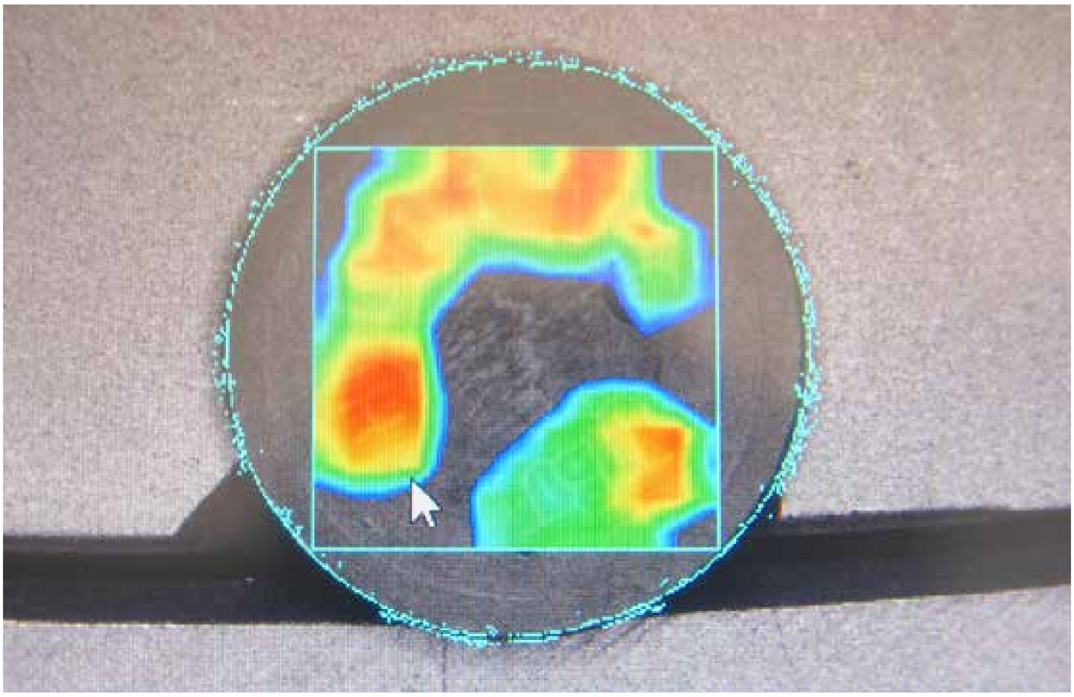
CASE STUDY



AI and measurement precision, the challenges in controlling titanium rivets for aeronautics

Designed specifically for the quality control of anodized titanium rivets used in the aeronautical industry, the sorting machine in this case study is an indexed metal table machine, model MCV1, equipped with dedicated stations and software.

In addition to the prerequisite of a selection rate of no less than 100 pcs/minute, the context poses 3 challenging controls.

1. Mandatory and very low production tolerances: 12 microns on the diameter of the rivet
2. Checking the footprint for the Allen key in the foot to discard the pieces with double broaching
3. Legibility check of the writing on the head

During the testing phase, the situation proved to be even more complex as the surface coating of the rivets is delicate and subject to scratching easily.

12 micron tolerance control

The vision systems usually used by Dimac are designed for the control of production tolerances up to 50 microns, a range that covers the majority of small metal parts applications.

For smaller tolerances, the control system must be designed ad hoc, adopting measures that are more stringent the lower the tolerances to be controlled.

In addition to increasing the resolution of the camera and using high quality telecentric lenses, a lens aberration correction algorithm (aimed at reducing the effects of glass inhomogeneities) and a backlighting system have been added. particularly stable over time (to make the diffraction effect at the edge of the piece uniform between the different images). The vision system is then completed by software filters that limit the effects on the measurement of dirt inevitably present in the production environment.

The entire measurement sequence, due to the various software corrections adopted, is particularly heavy in terms of calculation. To capture and process three images per piece (corresponding to three longitudinal sections arranged at 120°) at a rate of 100 pieces per minute, an industrial computer equipped with an NVIDIA graphics card was used.

The result is a machine capable of passing the MSA1 and MSA3 tests even with the design tolerance range of 12 microns.

It may be interesting to observe that the increase in camera resolution brings to significant advantages in terms of measurement quality, but, at the same time, affects the productivity of the sorting machine. The solution adopted is therefore the best compromise between the need for control and productivity, in order to provide the best quality-cost combination.

