

- Abstracts of IIW Documents

IIW Commission V : Testing, Measurement and Control of Welds.

Reported by - Baldev Raj
Chairman, Indian Commission V

IIW Doc : V-885-88

NDT OFFSHORE - A REVIEW

Mr. O. Forli, Chairman of Working Group 2 of Commission - V of IIW

Abstract

This paper is based on the developments that have taken place in the offshore NDT techniques and applications. This deals with the conventional NDT techniques followed by divers and also the present day attempts to use automated and remotely operated techniques and structural integrity monitoring.

Visual examination is performed underwater by divers. Still photography, TV cameras and video recording are used as aids.

Magnetic particle testing is the dominant underwater NDT method for detection of surface breaking cracks and if correctly used with qualified personnel, the same quality of examination will be obtained as in routine testing. On offshore constructions, the main application is in service, to detect fatigue and other service induced cracks on node and other welds. In most cases, fluorescent magnetic particles are used and viewed in ultraviolet light.

Underwater ultrasonic testing is mainly performed manually for detection and mapping of corrosion. Weld examination is considered too complicated to perform on a large scale and is only used for diagnostic purposes and in connection with repair etc. For thickness measurement, digital meters are most commonly applied.

Automated ultrasonic equipment has been in use under water since 1981 and is now quite extensively applied. The main use has been for mapping of corrosion and lamellar cracking on pipelines and risers and to examine girth welds on riser and platform legs.

Crack depth measurement based on AC potential drop is available for crack depth measurement under water. Such tools are available for critical crack assessment to provide inputs for fracture mechanics evaluation approach. Also, the ultrasonic time-of-flight technique has been developed for use underwater to obtain quantitative information about crack.

Radiography is not common to use directly in water, but gamma radiography is used for the testing of hyperbaric welds. If applied directly from air, it may be necessary to remove water from the beam path by using air filled cones, balloons or similar devices.

Acoustic emission is still in its infancy as an off-shore structural integrity monitoring technique.

The paper establishes that reliable NDT tool as mentioned above are available to assess more accurately areas which might be subject to fatigue or corrosion. It is possible to optimise inspection efforts for qualitative and quantitative inspection. Further cost saving can be envisaged through the use of remotely controlled or automated techniques and monitoring systems to reduce diving inspection time.

IIW Doc : V-940-90

ON THE PROBLEM OF PENETRANT FLUORESCENCE MEASUREMENT : STANDARDS AND INSTRUMENTATIONS.

M. Cevenini, F. Lezzi, R. Marmigi, F. Peri

Abstract

This paper describes the more important characteristics of the instrumentation and operating conditions in which the work was performed. Further, the analyses that were conducted in the series of experiments are dealt with. Detailed information is provided regarding the procedures used for the preparation of the test samples, the methods used for each single examination, the criteria used to evaluate the results and the constructive and functional features of the photofluorimeter used for the tests. The aim of the series of tests conducted was to verify the technical and functional suitability of the photofluorimeter. Penetrants having different grades of sensitivity were selected, in order to be able to clearly emphasize the response capability of the instrument to different values of fluorescence intensity.

The problems of liquid penetrant fluorescence measurements is of primary importance in the field of non-destructive evaluations, because they not only involve the chemical and physical properties of the products under test, but also the constructive and functional characteristics of the instrumentation to use in the analysis. Several standards referred to by the high - tech industries provide precise indications as to the tests to carry out and the instrumentation to use for verifying the liquid penetrant fluorescence properties.

The authors firmly believe that clarification should be provided as to the need to use only sophisticated equipment, which provides absolute measurements of fluorescence intensity (in LUX) or rather the required test reliability and accuracy can be met by using instrumentation able to provide relative intensity values (as percentages). The need for this clarification results from the fact that since it is necessary to process the results so as to be able to evaluate them as percentages, the use of extremely accurate equipment has a marked impact on running costs and is therefore not really warranted.

IIW Doc : V-938-90

WHITE LIGHT INTENSITY EFFECTS ON THE FLUORESCENT PENETRANT INDICATION SEEBILITY UNDER ULTRAVIOLET LIGHT.

G. Calcango, G. Costa, R. Marmigi

Abstract

The seeability is of considerable importance in cases in which fluorescent products are employed, since the higher sensitivity of these products is due, in addition to the physical and chemical properties, to the particular contrast conditions present between the fluorescent indications and the darkness of the ambient in which the tests are performed.

