HOW MODELS ARE MADE

The work that goes into creating models is often unappreciated, with new replicas typically taking from 6 to 18 months to develop. Steven Downes takes an in-depth look at the production process, from conception to delivery.

A meeting between representatives of the manufacturer of the real machine and a model company is usually the starting point for the creation of a new model. To establish what aspects of the model should function, what level of detail is required, the quantity of models required and any time-related constraints, such as delivery for an event or show where the model will be unveiled. Once the model company has all the details and drawings of the equipment, it can create a quote for the cost of producing the model, based on the quantity required and the complexity of development.

This feature's subject is the latest Sandvik scale model, the MT720 tunnelling roadheader, although many of the processes would apply equally to many 1/32 farm machinery replicas. Sandvik has released five different scale models from its range of construction and mining products, and its latest offering is another example of the complex and interesting machinery available to service a specific construction requirement. As with the other models, Conrad has been chosen to produce the replica, and once the order is given, it's full speed ahead. The first stage is to use the various drawings, photos and technical data to begin the process of producing a prototype of the model. This is achieved with a specialised 3-D printer, which gradually builds up three-dimensional plastic parts, 0.1mm at a time, using a laser to harden the liquid plastic on each pass. While these machines are becoming more common, it is invaluable to quickly generate a hand sample, which can be presented to the OEM to demonstrate the functions of the model.

Sandvik MT720 tunnelling roadheader

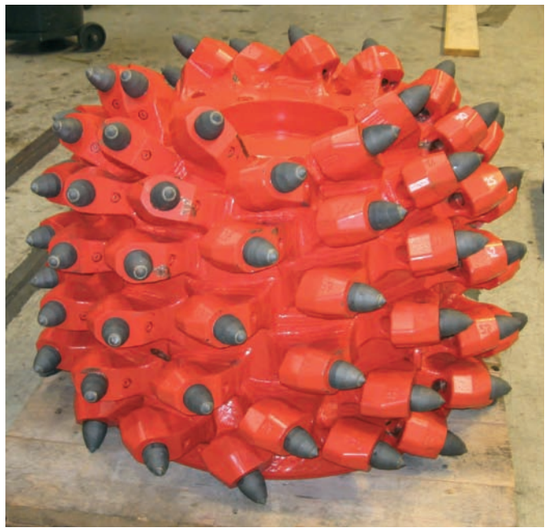
The prototype engineer at Conrad takes the various printed parts and works with them, painting and assembling them to form a full coloured tooling model. Once this has been completed, a meeting is arranged between Conrad and Sandvik where the hand sample can be discussed, with technical engineers scrutinising the sample thoroughly to identify any areas which are incorrect to the original, and ensure the range of movement of the functional parts is correct. Detailed notes are taken on the required changes and these are then acted upon. Depending on the number of changes, a second meeting may be required where an updated sample is once again scrutinised. For the roadheader model, tight time constraints were placed on the project, with the model required for an anniversary event at the Zeltweg factory in Austria. This required Conrad to pull out all the stops, working long hours and weekends to ensure the tooling was completed on time. As is typical of the firm, one of its strengths is delivering to the customer no matter what, even if that means the models are still being assembled the night before they are required and hand delivered to the customer just in time.

Sandvik continuous bolter miner final assembly

Sanvik's Zeltweg factory in Austria is where the full range of its underground continuous mining and tunnelling machines is produced, including high capacity continuous miners and borer miners, continuous bolter miners, hard-rock miners, reef miners, box-hole borers and roadheader tunnel miners. Each machine begins with the arrival of the chassis, with components gradually added until the machine is complete. Due to the size of the machines being built, all are assembled in situ, with the various parts and sub-assemblies transferred to the build area as required. Once fully assembled, the various systems are powered up and given a thorough test before the machine is stripped down for shipping to the customer.

Continuous miners are typically found in coal, rock salt and potash mining applications where the main, full-width cutter drum is fixed and can raise and lower to make a rectangular cut. The entire machine moves forward while the cut material is collected at the front before being transported through the body via a double chain conveyor and then discharged at the rear into a waiting hauler.

