GUIDANCE NOTES
GD 32-2022

CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR CLASSIFICATION OF AUTOMATED ANALYSIS TECHNIQUES FOR NON-DESTRUCTIVE TESTING DATA

2022

Effective from 1 December 2022

Beijing

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1 Scope of application

These Guidelines apply to evaluation of data analysis automation level of non-destructive testing. These Guidelines underline the classification of automated data analysis function of digital ultrasonic testing and other testing methods may refer to these Guidelines.

These Guidelines specify classification principles, elements, processes and judgment methods for automated data analysis as well as technical requirements for each level.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies.

GB/T 9445 Non-destructive testing — Qualification and certification of NDT personnel

GB/T 12604.1 Non-destructive testing — Terms —Ultrasonic testing

GB/T 20737 Non-destructive testing — General terms and definitions

GB/T 6417.1 Classification and explanation of imperfections in fusion welded joints

GB/T 11345 Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels and assessment

GB/T 40733 Non-destructive testing of welds — Ultrasonic testing — Use of automated phased array technology

GB/T 30821 Non-destructive testing — Practice for digital imaging and communication

3 Terms and definitions

Terms and definitions listed in GB/T 12604.1 and GB/T 20737 and below apply to these Guidelines.

3.1 Automated data analysis

The software or system evaluates, interprets, classifies, measures and makes judgment on partial or all data continuously in an automatic manner.

Evaluation: evaluating the integrity of original test data to check whether the requirement for data judgment is met;

Interpretation: the process determining the indication is relevant indication, irrelevant indication or false indication;

Classification: qualitative analysis on relevant indication;

Measurement: measuring relevant parameters of indicative signals according to relevant standards;

Making judgment: making judgment on whether specified acceptance standards are met after making interpretations on the indications noted.

3.2 Automated data analysis system

The system comprising hardware and software for automated data analysis.

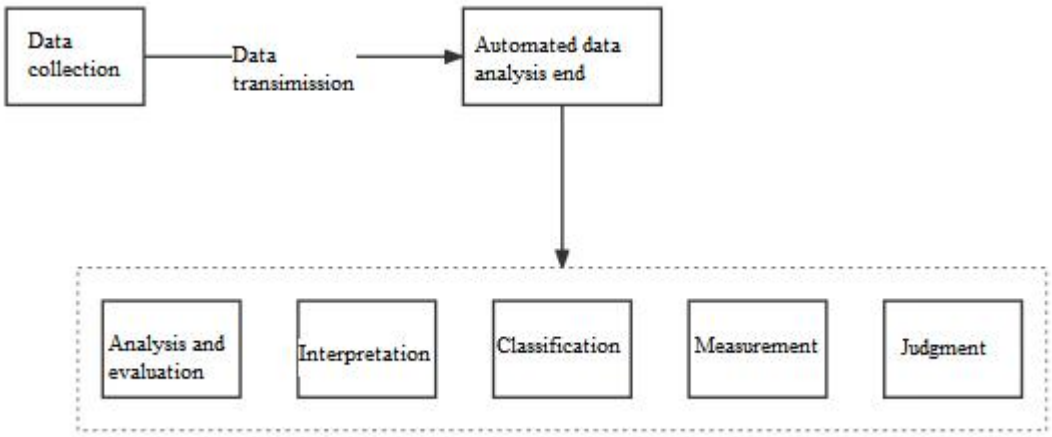

Figure 1 Diagram of automated data analysis system

3.3 Function of automated data analysis

The automated data analysis system's capability to carry out partial or all data interpretation and evaluation task within the specific design and operation conditions [1].

3.4 Data interpretation and evaluation task

Actions such as evaluation, interpretation, classification, measurement and judgment needed for data analysis, include but are not limited to:

(1) determination of whether it is relevant indication, irrelevant indication or false indication based on discontinuous signal or presentation;

(2) measurement and calculation of auxiliary information including coupling channel and data loss rate;

(3) classification of imperfections based on the imperfections included in relevant indication;

(4) measurement of one or more geometrical information of the imperfections (length, width or height);

(5) measurement of one or more location information of the imperfections (starting point, depth or offset);

(6) measurement of other information of the imperfections (amplitude, accumulative length, etc.);

(7) quality rating.

3.5 Design operation range

Testing equipment, testing subject, testing method, technological procedure and reference standards applicable to automated data analysis function determined at the stage of design.

3.6 Design operation condition

Conditions to ensure normal operation of automated data analysis function determined at the stage of design including design operation range, requirement for users and other necessary conditions.

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[1] One automated data analysis system can achieve the automated analysis function for one or more data and each function is correlated to the specific level of automated data analysis and operation conditions. To accurately describe the automated data analysis function, the level of automated data analysis and operation conditions are to be made clear (except for level 4).

3.7 Taking over of data interpretation and evaluation task

Behaviors where the user carries out data interpretation and evaluation task or the risk for data interpretation and evaluation is minimized by the user/ automated data analysis system if there is a failure in automated data analysis system, a failure in other auxiliary systems or non-conformity of design operation conditions.

3.8 Request for taking over

The notice sent by the automated data analysis system to request the user to take over data interpretation and evaluation task.

3.9 Failure in automated data analysis system

Due to the failure in automated data analysis system, the system fails to carry out partial or all data interpretation and evaluation task reliably.

3.10 User

Relevant personnel who can use the automated data analysis system to carry out partial or all data interpretation and evaluation task and/or take over data interpretation and evaluation task.

3.11 Minimum risk status

The status where the detectable rate of defects is acceptable after implementation by the user or the automated data analysis system when the system cannot complete scheduled tasks.

4 Classification of automated data analysis

4.1 Principles for classification of automated data analysis

The automated data interpretation and analysis is classified into 0-4 levels based on the extent to which the automated data analysis system can carry out data interpretation and evaluation task, role assignment in carrying out data interpretation and evaluation task and whether there are any design operation condition limits. The classification levels and elements of automated data analysis are listed in Appendix A. The roles of the user and automated data analysis system are listed in Appendix B.

4.2 Data quality

Data quality used for automated analysis such as integrity, sensitivity and contrast of data is to comply with the requirements for data quality in relevant standards.

