FAULT CORRECTION IN MECHANICAL SYSTEMS

V.V. Klyuev and **F.R. Sosnin**
Moscow Scientific Industrial Association, Russia

Keywords: fault, correction, mechanical system, welding, casting, bearing, motor vehicle.

Contents

Summary

Even when using the best materials, most perfect structures and technological processes in mechanical systems, there can be faults (defects). The problem of correction of such faults is particularly acute now, when the parameters of structures and machines have reached limiting values, and the consequences become potentially disastrous. The technique of correction of faults is multidisciplinary, in which to serve the purpose a lot of different, but complementary techniques are utilized. Some of them are presented in this chapter.

1. General Information about Faults

The failure of mechanical systems may be caused by the sudden influence of unexpected overloads, or by uncontrollable natural effects, or by errors committed at the design stage or during operation, or by a combination of the above mentioned circumstances. The failure, as well, may be the result of gradual accumulation of damages dispersed in the material that, in turn, trigger initiation and development of the macroscopic sources connected with excessive wearing of friction surfaces and parts contacting with working medium or environment.

The failure or damage as a result of cracks development - the typical form of failure of high pressure vessels: Such objects can be met almost in all areas of technique, in particular in energetics, transportation industry, chemical and oil and gas industries.

The next items are subject of wear: gear mechanisms, piston-cylinder internal combustion engines, etc. When gears surface is worn the micro geometry of contacting parts is changed causing the increase of friction and lateral gap, that finally cause the toothed profiles separation during gearing and as a result the shocking operating mode of gear mechanism. Because of a great variety of mechanical systems, it is impossible to group them according to faults and correction techniques. This is why there follows a sufficiently detailed review of faults (defects) of such items as welded joints, castings, bearings, motor vehicles together with the correction procedures. Welded items, castings and ball bearings are encountered in most of mechanical systems. For instance, welded items are found in steam boilers, pressure-vessels, underground and surface gas pipelines, lifting structures, main pipelines for oil products, technology pipelines of industrial enterprises, machines and devices used at potentially dangerous enterprises of chemical, petrochemical, oil- and gas-processing industries, etc. In machine building, for instance, casting makes about 50 percent of all parts.

The special importance of detection of materials and mechanical systems parts damages is due to the fact that all these damages cause final breakdowns. The faults analysis can be very simple and be like ordinary detection of foreign inclusions, weak points and abnormal functioning of the item. Nevertheless, in some cases the mechanism of the damage and caused by it breakdown can be very comprehensive and hardly detectable. Sometimes it is difficult to detect which of the damages are most serious for the material. For example, the risks in connection with the mechanical processing or the residual stresses, are not critical for steel articles but are catastrophic for articles fabricated from beryllium. Experienced personnel and modem technical solutions can provide such a high level of interaction that, in turn, will ensure sufficiently high level of reliability and safety of mechanical systems operation.

Lately, in addition to the traditionally used methods of NDT and technical diagnostics aiming at search of sources or causes of equipment malfunctioning, the counters of useful life, load indicators and damages counters are used.

The correlation between possible technical faults of mechanical systems and their diagnostic parameters, in some cases, may be described by means of a fault diagnostics matrix.

Very often in the technical documents the information about faults (defects) is presented like a system of tables where the faults (defects), causes of arising defects and correction procedures are listed. In this chapter the same principle of information presentation will be followed, such an approach will make the use of data by specialists more easily, facilitating comparison of information through columns or rows in the tables.

2. Defects in Welds, their Causes and Removal

When using classification of local faults of welded joints according to national standards and ISO 6520-1:1998 and generalizing the information about the reasons of faults origination and ways of their removal, it is possible to work out Table 1, where the main information is presented in wording.

The intolerable defects contained in Table 1 are to be eliminated as prescribed in standard and technical documentation. For example, the national standard of Canada CAN3-Z 183 – M6 requires that, scaling, split ends, cracks on pipe surface, cracks in circular, longitudinal, spiral welds should be removed by cutting off the length of the pipe together with the defect therein. Arc burn-outs and dents over 1.5 mm deep are considered to bear hazard and should be removed by cutting out a cylinder or pipe length that contains them. Other documents require that the repairs of a weld area containing intolerable defects should be made by grinding them out with abrasive rings followed by hand welding. This document prohibits the second repairs of one and the same defect.

