DOOSAN

D-Vision

Artificial Intelligence Non-destructive Testing
(AI NDT) Solution for Quality Innovation

DOOSAN

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Doosan Enerbility

Doosan Digital Solution

Faced with a rapidly changing energy market and multiple environmental challenges, Doosan Enerbility has been preparing for changes in the market environment by leading digital transformation and keeping pace with the technological innovation of the industrial revolution era.

Doosan offers digital solutions that combine IT technologies such as Artificial Intelligence (AI), IoT, and Big Data with Doosan Enerbility's unique capabilities in power generation equipment design and production.

Prognostic & Health Management	PreVision (Prediction/diagnosis of devices)	DOOVES (Vibration diagnosis of devices)	PreVision-CMS (Prediction/diagnosis of wind turbines)
Optimization	Optimization of Combustion (Combustion optimization)	Optimization of Soot Blowing (S/B optimization)	Optimization of DAF Chemical (DAF chemical optimization)
Big Data Analysis	D-Vision (Non-destructive testing)	DIVE (Big data collection & analysis system)	
Industrial/Common Service	Remote Monitoring Service	Building a Digital Twin	Building a Monitoring Center

OEM Package	T/G Package	GasPED (Prediction/diagnosis of GT performance)	DCAT (Automated tuning of GT combustor)	PreVision (Prediction/diagnosis of devices)
	Water Package	Optimization DAF Chemical (DAF chemical optimization)	EMS (Energy management in Desalination Plants)	
	Wind Package	PreVision-CMS (Prediction/diagnosis solution)	Power Generation Simulation	Integrated O&M System

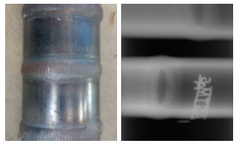
Artificial Intelligence Non-destructive Testing (AI NDT) Solution for Quality Innovation

"D-Vision"

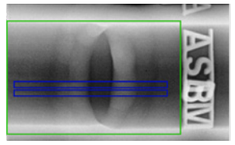
D-Vision is Doosan Enerbility's differentiated AI solution, which blocks human error and prevents equipment failure or accidents due to defects with the use of AI-based non-destructive testing (NDT) film and image analytics service.

D-Vision (Data-Vision)

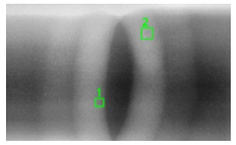
AI-based auto-reading solution for RT film



Digital radiography (DR) and digital image creation



IQI (Image quality indicator)



Automating defect detection with AI

Inspection report generation

Key Features

AI-based non-destructive testing (NDT) solutions
- Auto-reading solution for RT film
- Embedded solution for digital detectors

Applicable Technologies

Deep learning, Data augmentation and inference technologies, Virtual defect generation technologies, Auto IQI (Image Quality Indicator)

Business Status

· Set up a Non-Destructive Examination Dept, Doosan Enerbility
- Approximately 31,000 solutions under testing (as of October 2023)

· Listed on NHN Cloud SaaS Marketplace

· Expanded business to include shipbuilding, semiconductor, and aviation sectors in addition to power generation

· Delivered a keynote address at the Google DT Conference in Manufacturing (NA)