4.3 Elements for classification of automated data analysis

The levels of automated data analysis are classified based on the following four elements:

(1) whether the automated data analysis system can carry out one or more data interpretation and evaluation tasks;

(2) whether the automated data analysis system can carry out all data interpretation and evaluation tasks;

(3) whether the automated data analysis system can take over data interpretation and evaluation tasks;

(4) whether the automated data analysis system has design operation condition limits.

4.4 Classification of automated data analysis

4.4.1 Level 0 automated data analysis (auxiliary analysis)

The automated data analysis system cannot carry out all data interpretation and evaluation tasks but is to be capable of carrying out one data interpretation and evaluation task.

When carrying out a data interpretation and evaluation task, the user may set the condition parameters needed in advance. The condition where the user is required to set parameters during the implementation is not within the scope of automated data analysis.

Having the measurement function of multiple information in data interpretation and evaluation tasks listed in 3.4 is still considered as having the capability for carrying out a data interpretation and evaluation task. For example, having the function for automatic measurement of imperfection length and height but incapable for carrying out other data interpretation and evaluation tasks is to be classified as level 0 automated data analysis.

4.4.2 Level 1 automated data analysis (Combined auxiliary analysis)

The automated data analysis system cannot carry out all data interpretation and evaluation tasks but is to be capable of carrying out two or more data interpretation and evaluation tasks.

When multiple information in one data interpretation and evaluation task can be measured, the system is to be capable of covering reference standard requirements within the design operation range. For example, if the reference standard requires recording the length and height of imperfections, the system is to at least include length and height information when automatically measuring the geometrical information of imperfections. Level 0 automated data analysis may be exempted from this requirement.

4.4.3 Level 2 automated data analysis (Conditional automated analysis)

The automated data analysis system carries out all data interpretation and evaluation tasks within limited design operation conditions. The user monitors the system and takes over data interpretation and evaluation tasks.

4.4.4 Level 3 automated data analysis (Highly automated analysis)

The automated data analysis system carries out all data interpretation and evaluation tasks and taking over of data interpretation and evaluation tasks within the limited design operation conditions. When the system sends request for taking over, it can automatically reach the minimum risk status if the user does not respond.

4.4.5 Level 4 automated data analysis (Fully automated analysis)

The automated data analysis system carries out all data interpretation and evaluation tasks and taking over of data interpretation and evaluation tasks under all operational conditions.

4.5 Process and judgment method for classification of automated data analysis

The automated data analysis is classified according to the classification elements in 4.2 and process in Figure 2. The application cases listed in Appendix C may be referred to.

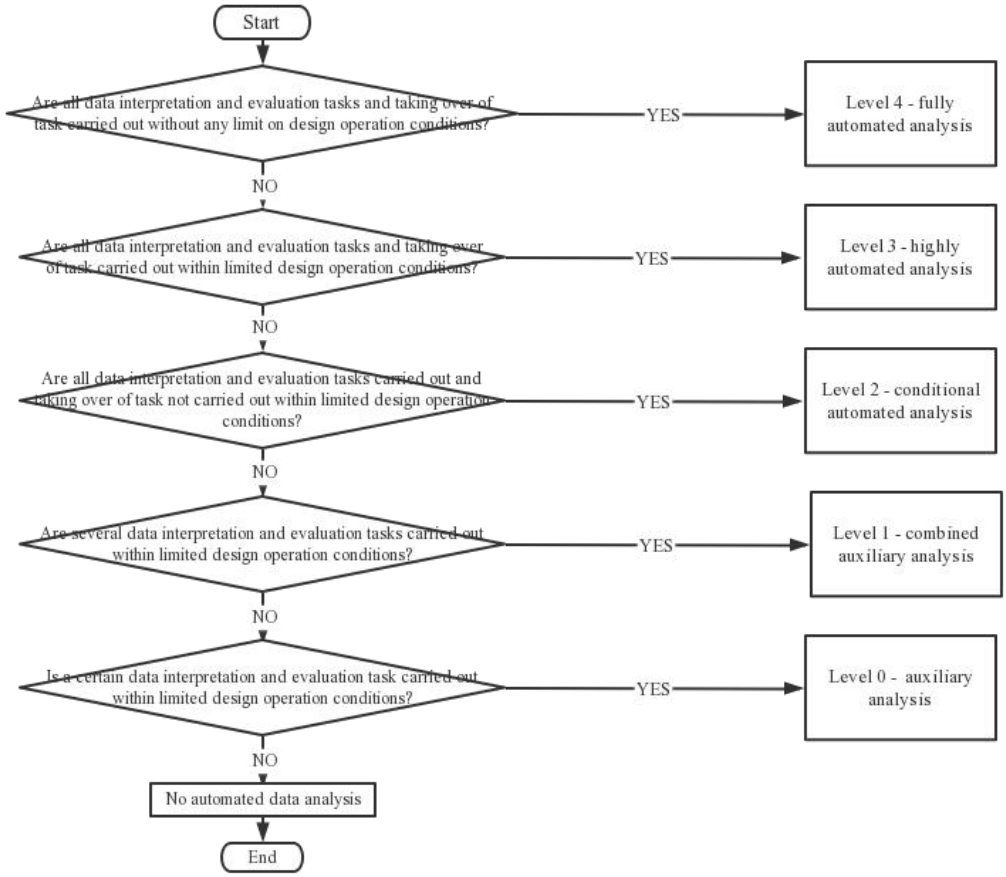


Figure 2 Process for classification and judgement of automated data analysis

4.6 Technical requirements for each level of automated data analysis

4.6.1 Design operation conditions

The automated data analysis system of level three and below is to make clear the operation conditions, including but not limited to user requirement, applicable testing equipment, testing subject, testing method, procedure specification, reference standard and operating environment.

4.6.2 User qualification

Users of automated data analysis system are to be subject to qualification verification and certification according to GB/T 9445 or certification programs/standards agreed by all parties and obtain qualification certificates on testing method and relevant industrial category required by design operation range. The qualification certificates are to include qualification to interpret and evaluate testing results. Users are to receive job training and authorization from the employer or their agents.

