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An Evaluation of Cracks Repairing Techniques in Metals

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ABSTRACT
Cracks are surface that develop in a material. Dissemination energy derived from mechanical, thermal, chemical, and metallurgical effects, or a grouping of these may affect crack beginning and growth. Numerous types of cracks exist in metals and can be characterized as grinding, solidification, cooling, crater, machining tears, plating, centerline, pickling, heat treatment, fatigue, creep, stress corrosion and hydrogen cracks. Cracks can grow and lead to complete fracture of the component posing significant threats to component life and may lead to serious injuries or loss of life. Brittle fracture in metals occurs with little or no visible warning. Discovery of any cracks warrants immediate interventions to arrest the cracks before they propagate to the point of fracture. Numerous crack recognition and repair techniques in metals have been developed, categorized and certified through examination. This paper presents the repair techniques of cracks in metals.

Keywords: cracks, crack repair techniques, metals

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INTRODUCTION

At present, a number of metal crack detection techniques have been developed and these include, examination through human senses, liquid penetration method, ultrasonic testing, radiographic imaging, magnetic particle inspection and eddy current testing, which are all non-destructive testing techniques (NDT). Various types of cracks exist in metals and the common categories include cooling, hot, solidification, centreline, crater, liquidation (hot tearing), grinding, pickling, heat treatment (quenching), machining tears, plating, fatigue, creep, stress corrosion, and hydrogen cracks [1]. Several techniques have been developed for the repair of cracks. These have been applied to a range of crack sizes, both macro and micro cracks. Hammer peening, grinding, vee-and-weld, doublers or splice plates, pulsed electron beam irradiation, carbon fiber reinforced polymer(CFRP) patches, stop-hole technique, bonded composite patches, crack stitching and laser additive crack cladding have been extensively studied. The aim of the present paper is to review the commonly used crack repair techniques in metals [2].

Some of the advantages of cracks repair process:

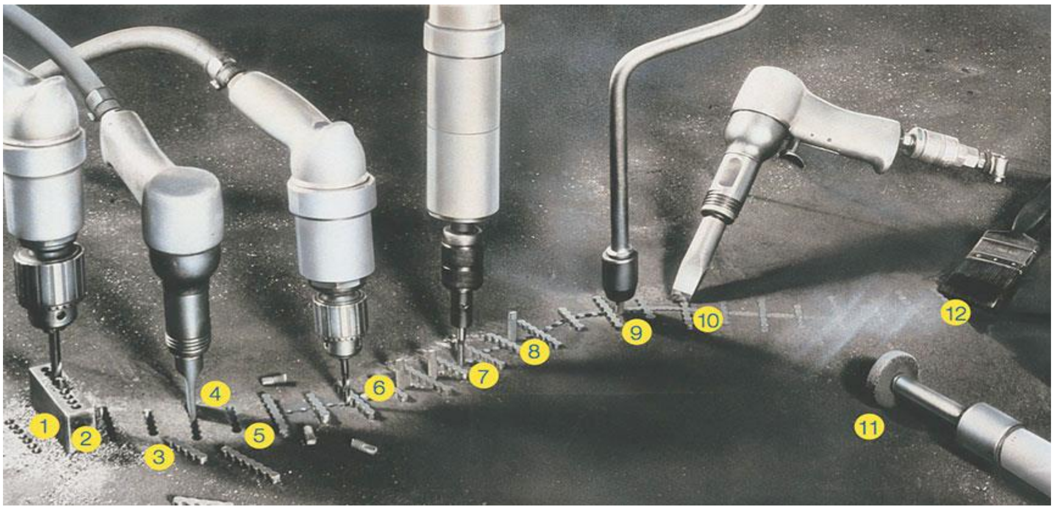
- Dampens and absorbs compression stresses
- Provides a good ‘expansion joint’ for such castings as cylinder liners, diesel heads or any vessels subject to thermal stresses
- Distributes the tension load away from fatigue points
- Maintains relieved conditions of inherent internal stresses where rupture occurred
- Maintains alignment and original surfaces, since lack of heat produces no distortion
- The vast majority of repairs can be done in situ, with consequent savings

in time with little or no dismantling [3].

