The fascination of mechanised tunnelling

Giant wheels turning in unison

In tunnel engineering, superlatives are the norm, and new records are set, somewhere in the world, almost every day. Kilometre-long bores through mountain massifs, deep below the seabed or only centimetres away from existing urban infrastructure: everywhere, man and machine successfully drill their way through. In most cases, tunnel-boring machines (TBMs) from Herrenknecht provide the driving force – with decisive support from high-performance Dillinger steels. It makes no difference, whether for efficient underground traffic arteries or supply and disposal systems: where precision is the top priority, all involved must be able to rely without reservation on everyone else. Trouble-free interaction, alongside top design, technology and product quality, plays a decisive role from the planning phase up to and including completion. One example of proverbially (and literally!) groundbreaking projects is the more than 15-year cooperation between Herrenknecht AG, the world market leader in mechanised tunnelling technology, and Europe's leading producer of heavy plate, Dillinger.

Tunnel engineering and the gigantic machines used in it are the stuff that young dreams are made of. This fascination for digging enormous holes in the ground has made internationally active family-owned Herrenknecht the global market leader in mechanised tunnel-heading systems. Whether transport, supply or disposal tunnels, pipelines or underground shafts: all over the world, tunnel-boring machines constructed by this Schwanau company, with diameters ranging from 0.10 to 19 metres, are in use in the most diverse soil conditions. 3,700 projects have already been successfully completed using such Herrenknecht machines – including gigantic "earthworms" of enormous size and power. 450 metres in length, and with a cutting diameter of 9.43 metres, were the data for the longest of them to date: Sissi drilled the Gotthard Base Tunnel with a torque of over 8,000 kNm. At 3,000 tonnes total weight, it was only a little lighter than the 120 metre long machine used for the Eurasia Tunnel under the Bosphorus. This

machine, with a cutting diameter of 13.7 metres, weighed in at 3,000 tonnes. Herrenknecht completes approximately sixty such large tunnel-boring machines each year. Of Herrenknecht's world total of some 5,000 employees, around 2,200 work at Schwanau, on three shifts in selected sectors, such as component production, using complex CAD and turning machines.

Genuine millimetre accuracy

More than 604 kilometres of rail tunnel and more than 2,800 kilometres of new transport tunnel around the world are the current balance in the "Traffic Tunneling" sector of this 1977-founded company. Stephan Göggel, responsible head of production in Schwanau, was involved in a good third of the large tunnel projects. A tunnel-boring machine consists of around 80,000 individual parts, with complex prefabricated and preassembled units accounting for around 30 percent of them. Because: no matter how challenging the task, "On-time delivery is always top priority at Herrenknecht", he states. In its entire corporate history, the company has never incurred liquidated damages on the grounds of late delivery. And the demands made on these machines are enormous – no tunnel is like any other tunnel. Differing geologies – cohesive, non-cohesive, friable or even swelling rock, groundwater-saturated soils, tunnel routings under sea channels, high soil loads, tight spatial circumstances and extremely subsidence-sensitive surface buildings: every TBM has to perform top-level tailor-made work. After kilometres of tunnelling under the most adverse conditions imaginable, these long colossi meet the specified horizontal and vertical target coordinates with centimetre accuracy. This is possible only because Herrenknecht designs every machine precisely to match the special local conditions. An earth-pressure balanced (EPB) shield is generally used for soft soil conditions consisting of clay, loam or other soils with only limited water permeability. Mixshields, on the other hand, are the TBM of choice in heterogeneous soils and for water pressures of up to 16 bar and cutting diameters of up to 19 metres. These machines are used in groundwater-saturated soils, since a liquid or a suspension is fed in this tunnelling method to support the tunnel face. When things get really tough in mountain massifs, gripper TBMs force their way through by clamping themselves to the rock at the side, i.e., on the already excavated tunnel wall. The thrust cylinder abuts on this clamped system and forces the rotating cutting head

forward, onto the face. Double-sealed TBMs combine this gripper characteristic with the parallel installation of concrete segments to line the tunnel walls. These so-called segmental lining elements are also installed by mixshield and EPB-shield machines, and in this way generate the raw tunnel carcass. Common to all these Herrenknecht TBMs is the fact that they are all so-called full-face machines, in other words, they cut the full diameter of the tunnel with every rotation of the cutting wheel.