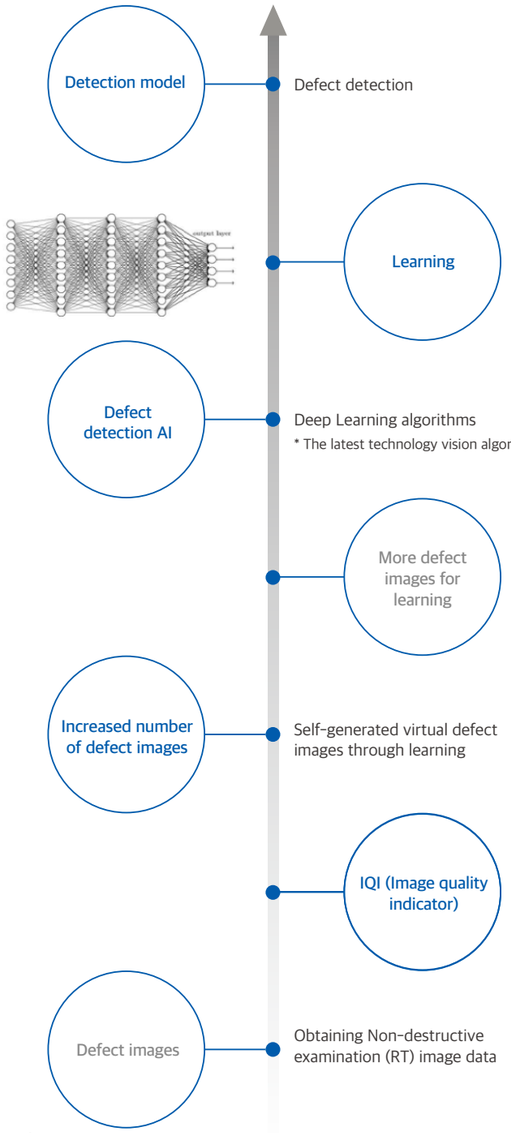
Implementation Direction

As-Is	To-Be (Expansion of Non-destructive examination (NDE) feature)	
RT (Tube, Pipe, plate welding)	UT/PAUT	Thinning

RT/UT: A volumetric examination among the non-destructive testing types, which is used to inspect welding defects and discontinuities using radioactive isotopes and ultrasound scans.

D-Vision
Core Technologies

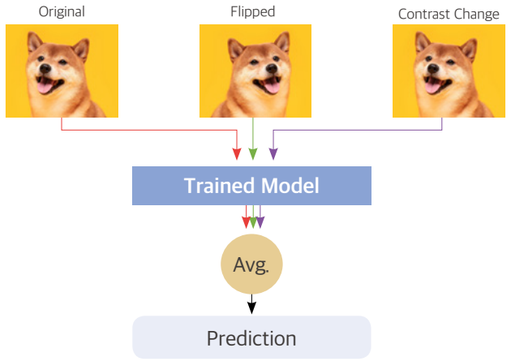
Specialized Technologies for Improving the Performance of Detection Models



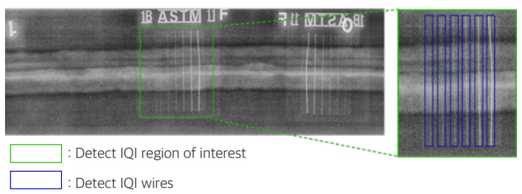
High Accuracy with Enhanced Inference

TTA (Test Time Augmentation)

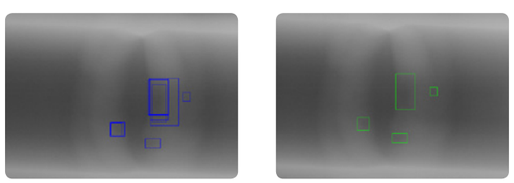
- Processing/rotating/flipping an image when testing or operating models with the increased number of inference images.
  → Increased volume of data
  → The final result derived from all enlarged images, rather than a single original image.



AI-based automated system for IQI (Image Quality Indicators)

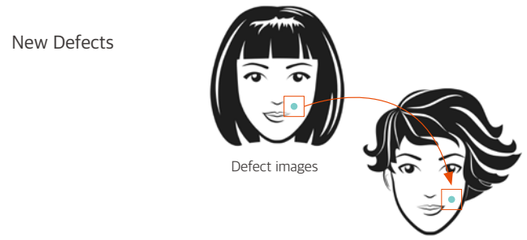


NMS (Non-Maximum Suppression)
High-accuracy detection of defects using NMS


Before applying the NMS
After applying the NMS

Advanced Virtual Defect Generation Technique

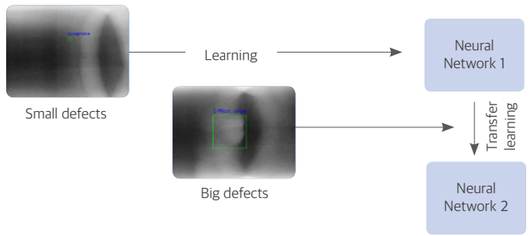
- Improved learning data by creating virtual defects using GAN (Generative Adversarial Network) deep learning algorithms and histogram compensation.
  **Doosan Enerbility patent application*



Transfer Learning for Big Defects

- Transfer learning is applied to improve the detection accuracy according to the characteristics of different types of defects.