Apart from universal testing methods, users are also to be familiar with the automated data analysis system and receive training. When using automated data analysis system of level three and below, users are to be capable of responding to request for taking over data interpretation and evaluation task and carry out risk mitigation strategy.

4.6.3 Level 0 automated data analysis (auxiliary analysis)

Level 0 automated data analysis system is to comply with the following requirements:

(1) the system can carry out one data interpretation and evaluation task;
(2) the user can confirm and revise the analysis results.
4.6.4 Level 1 automated data analysis (combined auxiliary analysis)
Level 1 automated data analysis system is to comply with the following requirements:
(1) the system can carry out two or more data interpretation and evaluation tasks;
(2) when multiple information in one data interpretation and evaluation task can be measured, the system is to be capable of covering reference standard requirements within the design operation range;
(3) the user can confirm and revise the analysis results.
4.6.5 Level 2 automated data analysis (conditional automated analysis)
Level 2 automated data analysis system is to comply with the following requirements:
(1) the system is only to be used within design operation conditions;
(2) the system can carry out all data interpretation and evaluation tasks;
(3) the system can identify whether design operation conditions are not met and send request for taking over to users in time when design operation conditions are not met;
(4) the system can carry out risk mitigation strategy in due time if the user does not respond to the request;
(5) the user can confirm and revise the analysis results.
4.6.6 Level 3 automated data analysis (highly automated analysis)
Level 3 automated data analysis system is to comply with the following requirements:
(1) the system is only to be used within design operation conditions;
(2) the system can carry out all data interpretation and evaluation tasks;
(3) the system can identify whether design operation conditions are not met;
(4) the data interpretation and evaluation tasks are taken over and the minimum risk status is reached automatically when one of the following situations occurs:
① the system is about to fail to meet the design operation conditions;
② the user does not respond to the request for taking over;
③ the user requests to reach the minimum risk status.
(5) the user can confirm and revise the analysis results.
4.6.7 Level 4 automated data analysis (fully automated analysis)
Level 4 automated data analysis system is to comply with the following requirements:
(1) there are no limits on design operation conditions;
(2) the system can carry out all data interpretation and evaluation tasks;
(3) the data interpretation and evaluation tasks are taken over and the minimum risk status is reached automatically when one of the following situations occurs:
① the automated data analysis system fails;
② the user does not respond to the request for taking over;
③ the user requests to realize the minimum risk status.
(4) the user is to confirm the analysis results but cannot revise them.

Appendix A

(Informative Appendix)

Relationship between Data Automation Analysis Levels and Classification Elements

Table A.1 specifies the relationship between data automation analysis levels and partition elements.

Table A.1 Relationship between Data Automation Analysis Levels and Classification Elements

Level	Name	Data interpretation and evaluation tasks	Takeover of data interpretation and evaluation tasks	Design operating condition
Level 0	Auxiliary analysis	User and system	User	With restrictions
Level 1	Combined auxiliary analysis	User and system	User	With restrictions
Level 2	Conditional automated analysis	System	User	With restrictions
Level 3	Highly automated analysis	System	System	With restrictions
Level 4	Fully automated analysis	System	System	Without restrictions[a]
[a] Restrictions such as commercial and regulatory factors are excluded.				

Appendix B

(Informative Appendix)

Roles of the User and Automated Data Analysis System

Table B.1 specifies roles of the user and automated data analysis system in performing data interpretation and evaluation tasks and takeover of data interpretation and evaluation tasks.

Table B.1 Roles of the User and Automated Data Analysis System

Level	**Roles of the User**	**Roles of the Automated Data Analysis System (activation of the automated data analysis system)**
Level 0-Analysis aid	User (continuous): 1. Performing most of data interpretation and evaluation tasks; 2. Supervising the automated data analysis system, and confirming the analysis results and making adjustments if necessary.	Performing part of data interpretation and evaluation tasks.
Level 1-Portfolio analysis aid	User (continuous): 1. Performing the rest of data interpretation and evaluation tasks not performed by the automated data analysis system; 2. Supervising the automated data analysis system, confirming the analysis results and making adjustments if necessary; 3. Deciding whether and when to start or shut down the automated data analysis system; 4. Being capable of performing all data interpretation and evaluation tasks immediately at any time.	Performing part of data interpretation and evaluation tasks.
Level 2-Conditional automated analysis	1. User (the automated data analysis system not activated): Deciding when to start the automated data analysis system; 2. Continuously monitoring the running status of the data automated analysis system;	1. Being only allowed to be activated within the design operation conditions; 2. Performing all data interpretation and evaluation tasks within the design operation conditions after activation; 3. Identifying whether the design operation conditions are not met, and

Level	Roles of the User	Roles of the Automated Data Analysis System (activation of the automated data analysis system)
	3. User (the automated data analysis system activated): (1) On receipt of a takeover request, timely performing takeover of data interpretation and evaluation tasks; (2) Timely performing takeover of data interpretation and evaluation tasks in case of system failures; (3) The analysis results are to be confirmed and adjusted if necessary; (4) Deciding whether and how to achieve the minimum risk status, and determining whether the minimum risk status has been reached; (5) Being capable of shutting down the automated data analysis system.	timely sending a takeover request to the user when the design operation conditions are not met; 4. Identifying the failure of the automated data analysis system, and timely sending a takeover request to the user in case of failure of the automated data analysis system; 5. After the takeover request is sent, if the user does not respond, timely implementing the risk mitigation strategy; 6. When the user requests the automated data analysis system to shut down, removing the system control.
Level 3-Highly automated analysis	1. User (the automated data analysis system not activated): (1) Deciding when to start the automated data analysis system; (2) Monitoring the running status of the data automated analysis system. 2. User (the automated data analysis system activated): (1) No need to perform takeover of data interpretation and evaluation tasks; (2) Being capable of receiving takeover requests, and performing takeover of data interpretation and evaluation tasks; (3) Being capable of shutting down the automated data analysis system, and performing data interpretation and evaluation tasks after the system is shut down.	1. Being only allowed to be activated within the design operation conditions; 2. Performing all data interpretation and evaluation tasks within the design operation conditions after activation; 3. Performing takeover of data interpretation and evaluation tasks and automatically reaching the minimum risk status in case of the following situations: (1) the design operation conditions are not met; (2) the automated data analysis system fails; (3) the user does not respond to the takeover request; (4) the user requires the minimum risk status to be achieved. 4. When the user requests the automated data analysis system to shut down, removing the system control.
Level 4-Fully automated	1. User (the automated data analysis system not activated):	1. There are no restrictions for design operation conditions;