Clever heads are the key

Mechanised tunnelling makes demands on heads – the heads of the designers and the heads of the machines. The starting point for selection of machine type and of the individual design of a TBM are the specific requirements and conditions for the particular project: geology, hydrology, site and soil conditions, and the customer's wishes. The most important, and frontmost, part of every TBM is the cutting head, known in the case of non-cohesive rock as the cutting wheel, the cutters of which remove the soil material and convey it away to the rear. Designed specifically for the particular geology of each new project, the cutting head is forced in hard rock, for example, against the face with enormous thrust energy. The several thousand tonnes of thrust of the double-shield cutting heads in the around 20 kilometre long twin bores of Norway's Follo Line Tunnel, for example, assure efficient excavation. These components are fabricated almost entirely from up to 280 millimetre thick, large-format, high-performance heavy plate supplied by Dillinger, to enable them to withstand these enormous forces. The four segments of the 7.9 metre cutting wheel for the Tulfes-Pfons exploratory tunnel for the Brenner Base Tunnel, full-penetration welded together to form a monobloc, would not have been possible without extra thick, extra wide plates supplied from Dillingen. "The ratio of width and thickness in Dillinger plates is extremely good", emphasises Stephan Göggel. "We use almost exclusively Grade S355 in a thickness of 200 millimetres – and in unusually wide plates, to economise on welds", he adds. Out-of-the-ordinary plate widths are also in demand for fabrication of the shield, which has approximately the same diameter as the cutting head. The shield protects the main drive system and also supports the excavated bore until it has been lined. Nine plates of up to 4.2 metres in width and ten metres in length are assembled and welded to achieve a shield with a

diameter of 15 metres. "We value from Dillinger the fact that we can always get the dimensions that we need, and that reduce wastage, despite the necessary short delivery times." Stephan Göggel continues.

Concentrated energy

Extremely thick Dillinger plates in large dimensions are also indispensable for Herrenknecht for the gearbox assembly, the dimensions of which are decided by the necessary torque and thrusts. The drive system and gearing are a pre-assembled unit and are the largest and heaviest part of every machine. Monobloc gearboxes are characteristic of the transmission systems of Herrenknecht tunnel-boring machines. They assure maximum strength for the also specially designed drive assembly and thus the operational reliability and safety required by the customer: in Herrenknecht machines, a large number of individual motors grouped together in a main bearing generate the torque for the cutting head. The record for number of motors is held at present by the forty-eight individual motors for the main bearing of the earth-pressure balanced shield machine used in the construction of Madrid's three-lane M 30 urban-freeway tunnel. The cutting head of this machine was driven by 96,000 kNm of torque. The diameter of this machine is topped by that of a machine of almost 16 metres cutting diameter, which is currently excavating the Santa Lucia road tunnel to upgrade the autostrada between Florence and Bologna. The cutting-head drive system installed in this machine is the largest gearbox assembly yet completed by the Herrenknecht production team.

To protect this sophisticated technology, all gearbox housings and drive assemblies are constructed in Schwanau – irrespective of where they will subsequently be used. For the construction of these heavy monobloc gearbox housings, Dillinger also supplies the thickest plates available anywhere on the market: heavy plates up to 240 millimetres in thickness, and with optimised length and width, to ensure that they have a maximum item weight of 25 tonnes and can therefore still be handled at Herrenknecht. For this reason, the plates are also directly purchased by Stephan Göggel's team in the component plant. "We know when we need which specifications, what requirements we have, and what components we will make out of each particular plate. The range of possible

suppliers is narrow, particularly for cutting heads and gearbox housings." Herrenknecht also builds its own spacer, support and adapter rings, bearings and seals, only hydraulic components are bought in. Up to ten rings are installed per drive unit, with diameters ranging from three to eight meters, and individual weights of up to 15 tonnes. Dillinger produces the plates for these rings, but they are rolled to a thickness of 120 millimetres and a width of 400 millimetres at Herrenknecht. For the larger formats, such as the machine for the Santa Lucia Tunnel in northern Italy, for example, the TBM specialist also makes use of Dillinger's special capabilities: rolling of the 200 millimetre thick plates previously cut to size by Herrenknecht is performed by Dillinger's Heavy Fabrication division.

Fast reaction

Once the design of the TBM and the finalised dimensions for the plates are known at Herrenknecht, things can then not happen fast enough, in the view of the production manager, as far as delivery of the necessary heavy plate is concerned. The reason: the entire machine is constructed around the gearbox housing, meaning that the progress of the project now depends critically on Dillinger's delivery performance. Herrenknecht has therefore, for good reason, relied on the heavy-plate experts from the Saarland for more than fifteen years. "Dillinger supplies our heavy plates, tailored specifically to our project, within ten weeks – and that's very fast!" enthuses Stephan Göggel. In his view, this steel producer also scores with yet another decisive benefit: "Reliable adherence to the delivery date also argues in Dillinger's favour – you can't always expect that in the steel industry", the Herrenknecht production manager continues. Around 80 percent of the plates supplied are in steels of Grade S355J2+N in accordance with Herrenknecht works standards, with reduced carbon equivalents to assure good welding properties. Dillinger's heavy plates assure higher Charpy V-notch toughness data than are required by the standard, and thus ensure the necessary safety level for the structure as a whole. In addition to the normal ultrasound inspections, Class S3E3 inspections in special application cases provide extra certainty that the plates are free of inclusions, impurities and large segregations in the plate-centre zone. Herrenknecht also puts its faith in high-performance plates from Dillinger for special products made in Z grades – Z15,

Z25 and Z35 – for stresses in the plate-thickness direction, in cases of thick plates and thick welds.