Metal Crack Stitching

Metal stitching or metalocking is a method of repairing cracks in cast metals without the need of welding. Cold repairs on all cracked or broken components made from cast iron cast steel or aluminium. Breakages usually occur because of overloading, accidents, equipment misuse or flaws in the casting [4].

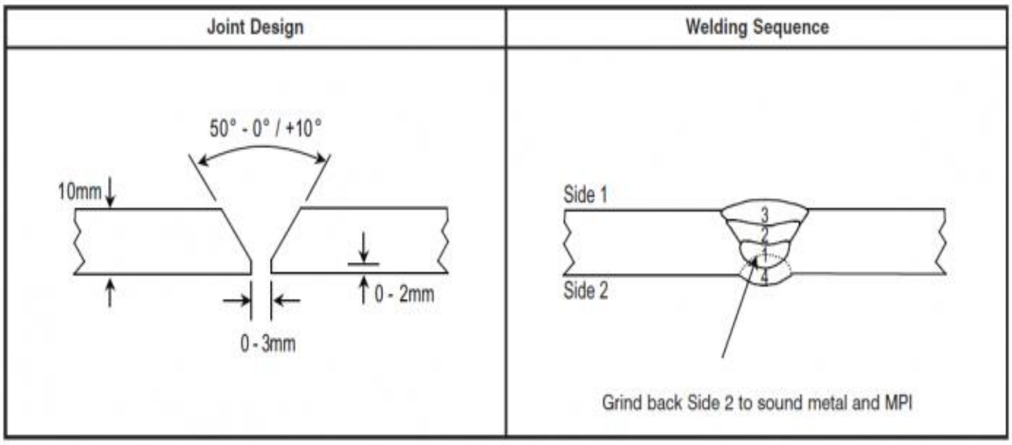
Cold Mechanical Stitching is a method used to repair cracks in industrial metal without welding or heating. This method is stronger and more durable than welding and can usually be performed on site. Other names are metal locking, metal surgery, cold welding, stitch welding and crack patching. Metal Crack Stitching has been providing cast iron and other metal crack repair without welding for over 25 years [5].



Vee-and-weld

A welding joint is a point or edge where two or more pieces of metal or plastic are joined together. They are formed by welding two or more workpieces (metal or plastic) according to a particular geometry. Five types of joints referred to by the American Welding Society: butt, corner, edge, lap, and tee [6].

- Butt Joint. A butt weld, or a square-groove, is the most common and easiest to use.
- Corner Joint
- Edge Joint
- Lap Joint
- Tee Joint



Stop-Hole Technique

Calculate the fatigue stress concentration factor of the stop hole K_f with the use of the measured crack size and an assumed stop hole size. Establish the long-term distribution of the stress range on the stop hole according to the intended voyages before the cracked structure enters a repair facility [7].

Bonded Crack Patches

Composite patches, bonded on cracked or corroded metallic aircraft structures, have shown to be a highly cost-effective method for extending the service life and maintaining high structural efficiency. Damage tolerant and fail-safe design of aircraft, aerospace and civil structures requires a substantial amount of inspection and defects-monitoring at regular intervals. There is a large number of high-cost inventory of aircraft structures in operation throughout Europe and the world, that are undergoing continuous degradation through aging. Moreover, this number is increasing by around 5% every year, resulting in significant negative impact on the economy of many nations. The degradation of defects critical structures is controlled through careful and expensive regularly scheduled inspections in an effort to reduce their risk of failure.