Sandvik continuous bolter miner being assembled

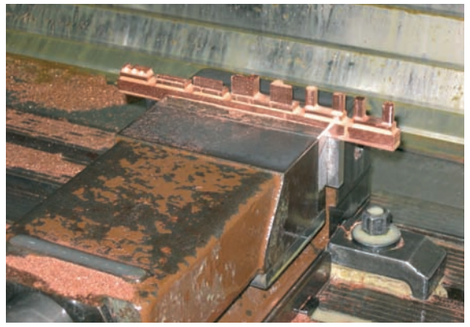


Sandvik roadheader cutter assembly

Sandvik borer miner cutter assembly

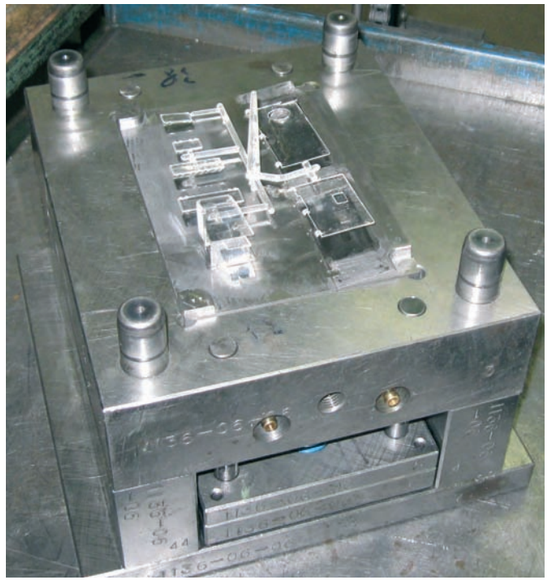
These types of miner are highly productive in soft material but are of no use for cutting rock. For this, the roadheader is needed, and several different versions are produced depending on requirements. The MT720 is the largest tunnelling roadheader in the range, designed for economical excavation of rock exceeding high compressive strength rock. Weighing 135t, the MT720 features a telescopically extending boom with unique transverse cutting technology to make light work of tough rock. The boom

Outside storage area for the manufactured castings before final machining

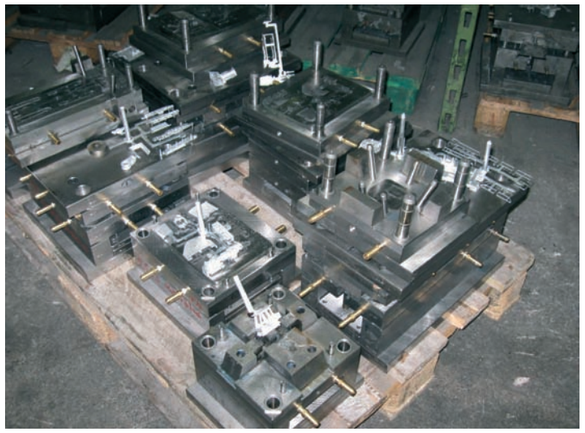


Copper master being machined

Set of copper masters which produce the base section of the conveyor



Tooling and sample of the clear plastic parts for the MT720 roadheader



All the tooling needed for the MT720 zinc parts

movement allows the cutter to cut a tunnel 6.6m high and 9.1m wide, and the machine has an installed power rating of 522kW (700hp), 300kW (400hp) of which is for the cutter motor. The installed chain-driven conveyor is 840mm wide with a capacity of 400 cubic metres/hr.

While a number of the parts and castings are produced at other factories and shipped in for final machining and assembly, all the gearboxes and cutter elements are developed and produced at the Zeltweg facility where the various gears and housings are machined in the workshops. Outside, staging areas are used to store the various cast sections for the different machines. These require additional machining which is done in the machine shops before assembly takes place. Each machine is only as good as the work tool, and it is this part of each machine which receives a vast amount of research and development to ensure it will perform to the customer's expectations. To aid this, there is an R&D area within the factory where rock samples from around the world are used on a special machine to test the cutting characteristics of the various tools. High-speed cameras and sensors allow the research team to analyse cutting performance.

The research also carries out investigations on various machine parts to ensure the structures are strong enough for the job they are designed for. To further this research, for each new prototype machine developed a special test is performed on a large concrete structure which can optionally be filled with different types of rocks to ensure the prototype's cutting performance. This special structure is then refilled with different densities of concrete for the next set of tests.