At the component plant in Schwanau, all the necessary shapes are cut, and the individual elements are then assembled, welded, machined and preassembled to make the completed gearbox housing. A large tunnel-boring machine has a length of six to ten metres, measured from the cutting head to the end of the shield. Its ultimate "giant earthworm" dimensions of up to several hundred metres in length results from the so-called back-up systems, which carry the entire infrastructure for operation of the machine, including belt conveyers or a conveying circuit, electrical control cabinets and hydraulic units, the operating cab, transformers and, in the case of gripper TBMs, even spraying robots for application of shotcrete to the surfaces of the tunnel. For customer acceptance inspections, the machines are assembled at the Herrenknecht plant, filled with all the necessary operating and auxiliary utilities, and connected to a low-voltage electricity supply, in order that the transformers can also be tested. These giant machines are then delivered to wherever necessary in the world, commissioned and put to work. "This is why our most exacting demand on Dillinger is", production manager Göggel continues, "that our target delivery deadlines are met as accurately as possible." An expectation that the Saarland steel producer has been successfully fulfilling for years, despite the narrow time window. "Such reliable delivery is a top feature!" Stephan Göggel affirms. In addition, in his experience Dillinger also offers the broadest product range of plate thicknesses, lengths, widths and grades. "We need a very large number of plates with demanding specifications and high item weights, such as a plate 220 millimetre thick and four metres wide. Dillinger has pole position globally here, using continuous casting." The joint pursuit of new tunnel-engineering records continues. Herrenknecht's order book for tunnel-boring machines is full. Whether for road traffic, for railways or for rapid-transit systems: all around the world, major cities rely on technology from Schwanau, made reality using plates from Dillingen, for the development and upgrading of their transport infrastructures.

14.302 Zeichen inkl. Leerzeichen

AG der Dillinger Hüttenwerke

A literally weighty success product has driven Dillinger for more than 325 years: steel, from the ore to the tailor-made heavy plate and ready-for-installation structural element. This unique range of experience makes this heavy-plate producer the global quality and technology leader, with grades of steel, the majority of which are less than ten years old. These high-performance materials for applications that demand extreme durability under the most adverse conditions of service make the building, earthmoving machinery, mining and mechanical engineering business unit the valued and preferred partner for the best in the industry.

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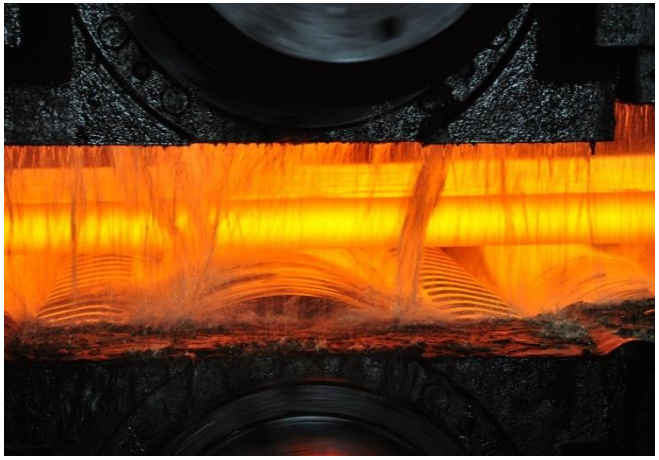

Images 1-2: Around 80 percent of the heavy plates supplied, as always, on-time by Dillinger, consist of steels of Grades S355J2+N in accordance with Herrenknecht standards, with reduced carbon equivalents to assure good welding properties.

Image 3: Successful breakthrough: in the Gotthard Base Tunnel, Dillinger's high-performance plates played an important role in the construction of the Herrenknecht TBMs used.

Image 4: 450 metres long, 3,000 tonnes in weight, 9.43 metres cutting diameter: Sissi, the longest Herrenknecht TBM yet, headed the Gotthard Base Tunnel using heavy plates from Dillinger.