This paper illustrates the results obtained in some experimental

analyses, aimed at verifying whether the sensitivity and reliability degree of a test by fluorescent penetrants carried out in an ambient not suitably darkened and with excessive white light, may be preserved by increasing exclusively the intensity of the ultraviolet light used for the test. The series of tests described in this paper define the correlation existing between the intensity of the ultraviolet light and the intensity of white light and the seeability of the fluorescent indications by the operators' eyes. The tests clearly demonstrate the need to inspect components subjected to fluorescent penetrant examination under suitable light (lamp plus ambient) of 30 to 40 lux.

IIW Doc : V-929-90

TRENDS IN ARCHITECTURE AND IMPLEMENTATION OF INTERNATIONAL/EUROPEAN STANDARDS AND CERTIFICATION SYSTEMS IN THE QUALITY ARENA DURING THE 1990'S.

Abstract

Based on the manifold changes and harmonising efforts which have emerged, this report attempts to deal with some priorities in respect of quality management in general, qualification and conformance certification in particular. Consistent with developments in recent years and in view of the unification of the European market by early 1993, special emphasis is laid on European requirements.

IIW Doc : V-930-90

THE ON-LINE ULTRASONIC ASSESSMENT OF WELD QUALITY

C. B. Scruby, I. J. Stares, C. Duffill & B. C. G. Haywood

Abstract

This paper presents some examples of recent work in the NDT Centre, Harwell Laboratory regarding applications of ultrasonics to the characterisation of the melt pool and defect detection during the welding of stainless and ferritic steels.

There is a growing industrial need for active methods to control weld quality online. Ultrasonic waves are able to penetrate deep within the weldment, and provide vital information about the solid liquid interface and the formation of defects, so that a feed back signal can be sent to control the welding parameters.

The experiments highlighted in this paper, demonstrate the physical principles involved in the technique, and show how the method could be used for online weld process control. In addition, data are presented, in which angled compression waves are used to monitor the root pass of V preparation butt joints in stainless and ferritic steels. Not only do these results confirm the potential of ultrasonic sensors for determining the weld pool dimensions online, but they also demonstrate the detection of fabrication defects as they form while welding is in progress. It is, however, reported that the reflection from the interface are not as strong as might be desired. It is, therefore, concluded that an ultrasonic instrument that is capable of rapid online signal averaging is essential for an adequate signal/noise ratio.

IIW Doc : V-936-90

THE RELIABILITY AND COST EFFECTIVENESS OF OFFSHORE INSPECTION

Olav Forli

Abstract

A review is presented based on available information on the reliability and cost effectiveness of inspection of offshore installations in service. The paper describes current efforts to establish inspection reliability data for use in cost and safety optimisation of the in-service inspection. General principles and systematic approaches to

in-service inspection planning are presented with emphasis on steel platforms in the North Sea.

IIW Doc : V-939-90

HANDBOOK ON THE ULTRASONIC EXAMINATION OF AUSTENITIC CLADDED MATERIALS

Drafted by - Commission V of International Institute of Welding

Abstract

Austenitic cladding is commonly applied to ferritic base materials for corrosion protection. The fitness for service of the component depends on the quality, integrity and thickness of the cladding. The cladding structure strongly influences ultrasonic examination of the cladding itself as well as examination of the underlying base material and welds. Special procedures, therefore, are required to ensure effective examination of clad material.

This handbook describes the problems and gives recommendations for examining austenitic clad materials. Common cladding processes, possible irregularities and defects and propagation of ultrasound are discussed. Simplified descriptions of wave propagation are included as a bridge between theory and practical examination procedures. The information in this handbook can be used to develop examination procedures. This handbook is intended for ultrasonic examination practitioners, procedure developers and personnel interpreting examination results.

IIW Doc : V-925-90

FUTURE WORK PROGRAM OF SUB-COMMISSION V A

Abstract

The future work of SC VA will concentrate on the fields of standardisation and test reliability. The second part of a standard on film system classification will be finalised. A report on properties and use of radioscopic systems for weld inspection will be prepared. Revision of ISO standards on weld inspection will be done.

