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An interim product during the vacuum precision casting of turbine blades: clusters with ceramic moulds

Production of turbine blades

Robot-controlled tool construction for precision casting

A wireless connection to a rotating robot gripper – the industrial engineers at Doncasters Precision Castings in Bochum have now single-handedly realised this type of signal transmission. Their chosen solution deploys a wireless sensor from steute: it signalises the operational status of a gripper which removes clusters from a suspension track. Here an overview of the technology.

A robot removes a wax cluster from a suspension track, dips it into a basin containing a thick white ceramic-based liquid and moves the cluster around so that the liquid also reaches into any undercuts. Then it holds the cluster in a rotating drum, where it is

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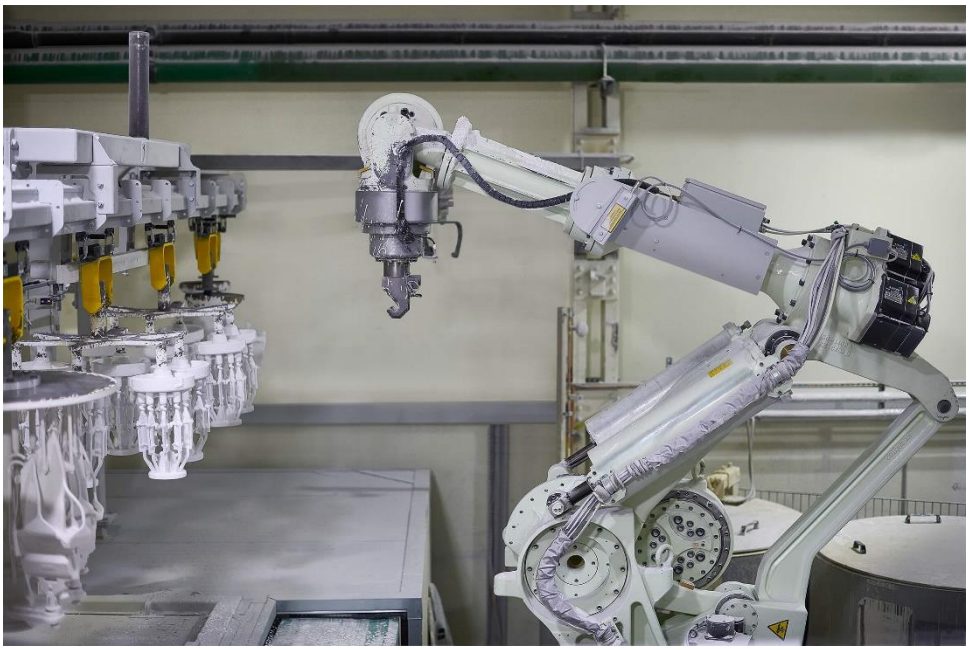

The robot identifies the cluster via RFID, takes it from the rack, dips it into a ceramic basin and allows any superfluous material to run off in a predefined movement profile

"sanded", i.e. the cluster is covered in sand while it is still wet. This process – which also includes drying the sanded ceramic mass in a special chamber – is repeated multiple times. The result is a ceramic casting mould around the wax model featuring very high form stability. In a subsequent process, the wax is then melted out of the casting mould. Once the empty mould has been fired, liquid metal can be poured into the cavity.

Highly complex production process

This is how Doncasters Precision Castings-Bochum (DPC) makes casting moulds for blades and vanes used in stationary gas turbine power plants and aircraft engines. It is just one of many steps in the highly complex precision casting process, in which turbine blades of up to 80 cm in length are created using the lost-wax technique. They are able to meet the highest of demands: in the gas turbines, the blades are blasted with gas at temperatures of up to 1,400 °C and achieve rotational speeds of 50 to 60 Hz (rotations per second). Under such extreme conditions they still have a lifetime – as required by the turbine manufacturers – of at least 10,000 hours.

The industrial engineers at Doncasters have comprehensive expertise not only in precision casting, but also in manufacturing. Guido Neef, maintenance expert at the Bochum plant, began to research options after it transpired that the above production process involving robot-aided mould production – or more precisely, the robot grippers themselves – required some optimisation. Neef describes the process as follows: "The cluster travels from station to station via a suspension track and is removed by the gripper from its rack. Here a bolt drives pneumatically into the core of the hanger to fix the swinging cluster – a prerequisite for accurate three-dimensional movement of the cluster into the basin."

Wanted: position monitoring solution

Visitors are always astonished to see how many different clusters hang from the suspension track. The variation is very wide, and each part demands different movements of the robot during the mould production. Each robot station therefore has an RFID reader which

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identifies the part in question and starts the corresponding programme.

Optimisation was required because in some cases the bolt of the robot gripper could not drive into the hanger. This can happen, for example, if the bolt is tilted or otherwise not perfectly positioned. Then the machine fails to detect that the cluster guided by the robot is still able to swing. This in turn means the risk of a collision with machine components. The idea: a sensor which detects whether the bolt has driven fully into the core of the hanger. Such monitoring is fundamentally simple to realise, for example using an inductive sensor. In this case, however, the challenge was the power and signal supply: "Because the gripper has to be able to rotate 360°, a power supply is difficult to realise. This is why the bolt is driven pneumatically", Neef explains.

