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(54) INTEGRITY MANAGEMENT FOR TARGETED RESIDUAL MECHANICAL STRESS RELIEF

(57) The invention concerns a method for residual stress relief, in which stress zones are detected area-wide by means of mechanical stress detection and the extent is determined in each case. The stress zone is then relieved by means of appropriate local acoustic variations, after which the relieved stress zones are checked again by means of mechanical stress detection.

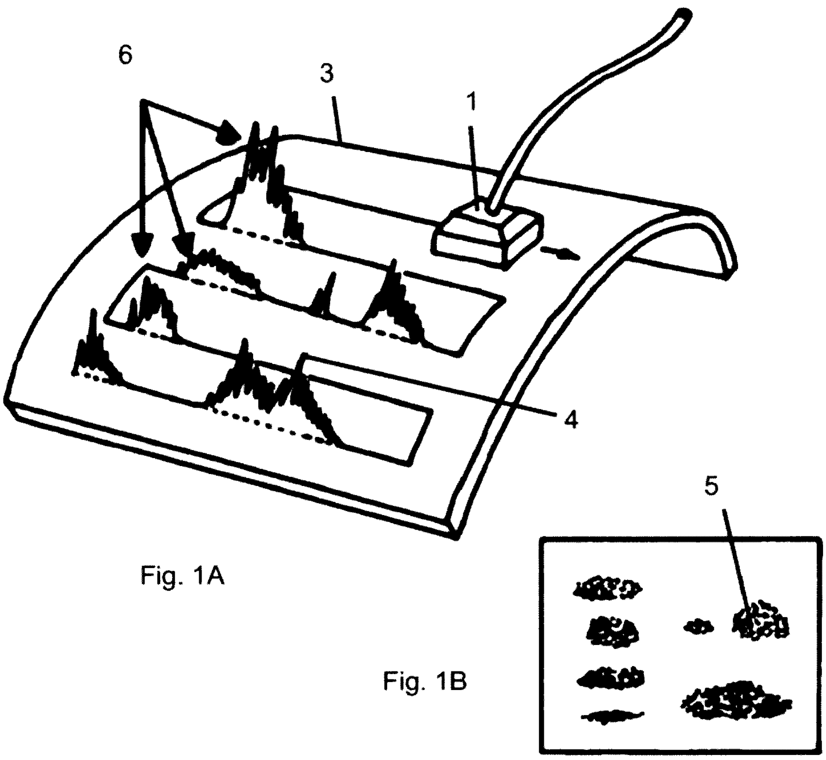

Fig.1

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Description

Technical Field

[0001] The invention concerns method for highly effective and targeted residual mechanical stress relief for both ferroelectric and non-ferroelectric material.

Background

[0002] In today's industry there is a long-standing and costly problem with harmful residual stress in parts and structures. These invisible residual stresses can often be the cause of critical and catastrophic fatigue failure. Currently available methods for the detection of these residual stresses can identify stress location and severity information. Asset owners typically use this information only for safety assessment and/or repair and maintenance measures without consideration of preventative actions. Methods for the removal of residual stresses is also known, including by the acoustic vibration or impact treatment, and these methods are currently applied in a separate and blind manner with a focus on typical or historical residual stress locations such as weld joints and known failure zones. These two known methods, stress detection and stress relief, are currently used separately. Today, there is no preventative solution that uses measurable methods to combine residual stress detection and removal to prevent fatigue failure caused by the presence of the undesirable residual mechanical stress.

[0003] Material fatigue problems are typically caused by dynamic and thermal stress developed during application and/or the manufacturing processes and are often the cause of cracking and corrosion. Furthermore, there is a general trend in many industries to reduce the weight of components to save costs or to increase a components load capacity (e.g. weight, pressure, temperature) to allow for higher performance. These new requirements may increase the occurrence of fatigue failure due to additional stress conditions. Therefore, there is a need for a complete and effective method that offers a preventative solution for stress related failures through the combination of stress detection and stress removal techniques.