IIW Doc : V-924-90

ANNUAL REPORT 1990 FOR SUB-COMMISSION V A

Abstract

This document narrates the work done by Sub-commission VA on classification of film systems, radioscopic systems for weld inspection, radiographic acceptance criteria for weld inspection, revision of ISO standard ISO 5579 and collection of reference radiographs. It has also recommended Doc. V A-434-90 on Focal spot size measurements for microfocus x-ray sets by U. Madsen for publication. The paper gives comprehensive information about the different evaluation methods and important hints for the user of microfocal equipment.

IIW Doc : V-928-90

WORKING GROUP 3 OF IIW COMMISSION V "QUALITY ASSURANCE IN WELDING TECHNOLOGY" ANNUAL REPORT 1989/90

Abstract

This report insists on the need of Quality Management and Quality Assurance in the field of welding technology. Work done in the areas of computer aided weld inspection and quality assurance, new aspects of online inspection and quality assurance and the human factor are highlighted. It has also indicated the work program for 1990-91 which includes support of QA activities and weld inspection, monitoring to welding parameters for early prevention of weld defects and online inspection by modern visual and dimensional checking.

IIW Doc : V-932-90

ANNUAL REPORT 1990, SUB COMMISSION V F

Abstract

This commission has fully concentrated during the period of report on the preparation and printing of the IIW recommendation on "IIW Guidance on Assessment of the Fitness for Purpose of Welded Structures. Draft for Development".

IIW Doc : V A-441-90

BACKGROUND INFORMATION FROM THE NIST SPHERE DEVELOPMENT PROGRAM

Abstract

The advent of image intensifying systems and automated image processing systems has introduced the need for evaluating the image quality in these cases. Conventional IQI's used as the plaque type or wire type are ideally suited for film radiography wherein the object and film are stationary. When image intensifiers are used, the object may be rotated and there is also the possibility of projective magnification. This paper discusses the design of a new type of image quality indicator consisting of a thin high density coating over a low density core. The new IQI would have symmetrical shape which would provide for rotational variance about two axes, high attenuating edges for easier detection and size independent of orientation so that the magnification of the image can be calibrated. As indicated by the author, experiments with these IQI's using films have indicated that their performance is quite satisfactory.

IIW Doc :

ROC - STUDY OF INSPECTION PERFORMANCE IN RADIOGRAPHIC TESTING OF WELDED JOINTS

Abstract

Present day NDT techniques use image processing and signal analysis to a very large extent. In most of these techniques the signal to noise ratio or the ratio of true indications to false ones should be quite high. In these cases, a threshold signal is normally fixed above which the counts are made. The accuracy of the inspection system is judged by this limit. In this paper, the authors explore the possibility of the use of relative or receiver operating characteristic method for assessing the accuracy of an inspection system for a variety of thresholds. Experiments indicated that ROC could be used for indicating the accuracy of detection due to different detection modes of one equipment as well as to evaluate the performance of various inspection equipments or detection methods.

IIW Commission II : Arc Welding

*Reported by - P. S. Visvanath
Chairman, Indian Commission II*

IIW Doc : II-1144-90/IIA-802-90

NEW RESULTS ON THE STUDY OF A SIMPLE METHOD TO EVALUATE THE MOISTURE RESISTANCE OF MMA WELDING ELECTRODES

*Eng. Eduardo Maraniello, Eng. Maria Smocovich,
Lic. Raul Timerman*

Abstract

This study is the continuation of the research begun in the Doc. II-A-777-89. The aim is to standardize a simple method to determine the increase of the diffusible hydrogen of the weld metal, deposited by basic covered electrodes, according to their exposure to settled conditions of temperature and humidity. This method should be suitable to establish the difference between a moisture resistant and a non moisture resistant electrode.

IIW Doc : II-1145-90

EFFECT OF NICKEL AND MANGANESE ON STRUCTURE AND PROPERTIES OF MULTILAYER WELD METAL

*AA Alekseev, GA Shevehenko, IK Pokhodnya BV
Yurlov, IR Yavdoshchi*

Abstract

The paper studies the effect of nickel and manganese on structure and properties of multilayer weld metal. It is shown, that for each level of manganese in weld metal there exists the optimum nickel content that ensures the high impact toughness at negative temperatures. The highest cold resistance of multilayer weld metal can be achieved at such contents of manganese and nickel: (Mn - 0.5%, Ni - 3.1%; Mn - 1.2%, Ni - 2.2%), when in the columnar structure zone of heat-treated beads with the prevailing acicular ferrite the second phase is characterized by islands of retained austenite and the small amount of fine carbides.