Found: inductive wireless sensor

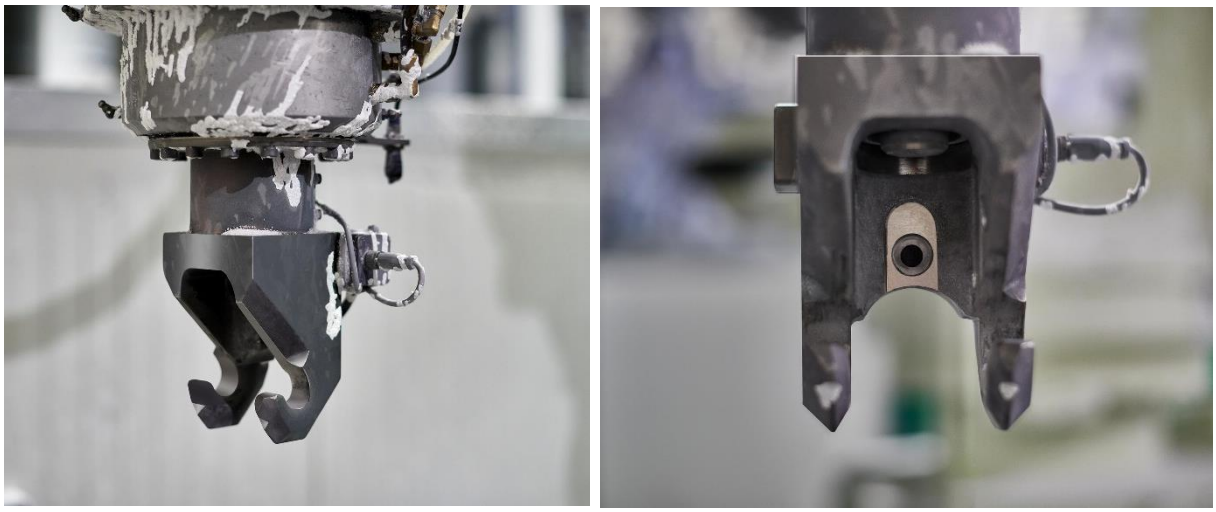
The logical solution: a battery-powered sensor which sends its signals remotely. This enables cables to be eliminated all the way to the end of the gripper head. Intensive searching for a suitable sensor led Neef to the website of steute business division "Controltec", which offers a comprehensive range of industry-compatible wireless switches and sensors. These devices are supplied with power via a long life battery and communicate via radio with the corresponding receiver unit, which in larger machines is located inside the control cabinet.

Following advice from steute, a wireless inductive IS M 12 sensor was selected. A separate compact module manages both the power supply and the signal transmission. It uses the sWave wireless technology developed by steute, which guarantees reliable signal transmission even in adverse industrial conditions.

The maintenance team at Doncasters initially installed one such sensor on a robot gripper for test purposes – protecting the separate battery module with an enclosure they had built themselves. The sensor is fixed inside the gripper and detects reliably whether the bolt is fully extended and the otherwise swinging link between gripper and cluster rigid. The robot does not start until the sensor emits the corresponding signal. This signal arrives at a receiver unit with an antenna, fixed to the control cabinet a few metres away.

Minimised risks, increased availability

Admittedly: it is an exceedingly skilled operation for users of highly automated



The robot gripper (a) with a retrofitted wireless sensor central to the bolt receptacle (b)

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Guido Neef (r.) solved the problem of how to send signals from the rotating gripper to the robot control system and incorporated the wireless sensors in the Doncasters cast manufacturing process. Left: Sascha Elsner, Product Manager Wireless Applications at steute

machines to intervene in both the mechanics (installation of the wireless sensor inside the gripper) and the control technology (integration of the sensor signal in the robot programming). Not every manufacturer will have the necessary skills to do this. Doncasters had the expertise to tackle and realise this complex task. And the result speaks for itself: the wireless sensor with point-to-point wireless connection functions perfectly, even within threshold ranges. The robot does not start until the bolt is completely driven into the gripper. This eliminates any risk of loss or damage to the machine, and also to the casting moulds. The consequence, according to Neef: "Out of the five robots we have in the mould production, we have already equipped three with wireless sensors, and the other two will follow."

Precision casting of turbine blades

The casting process at Doncasters Precision Castings-Bochum (DPC) begins with the melting of nickel-based (super)alloys. The moulding shells for the casting process are created at their own factory. They also make the cores, which within the cast part represent the hollows inside the blades. They are created from a ceramic material using an injection moulding technique, then fired and processed using precision CNC machining. The cores are coated in wax, which acts as a "placeholder" for the molten cast and therefore also the part. The wax is then encased in ceramic material, creating a mould which – at a pre-defined temperature and humidity – is dipped into a liquid ceramic mass multiple times, "sanded" in drums and then dried. After the mould shell has been built up layer for layer, the wax is then melted and removed, and the mould shell filled with hot liquid metal up to temperatures of 1,500 °C in a vacuum furnace. The final stage is a controlled and very slow cooling process.

About Doncasters

At more than thirty production sites across Europe, the US and Mexico, the Doncasters Group, which was founded by Daniel Doncaster in England in 1778, creates complex cast parts for applications with critical tolerance levels. The approx. 500 employees at Doncasters Precision Castings-Bochum GmbH (DPC) use precision casting methods to produce blades and vanes deployed in aircraft engines and industrial gas turbines. There are not many companies in the world which manufacture highly robust cast parts with this level of precision, and which can also cast polycrystalline and monocrystalline-based solidified parts. The company profits from its high level of expertise: the high demand for blades and vanes, especially for gas turbines – buzzword alternative energies – has led to the Bochum site currently planning an expansion.

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