The cutter drums are accurately adorned with the holders that secure the replaceable picks. Based on the research, these housings are welded into place at specific angles and distances to achieve optimal cutting performance. Once fixed onto the drum, the welders get to work building up the metal one weld at a time until the full contour is achieved.

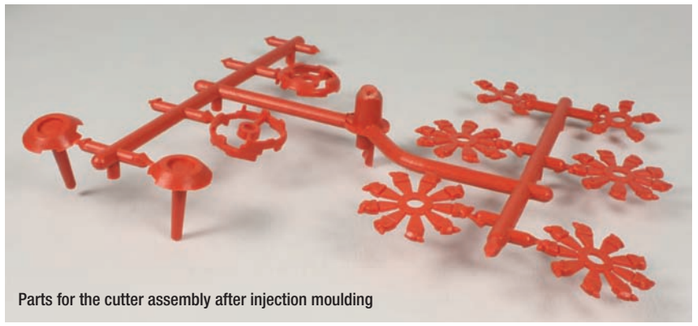
Computerised cutters produce the various gears and pick housings and, once machined, the parts are sent to the heat treatment area where the hardening of the gears and wear parts takes place. Large cranes are used to lift the cradles, containing the different parts to be treated, which are placed into large ovens where the temperature is raised to 800 degrees. This can take several hours before the cradle is removed from the oven and quenched in a tank of specially formulated oil. The quenching process is a sight to see, producing plenty of flames.

The highly detailed 1/50 scale MT270 model from Conrad has captured all the functional movements and details of the full sized machine very well. Consisting of 270 parts, the amount of tooling that has gone into it is impressive, particularly considering the time it takes to produce each mould. Once everyone is happy with the hand sample, the real work begins with the production of the tooling. This is carried out at another Conrad facility, about five miles from the main assembly plant, where the zinc parts are cast. The first stage in the tooling process is to decide on the layout of the parts for each tooling mould, staff using years of experience to lay the various parts to ensure they will cast correctly.

The machinery used to produce the tooling moulds from the copper master

From this, the copper masters are machined. This process is very time-consuming, and uses a selection of cutting tools, some of which are less than 0.5mm for extremely fine detailing work. During a visit to the factory, the computer controlled machines were busy at work with the various cutting operations taking up to 32 hours to complete, running 24 hours a day.

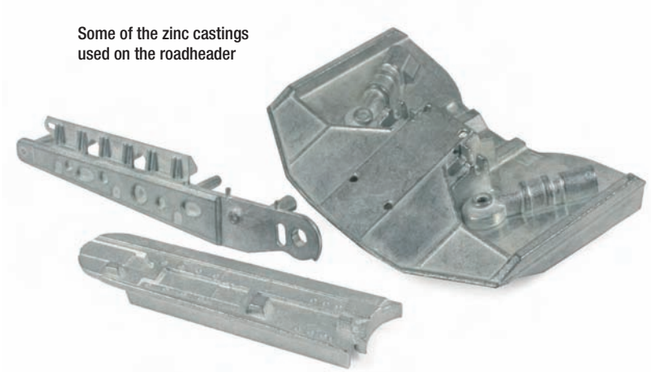
Once the copper masters are complete, they are fitted to the machinery that makes the tooling moulds used for the actual casting of the parts. Because the moulds need to be strong, it's not possible to cut the metal using cutters as they would constantly break or become blunt, so the copper masters are fitted to a machine which uses electrolysis to gradually form the pattern in the mould. The entire platform is submerged in a special oil formation and the machine applies current to the copper master, effectively causing a series of tiny explosions where the positive copper master contacts with the steel mould. This process continues, gradually forming the void where the part will be cast. The number of copper masters required for a single piece is remarkable, and demonstrates the vast amount of time and effort that goes into producing each individual mould.