No	Defect (name according to ISO 6520-1) Notes	Cause	Method of removal
1.	**Crack** 100	- Base metal with high C or S content; - Improper additive; - Damp additive and/or auxiliary material; - Ambient temperature was disregarded; - Extremely small cross section of the weld at break; - Shrink restriction; - Overheat.	- Use basic additive material or fusing agent; - Pay due regard to composition of welding materials; - Dry additive and/or auxiliary material; - Pay due regard to external factors and welding sequence; - Change welding speed by a width of welding roller; - Make changes to design; - Use prior heating.
2.	**Crater crack** 104	- Composition of welding material disregarded; - Welding tensions disregarded; - Overheat.	- Fill up end crater, use end crater filling device; - Provide for a sump; - Change welding parameters; - Use pre-heating.
3.	**Gas pore** 2011 2012 2014 2017	- Dirt in weld area; - Weldpool was either very warm or very cold; - Blistering; - Base metal with very high C content;	- Clean welding area; - Change welding parameters; - Change sequence of welding, in this case – a cooling pause; - Use prior heating;
		- Damp additive or additional material (fusing agent, gas);	- Dry up additive or auxiliary material;
		- Insufficient melt bond at weld area; - Impurity of additive or auxiliary material; - Inappropriate composition of welding gas;	- Remove melt at weld point or file it clean; - Clean or change additive or auxiliary material; - Change quantity of welding gas applied; - Check composition of welding gas;
		- Defect or dirt at welding blowpipe nozzle;	- Replace weld base backing or position it properly;

		- Overheat of welding metal; - Too low current value; - Improper blowpipe position; - Too long an arc; - Strong air intake or distance between the welded item and blowpipe nozzle too large	- Clean or replace blowpipe nozzle; - Adjust blowpipe position; - Change connections of lead-out cable; - Adjust blowpipe position.

No	Defect (name according to ISO 6520-1) Notes	Cause	Method of removal
4	**Elongated cavity** **Worm-hole** 2015 2016	- Defect in weld base backing; - Damp additive and/or auxiliary material (protective gas, fusing agent); - Base layer insufficiently clean; - Improper quantity of protective gas; - Welding speed too high; - Air gap too wide; Too low current value.	- Replace weld base backing or position it properly; - Dry up additive and or auxiliary material; - Remove the remains of slag from intermediate layer; - Change quantity of protective gas; - Reduce welding speed; - Lessen air gap or provide for weld base backing; Change welding parameters.
5	**Solid inclusion** 300 3011 3012 3012 302 303 304	- Intermediate layer is insufficiently clean; - Too great convexity of weld base layer; - Improper weldpool feed (feed of welding smelt); - Penetration of slag in welding smelt; - Blistering;	- Remove the remains of slag in intermediate layer; - File out the convexity; - Adjust weldpool feed; - Alter blowpipe position; - Alter connection of the outlet cable;
		- Too low current strength, the additive is insufficiently molten; - Overload across tungsten electrode; contact with basic or additive metal; - Improper weld-on of layers.	- Change welding parameters; - Avoid contact with basic or additive metal; - Change manner of welding on layers.

6	**Copper inclusion** 3042	- Contact of gas blowpipe or current-carrying piece with the edge of strip or molten welding compound.	- Improper performance of welding work; - Provide proper training in welding.

No	Defect (name according to ISO 6520-1) Notes	Cause	Method of removal
7	**Lack of penetration (incomplete penetration)** 402	- Unsatisfactory or improper weld preparation; - Bad or improper fencing of weldpool; - Bad or improper protection of the weld base; - Insufficient heat supply; - Welding loop at crater's end or weldpool feed do not comply with welding method; - Improper selection of the strength of current.	- Alter weld preparation; - Replace fencing or position it properly; - Change quantity of forming-up gas; - Use prior warming-up in this particular case; - Re-train the welding operator.