* (E.O. Paton Electric Welding Institute of the Ukrainian SSR Academy of Sciences, Kiev, USSR).

IIW Doc : II-1146-90/(IIA-796-90)

THE EFFECT OF ALUMINIUM IN SHIELDED METAL-ARC C-Mn STEEL MULTI-RUN DEPOSITIONS

*G.M. Evans, Swiss delegation, Welding Industries
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Abstract

The effect of varying the aluminium content of an E 7018 type electrode on weld metal composition, microstructure and properties has been studied. It was found that aluminium modified as-deposited and reheated microstructure and changed the composition of the non-metallic inclusions. The weld metal hardness and tensile properties increased with increasing aluminium, and optimum impact properties, for both the as-welded and the stress-relieved condition, were exhibited at zero aluminium and at an intermediate aluminium content of approximately 350 ppm.

IIW Doc : II-1147-90

A STUDY ON IMPACT TOUGHNESS AND CORROSION RESISTANCE OF TYPE 317LN AUSTENITIC STAINLESS STEEL WELD METALS

*Toshiyuki Miyake, Yoshio Kanbe, Hiroyuki Koike,
Tatsuo Enomoto, Hajime Nagasaki, Tadao Ogawa*

Abstract

Type 317LN austenitic stainless steel (lowC-18.5Cr-13Ni-3.5Mo-0.14N) has high strength and good resistance to corrosion due to its increased nitrogen contents.

Effects of alloy elements, δ - ferrite, and welding conditions on microstructure, Charpy impact toughness and corrosion resistance of Type 317LN weld metals were studied on Shielded Metal Arc Welding (SMAW) process.

Investigation of the microstructures of weld metals was performed by optical microscope and SEM with EDX, and specifically precipitation behaviour was examined using a modified Murakami etchant. Corrosion tests of weld metals were conducted with 5% sulfuric acid and crude phosphoric acid solutions.

The precipitation of intermetallic compounds of σ - and χ - phases in the weld metal increased with the increase of molybdenum and nickel contents, and especially beyond the molybdenum contents of approximately 3.5%, degradation of Charpy impact toughness and corrosion resistance resulted. Addition of aluminum accelerated significantly these precipitations, while that of boron suppressed a little. Amount of delta ferrite itself did not have a definite influence on the precipitation behaviour, depending on molybdenum content, though.

Concerning welding conditions, effects of welding pass sequences were quite important on the precipitation behaviour. Heavy precipitation of intermetallic compounds were confirmed in the double-reheated portions in weld metals, which were exposed presumably to the temperature range from 600°C to 900°C, leading to the deterioration of toughness and corrosion resistance.

From these findings, optimum chemical compositions of the weld metal for SMAW of Type 317LN austenitic stainless steel were obtained.

IIW Doc : II-1148-90

SPECIFICATION FOR LOW ALLOY STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

Abstract

1. Scope

1.1 This Standard prescribes requirements for classification of covered low-alloy steel electrodes for shielded metal arc welding of carbon-manganese and low-alloy steels.

1.2 Test conditions prescribed and results required should not be considered to be requirements or expectations for a procedure qualification.

(The specification has Seven sections with figures and tables, Total number of pages-seventeen)

IIW Doc II-1050-90

THE EFFECT OF THE RATIO BETWEEN GAUGE LENGTH AND DIAMETER ON ELONGATION IN TENSILE TESTS ON C-MN AND LOW-ALLOY STEEL ALL-WELD METALS BY SHIELDED METAL ARC WELDING

Kobe Steel, Ltd., Japan

Abstract

The IIW Commission II is drawing up a draft of ISO specifications for low-alloy steel electrodes for shielded metal arc welding. The ISO uses the 5D tensile test specimen in which the gauge length (G.L.) is five times the diameter of the parallel length (D:10mm), whereas the G.L. of the AWS type tensile specimen is four times D (12.7mm), hereafter referred to simply as the 4D type. The JIS (the Japanese Industrial Standard) uses the 4D type for tensile tests. In general the 5D type has a lower elongation than the 4D type. Japanese companies, however, do not have sufficient data to judge the validity of the elongation requirements in the draft of the ISO specifications. The Japan Institute of Welding therefore investigated the effect of G.L./D ratio in tensile tests on C-Mn and low-alloy steel all-weld metals by shielded metal arc welding by making collaborative experiments. Tests were carried out by Kawasaki Steel Co., Kobe Steel, Ltd., Nippon Steel Welding Products & Engineering Co., Ltd. and Sumikin Welding Industries, Ltd.