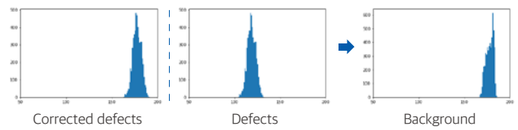
**Transfer learning: A specialty of machine learning that focuses on storing knowledge gained while solving one problem and applying it to a different but related problem*



Harmonization

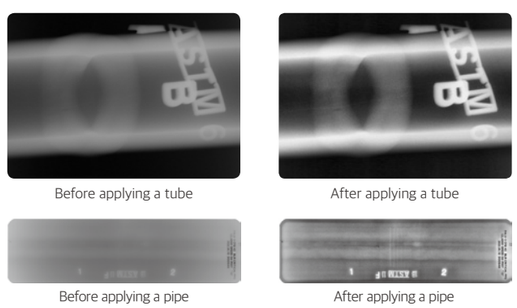

Input
Harmonization results

Histogram compensation


Corrected defects
Defects
Background

Application of Advanced Image Processing Technology

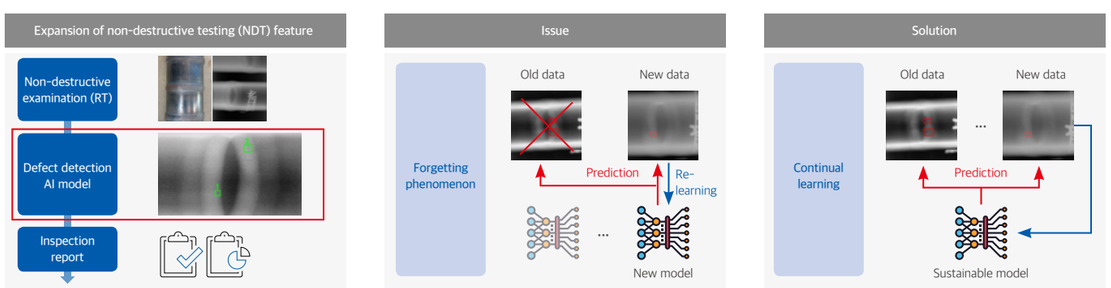
- A technology that transforms the properties of an image to improve the visibility of defects which can't be seen with the naked eye


Before applying a tube
After applying a tube
Before applying a pipe
After applying a pipe

Application of Continual Learning for Advancing Model Learning

- Advanced model with continual learning to prevent model performance degradation due to catastrophic forgetting of previously learned knowledge in transfer learning for new defect data

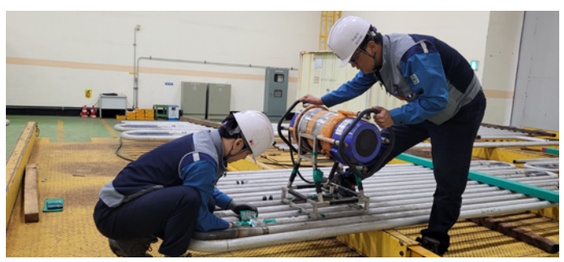
**Continual learning: A learning technique to solve the stability-plasticity dilemma to avoid catastrophic forgetting by accommodating new knowledge while retaining previously learned experiences*



D-Vision
Features & Benefits

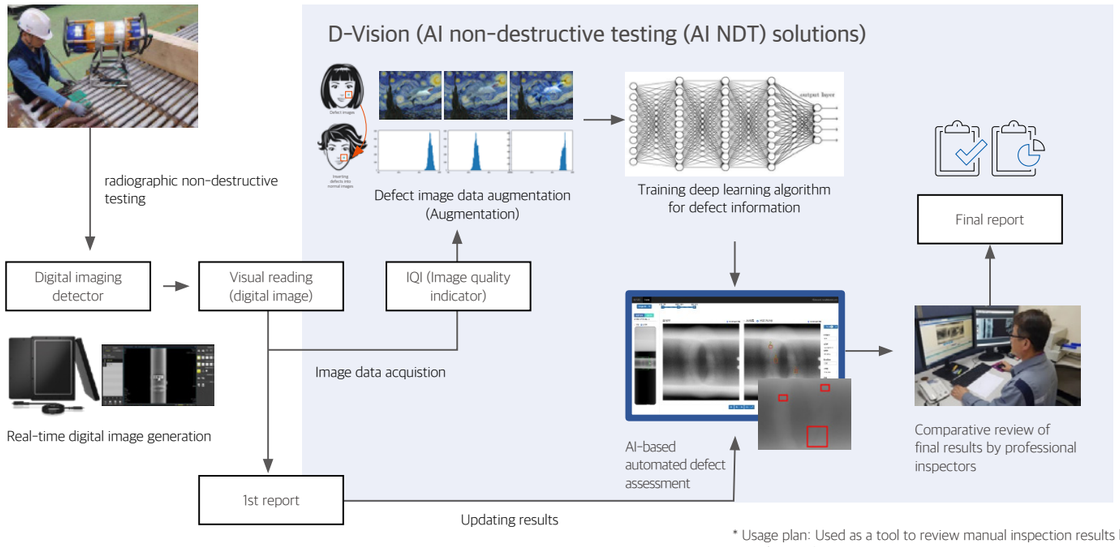
What is Non-destructive testing (NDT)

Non-destructive Testing (NDT) refers to an external inspection for the detection of pores or cracks in products or internal defects in welding joints without destroying the products.