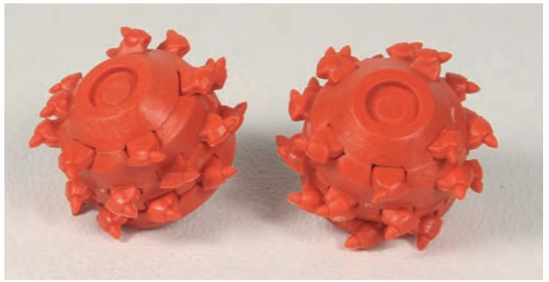


Parts for the cutter assembly after injection moulding

The tooling moulds for the Sandvik MT720 are used to produce both the zinc and plastic parts for the model. Only the zinc components are produced at the casting facility, with several moulds required to produce the metal parts for the roadheader. A nearby image shows the tooling with examples of the cast parts placed above, demonstrating the way the molten zinc material flows outward from the centre of the mould to cast the different parts. Once the tooling is fixed to the casting machine, the mould closes, followed by the injection of the material. A short period is needed for water to be flushed through the mould to cool the

Some of the zinc castings used on the roadheader





Assembled cutter heads for the MT720


Manual spraying of small parts


Paint spray booth in operation


Painted parts stored and awaiting assembly

newly cast parts enough for them to solidify before the mould opens and the parts are extracted by small rods pushing them out. Depending on the size of the parts, some casting machines allow the parts to drop onto a conveyor, while larger or heavier parts need to be carefully extracted by an operator to ensure they are not damaged.

The castings have rough edges due to the casting process, and these require cleaning off. Some are cleaned by hand, while others are added to a vibrating drum filled with small grinding stones which rub against the cast parts, removing the sharp edges and flash material. Once the parts are completed, they are stored in bins awaiting transport to Conrad's main assembly facility.

While the original drawings and CAD files are used for developing the moulds, there are some areas on the model where it is not possible to cast the parts in a single piece, due to the casting process and intricate nature of the item. One example is the cutter head on the MT720, which is impossible to cast in a single piece due to its complex construction. Conrad's technical engineers' clever solution was to make each side of the cutter head from seven pieces which interlock to form the completed item, which is then painted to match the rest of the model.

Once the tooling has been completed, the first zinc and plastic parts can be cast, painted and printed, and these are then used to produce the pre-production sample. At this stage, any small issues with the tooling can be adjusted to ensure the model can be assembled without any problems. Due to material shrinkage from the casting process, all the various holes are checked, ensuring the parts still fit together snugly. Any under or over-sized holes can be adjusted in the moulds before production commences.

The pre-production model is also the opportunity for the customer to have a final look, highlighting any decoration issues on the model or any small problems, which were not picked up on the earlier samples. In the case of the Sandvik MT720, 92 pre-production models were produced for the anniversary event, a quantity far larger than normal. This is also the stage at which the final packaging is signed off, ensuring that all the technical information and images printed on the outer box are correct.

Located in Kalchreuth, a small village on the outskirts of Nuremberg, the Conrad factory houses facilities for assembly, painting, printing, injection moulding, spare parts storage, main warehouse, showroom/museum and offices.

As the cast parts arrive, they are transported to the paint department, where workers place the pieces onto metal trays which have a mesh weave. As each tray is filled, it is either temporarily stored in wheeled racks or placed directly onto the continuous painting conveyor which slowly rotates, taking the trays through to the spray heads.

Spray guns are mounted to a moving framework which travels back and forth under computer control. As a tray enters the opening, a sensor detects that the parts are entering and the motion begins. Each head is positioned at a different angle to ensure full coverage. Adjustments to the height and angle can be made by the operator as the first tray passes through the bay to ensure correct coverage, while numerous controls allow the strength of the spray heads to be adjusted to prevent small or light components from being blown off the trays.

The trays exit the paint bay and continue travelling into the drying station where air is blown onto them. The next stage in the drying process involves the trays passing under hot blowers which dry the paint, before they exit the dryer onto a continuous conveyor. At this stage, if the parts are complete, the trays are removed and stored in racks.

