CHROMIUM-MOLYBDENUM

A high-power fabrication steel

DILLINGER

DILLINGER.
A PASSION FOR STEEL.

Steel is our passion. For more than 330 years, we have put our faith in our wealth of ideas and innovation, combined with our love for detail and perfection.

The better the steel, the greater our customers' success

Steel is a unique and fascinating material, and those who understand and master it are rewarded with outstanding properties. At Dillinger, the entire production process – starting with research, and proceeding via steelmaking, up to and including rolling – is focussed solely on the heavy-plate product. This specialization is the basis of our unparalleled know-how, which we use for the benefit of our customers. Knowledge, experience and the systematic deployment of ultra-modern AI applications enable Dillinger to produce even highly critical grades with process certainty and to power innovative product developments. Whenever top quality, reliability and increased productivity are required, Dillinger is there for you – promised.

Dillinger offers an unequalled portfolio of products, consisting of more than 2,000 different grades of steel in an impressive selection of formats. This range is optimally rounded off by our individualised advisory services for our customers and, increasingly, by a diverse spectrum of digital information features.

In high regard around the globe

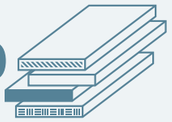
The Oresund Bridge connecting Denmark and Sweden, Shanghai's World Financial Center – one of the world's highest buildings –, gigantic offshore wind-power facilities and drilling platforms, and the Louis Vuitton Museum in Paris, with its breathtaking architecture, are all impressive examples of the diverse applications for Dillinger's high-tech steels, that meet maximum demands and safety requirements.

A credo of sustainability

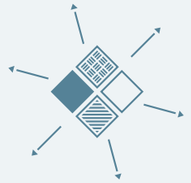
Steel is especially sustainable, like no other material, not least of all due to its extreme recyclability. Environmental protection, furthermore, is assigned special importance at Dillinger. The core feature of our sustainability structure consists of low-CO_2 steel production, environmentally safe products, continuous enhancement of energy-efficiency and resources conservation, the reduction of emissions and improvement of the environmental protection of water. Dillinger identifies with the aims of the Paris Climate Agreement. Our credo is: „Top-grade industrial technology coupled with sustainable management" – no more, no less.

DILLINGER AT A GLANCE

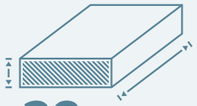
More than **330** years of experience in steel



Over **2.000** different grades



Expert advice for more than **10** diverse fields of application



Heavy plates up to **28 m** length and **500 mm** thickness

Plate weights up to **52 t**

More than **200** international approvals, certificates and customer qualifications

YOUR PARTNER FOR PETRO-CHEMICAL REACTOR FABRICATION

Whether in hydrotreaters, hydrodesulphurisers or hydrocrackers – high temperatures and pressures in reactors, and in petrochemical reactor fabrication, in particular, make extreme demands on the low-alloyed chromium-molybdenum steels used. So it's a good thing to be able to rely on a highly capable producer who meets those most demanding specifications that will assure long and safe operation.

Groundbreaking in reactor fabrication

Around the globe, Dillinger enjoys an outstanding reputation as a dependable partner in petrochemical reactor fabrication – with high product quality and on-time delivery anywhere in the world. Our heavy-plate rolling-mills in Germany and France are among the world's most efficient, and are each equipped with two high-power four-high rolling stands. These facilities are backed up by many decades of experience, unique technological potentials and intensive cooperation with designers, steel users, equipment operators and standardisation organisations. Our employees act as experts in the drafting of industrial standards and codes, as in the case, for example, of the API 934 RP series.

Customised solutions, in-house test and inspection laboratories

Dillinger supplies CrMo steels in conformity to the most widely used international standards, such as ASTM/ASME and EN 10028, Part 2. Dillinger's own Research & Development department enables us to modify the steel design individually to meet our customer's needs and nonetheless remain conformant to the standard. A broad range of primary material permits us to produce plates with high degrees of deformation which may nonetheless by far exceed the requirements set down in the relevant standards. Our products are tested and inspected in our own accredited laboratories in conformity to ISO 17025. At the customer's option, we can also perform the initial and sometimes complex working operations in reactor fabrication. Contact our experienced experts for comprehensive advice.

