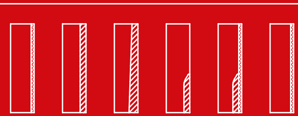
Size 560 x 265/100 mm

1969/70
Supply of adjustable slab moulds

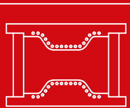


Various sizes

1975
Continued development of electrodeposited nickel coatings + ceramic coatings

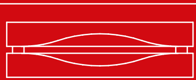


1986
Supply of the first beam-blank moulds, 4-piece design



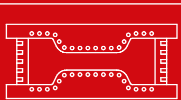
Size 685 x 225/50 mm

1988
Supply of the first thin slab moulds



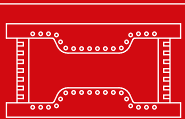
40 - 50 mm thickness x 900 - 1100 mm

1990
Supply of wide flange beam-blank moulds 4-piece design



Size 500 x 410/123 mm

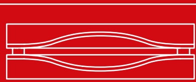
1994
Supply of wide flange beam-blank moulds 4-piece design



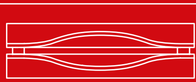
Size 1120 x 500/130 mm

1998
Gun-drilled funnel mould with optimised cooling design by KME

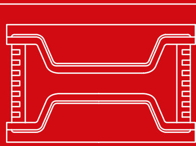
2003
Development of the KME AFM® mould



2006
AFM® mould running in industrial-scale production

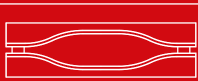


2007
Development of the KME ABBM beam-blank mould



2009
Development of the ASM Advanced Slab Mould

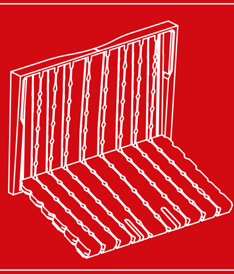
2009
Development of the ESP®-Mould



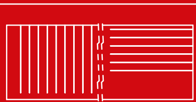
2012/2013
Development and use of the special alloy Elbrodur® GD-NS

Elbrodur® GP-NS
– fatigue behavior
– creep strength

2017
Development of the ATSM-Mould



2019
Supply of Mould with Fibre Optical Systems



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