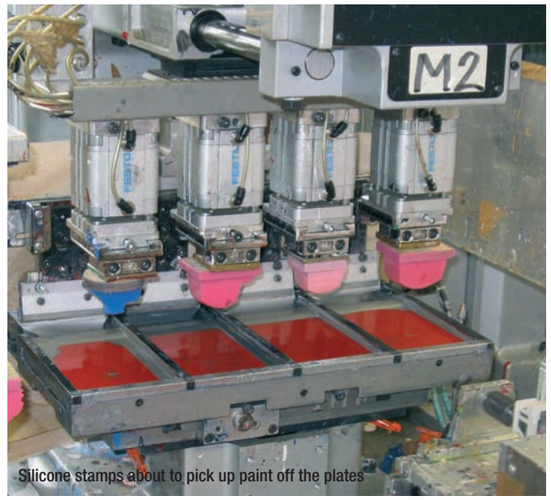
For vast numbers of parts, the automated paint system is very effective, but very small components often need painting in a different colour, such as the Sandvik MT720's exhausts. For this, the parts are laid onto the tray and taken to the manual spray booth where a worker carefully sprays the components by hand, before taking the tray and inserting it into the dryer. All the paints used by Conrad are water-based, and each change of colour requires all the heads and piping to be thoroughly cleaned. Depending on the models being produced, this can happen several times a day. Once the parts have been painted, it's off to the printing room.

Several different operations take place simultaneously within the factory so that all the parts arrive at the same time for assembly. While the printing operation is underway in one part of the factory,

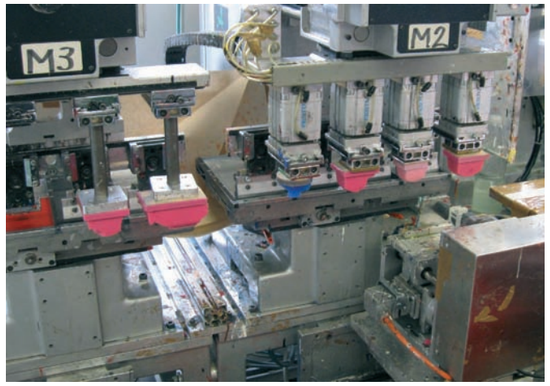
Sample of the packaging showing the technical information


Pre-production sample of the fully assembled MT720, ready for final approval by the customer


Trays of parts loaded onto the conveyor and entering the spray booth



Silicone stamps about to pick up paint off the plates



16-colour printing machine at work printing the cab

the plastic injection moulding machines are busy producing the plastic parts for the roadheader. The colour match of the parts is very impressive, although in order for a plastic part to look the same as a cast zinc part, it is also passed through the paint shop to give the same quality of shiny finish. Other parts can be used without painting, like the individually linked plastic tracks, which are moulded eight pads at a time. The tooling for the plastic injection moulding is made in the same way as the zinc parts, with the moulds closing and the molten plastic injected into the mould before water flows through the channels in the mould to cool and harden the plastic, the mould then opening and the parts ejected onto the conveyor. For all clear parts, the interior sections of the mould need to be highly polished – a time-consuming job taking several days – to ensure that the plastic is crystal clear.

Different parts require different types of plastic, from the soft and pliable types used for the hydraulic cylinders to the hard plastics required for structural components. A vast array of different types of plastic pellets are blended with special colour pellets to obtain the correct colours for the model. Trial and error is initially used to obtain the perfect combination of colour for a very close match, and once obtained the formula is recorded for future use.

In the machine shop, various guides and assembly aids are produced to allow the workers to hold the model parts during the production and printing processes, while small adjustments can be made to the tooling when the parts don't quite fit together and tolerances need to be adjusted slightly for a perfect fit.

The printing room houses several machines used to produce the various markings and artwork onto the parts before assembly. Once the design has been completed, each colour is separated and the design for each one is etched onto a plate. The depth of the etch depends on the amount of paint required on the model.

Once etched, the plate is fitted to the printing machine, one per colour. The centrepiece of the printing room is the 16-colour printer which can be configured to operate in a number of different ways. The entire bed is computerised and the part is fixed to the jig, which can rotate through 360 degrees, allowing intricate printing. For the Sandvik cab, six different prints are required. Each of the silicone stamps is shaped for maximum transfer of the paint to the model, with the different colours representing different strengths of stiffness of the silicone to match the printing requirements of the part.

As each component is fixed to the jig, the plates are covered with paint, which a blade then removes to leave a small amount in the etched area. The arm moves back in one motion and all six silicone stamps are pressed against the plates, transferring the paint onto the silicone. The entire frame then moves forward, lining up over the part to be printed before lowering and transferring the paint from the silicone onto the part. This is repeated for the remaining operations, with the cab rotating to allow printing of the design (both dark grey and silver) on all four sides.