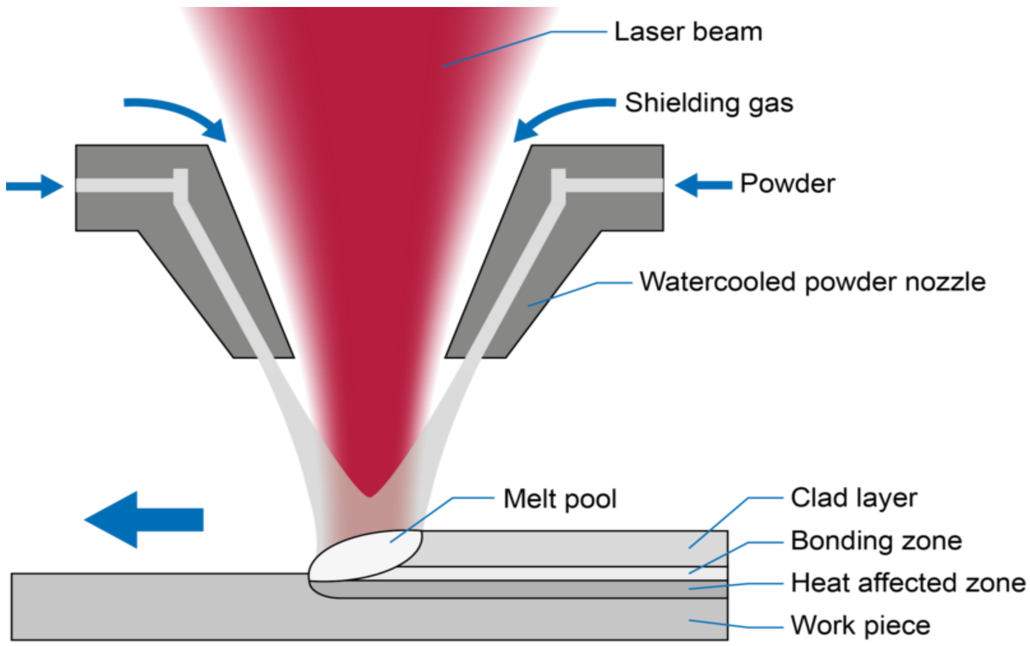
The replacement of a damaged structural component has a relevant impact on the life cycle cost of an airplane. Bonded composite patches for repairing cracks and defects in aircraft structures have been widely used in the last years. This technology offers many advantages over mechanical fastening or riveting, including improved fatigue behavior, restored stiffness and strength, reduced corrosion and readily formed into complex shapes. The success of a bonding repair depends on the properties of both the adhesive and the patch. The quality of the repair depends upon bonding process and surface treatment as well [8–10].

Laser Additive Crack Cladding

Laser additive manufacturing is state-of-the-art and regarded as a key technology in the future of production engineering. Originating from a computer model, a new freedom of design can be achieved by simply adding layer by layer.

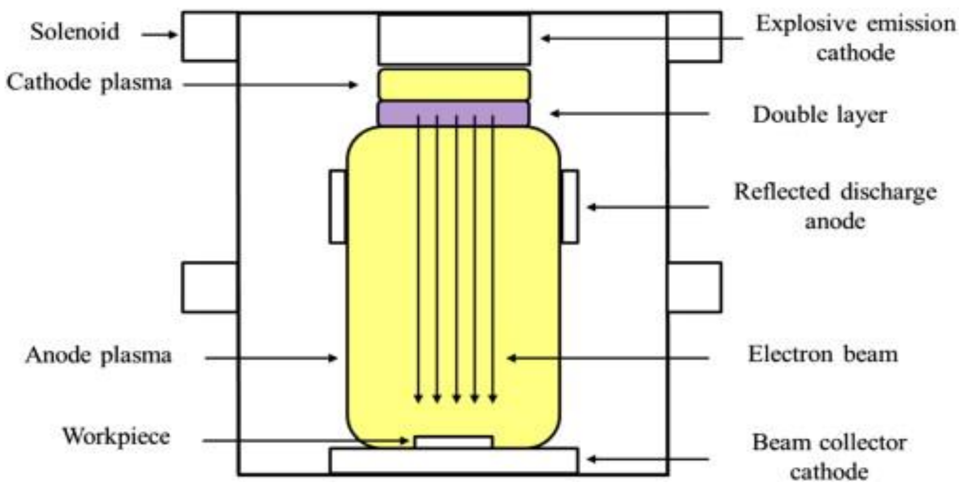
Beyond the new perspectives and extended possibilities of conventional processes there are fields of application which already have been opened up. One of those is the highly innovative but demanding field of processing with heat resisting alloys. This field of engineering has traditionally been a door opener for high tech technologies such as aerospace or energy [11].