Your product benefits at a glance

- Broad range of grades
- Extreme plate formats and item weights
- Ultra-high toughness
- Exceptional range of plate thicknesses combined with high-performance rolling mills
- Low trace-element contents minimise susceptibility to temper embrittlement
- Cost-efficient completion thanks to reduced needs for welding and inspection on the reactor
- Specifications over and above the standard are possible

Your service benefits at a glance

- Comprehensive advisory services by experienced professionals
- Development of tailor-made special solutions in steel design
- Heavy fabrication at Dillingen (initial fabrication work)

Discover our **E-Service area** with various tools, important information and the **E-Connect App** for the identification of plates and the download of certificate data.

STANDARDISED BUT TAILOR-MADE

Not just any steel will do. Every order has its own totally different requirement profile for steel design. In close cooperation with designers and steel users, Dillinger firstly clarifies for every order the precise project-specific conditions, in order to select precisely the steel that optimally meets the requirements made – standardised but tailor-made.

High requirements and demanding standards

Process reactors for petrochemicals are designed to assure the longest possible service life despite operating at high pressures, high temperatures and under exposure to high pressure hydrogen. The relevant standards provide the essential orientation data for the design of the steel, such as the mechanical and the technological characteristics data, for example. The potential applications for such steels are outlined by the so-called Nelson diagram and API 941.

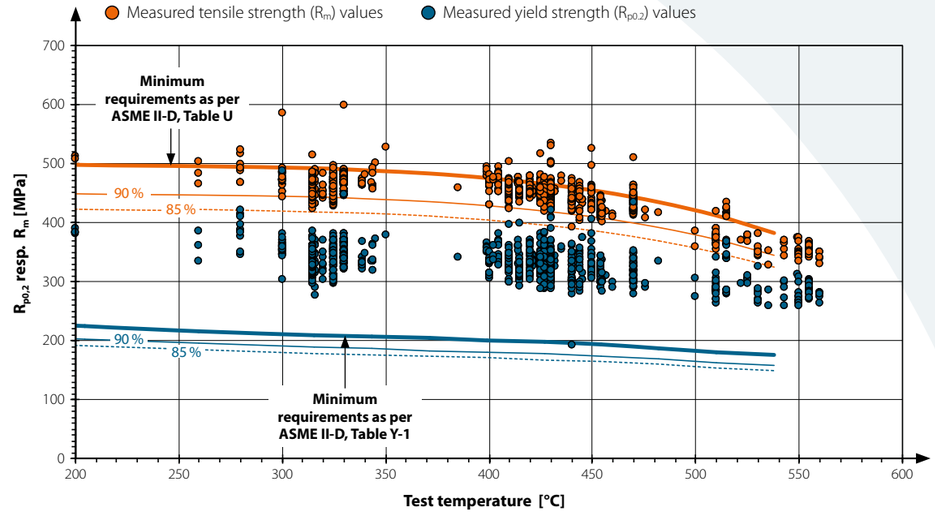
Investigation of a CrMo steel in a scanning electron microscope (SEM).