[0004] The main industrial sectors where catastrophic failures occur are energy, oil and gas, offshore, aerospace, rail and civil structures. When failures occur it can often lead to loss of life, long downtime resulting in lost production time, and extreme unexpected costs. In the aerospace industry, part distortion and potential failure due to resulting residual stresses will lead to repeated hazardous situations, rework and possibly scrap worth several million Euros during the development and manufacturing lifecycle phases. In a high speed trains, many fatal events were attributed to the presence of residual stresses in wheel and axle parts. Oil and gas pipelines and structures are susceptible to failure due to residual stresses developed through cyclical loading or during initial forming and welding operations. Welded joints on offshore rigs are also exposed to constant loads due to rough sea conditions. The same applies to ships such as floating production storage and offloading vessels that are additionally exposed to the demands of cyclic loading, especially in fatigue-prone areas. When welds reach the end of their known life, customers are challenged to repair and maintain failing joints. Normal repairs to these high-load connections are often temporary and not sufficient for long-term operation. The cost of failure in this industry can be massive in terms of loss of life and loss of production that can often be in the tens of millions of Euros per day. Therefore, it is an object of the present invention to propose a preventative solution that uses measurable methods for residual stress detection and removal to prevent fatigue failure caused by the presence of the undesirable residual mechanical stress.

Description of the invention

[0005] The object is solved according to claim 1. Advantageous embodiments are claimed in the sub claims.

[0006] Accordingly, the invention proposes a novel solution for preventing fatigue failure. The solution is based on detecting in a first step the location and extent of residual stresses and then, in a second step, focusing the process of removing mechanical stresses (e.g. acoustic vibration or impact treatment techniques) on these predefined regions, in a very efficient and effective manner. After residual stress removal treatment in the second step, the processed object can again be checked according to a preferred embodiment in a third step by the residual stress detection method for any remaining residual stress as a confirmation of the stress removal process. The process method allows for repeated cycles of stress detection, stress removal, and, preferred, stress removal detection to achieve a desired stress removal level for any given object. Stress data at all stages can then be stored in the Asset Health Management software, enabling a highly efficient and effective method of predicting and preventing future fatigue failure. The process of residual stress relief can be carried by out any known technique, as well as the residual stress removal, which is selectively and effectively performed also by any known technique known by a person skilled in the art. The residual stress relief is carried out selectively only after identifying a mechanical stress zone and quantifying the magnitude of the stresses by a common detection technology and the results of the stress relief process are verified by the stress detection technology.

[0007] The invention is applicable to any material. It is directed to ferroelectric and non-ferroelectric material, conceivably this would also include polymers that are non-ferroelectric unless they are purposely dosed to make conductive then maybe they would be ferrous. The present invention serves as a method for predicting and preventing component parts and assembly degradation due to corrosion resulting from residual stress or fatigue failure resulting in cracks in both ferrous and non-ferrous materials. The invention serves as a unique method for preventing material defects and extending life.

[0008] According to preferred embodiment of the invention the workpiece is firstly scanned by a movable mechanical stress measuring device, preferably in a complete gapless process fully scanning the workpiece for the detection of mechanical stress zones.

[0009] Advantageously the result of the residual mechanical stress measurement is available by meter reading or by data for processing on a two-dimensional plane or three-dimensional plan by software. The size of the stress zone and the strength of the mechanical stress are available and can be displayed and/or recorded.

[0010] Preferably, according to another embodiment of the invention, the results of the first measurement of the workpiece residual mechanical stresses are recorded and may be stored for risk assessment and for use by an integrity management system.

[0011] The results of the measurement of residual mechanical stress are utilized according to a further embodiment of the invention for the exact planning and execution of subsequent residual mechanical stress relief. The stress measurement results determine the location of residual stress that must be reduced and the degree of mechanical residual stress relief that must be performed to achieve targeted and highly efficient results.

[0012] According to an embodiment of the invention, the measurement of residual mechanical stress is made by a Metal Magnetic Memory method or by other magnetic field techniques providing. The methods shall provide comparable results to reduce the time required for the stress relief process and through targeted treatment minimizes the risks to the workpiece and offers both economic and time saving benefits.