While the automated printing ensures accurate placement, there are also a number of small single and two colour printing machines. To increase the printing speed, the machine shop produces assembly aids which are fitted to the bed of the printer. The operator places the part against the aid and holds it in place while the design is transferred to the part.

Assembly of the model starts once all the parts have been cast, painted and printed. There are several different models being produced on the assembly line at any one time, and the assembly process is split into a number of distinct steps, depending on the complexity of the model. With 270 parts, some pre-assembly of the roadheader's major components takes place. The track frames are assembled and the tracks fitted, while another worker assembles the stabilisers to the main chassis casting.

Two of the plastic injection moulding machines busy producing the MT720 track pads and white plastic components

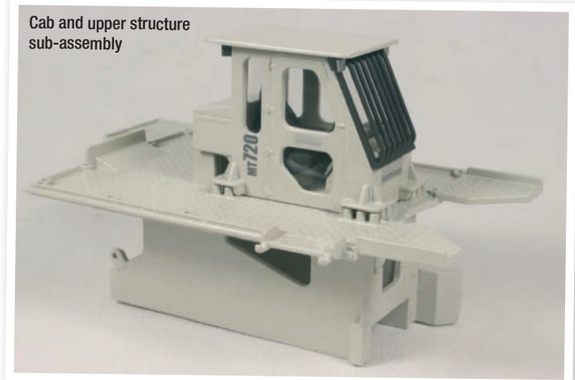
Paul the production manager demonstrating the assembly stages

At another assembly station, the front section of the model is assembled. These components are then transferred to the next worker, who fits the engine and deck components. Once all the sub-assemblies are complete, they are transferred to the final assembly where the model finally takes shape, connecting the cab, upper deck, track frames, conveyor and cutter arm. The range and type of tools required for assembly is surprising, with a vast array of hand-operated presses with different jaws and attachments used to crimp the various rivets. Glue is used sparingly to ensure components remain in position during shipping while screws are used to join the main sub-assemblies together.

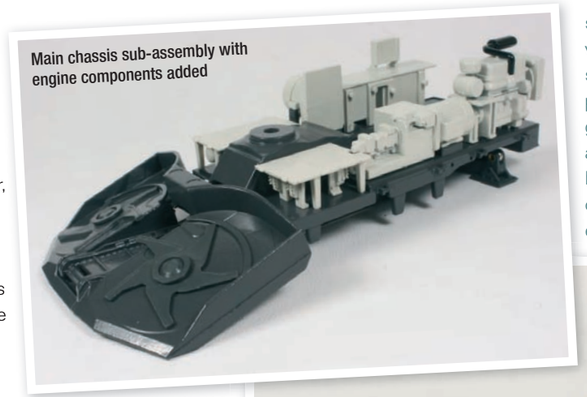
The final stage in production is a final inspection before the model is securely packed ready for shipping, the materials used depending on the type and weight of the model. Truck models are typically packed in the traditional foam-lined cardboard packing, while other options include polystyrene cartons or, in the case of the roadheader, a stiff cardboard box with pre-formed foam inner, which securely holds the model. The entire process incorporates quality controls at each stage, with each worker, while performing his/her stage of assembly, checking for defects or errors from the previous stage. This helps ensure that, by the time the model gets to the final packing stage, it is in perfect condition.

An important part of quality control is the spot check. The production manager selects one of the finished pieces, unpacks it and then gives it a full inspection, ensuring that the hydraulics are stiff and remain in position as the model is tapped on the desk. All moving parts are checked for correct function before the model is repacked.

Staging areas adjacent to the assembly area contain the parts for the next models to be produced, and in a typical week, it's not unusual to have several models waiting to be produced, with the factory running at full pace to ensure the models arrive with the customer on time.



Cab and upper structure sub-assembly



Main chassis sub-assembly with engine components added

Thanks are due to Conrad for inviting me to see the entire production procedure. I was very privileged to be able to spend two days seeing firsthand the entire manufacturing process, not to mention actually being given the opportunity to try my hand at assembling several sub-assemblies for the MT720 and, for a short time, operating one of the printing machines. It was an experience I won't forget!

Bringing all the sub-assemblies together for final assembly