Steel design is subject to many influencing factors

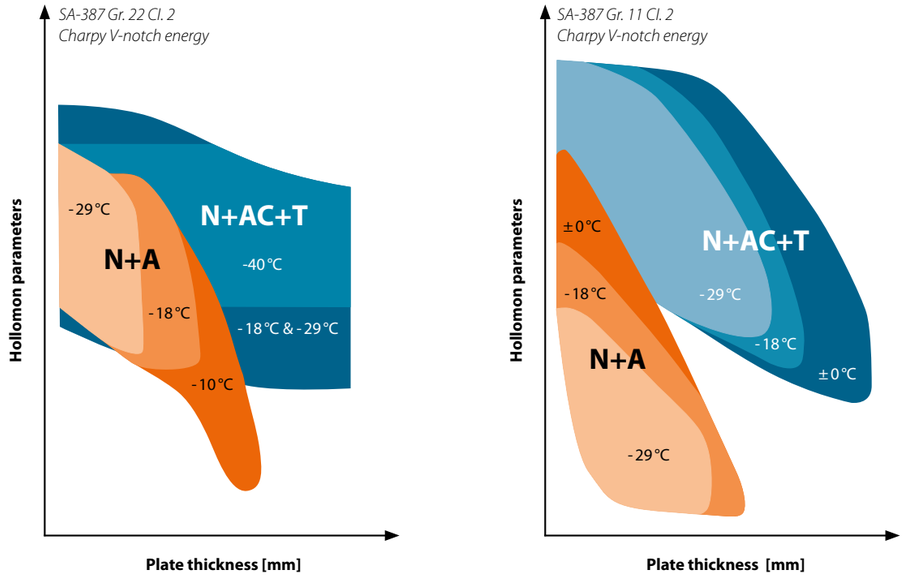
But not only the chemical analysis and plate thickness influence materials properties. The heat-treatment conditions (normalising, tempering, water quenching and tempering, stress-relieving annealing) and the downstream forming processes also play a decisive role in further processing. All of these parameters are incorporated into the selection of the particular steel design, in order to assure optimum safety and cost-effectiveness.

Only water quenched and tempered CrMo steels for thick plates

How heat treatment affects technological feasibility is illustrated by tests performed at Dillinger, selecting the example of the tempering and stress-relieving annealing of air-cooled and water-quenched CrMo steels. The correlations between temperature and residence-time during heat treatment are well illustrated using so-called Hollomon parameters (in the US standards better known as Larsen-Miller-Parameter). The diagrams demonstrate that only water-quenched CrMo steels (N+AC+T and Q+T) meet the necessary mechanical strength and toughness requirements when specifications for stress-relieving annealing are combined with large plate thicknesses.



Determination of suitable minimum requirements for hot tensile test on the basis of ASME II-D for SA-387, Gr. 22 Cl. 2.



The two graphics illustrate the effect of complex requirements on the feasibility of a 1¼Cr ½Mo steel (SA-387 Gr. 11 Cl. 2) and of a 2¼Cr 1Mo steel (SA-387 Gr. 22 Cl. 2). For one specific analysis type in each case, the examples show how feasibility potentials vary as a function of delivery condition, Hollomon parameters (heat treatment) and plate thickness. The diagrams take as their basis a yield-strength requirement of $R_{p0.2} \geq 311$ MPa and a tensile-strength requirement of $518 \leq R_m \leq 690$ MPa. The adopted toughness level for the various test temperatures for the individual areas is 54 Joule on average.

CONSTANTLY HIGH TOUGHNESS

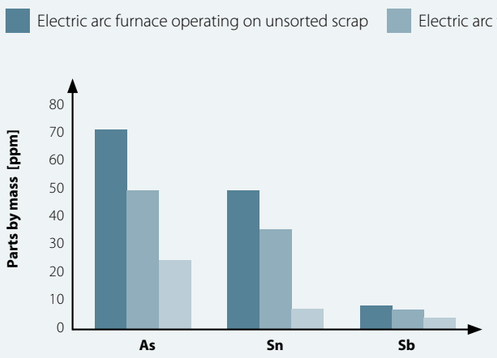
The phenomenon of so-called temper embrittlement (TE) impairs the toughness of chromium-molybdenum steels. Reducing susceptibility to temper embrittlement plays an important role in the safety of plants and facilities, however.