[0013] Advantageously, in a third step according to another embodiment of the invention the result of the residual stress relief process can be measured again by the method of detecting the stress in the identified processing zone to confirm the level of mechanical stress that has been removed and the resulting level of stress remaining.

[0014] The mechanical residual stress measurement information obtained from a treatment zone after the mechanical stress relief treatment is in a further embodiment available to be stored and utilized together with data collected from the same treatment zone in previous stress measurements. The data may be used for further risk assessment or predictive analysis and managed by an Integrity Management system.

[0015] Preferably, the whole process with respect to the treatment of the mechanical stress is performed step by step and exactly in accordance with the definition of the integrity management.

[0016] According to another embodiment of the invention, the process and information obtained from residual mechanical stress detection and the mechanical residual stress relief are used to provide raw data and insight to asset health, risks of failure, maintenance objectives, and to predict future trends or hazards related to an asset. This can be performed with an integrity management system. where data can be stored and used to schedule inspections, make stress relief efforts, and other life-extending measures.

[0017] There are three procedures that make up the complete method. First is a residual stress detection process, preferably the Metal Magnetic Memory method, is performed on the metal object or structure under evaluation. This procedure can detect both the location and the amount of residual mechanical stress present in the metal. Using this information, the second procedure of residual stress removal is applied in a targeted and highly effective manner. Now the third procedure is applied to again detect, preferably through the Metal Magnetic Memory method, any remaining residual stresses within the object or structure and this serves as a confirmation of successful stress removal processing or a need for repeated stress removal processing and retesting for remaining residual stresses to complete procedure. It is possible to apply this method to both dry environment objects and underwater objects.

[0018] There are several important benefits when applying this unique method when compared to conventional Non-Destructive Testing methods and standard residual stress removal methods. Through the combination of the two methods, stress detection and stress removal, a unique maintenance and life extension solution is offered to the owners of metal structures and assets. It is now possible to integrate the raw data and information produced by this method into most of today's standard Asset Integrity Management software systems. This enables not only a much more effective prediction of location of future failure due to harmful residual stresses but also a preventative method enabling removal of the initiating residual stresses. The overall benefit to the asset owner is a highly reduced failure rate, often hazardous to life, and can greatly extended asset lifetime. The use of this invention serves to provide increased plant safety and often tremendous cost savings.

[0019] The invention concerns a method for residual stress relief, in which stress zones are detected area-wide by means of mechanical stress detection and the extent is determined in each case. The stress zone is then relieved by means of appropriate local acoustic variations, after which the relieved stress zones are checked again by means of mechanical stress detection.

[0020] The features and feature combinations described above and below in connection with the drawings as well as the features and their combinations shown in the figures are also useable alone or in other combinations. For carrying out the invention, not all features of independent claims must be realized. Also, any single feature of any independent or parallel claim may be replaced by another disclosed feature or feature combination. All features and/or advantages derivable from the claims, the description or the drawings, including structural details, spatial layout and process steps may be, per se or in any combination, essential to the invention.

Brief Description of the Drawings

[0021] The figures show:

Figure 1 a perspective view of a workpiece, and a device for measuring the mechanical stress moving across the workpiece, together with ex-amples for the extent of mechanical stress in Figure 1A and a depic-tion of the stress zone before respective treatment in Figure 1B;

Figure 2 a second perspective view of the workpiece of Figure 1 now with an acoustic vibration source in Figure 2A together with a diagram in Figure 2B showing the extend of stress over the time for stress re-lief;

Figure 3 a third perspective view of the workpiece of Figure 1 now again with the device for measuring the mechanical stress together with ex-am-ples for the extent of mechanical stress in Figure 3A and a depiction of the stress zone after the treatment in Figure 3B; and

Figure 4 a diagram showing integrity management.

Detailed Description of the Drawings

[0022] Figure 1A shows a workpiece 3 of a ferroelectric and non-ferroelectric material and a device 1 for measuring the extent of the mechanical stress by moving across the workpiece 3. Along the path of the device 1 across the workpiece 3 the figure shows exemplary graphs 4 of the mechanical stress extent 6. In Figure 1B additionally the stress zones 5 on the workpiece 3 are depicted before any further treatment of the workpiece 3.

