PRACTICE REPORT ABOUT THE X-RAY INSPECTION OF CHASSIS UNITS IN ALUMINIUM CASTINGS FOR THE AUTOMOBILE INDUSTRIES

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Abstract: In the future, the increasing customer requirements with respect to automatic x-ray inspection of chassis units, produced in aluminium casting, will demand an intensified co-operation between the customer, the producer of aluminium casting and the manufacturer of x-ray stations.

Depending on the available cycle time and the structure of the inspected part, different influences have to be considered.

An example will demonstrate the necessary effort needed for an automatic inspection with a flaw-detection of 0.8 mm^2 diameter.

Introduction:

ThyssenKrupp Fahrzeugguss GmbH

Headquarter Kloth-Senking Metallgießerei, Hildesheim

Competence Center Light metal Castings

Employees 1800
Apprentices 73

- Aluminium – High pressure die casting
- Magnesium – High pressure die casting
- Aluminium – Permanent mold
- Machining
- Module assembly
- System Development
- Prototypes

100% Automotive Supplier

Main Customers

- VW
- DaimlerChrysler
- Bosch
- BMW
- Fiat
- Getrag
- Porsche

Certified as per
DIN EN ISO 9001 :2000 + DIN ISO 14001 + ISO/TS 16949:2002

Plants

Kloth-Senking Metallgießerei, Hildesheim

Fritz Völkel, Wuppertal

DGT, Radevormwald

ThyssenKrupp
Rautenbach Castings GmbH,
Wernigerode

ThyssenKrupp Guss S.A.
Mieres (Spain)

Concordiahütte, Bendorf

ThyssenKrupp
Aluminium-Technik s.r.o.,
Hradek nad Nisou
(Czechoslovakia)

Introduction: Depending on the component size and geometry and the error variables to be detected, there is a direct relation to the necessary expenditures for a test application.

The minimum duration of a test cycle is basically determined by the necessary recording time of the picture series per casting and by the positioning times.

The picture evaluation is effected at the same time as the picture creation. The recording time is to be determined according to the picture-providing system and the necessary SNR (signal Noise Ratio).

Depending on the used x-ray tube, the error variable and error extent to be detected are at least 1 mm in all directions in case of material of 20 mm thickness. They are basically determined by the dissolution of the existing picture-providing system and the maximally possible direct enlargement (depending on the tube focus).

Usual enlargement values are for instance factor two, which corresponds to a resolving capacity of approximately 0,2 mm with a flat picture detector with a pixel size of 0,4 mm. Higher enlargements are not recommendable in the radioscopy in case of use of macro tubes with usual focal spots of 1,0 mm (according to EN 12543) due to the geometrical blurring.

X-ray tubes with smaller focal spots are often impossible to be used due to the smaller capacity. The increase of the enlargement requires an increased number of test positions. Due the larger distance of the component from the detector, the input signal decreases, which is to be compensated by a higher number of frames and / or has to adjust the smaller quantum statistics.

That means: The minimum errors to be detected should have a pixel diameter of 5 pixels and more for a more reliable detection. Moreover, errors to be detected should have a minimum contrast of 4% concerning the digitisation depth of the picture-providing system.

Due to the two-dimensional illustration of the test specimen in the test picture and the resulting evaluation, there might be difficulties regarding different test specifications in a test position. This leads to an increased portion of detections which can only be clearly assigned by additional test positions.

In Fig. 1, the red-marked test region represents the range of the basic body, the green-marked range represents die tension strut connection. The range where the range of the basic body overlays the connection range is marked with yellow colour.

Due to the higher requirements for the tension strut connection, this range has to be tested with the higher test specification.

In case the permissible error is to be found in the basic body, the error is shown also in the tension strut range due to the two-dimensional representation of the error, thus resulting in the wrong evaluation of the component.

Parameterised test specifications like the failure rate criterion cause in this connection additional detections.

Due to the component geometry and the limited degrees of freedom of the manipulator systems (robots with gripping fingers), you cannot exclude the avoidance of overlapping ranges.