The challenge of temper embrittlement

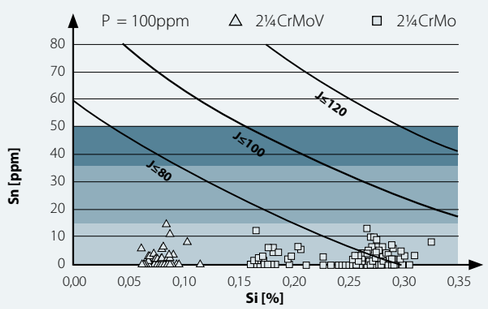
To achieve higher efficiency, pressure vessels in oil refineries are being designed ever larger by their engineers. The result is that both the temperature and the pressure in these vessels are also becoming ever higher. Due to their service conditions, 2¼Cr1Mo steels are prone to temper embrittlement, which impairs the toughness of the steel. This typically occurs in the temperature range between 370° C and 580° C. The impact energy transition temperature shifts toward higher temperatures. This failure mechanism is attributed to the influence of the trace elements antimony (Sb), arsenic (As) and tin (Sn) in the steel, which segregate and accumulate on the grain boundaries during service. The J factor can be used as a measure of susceptibility to TE caused by these trace elements.

The BOF route makes the difference

Dillinger takes measures against temper embrittlement as early as the steelmaking phase. Susceptibility to temper embrittlement is diminished to an extremely low level by reducing trace elements. Hot metal and steel scrap are charged into the BOF (Basic Oxygen Furnace) converter (hot-metal charging) and so-called slag formers, such as lime, added. Thanks to the BOF route, such trace elements are kept at an extremely low level. For this reason, Dillinger's CrMo steels retain their high resistance and toughness even after long periods of continuous operation.



Percentage of trace elements in steel from various melting routes.



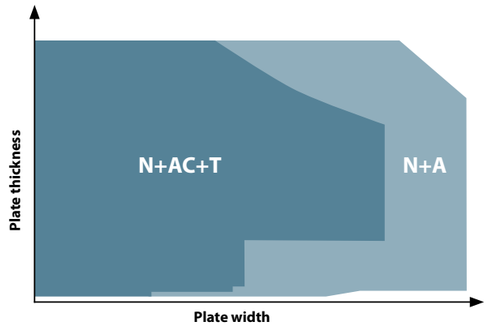
J factors as a function of various melting routes. J factors for 2¼Cr1Mo steels calculated in accordance with Watanabe: $J = (Mn + Si) \cdot (P + Sn) \cdot 10^4$ in [%]. Concept of the J factor is of little informational value for steels with other CrMo contents. Calculation is performed using an X factor in accordance with Bruscato for weld filler materials.

WIDER, THICKER, HEAVIER

We at Dillinger concentrate on just one thing: Heavy plate. Our uniquely broad product portfolio contains steels of out-of-the-ordinary dimensions, in extreme thicknesses, with ultra-heavy item weights and for the most varied and demanding applications.

Unique plate dimensions

The finished liquid steel is cast on our continuous-casting machines to slabs of a thickness of up to 600 mm. As an alternative, Dillinger also has the ingot-casting route available if even larger feed material thicknesses are needed. This makes it possible to advance into dimension ranges which could otherwise scarcely be achieved. Here, heat treatment has a decisive influence on the attainable plate dimensions.



Qualitative graphic showing plate dimensions as a function of heat treatment.

Cost reductions thanks to extremely modern rolling-mills

We produce our heavy plates using two of the world's most effective and efficient rolling-mills. High Shape Factor Rolling achieves extremely good toughness data – even at half plate thickness and even in thick plates. The high-torque drive systems of our rolling stands permit high reductions per rolling pass, which completely deform the plate centre even at an early point in rolling. These benefits make Dillinger heavy plate a lower-cost alternative to rolled rings in thick-walled reactors.

Enhanced component safety, less testing

Out-of-the-ordinary plate formats reduce the scope of welding and permit the forming of seamless vessel ends in large diameters. This gives designers greater freedom in vessel design when planning reactors. Further benefits include enhanced component safety and cost reductions thanks to reduced fabrication and inspection complexity.

Your product benefits at a glance

Dillinger CrMo grades

- from 1Cr½Mo to 3Cr1Mo (e.g. SA-387)
- and vanadium-alloyed steels 2¼Cr1Mo¼V (e.g. SA-542)

Dillinger supplies CrMo steels

- in lengths up to 28 m*
- in widths up to 5,200 mm*
- in thicknesses up to 290 mm*
- in plate weights up to 42 t*

* Maximum dimensions, combination only in conformity to Dillinger Supply Programme

WITH NETWORK AND DOUBLE OPTIONS

Well-founded research work assures quality and powers innovation. Dr. Ingo Detemple, responsible as a researcher for Dillinger's new and further developed CrMo steels, on the targets of his research activities, neural networks, the limits of the feasible, climate protection and the "limp brother".