[0023] In Figure 2A the workpiece 3 is treated with an acoustic vibration source 2 at the stress zones 5 depicted in Figure 1. The graph in Figure 2B shows the extent of stress over the time for stress relief.

[0024] After the treatment with the acoustic vibration source 2 the device 1 is moved again across the workpiece 3 with the new graphs 4 of the mechanical stress extent 6 in Figure 3A and a depiction of the stress zones 5' after the treatment in Figure 3B.

[0025] Figure 4 shows a diagram of an integrity management method and system IM comprising several different steps. The plan step P includes asset management, strategy policies, objectives and plans. The inspection step I includes residual stress screening, identification, measuring and defect localization and visualization, data recording (before) and storage. The action step A includes residual stress relief by using penning technology, management review. The final check F step includes re-screening and assessment result, checking of penning action, data recording and storage for the integrity, management purpose improvement .The data received from the measurement are used to optimize the management.

Claims

1. A method for highly effective and targeted residual mechanical stress relief for both ferroelectric and non-ferroelectric material (3) **characterized by** the combination of a mechanical stress detection technique and a residual stress removal technique, including in a first step the localization of the mechanical stress (5) and the determination of the extent of the mechanical residual stress (4), and in a second step selectively carrying out the residual stress relief.

2. The method according to claim 1, **characterized in that** the result of the residual stress relief is measured again by the mechanical stress detection technique.

3. The method according to claim 1 or claim 2, **characterized in that** the workpiece (3) is firstly scanned by a movable mechanical stress measuring device (1), preferably in a complete gapless process fully scanning the workpiece for the detection of mechanical stress zones.

4. The method according to any one of the preceding claims, **characterized in that** the result of the residual mechanical stress measurement is available by meter reading or by data for processing on a two-dimensional plane or three-dimensional plan, wherein the size of the stress zone (5) and the strength of the mechanical stress (4) are available for displaying and/or recording.

5. The method according to any one of the preceding claims, **characterized in that** the results of the first measurement of the workpiece (3) residual mechanical stresses are recorded and may be stored for risk assessment and for use by an integrity management system (IM) .

6. The method according to any one of the preceding claims, **characterized in that** the results of the measurement of residual mechanical stress are utilized for the exact planning and execution of subsequent residual mechanical stress relief, whereby the stress measurement results determine the location of residual stress that must be reduced and the degree of mechanical residual stress relief that must be performed to achieve targeted and highly efficient results.

7. The method according to any one of the preceding

claims, **characterized in that** the measurement of residual mechanical stress is made by a Metal Magnetic Memory method or by other magnetic field techniques.

8. The method according to any one of the preceding claims, **characterized in that** the result of the residual stress relief process is measured again by the method of detecting the stress in the identified processing zone to confirm the level of mechanical stress that has been removed and the resulting level of stress remaining.

9. The method according to any one of the preceding claims, **characterized in that** the mechanical residual stress measurement information obtained from a treatment zone after the mechanical stress relief treatment is available to be stored and utilized together with data collected from the same treatment zone in previous stress measurements and may be used for further risk assessment or predictive analysis and managed by an Integrity Management (IM) system.

10. The method according to any one of the preceding claims, **characterized in that** the whole process with respect to the treatment of the mechanical stress is performed step by step and exactly in accordance with the definition of the integrity management (IM).

11. The method according to any one of the preceding claims, **characterized in that** the process and information obtained from residual mechanical stress detection and the mechanical residual stress are used to provide raw data and insight to asset health, risks of failure, maintenance objectives, and to predict future trends or hazards related to an asset.