Level	Roles of the User	Roles of the Automated Data Analysis System (activation of the automated data analysis system)
analysis	(1) Deciding when to start the automated data analysis system; (2) Monitoring the running status of the data automated analysis system. 2. User (the automated data analysis system activated): (1) No need to perform takeover of data interpretation and evaluation tasks; (2) Being capable of receiving takeover requests, and performing takeover of data interpretation and evaluation tasks; (3) Being capable of shutting down the automated data analysis system, and performing data interpretation and evaluation tasks after the system is shut down.	2. Performing all data interpretation and evaluation tasks after activation; 3. Performing takeover of data interpretation and evaluation tasks and automatically reaching the minimum risk status in case of the following situations: (1) the automated data analysis system fails; (2) the user does not respond to the takeover request; (3) the user requires the minimum risk status to be achieved. 4. When the user requests the automated data analysis system to shut down, removing the system control.

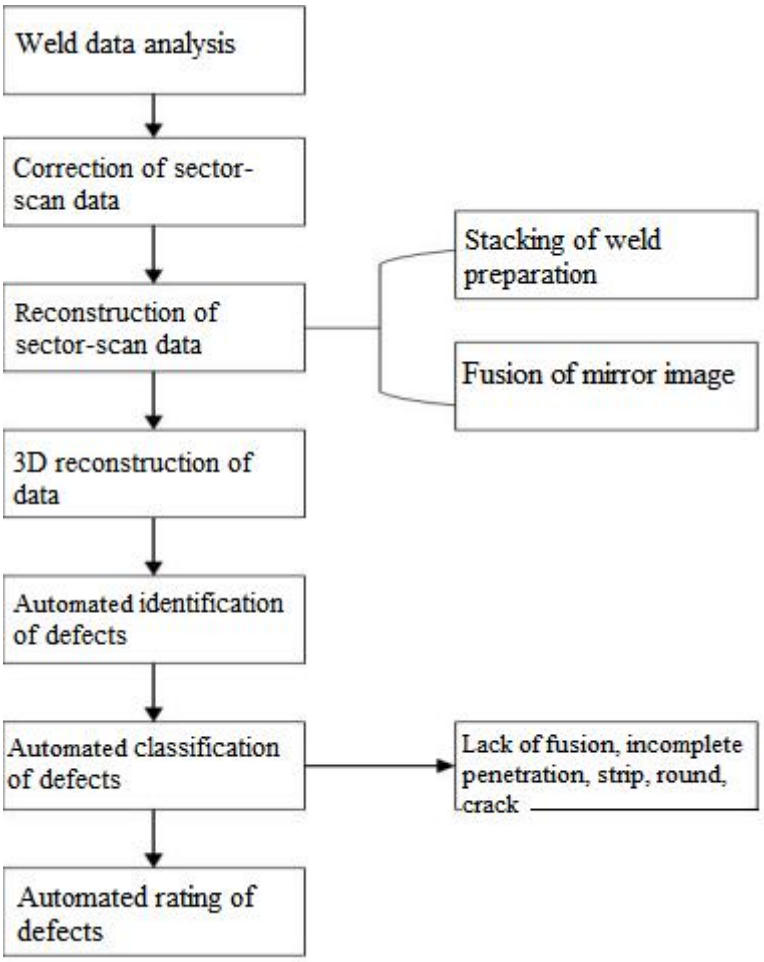
Appendix C

(Informative Appendix)

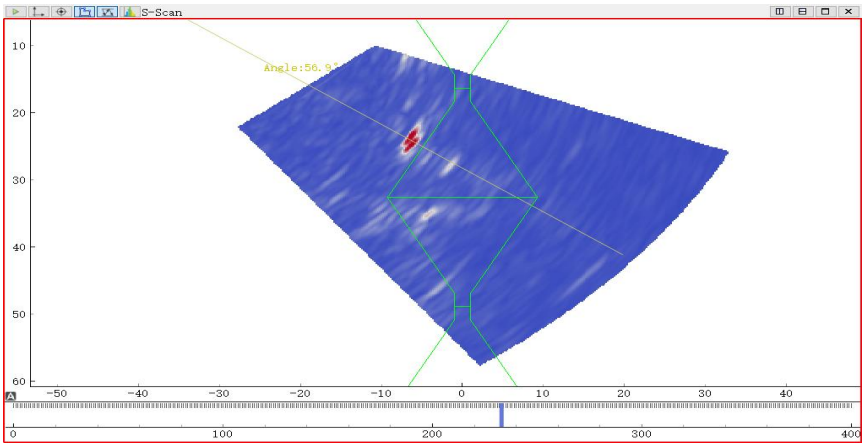
Application Case 1 Classification of Automatic Analysis Software for Weld Phased Array Ultrasonic Testing (PAUT) Data