Dr. Ingo Detemple

Career

The university-trained Materials Scientist moved from the Fraunhofer Institute in Saarbrücken to Dillinger's research department around twenty-five years ago. Here he is responsible for the design and further development of both boiler-making and pressure-vessel steels and of toolmaking, quenching + tempering (Q+T), case-hardening and armoured steels. As an esteemed expert, he regularly publishes articles in well-known German and international journals and also presents papers at congresses and conferences.

Just take a look at our technical literature.

Dr. Detemple, what targets is Dillinger pursuing with its intensive commitment to Research & Development?

Our core task is product- and application-orientated research for the design of steels that meet specific customer requirements. The better we understand the microstructure of the steels, the better we can achieve this. Bearing the responsibility for our products, we are the link between basic research, marketing and production. Ultimately, we set the process parameters for a specific heavy-plate design for production. We all work in a highly networked system, and Marketing, for example, uses the results obtained in its advisory services for customers.

» We make the risk masterable. «

Dillinger steel is used, among other things, in highly sensitive projects like reactor and power-plant construction. How does risk management function vis-à-vis the client?

By making the risk masterable! Our aim is to be a long-term partner for our customers. Reliable performance in terms of quality and on-time delivery are of fundamental importance for this. This is why we initiate a highly conscientious feasibility study as early as the enquiry stage, and also, if necessary, present alternative steel concepts.

And how does that look in detail?

Even for Quality Assurance reasons alone, we provide clear alternatives for the most diverse risk situations. We thus assure that our plates can be delivered on time with the highest possible level of quality. This procedure is backed up by measurement of relevant process parameters throughout production, since a property profile can be finely adjusted in one direction or another at many stages in the process. I have already mentioned "alternative steel concepts". An example: in internal company jargon, we talk about "limp brother" SA-387 Gr. 11 Cl. 2. Although we receive many enquiries for this, as a standard grade, it is often not the optimum choice of material, in view of the frequently highly ambitious mechanical and technological requirements. The "robust brother", SA-387 Gr. 22 Cl. 2, is better, because it is safer (he laughs).

The decision for a steel design adequate for the project is a highly complex process. How do you go about this?

Many companies are involved as decision-makers in the construction of pressure vessels: plant operators, EPCs, licensors and, not least of all, the vessel fabricator. Dillinger is frequently in dialogue with all those involved. Thanks to our profound knowledge of steel and the relevant codes and standards, we are able to balance out the various needs and requirements and to arrive at solutions that are supported by all parties.