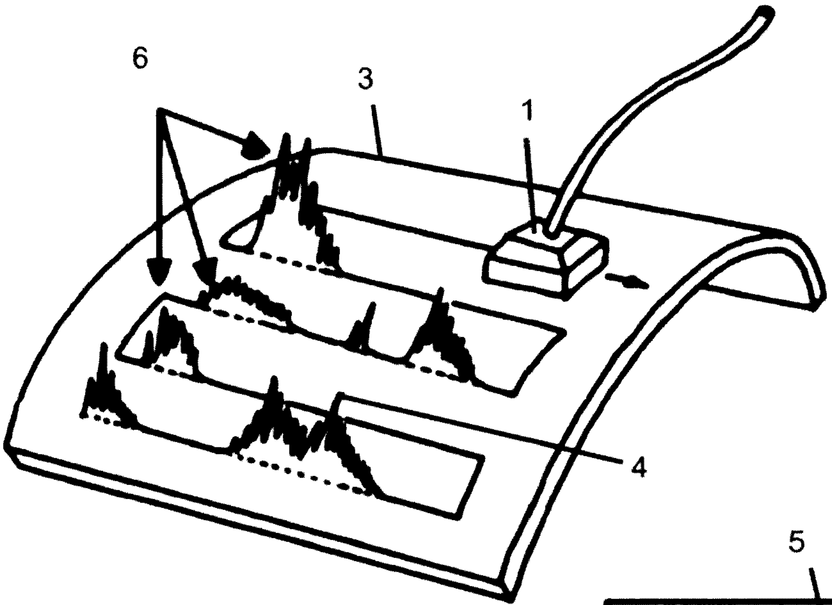

Fig. 1A

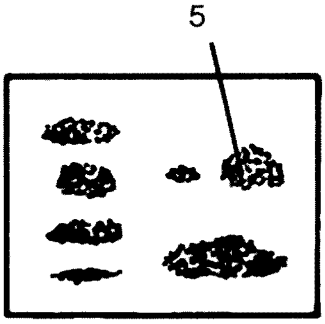

Fig. 1B

Fig.1

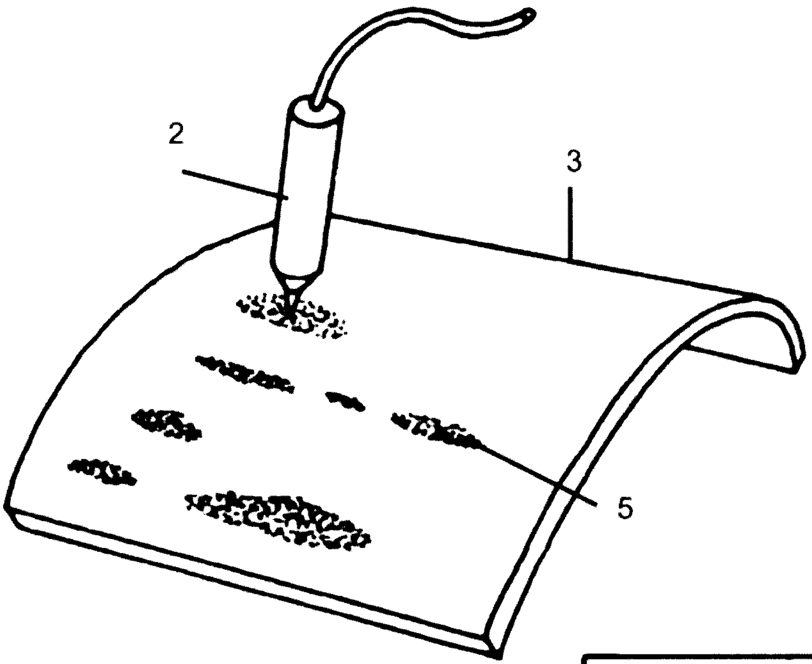

Fig. 2A

Fig. 2B

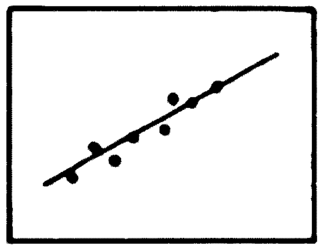

Fig. 2

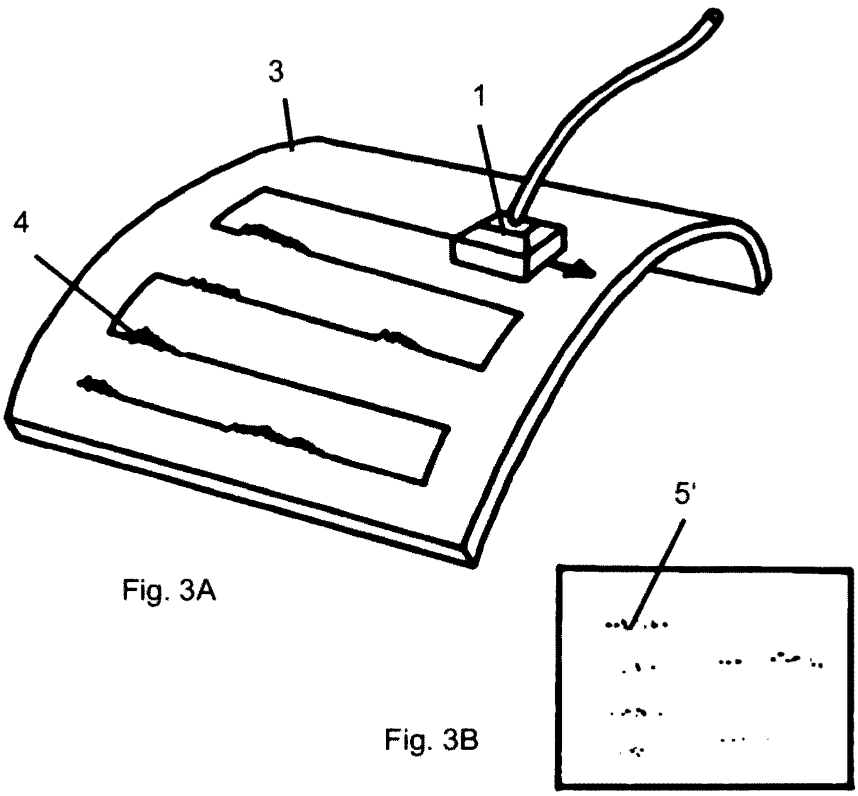

Fig. 3A

Fig. 3B

Fig. 3

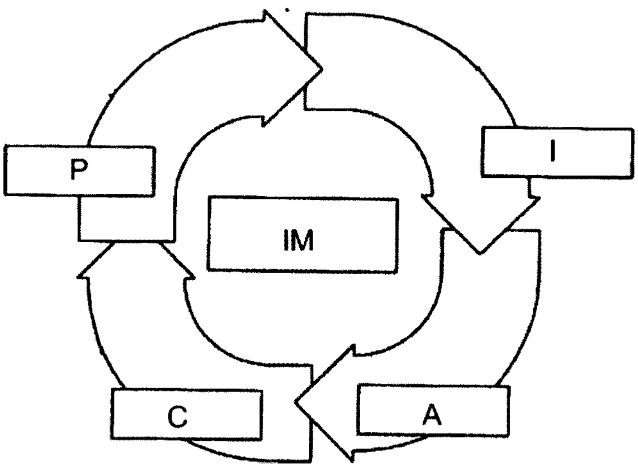

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 19 20 6909

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DATABASE WPI Week 201881 Thomson Scientific, London, GB; AN 2018-92688K XP002799640, & CN 108 796 207 A (JSTI GROUP CO LTD) 13 November 2018 (2018-11-13) * abstract; figures 1,2 * -----	1-11	INV. C21D10/00 C22F3/00 G01N27/72
X	DATABASE WPI Week 198940 Thomson Scientific, London, GB; AN 1989-291695 XP002799641, & SU 1 447 876 A (KAUN ENG PRODN) 30 December 1988 (1988-12-30) * abstract; figure 1 * -----	1,3	
X	DATABASE WPI Week 201163 Thomson Scientific, London, GB; AN 2011-L23292 XP002799642, & CN 102 146 504 A (CHINESE ACAD SCI INST MECHANICS) 10 August 2011 (2011-08-10) * abstract * -----	1	TECHNICAL FIELDS SEARCHED (IPC): C21D C22F
A	DATABASE INSPEC [Online] THE INSTITUTION OF ELECTRICAL ENGINEERS, STEVENAGE, GB; 2008, JURCIUS A ET AL: "Reduce of material residual stresses using vibration energy", XP002799643, Database accession no. 10643224 * abstract * -----	1-11	

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	7 July 2020	Rischard, Marc

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82