1. Display of some functional modules

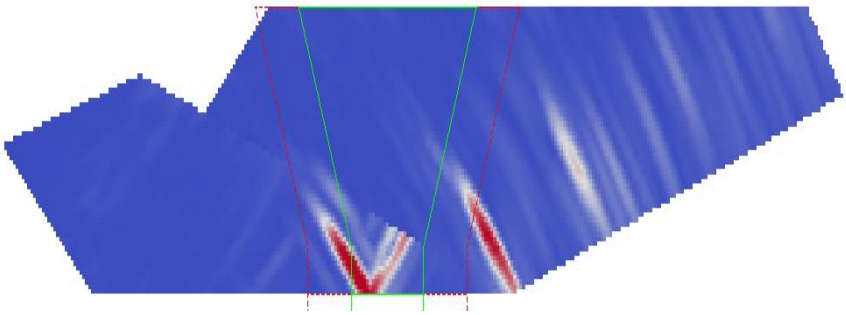
1.1 Overall functional flowchart



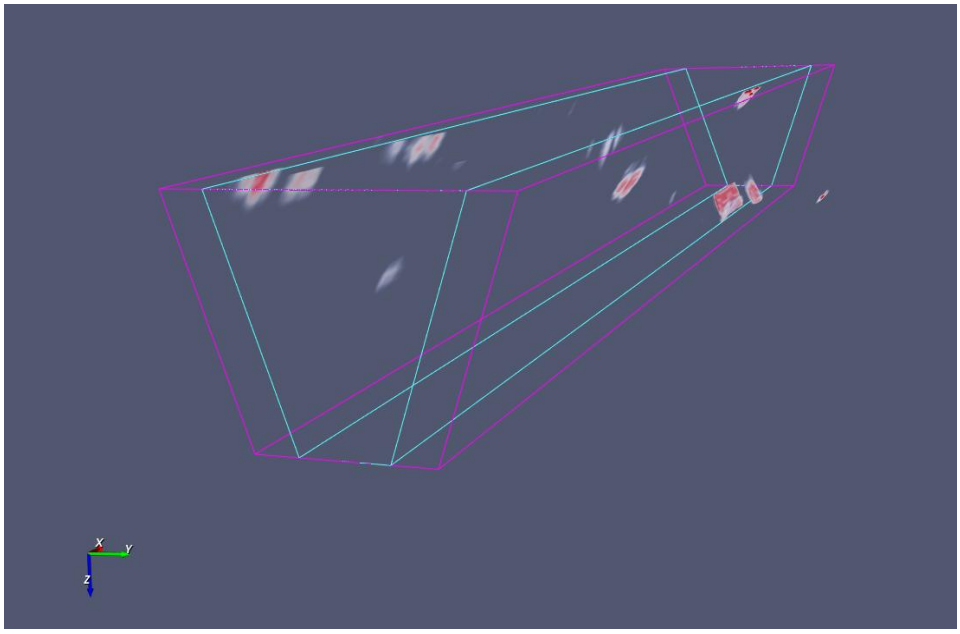
1.2 Correction of sector-scan data



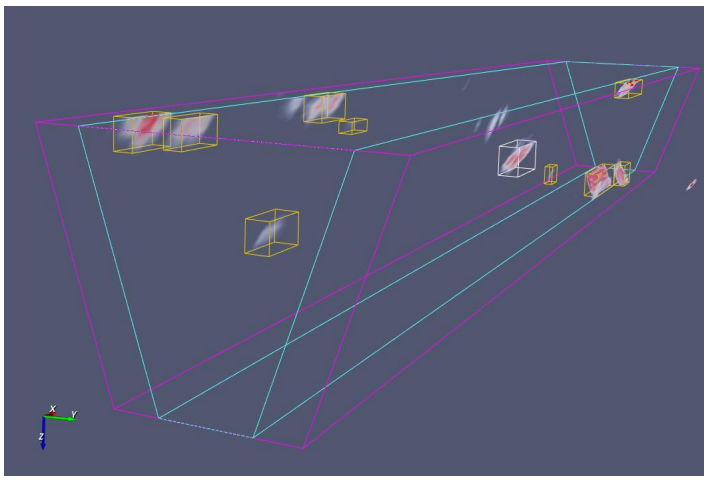
1.3 Reconstruction of sector-scan data



1.4 3D reconstruction of data

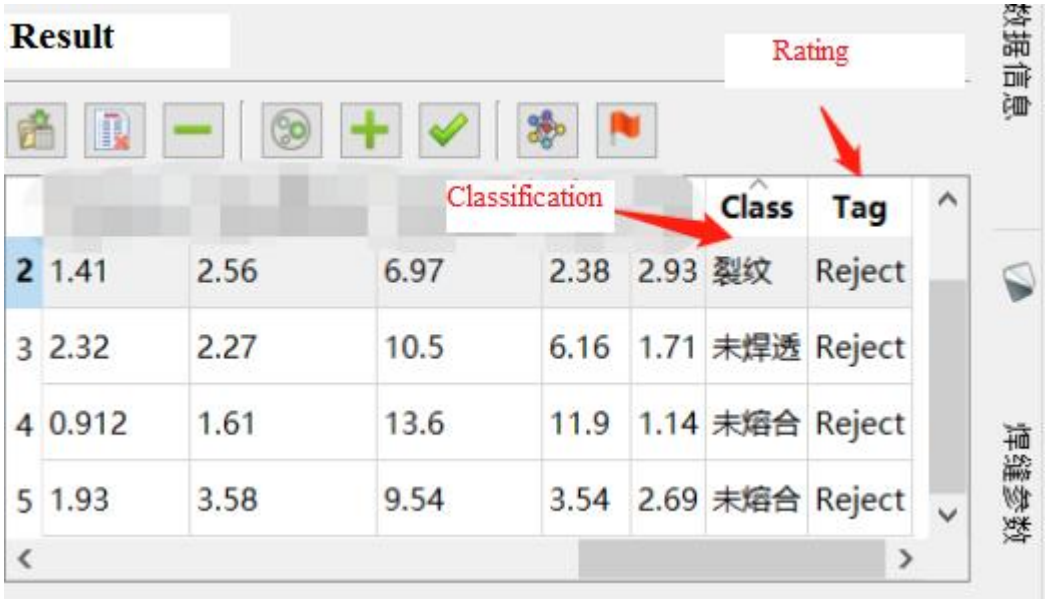


1.5 Identification and measurement of imperfections



ID	Max	Min	Start	Depth	Length	Height
1	49.8	24.9	12	15.4	12	6.2
2	100	50.1	19	0	14	6.8
3	74.8	37.4	23	0	14	6.2
4	39.3	19.7	42	0	8	2.4
5	83.8	41.9	97	0	15	6.6
6	100	50	134	13	19	7.8
7	100	50	238	0	29	5.2
8	41	20.5	257	33.4	8	6.4
10	100	50	303	40.8	37	9
11	100	50	341	41	14	8.8

1.6 Classification and rating of imperfections



2. Level evaluation

2.1 Design operation conditions

Testing equipment	Olympus OmniScan MX2, automatic scanning machine
Testing object	Butt welds; single V or double V preparations
Testing method	Sector scan or linear scan
Procedure	Set-up according to plate thickness and preparation parameters
Reference standards	ISO 13588, ISO 19285
Requirements for the user	Personnel for software operation and data check are to have PAUT-II certificate.