Checking the hexagonal footprint in the foot of the piece

It is required to check the presence of the hole in the foot, the presence of the hexagon and the absence of signs of double broaching.

If this last defect is present, the impression takes on a star-like shape, generated by the slight phase shift that occurs between the first and second passage of the cutting edge.

The check, generally required for the head impression, in this case carried out on the foot impression with a size of 2 mm.

The main difficulties are once again the stability of the image, the difficulty of adequately highlighting all the defective situations and the implementation of an interpretation algorithm capable of effectively recognizing the defect, without false rejection.

As regards the image, we opted for an entocentric camera with annular illuminator directed on the lower edge of the foot. This illuminator, for obvious geometric reasons, provides homogeneous lighting only if the framed piece is placed exactly in the center of the frame (tenths of a millimeter are relevant). Taking advantage of the production tolerance of 12 microns on the diameter, care was taken to create the grooves of the transport table so that they constitute the verticality constraint of the piece. Through a spring catch positioned above the table and the perfect coupling of the chamfer of the slots with the head of the piece, this remains in the position even in the presence of vibrations.

The result is an image in which the hexagonal imprint stands out in black within the light circular crown of the foot of the piece.

For interpretation, the problem is once again dirt, because the edges are not perfectly clear: it is not sufficient to identify the presence of the hexagon, because in the case of double broaching it would be detected anyway; it is not sufficient to check the minimum or maximum hexagon dimensions that describe the transition area of the wrench, because dirt could have a decisive influence.

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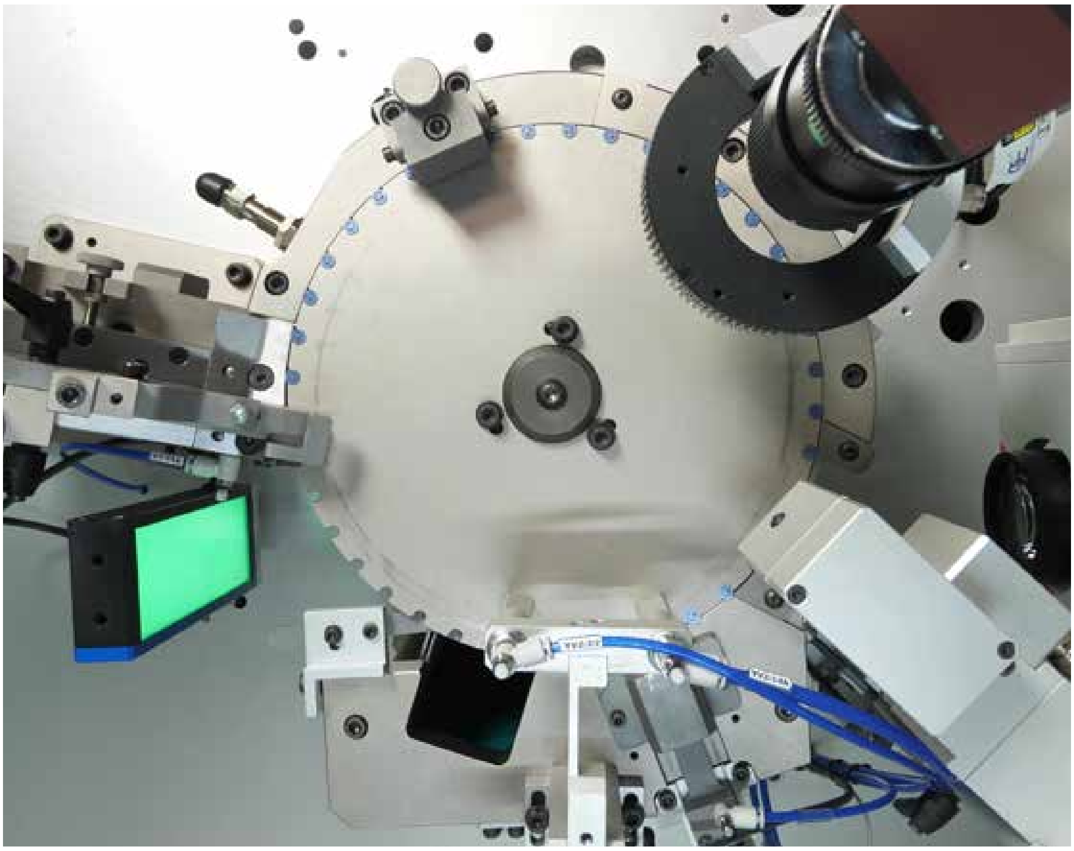

It was necessary to develop an algorithm based on the gradient of light, i.e. on the extension of a band of gray around the circumference inscribed in the hexagon, counting the number of times in which the gradient crosses a second circumference of a diameter set by the user. The measurement of this circumference establishes the threshold between the acceptable dirt and the real defect, thus making the sensitivity of the control adjustable.