IIW Commission XIII : Fatigue Testing

*Reported by : Professor V. M. Radhakrishnan
Chairman, Indian Commission XIII*

IIW Doc : XIII-1250-87

A CASE OF SERVICE FAILURE : TURBINE CONE.

Abstract

The damage of a mechanically welded part in the shape of a truncated cone which acted as a guide for the flow of water at the outlet of the distributor of a hydraulic turbine is presented in this paper. The stresses in service could not be calculated because of the complexity of the phenomena involved. Investigations revealed that various defects like lack of penetration, slag inclusions etc., were responsible for crack initiation. The crack growth was due to corrosion fatigue which caused the final failure.

IIW Doc : XIII-1363-89

STRUCTURAL STRESS, NOTCH STRESS AND STRESS INTENSITY FACTOR APPROACH FOR ASSESSMENT OF FATIGUE STRENGTH OF SPOT WELDED JOINTS.

D. Radaj

Abstract

In this paper Radaj discusses the methodology to assess the fatigue strength of spot welded joints. Different shapes and configurations of spot welded structural parts are taken for the analysis. The equivalent stress intensity factor range ΔK_m which takes into account all other factors including types of loading, is related to the number of cycles N_f to failure by a power function. The equation for the lower bound line of the scatter band can be given by

$$(\Delta K_m)^{0.23} \cdot N_f = (300)^{0.23} \times 10^3$$

where K is in $N/mm^{3/2}$. The threshold stress intensity factor is found to be 180 $N/mm^{3/2}$. Thus, if the equivalent ΔK_m can be calculated for a given spot welded structural part, the fatigue strength can be easily assessed.

IIW Doc : XIII-1377-90

FATIGUE CRACK PROPAGATION IN ALUMINIUM.

R. Jaccard

Abstract

The use of Linear Elastic Fracture Mechanics (LEFM) models to predict the fatigue life of aluminium structures requires adequate Fatigue Crack Propagation Rate (FCPR) data. In case of short cracks or high residual tensile stresses it is necessary to use data that are free of closure. The FCPR curves of constant R = 0.8 and $K_{max}=10$ constant are applicable. Investigations have shown that in the case of AA6005A-T6 aluminium alloys FCPR curves of $K_{max}=10$ constant yield excellent results in the evaluation of early FCP in fine grained material. FCPR curves of ten aluminium alloys are compared to the SST-1141-89 FCPR derived from steel. There is a steel-relatable domain, where the FCPR are insensitive to the microstructure of the alloy. The SST-1141-89 FCPR are too conservative below the Steel-relatable domain and beyond of it unsafe.

IIW Commission IV : Special Welding Processes

*Reported by : Mr. A. V. Thakur
Chairman, Indian Commission IV*

IIW Doc : IV-502-89

APPLICATION OF MULTISTATION LASER WELDING SYSTEMS.

K. Mikame, H. Nagata & M. Kondo (Japan)

Abstract

Multistation laser systems are important for economical use of high priced CO_2 lasers. In these systems laser beam from one oscillator is transmitted to number of work stations hence distance between the oscillator and a work station is large and it is different for different work stations. Because of this variable distance, while designing such a system one has to take in to account variable laser beam parameters mainly effective focal length, beam diameter, optical axes of laser beams and beam power.

In this document in the first part the authors give a method for estimating these variations by theoretical calculations and bring out critical conditions of system design for welding and design method. In the second part they present a multistation laser welding system consisting of 3 oscillators and 7 work stations which is being used for welding of automatic transmission gear parts and

finally they compare the calculated values with measured values on the actual system and find a very good matching.

The design method developed by the authors is valid under following conditions :

1. Distance from the oscillator to the work station is less than 20m.
2. The absorption rate of the partial reflector is less than 0.6%.
3. The oscillator radiates multimode laser beams.