Other prerequisite conditions	The data collected are to meet the basic quality requirements.

2.2 Evaluation process

Evaluation element	Content	Status	Conclusion
Data interpretation and evaluation tasks	Determining whether it is a relevant indication, a non-relevant indication, or a false indicator	Can not be executed at present	1. Being capable of performing 5 data interpretation and evaluation tasks, meeting the requirements of 4.6.4 (1); 2. Being capable of measuring length, width, height and amplitude, meeting the requirements of 4.6.4 (2); 3. The results can be confirmed and modified to meet the requirements of 4.6.4 (3)
	Measurement and calculation of auxiliary information (coupling channel, data loss rate, etc.)	Can not be executed at present	
	Classification of imperfections according to the imperfection nature information contained in the related indications	Imperfections can be divided into five categories: lack of fusion, incomplete penetration, crack, strip, round	
	Measurement of one or more geometric information (length, width, or height) of imperfections	Length and height information of imperfections can be measured	
	Measurement of one or more location information (starting point, depth, or offset) of imperfections	Starting point and depth information of imperfections can be measured	
	Measurement of other information (Amplitude, cumulative length, etc) of imperfections	The maximum amplitude can be measured and adjacent imperfections can be aggregated	
	Quality rating	Imperfections can be rated according to ISO 19285	
	Result confirmation	The result list is	

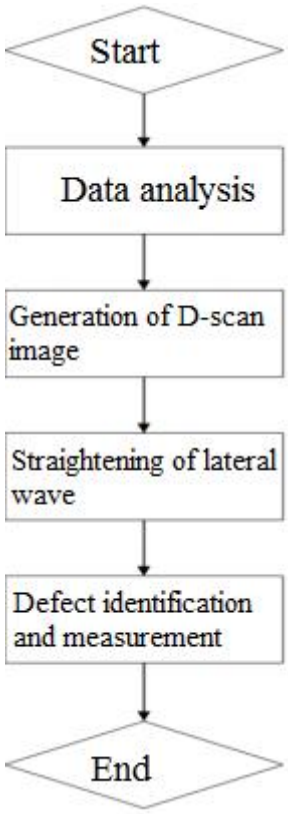
	and modification	generated automatically, and the user can manually add or delete defect information, and export the result	
Takeover of data interpretation and evaluation tasks	When the system fails or does not meet the design operation conditions, the user performs data interpretation and evaluation tasks or the user/data automated analysis system makes data interpretation and evaluation to reach minimum risk status	Can not be executed at present	Can not be executed at present

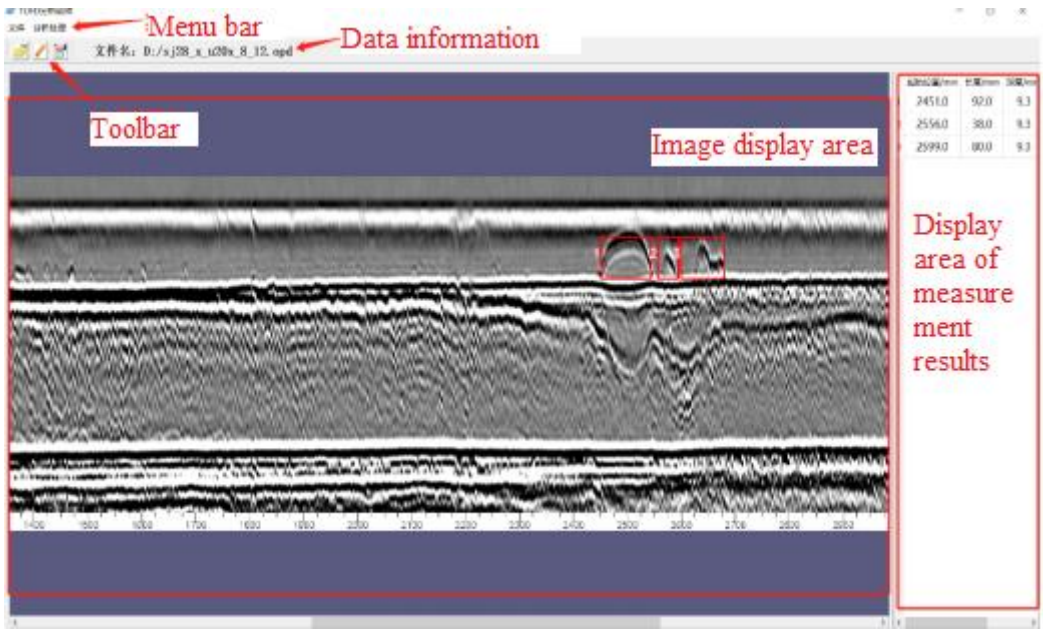
3. Conclusion

According to the classification process of the automated system, automated analysis software of weld PAUT data can perform several data interpretation and evaluation tasks within the restricted design operation conditions and cannot perform takeover of data interpretation and evaluation tasks in the process. In summary, this automated analysis software is rated as Level 1 - combined auxiliary analysis software.

Application Case 2 Classification of Automatic Analysis Software for TOFD Testing Data

1. Overall function





2. Level evaluation

2.1 Design operation conditions

Testing equipment	Olympus OmniScan MX2
Testing object	Butt welds with plate thickness of10 mm~30 mm
Testing method	TOFD testing
Defect type	Bottom opening crack
Procedure	Set-up according to plate thickness and preparation parameters
Reference standards	ISO 15626, NB/T 47013
Requirements for the user	Personnel for software operation and data check are to have TOFD-II certificate.
Other prerequisite conditions	The data collected are to meet the basic quality requirements.