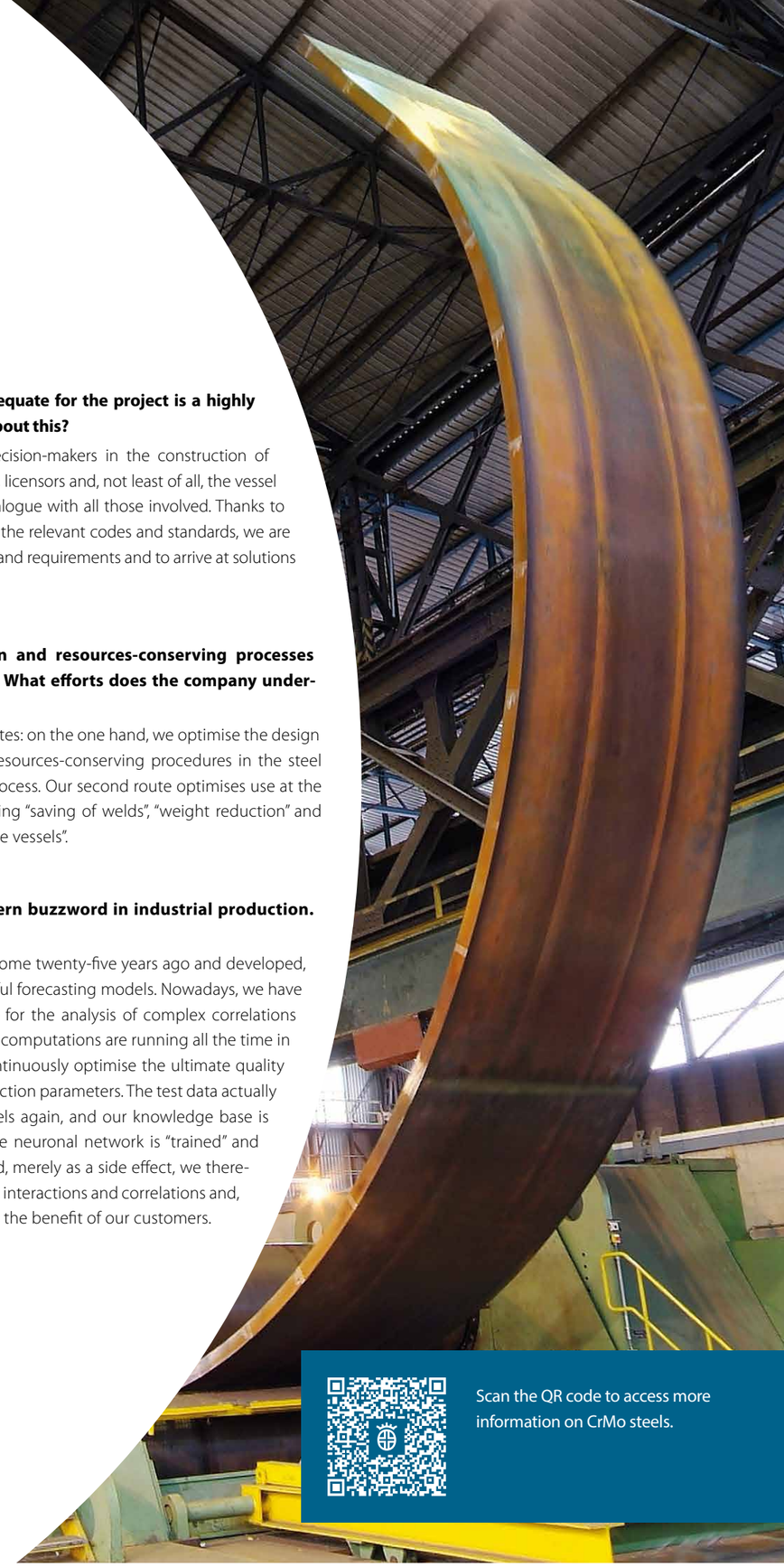
Provisions for climate protection and resources-conserving processes enjoy a high ranking at Dillinger. What efforts does the company undertake to justify these claims?

As steel designers, we pursue two routes: on the one hand, we optimise the design to ensure that we select the most resources-conserving procedures in the steel formulation and in the production process. Our second route optimises use at the customer's, the watchwords here being "saving of welds", "weight reduction" and "prolonging the service-life of pressure vessels".

Artificial Intelligence is the modern buzzword in industrial production. At Dillinger, too?

We began using neuronal networks some twenty-five years ago and developed, using the simplest elements, successful forecasting models. Nowadays, we have much more powerful tools available for the analysis of complex correlations and interactions. Complicated model computations are running all the time in parallel to actual production and continuously optimise the ultimate quality level on the basis of up-to-date production parameters. The test data actually achieved are fed back into the models again, and our knowledge base is thus continuously expanded, and the neuronal network is "trained" and becomes a "self-teaching system". And, merely as a side effect, we therefore gain ever deeper insights into the interactions and correlations and, ever more, into process reliability – to the benefit of our customers.

Many thanks for this talk.



Scan the QR code to access more information on CrMo steels.

For advice, whether technical or commercial,
please mail or phone our internal contacts.

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