Table 1. Welded Joint Defects: Causes and Methods of Removal

-
-
-

Bibliography

Annual Book of ASTM Standards. (1996) Section 3 *Metals Test Methods and Analytical Procedures*, Vol. 03.03 *Nondestructive Testing*, 922 pp. ASTM,USA.[This annual book Contains more than 120 standards for NDT].

ISO 6520-1:1998. *Welding and allied processes - Classification of the geometrical imperfections in metallic materials - Part 1: Fusion welding.* Switzerland: International Organization for Standardization. [In the document more than 130 imperfections of fusion welding are classified].

National standard of Canada CAN3-Z 183-M 86. *Oil Pipeline Systems*. [The document comprises calculations, procedures of the materials selection, of the fabrication, of laying, inspection, operation, technical maintenance and repair works of on-line oil pipelines and condensed gas pipelines].

Nikolaev G.A., ed. (1979). *Welding in Mechanical Engineering*. Handbook in 4 volumes (ed. V.A. Vinokurova). Vol. III, 567 pp. Moscow: Maschinostroyenie (in Russian). [This handbook describes rational manufacturing processes when fabricating welded structures].

SKF handbook for maintenance of ball bearings. (1995). Publication 4100 R. Reg. 70 3000 (in Russian). Published in Hungary. [This Maintenance Manual is to provide the reliable operation of ball bearings].

VSN 006-89. (1990). *Construction of Main and Field Pipelines. Welding.* Moscow: All Union Research Institute on Construction of Main Pipelines (in Russian). [Norms regulating the welding procedures covering the requirement imposed on welded joints in case of electrically welded tubes, fittings and shut down equipment].

Biographical Sketches

Klyuev Vladimir V. was born on January 2, 1937, Moscow, Russia. He graduated from the Moscow State Technical University named after Bauman in 1960 and Received the Degree of Candidate of Technical Sciences in 1964 and the Degree of Doctor of Technical Sciences in 1973.

Professional Employment: 1960-1964, engineer of the Moscow State Technical University named after Bauman; 1964-1970, Senior Researcher, Head of Laboratory, Head of Department at the Institute of Introscopy; 1970 – present, General Director of the Moscow Scientific Industrial Association "Spectrum".

Author of about 250 research papers,15 monographs, 100 patents.

Author of books: Non-Destructive Testing and Diagnostics, 1995; Theory and Practice of Radiographic Testing, 1998; Measuring, Inspection, Testing and Diagnostics. Mechanical Engineering. Encyclopedia in 40 volumes,Vol. III-7; Reliability of Machinery. Mechanical Engineering. Encyclopedia in 40 volumes, Vol.IV-3; Security of Russia. Ecological Diagnostics, 2000.

President of the Scientific Council on Automated Systems of Diagnostics of the Russian Academy of Sciences, President of the Russian Society for Non-Destructive Testing and Technical Diagnostics, Member of Editorial Board of journal "Defectoscopiya", Editor-in-chief of Journal "Testing. Diagnostics."

Elected Corresponding Member of the USSR/Russian Academy of Sciences, Member of Academia Europaea, Member of the Board of Directors of the European Federation for Non-Destructive Testing.

Prize of the Council of Ministers of the USSR, State Prize of the Russian Federation in the field of science and technology.

F.R. Sosnin was born on June 25, 1933, Ulyanovsk, Russia. He graduated from the Moscow Engineering and Physical Institute (experimental nuclear physics) in 1962 and received the Degree of Candidate of Technical Sciences in 1975 and the Degree of Doctor of Technical Sciences in 1983.

Professional Employment: 1962 – 1966, engineer –experimenter; 1966 – 1984, Head of the Laboratory of The Moscow Scientific Industrial Association "Spectrum"; 1984 – 1991, Deputy Director on Scientific Work, 1991 – present, Director of the Training Center of the above-mentioned Association.

Author of about 100 research papers and 10 monographs, textbooks and handbooks. Among them: Reliability of Machinery. Mechanical Engineering. Encyclopedia (in Russian, 1998).

Corresponding Member of the Russian Academy of Electrical Engineering.

Prize-winner of the Council of Ministers of the USSR.