2.2 Evaluation process

Evaluation element	**Content**	**Status**	**Conclusion**
Data interpretation and evaluation tasks	Determining whether it is a relevant indication, a non-relevant indication, or a false indication	Can not be executed at present	1. Being capable of performing 2 data interpretation and evaluation tasks; 2. Being capable of measuring length, width, height and amplitude, meeting the measurement requirements of ISO 15626, NB/T 47013; 3. The results can be confirmed and modified
	Measurement and calculation of auxiliary information (coupling channel, data loss rate, etc.)	Can not be executed at present	
	Classification of imperfections according to the imperfection nature information	Can not be executed at present	

	contained in the related indications		
	Measurement of one or more geometric information (length, width, or height) of imperfections	Length and height information of imperfections can be measured	
	Measurement of one or more location information (starting point, depth, or offset) of imperfections	Starting point and depth information of imperfections can be measured	
	Measurement of other information (Amplitude, cumulative length, etc) of imperfections	According to the standard requirement, amplitude measurement is not required in TOFD data evaluation	
	Quality evaluation	Can not be executed at present	
	Result confirmation and modification	The result list is generated automatically, and the user can manually add or delete defect information, and export the result	
Takeover of data interpretation and evaluation tasks	When the system fails or does not meet the design operation conditions, the user performs data interpretation and evaluation tasks or the user/data automated analysis system makes data interpretation and evaluation to reach minimum risk status	Can not be executed at present	Can not be executed at present

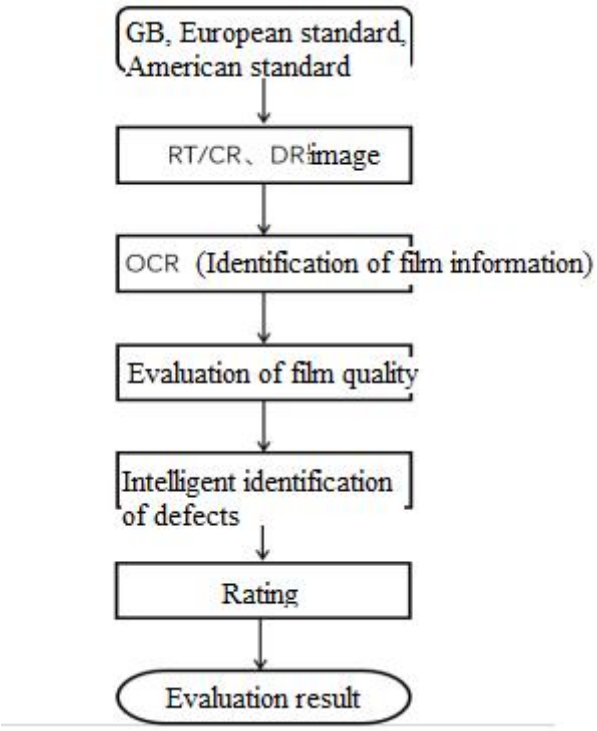
3. Conclusion

According to the classification process of the automated system, automated analysis software of weld TOFD data can perform two or more data interpretation and evaluation tasks within the restricted design operation conditions, covering the measurement requirements of reference standards ISO 15626 and NB/T 47013 in the design operation range, and can confirm and modify analysis results manually but cannot perform takeover of data interpretation and evaluation tasks in the process. In summary, this automated analysis software is rated as Level 1 - combined auxiliary analysis software according to 4.6.4.

Application Case 3　Classification of Automatic Analysis Software for Weld Radiographic Testing Data

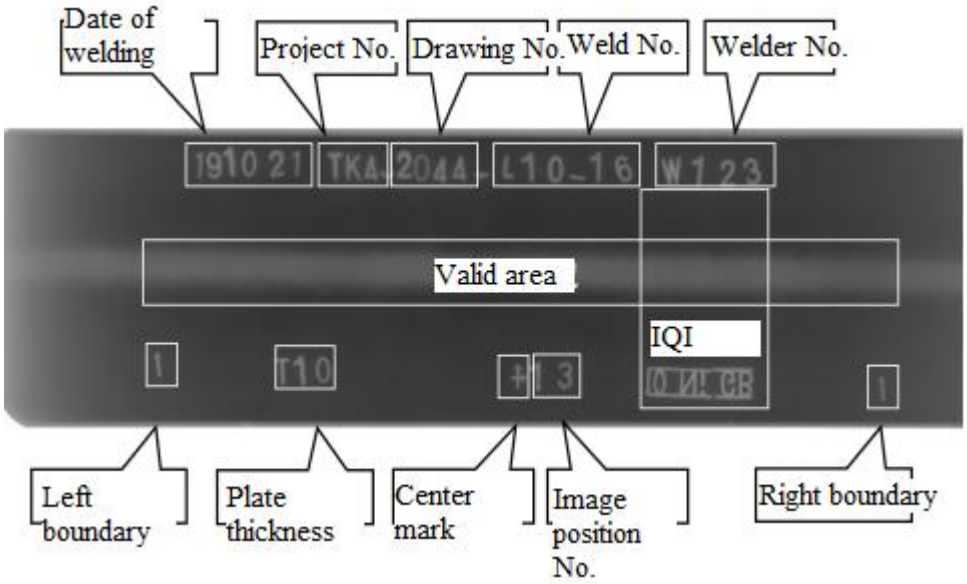
1. Display of some functional modules

1.1　Overall functional flowchart

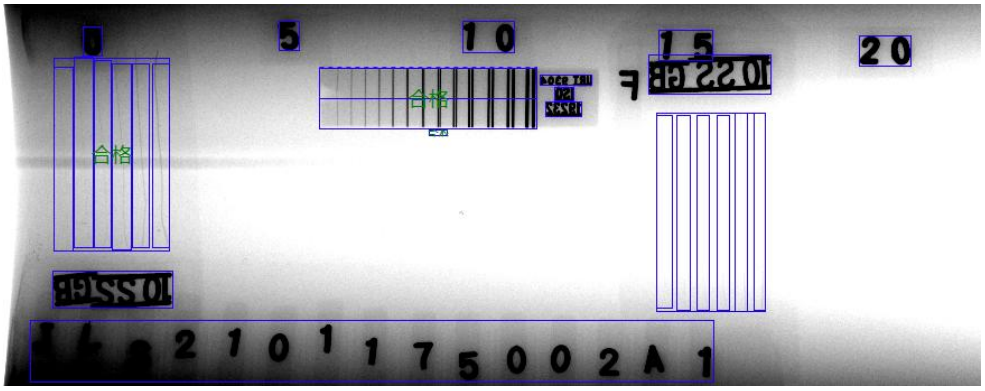


When OCR, film quality and AI defect identification and rating fail in the process, manual intervention can be performed for manual evaluation.