Legibility check of the writing on the head

In the flat head of the rivet, a writing with variable content is imprinted by marking, for example the production batch. When the piece moves under the marker, the writing appears double or blurred and therefore illegible.

This type of defect, undetectable with traditional image analysis techniques, is now detected using artificial intelligence.

The AI usually integrates valid OCR (Optical Character Recognition) functions for common situations and can also be trained to recognize characters with special fonts, randomly arranged in space and along curvilinear paths. In the specific case, however, the OCR functions require long computational times and would not make it possible to control at the required rate of 100 pieces per minute. The solution adopted is instead based on a training of the neural network that is indifferent to the reading of writing, trained exclusively on the recognition of the defect. In essence, therefore, the AI was not trained to read the writing, the content of which is not of interest, but it was trained to look for the defect, looking for peculiarities independent of the textual content. For this procedure to be effective, the stability of the image plays an important role: instabilities constitute a sort of background noise in the training process which blurs the boundary between compliant and non-compliant components. Again, as with the previous checks, the theme of the search for technical-economic optimization arises between computational times, ability to discern the defect, investment in the quality of the components.

Handling parts with delicate surface coating

Rivets, made of titanium, are normally not handled with particular care. The delicacy of the coating manifested itself exclusively during the machine setup phase, in the 360° rotation of the piece inside the slots of the transport disc: the side wall of the rivet was occasionally abraded, however with exclusively aesthetic repercussions.

The phenomenon, clearly caused by the contact between the disc and the piece during rotation, is episodic and generated by the combination of a series of elements that prevent the measures normally used in these cases from being adopted.

The first method to avoid any risk of abrasion consists in lifting the piece above the disc surface: in the case in question it is not feasible because the lifting time would significantly influence the reduction of the cadences.

An alternative is to increase the light of the slots: this is not feasible since the precise coupling between the slot and the piece, as we have seen, is functional to the control station of the impression in the foot.

The only way left is to contain the rotation oscillations of the piece, including games, within the clearance of the slots (5 hundredths of a millimeter): a mechanical challenge that can only be overcome with craftsmanship in the care of the individual components and the assembly.

AI and Training

By definition, control with Artificial Intelligence is not achieved through an analytical calculation that follows rules pre-established by the programmer, as happens with traditional vision software. The Artificial Intelligence algorithm calculates a series of variables that define the degree of similarity between homogeneous images by category (for example compliant and non-compliant parts). This series of variables, called a neural network, is then used to evaluate the degree of belonging of a new image to one category or another, based on a sort of percentage of similarity.

AI therefore does not have the limits of the analytical interpretation of the image but, by generating search criteria autonomously, follows logics that are not directly comprehensible to the human mind. This makes it a very versatile and powerful tool, but the results are not completely predictable a priori and, for this reason, a phase of careful validation in the field must be taken into account.

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The AI training process (the creation of the neural network) requires, in addition to an appropriately equipped computing station and the necessary software licenses, specific expertise to quickly arrive at solutions that are effective in selection and efficient from a computational point of view.

It also requires a considerable amount of calculation time, both in the training and validation phases, a reason which, alone, pushes us to avoid carrying out the training on the sorting machine to avoid long non-productive times.

While leaving users the possibility of equipping themselves, Dimac has structured itself to perform neural network training and offer it as a remote service. To make the process efficient, a simple procedure was implemented in the machine software, which supports the operator in acquiring images of compliant and defective samples in sufficient quantity. Dimac performs training on these images, refines it and validates it, and then installs the trained neural network on the machine.

The 100% control of writing on the heads of the rivets is a problem that cannot be solved with traditional techniques, where AI is currently the only way forward other than the human eye. And the human eye is necessary today, and perhaps will always be, in defining and optimizing the AI work process.