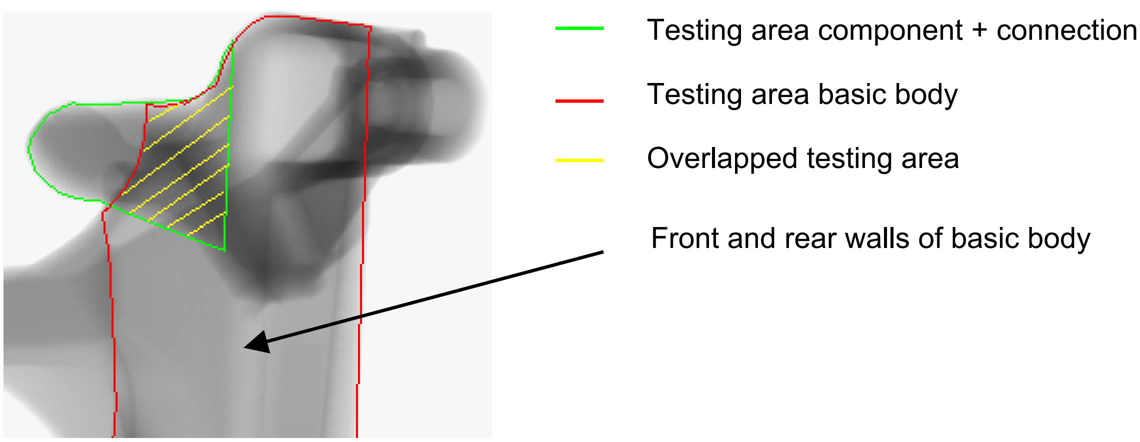

Fig 1: Overlapped testing areas

Plants with automatic picture evaluation are to be adjusted with relatively sensitive filter algorithms in case of detections of errors 0,8 mm^2. Depending on the place of setting up the test system in the production cycle and the condition of the component, this can lead to substantial false detections.

Fig. 2 shall allegorate the balance. Components with burrs cause detections along the burr edge, which would lead to rejects in the course of a fully automatic examination.

For technical reasons and especially for cost reasons in case of following machining steps, there is an X-ray test before the following machining steps, i.e. high requirements regarding the minimization of detections and high requirements for the component quality.

Fig. 2: Balance Pseudo Detection - Detecting Ability

A further important aspect in the detection of defects and their reproducibility, especially when comparing different plants with the same testing task, is the condition of the manipulator system. Robots with gripping fingers made of plastic are used predominantly as manipulator in the basic structure analysis.

Small deviations when seizing within the range of only a few degrees may produce different surfaces in the two-dimensional illustration of the error which can thus lead to different results.

In addition, there is the aspect of the radiography direction. Errors, which are evaluated in the picture evaluation as surface criterion, can present themselves as "in order" in case of only one test view, in case of a modified radiography direction, however, they may be "not in order".

For a clear evaluation, views from different angles are necessary in this case (see fig. 3 to 5). In Fig. 4, the error is not seized with regard to the surface, but laterally due to the radiography direction.

In case of a modified radiography direction (fig. 5), the shown projection of the error surface is improved and clearly classified in the following image processing as "not in order". Just for comparison: In the manual X-ray examination (fig. 3), the error spot was turned to ensure the best possible view and was compared to a well-known sphere size.

The situation of the shrink hole is determined by the casting process and therefore stationary.

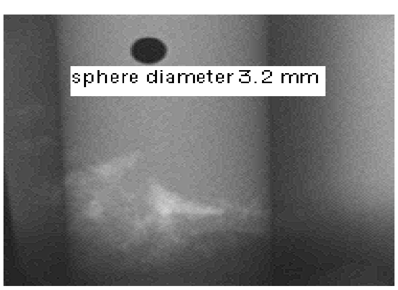

Fig. 3: View in manual radioscopy

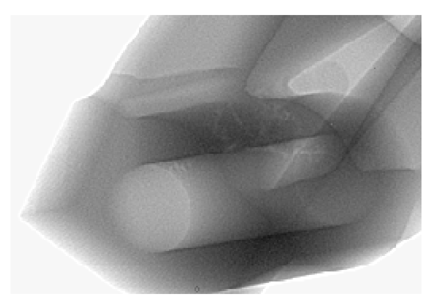

Fig. 4: Original testing position

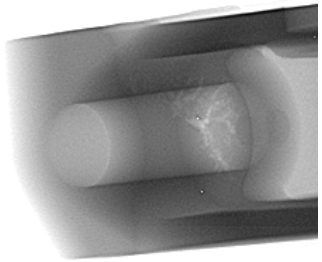

Fig. 5: Modified testing position

Results: In order to better fulfil the high requirements of the test tasks in the future, further improvements regarding the picture-providing system become necessary. X-ray tubes with smaller focal spots ≤ 1.0 mm (acc. to EN 12543) must have a higher performance and also flat picture detectors with larger surfaces and smaller pitch will become necessary starting from certain component sizes .