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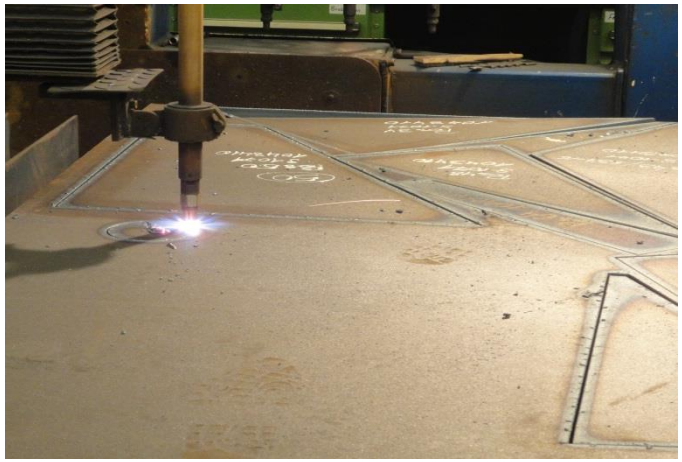

Images 5-6: Heads are the key: the cutting wheel is flame cut from large-format high-performance Dillinger plates of up to 280 millimetres in thickness before the most important, and frontmost, element of any TBM is welded together to form a monobloc and then finish machined.

Image 7: 100 percent Dillinger steel: extremely thick plates from Dillingen are indispensable for the gearbox housing, the dimensions of which are a function of torque and thrust.

Image 8: : To assure stabilisation, Herrenknecht fits I-beams to the back plate of the gearbox housing, which consists of four segments of Dillinger steel.

Images 5-8: © Dillinger

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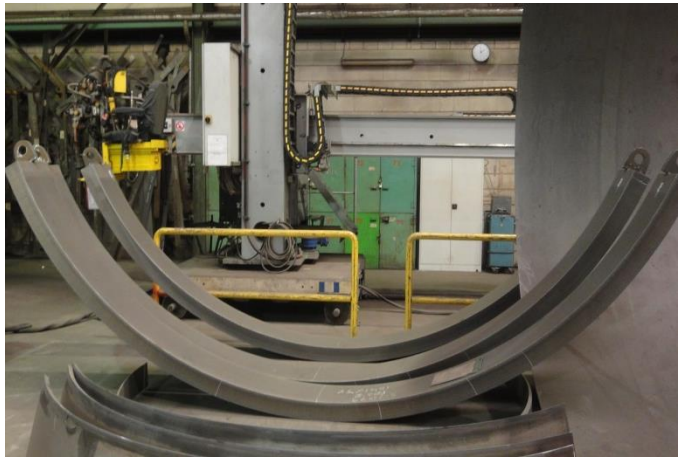

Images 9-10: For each drive system, Herrenknecht installs up to ten spacer, support and adapter rings with diameters of three to eight metres and an item weight of 15 tonnes, each fabricated from Dillinger heavy plates.

Image 11: Monobloc housing: for the largest and, at up to a maximum of 25 tonnes, heaviest unit in the TBM, Dillinger supplies heavy plates of up to 240 millimetres in thickness.

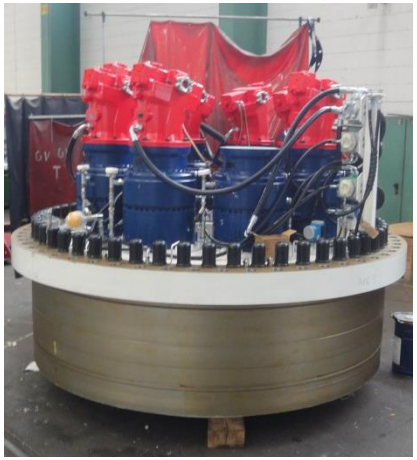

Image 12: The completely preassembled drive unit, with plug-in gearboxes and hydraulic motors, is mounted on a 200 millimetre thick plate from Dillinger.

Images 9-12: © Dillinger

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Images 13-14: 62 metre long "earthworm" for the Albvorland Tunnel: Herrenknecht TBMs are assembled for acceptance inspection by the customer in the just on 75 metre long assembly yards in Schwanau.

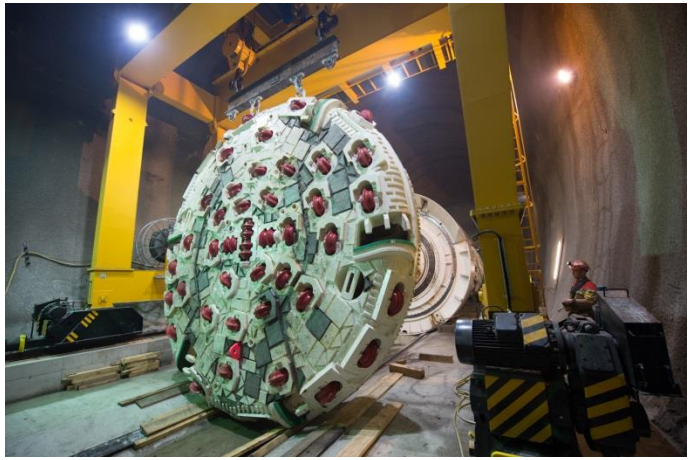

Image 15: Dillinger supplies exceptionally wide plates to Herrenknecht for fabrication of the shield, which protects the TBM's main drive.

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