(Example of inspecting the quality of boiler tube welds for power generation, Doosan Enerbility)

> D-Vision allows users to detect internal defects in welding joints that are difficult to detect with the naked eye and prevent serious accidents by performing Digital NDT (Non-destructive Testing).



* Usage plan: Used as a tool to review manual inspection results by professional inspectors

Easy & Accurate Inspection Process

- With a DR detector, allow quick and easy evaluation of results using digital images without developing film
- Prevent human error due to fatigue using AI-based reading and fundamentally block inspection errors through crosscheck inspections by professional inspectors
- Enable quick defect analysis and remote collaboration in Cloud environments without building a separate system

Safe Asset Management and Cost Reduction

- Secure the skills and know-how of experienced inspectors in an objective manner
- Manage inspection results using digital images to shorten the time to check and read data for reexamination
- Achieve a 100% reduction in cost and space required for purchasing, storing, and disposing of RT film
- Eliminate the process of disposing of film to fundamentally reduce emissions of environmental pollutants and contribute to the company's ESG activities

Compliance with Industry Standards

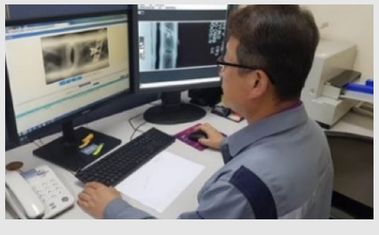
- Carry out an industry-leading collaboration on national projects to establish AI measurement standards in the domestic non-destructive testing field (selected as a joint research institute)
- Establish objective reference evaluation standards in terms of quality control and derive insights for improvement direction through data accumulation
- Secure reliability of inspection results through global standard certification for the power generation industry where stability is important and 60 years of practical welding and non-destructive testing experience

Customized Defect Detection Model

- Enable to build a customized defect detection model with learning using customer data
- Detect defects with only a small amount of defect data through reinforcement learning based on virtual defects
- Shorten the AI image transfer learning time based on Doosan Enerbility's global top-tier inspection capability

Application Areas

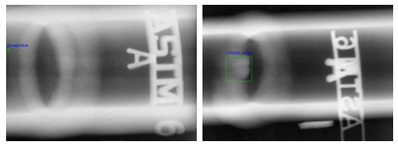
Used for evaluating tube, pipe, and flat welding defects across a variety of industries such as public infrastructure, power generation, aviation & space, semiconductors, oil & gas, automobiles, shipbuilding & marine, etc.



"With the adoption of the AI automatic evaluation solution, we were able to pass on the know-how of experienced inspectors in an objective manner and fundamentally prevent inspection errors due to inspector fatigue."

Doosan Enerbility **Non-Destructive Examination Dep't**

D-Vision
Key Features

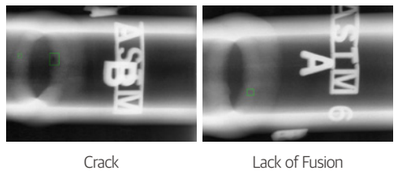


Critical Large

Acceptable

Classification of Defect Risks

Going beyond simple defect detection, we classify defects into defined classes based on their risk based on Doosan Enerbility's non-destructive testing know-how. (Classification)

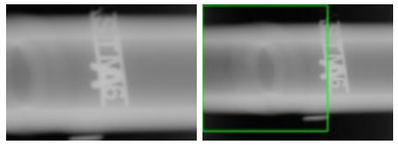


Crack

Lack of Fusion

Location Analysis

The application of deep learning algorithms for objection detection enables the detection of defects with high accuracy and even detect defects in locations that are difficult to find.

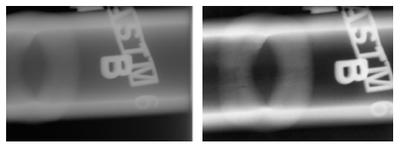


Original

ROI

Automatic Selection of Analysis Areas (welding defect detection)

Differentiated algorithms are used to automatically select only the welding part (region of interest, ROI) that needs analysis from the entire film image and intensively detect it.
*Doosan Enerbility patent application

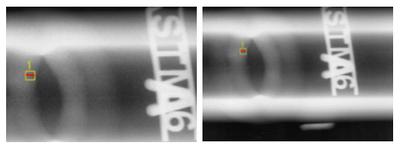


Before

After

Digital Image Processing

The advanced technology of digital image processing enables to check detection results with clear and optimized images.