Inaccuracies and / or deviations in the positioning of the components can be better adjusted by the manipulator system. As starting point, it could be considered whether an examination of the component's position in the grip arm can be effected before the actual test sequence and whether this position will be corrected independently if necessary. In the systems available at present, one tries to adjust positional variations to a certain extent by adjusting the image processing parameters.

Regarding a safe evaluation of the components, the additional information of the error expansion in radiography direction is necessary. It would be recommendable to think about a more intelligent and also more flexible control, which in cases of a detection outside the permissible specification sees to it that the system starts over to additional positions to get a clearer evaluation.

Discussion: As presented in fig. 6, action is needed at present regarding common development and provision of practical error specifications. Often separate discussions are led and possible problems are not discussed in common. In order to arrange test tasks both economically and practically in connection with increased requirements to the system, both the physical as well as technical basic conditions have to be clearly defined before. From the physical point of view, reliably reproducible detection of 0.8 mm ^ 2 in a wall thickness ≥ 20 mm can only hardly be realized with the means available today. Based on a common co-operation of all participants (fig. 7), the challenges of such test tasks are to be realized and to be converted practically.

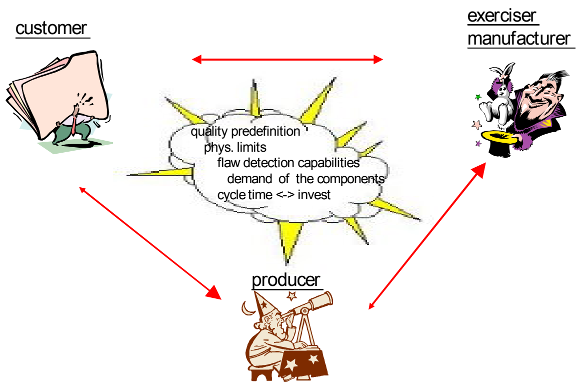

Fig. 6: Communication up to now

Fig. 7: Necessary communication

Conclusions: In co-ordination with the customer, the necessary ranges with increased requirements are to be defined depending on the relevant component and are to be examined together with the test system manufacturer regarding their controllability. The responsible specialized division for the casting process has to evaluate problem areas caused by specific casting techniques and has to plan the test application together with the customer and the test system manufacturer.

The detection limits are to be evaluated in relation to the specific test task to be considered with regard to the physical limits in the test specifications.

For detection safety, it is helpful not to exhaust the detection limit with the test specification. The specification limits should have a sufficiently large distance to avoid false detections.

The minimum detectable error sizes are to be determined and to be considered in the test planning considering radiated material thickness and the attainable dissolution of contrast . Different error sizes depending on different failure rate criteria as presented in Table 1 cannot be converted clearly at present.

Error Size	Distance	No. of Errors
0.8 - 1.5	= 10 mm	4
1.5 - 2.5	= 20 mm	2

Table 1: Test requirement Failure Rate / Error Size

Defaults as described in the VDG - instructions P 201 cannot be fully converted acc. to today's possibilities of parameterisation. Due to the two-dimensional illustration of a spatial body and the resulting loss of information, the reference areas cannot always be defined clearly (see fig. 1). The test specification of the error rate is to be determined for a safe evaluation by correlating investigations. An evaluation with regard to reference diameter can only be effected indirectly and taken as equivalence diameter in today's parameterisation.

X-ray systems with automatic picture evaluation are submitted to a constant learning process. Sample controls of the results are to be verified by manual radioscopy.

Basically, this is necessary if:

- there are changes during the casting process
- there are changes during the casting production
- changes in the testing equipment were accomplished.

According to changes of the position or type of the errors to be detected, the test positions and image processing algorithms are to be adapted to the new error pattern.

The better the error pattern is known to the operator of an x-ray unit, the better the error can be recognized by a system.

Without having influence on the inspection results on behalf of the operator of such plants, a fully automatic examination can often not be effected under these circumstances.

References:

VDG instructions P 201