IIW Doc : IV-509-89

ELECTRON BEAM WELDING OF THE PRECIPITATION HARDENING STAINLESS STEEL.

S. Matsui, N. Kamoi, H. Matsumura, M. Imamura, S. Nakayama, T. Takeda, A. Murakami, S. Koga & K. Onkubo

Kawasaki Heavy Industries Limited, Japan

Abstract

The weldability of heavy section 15% Cr - 5% Ni precipitation hardening stainless steel using electron beam welding and joint properties were studied. Results of these studies established E. B. Welding as a suitable method for manufacture of strut, foils and yoke which are located in front and rear of the hydrofoil and are fully submerged on cruising at high speed. 15-5 PH Steel is used in consideration of the strength and corrosion resistance against sea water.

Initial studies showed that weld cracking and beam deflection caused by residual magnetism as critical problems in EB Welding of thick section 15-5 PH Steel.

Welding speed was found to be a major factor which influences crack occurrence. When welding at low speeds, columnar grains grow epitaxially from fusion boundaries on both sides and finally the direction of grain growth becomes same as the welding direction i.e. columnar grains follow the molten pool. While welding at high speed where cracks appear intermittently change of grain growth direction is less than in low welding speed and columnar grains meet in the center of weld metal. It was observed that for 15-5 PH Steel when weld speed is less than 375 mm/min occurrence of weld cracks is avoided.

Other critical factor is residual magnetism which deflected the electron beam away from weld joint line, Ferritic PH Steel can be magnetised easily and it is difficult to remove residual magnetism. Hence a two pronged approach was used. Firstly the work pieces were demagnetised using AC & DC Power supply and then a magnetic shielding pipe was used around the beam path. This pipe is made of ferro-magnetic alloy, with this satisfactory welds could be obtained.

Finally mechanical properties of weld and heat treatments to optimise these were studied. It was observed that tensile strength decreased as aging temperature increased. On the other hand toughness (Charpy absorbed energy) increased with increasing aging temperature. So the combination of strength and toughness must be considered when ageing temperature is determined.

As a result of these studies EBW process was applied to production to yoke & yoke support parts made of 15-5 PH steel for hydrofoils, parts up of 40 mm thickness are routinely welded and process is being extended to parts up to 100 mm thickness.

IIW Doc : IV-510-89

ELECTRON BEAM WELDING FOR PRINTING HEAD.

K. Hara, T. Maruyama, H. Murakami, Y. Chikaoka, A. Sakaida and Y. Suzuki - Japan

Abstract

As high speed, long life printers are required improvement in reliability over extended periods is of great importance particularly for printer heads. For this reliability improvement it is essential to weld spring plate of the printing head with armatures with high accuracy.

Authors have studied welding of plate spring to the armature using electron beam deflected at high speeds intending to solve various kinds of problems of soldering or by YAG laser welding which have been employed as usual method so far and have obtained good results.

Printer head is a small precision assembly which needs spot welds at 96 places and problems associated with this type of welding are:

1. It has small heat capacity hence shorter weld times are required.
2. Transient instabilities during beam on/off operation are liable to generate displacement of beam position and increase of weld width as weld length is short.
3. Welding method which requires mechanical movement of work piece for carrying out multi place welding takes much more time because time for work positioning is much longer than welding time.

To overcome these problems authors have used a method where work piece remains stationary and welding is carried out by programmed E.Beam scanning at high speed. Welding procedure is as follows :- Electron Beam is switched-on on a collector plate away from the work piece. When the beam is stabilized it is moved successively to various weld locations by the preprogrammed deflection sequence. Beam is transferred from one weld location to next at high speeds of the order of 150m/sec or more so that no trace is left on the workpiece during transfer. When all the welds are completed the beam is again shifted to the collector plate where it is switched off.

Using this method they could produce sound welds at high speed which were free from any micro cracks, with good fatigue properties and without significant thermal influence which affects spring properties. Good spot welding at 96 places could be completed in 2.5 seconds and repetitive fatigue life of over 3×10^8 cycles could be obtained at printing speed of 70 cps.

In short effective use of the favourable controllability of Electron Beam can solve various problems in conventional brazing and YAG laser welding when applied to precision assembly of electronic parts, optical and mechanical parts such as printing heads where high accuracy and high reliability are essential.

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