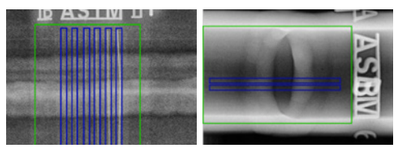


Ruler

Zoom In & Out

Convenient, Additional Functions

Convenient functions including a ruler that measures the length of detected defects and zoom-in and zoom-out of an image to provide user convenience.



Pipe or Plate

Tube

Automatic Film Quality Assessment

Various techniques of domain conversion and image filtering enable the assessment of film quality by detecting the Image Quality Indicator (IQI) wire to accurately match what the human eye sees.

Qualitative Effects of D-Vision

- Reducing human error
- Preventing loss of experienced assets of experienced inspectors
- Responding to environmental regulations strengthened due to digitalization of RT film
- Saving space required for RT film storage

Quantitative Effects of D-Vision

- Expected to reduce reading labor costs by approximately KRW 200 million per year (based on 150,000 sheets of RT film per year)
  * Based on approximately 2000 M/H per person per year
- Reducing time for the development of film by 38% (saving 3 hours per day, approximately 2,508 hours per year)
  * Based on monthly working hours of 209 hours x 12 months (when used with a radiation imaging detector)
- Reducing manual labor time through Cloud-based real-time remote collaboration

D-Vision
Patents & Achievements

PATENT CAPTURED

We have obtained numerous certifications, including the ASME (The American Society of Mechanical Engineers), KEPIC (Korea Electric Power Industry Code), ISO 9001/14001, and ISO 45001, from international certification bodies for our quality assurance system and environment & safety management system. We meet global standards in the power generation industry that focuses on stability, securing customer trust by obtaining patents for AI technologies such as defect image generation.

Acquisition of 33 Patents and Certifications Applied for Various Domestic and Overseas Projects

Domestic Patents

Obtained 1 domestic patent and applied for 2 patents

ASME

Acquired 14 types of certificates in nuclear and non-nuclear fields

KEPIC

Acquired 8 types of certificates in nuclear energy fields

ISO

Acquired 6 types of international standards required across industries, including ISO 9001 Quality Management System/ ISO 14001 Environmental Management System

Doosan Enerbility's Digital Solutions

Doosan offers digital solutions that combine IT technologies such as Artificial Intelligence (AI), IoT, and Big Data with Doosan Enerbility's unique capabilities in power generation equipment design and production.

Achievements with Solutions

Order by	Site	Solution
Korea Southern Power Co., Ltd.	Shinsejong Combined Cycle Power Plant	Remote Monitoring Service
Korea Southern Power Co., Ltd.	Yeongwol Combined Cycle Power Plant	Remote Monitoring Service
Korea Midland Power Co., Ltd.	Shinboryeong Thermal Power Plant #1	Optimization-Combustion
Korea Western Power Co., Ltd.	Gunsan National Industrial Complex	DOOVES (POC)
Approtium	Ulsan 1~3 Facility (Hydrogen Production)	PreVision
SK E&S	Hanam Narae CHP Power Plant	PreVision
SK E&S	Paju Energy Power Plant	PreVision
SK E&S	Wirye CHP (Combined Heat and Power) Plant	PreVision
SK E&S	Hanam Narae CHP Power Plant	Remote Monitoring Service
GPSC	GHECO-One TPP	Optimization-Soot Blowing
Doosan Enerbility	Non-Destructive Examination Dep't	D-Vision
Korea Energy Agency	-	D-Vision (POC)
KPJB	Tanjung Jati B #3	Advisor-Coal Blending
Reliance Power	Sasan Power #1	Optimization-Combustion (POC)
Korea East-West Power Co., Ltd.	Dangjin Thermal Power Plant #1~10	PreVision
Korea East-West Power Co., Ltd.	Honam Thermal Power Plant #1, 2	PreVision
Korea East-West Power Co., Ltd.	Dangjin Thermal Power Plant #5	Remote Monitoring Service
Korea District Heating Corporation	Dongtan CHP (Combined Heat and Power) Plant	Remote Monitoring Service
Daeryun Power Co., Ltd.	Yangju CHP (Combined Heat and Power) Plant	Remote Monitoring Service