1.2　Identification of OCR

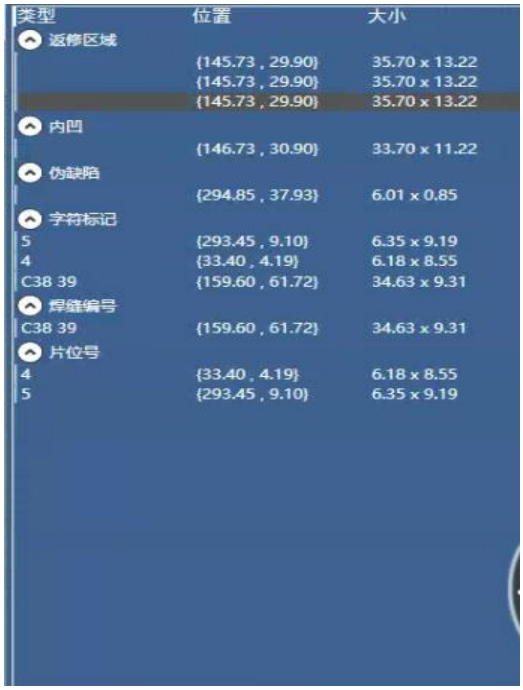


1.3 Single and double filament image quality meter identification

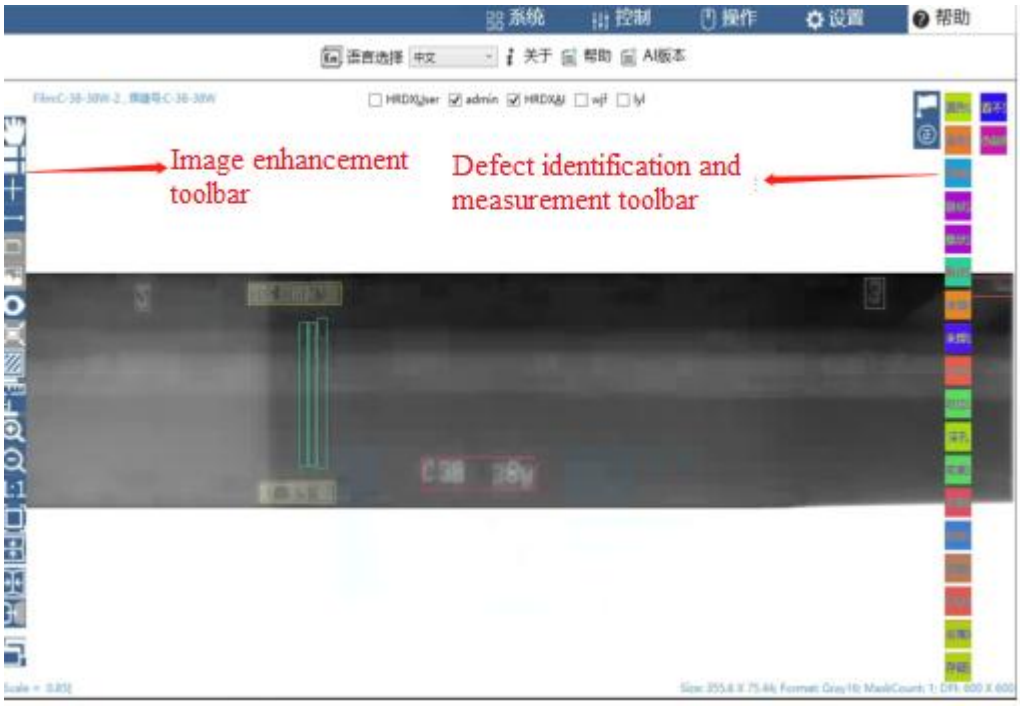


1.4 Identification and measurement of defects

1.5 Classification and rating of defects



1.6 Manual classification and rating of defects



2. Level evaluation

2.1 Evaluation process

Evaluation element	Content	Status	Conclusion
Data interpretation and evaluation tasks	Determining whether it is a relevant indication, a non-relevant	False defects can be identified	1. Being capable of performing all data interpretation and evaluation tasks,

	indication, or a false indication		complying with the requirements of 4.6.5(1); 2.Being capable of measuring length, width, complying with the requirements of 4.6.5(2); 3.Being capable of result confirmation and modification, complying with the requirements of 4.6.5(5)
	Classification of defects according to the imperfection nature information contained in the related indications	Defects can be divided into 13 categories: pore, slag inclusion, lack of fusion, incomplete penetration, crack, strip, round, dense, chain, depression, undercut, metal inclusion, cavity, etc.	
	Measurement of one or more geometric information (length, width, or height) of imperfections	Length and width information of imperfections can be measured	
	Measurement of one or more location information of imperfections	Location information of imperfections can be measured	
	Imperfection rating	Defects can be rated according to NB / T 47013.2	
	Quality evaluation	The quality of digital film can be evaluated by image quality meter, gray value and normalized signal-to-noise ratio	
	Result confirmation and modification	The result list is generated automatically, and the user can manually add or delete defect information, and export the result	
Takeover of data interpretation and evaluation tasks	When the system fails or does not meet the design operation conditions, the user performs data interpretation	When the system fails the user can perform defect evaluation and measurement manually. When the	Complying with the requirements of 4.6.5(3) and 4.6.5(4)

	and evaluation tasks or the user/data automated analysis system make data interpretation and evaluation to reach minimum risk status	system fails and the user does not respond, the automated analysis task will stop operation	

3. Conclusion

According to the classification process of the automated system, automated analysis software of weld radiographic data can perform all data interpretation and evaluation tasks within the restricted design operation conditions, but cannot perform takeover of data interpretation and evaluation tasks in the process. In summary, this automated analysis software is rated as Level 2 - conditional automated analysis software.