Tailored temperature support is necessary to achieve a defect-free material build-up with crack-sensitive materials. However, the additional heat input makes the geometry build up even more demanding resulting in unwanted and non-precise material deposition. Remedy can be found by the combination of the hybrid laser technology and the system for temperature monitoring and control: Based on precise measurements and a suited process interaction, it becomes possible to realize the defect-free material build-up as well as geometrical precision [12].



Pulsed Electron Beam Irradiation

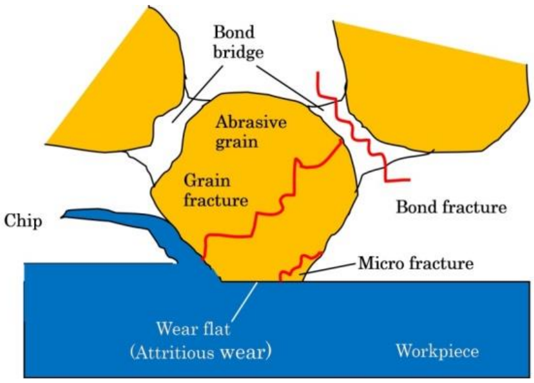
The pulsed electron beam irradiation process for surface melting is an effective method of rapidly improving the surface finish and morphology of an EDM'd steel surface. The irradiation process is carried out in an air-tight chamber into which an inert gas, argon at a pressure of 0.05 Pa is supplied, after an initial 10 minutes vacuum cycle time. This argon gas is used as the medium for plasma buildup required for the electron generation and beam propagation. Bombardment of the high current electrons with a workpiece causes rapid heating and cooling cycles at its surface. The diameter of the beam is 60 mm; with a pulse-time of 0.8–3 µs and pulse interval of 11 s. The beam has been shown to extend further than its 60 mm diameter although the energy density is significantly diminished beyond this point. Within the 60 mm diameter, energy density has shown to be uniform [13].



Grinding

Surface grinding is used to produce a smooth finish on flat surfaces. It is a widely used abrasive machining process in which a spinning wheel covered in rough particles (grinding wheel) cuts chips of metallic or nonmetallic substance from a work piece, making a face of it flat or smooth.

A grinding machine, often shortened to grinder, is any of various power tools or machine tools used for grinding, which is a type of machining using an abrasive wheel as the cutting tool. Each grain of abrasive on the wheel's surface cuts a small chip from the work piece via shear deformation. Grinding is an abrasive machining process that uses a grinding wheel as the cutting tool. A wide variety of machines are used for grinding: Hand-cranked knife-sharpening stones (grindstones) Handheld power tools such as angle grinders and die grinders. In the manufacture of ceramic components, it has been well documented that the grinding costs can be as high as 80% of the total cost. To reduce the grinding cost, massive research studies have been conducted and new types of high-performance machining techniques have been developed based on the fundamental understanding of the prevailing grinding mechanisms for engineering ceramics [14].



Hammer Peening

Peening is the process of working a metal's surface to improve its material properties, usually by mechanical means, such as hammer blows, by blasting with shot (shot peening) or blasts of light beams with laser peening. The Machine Hammer Peening (MHP) surface treatment technology was developed to replace the manual polishing procedure of workpiece surfaces by an automated process. During the treatment, a tool with a spherical carbide tip is used to hammer the surface of a workpiece by well-directed hits. Therefore, the tool is performing an oscillating movement produced by an actuator. This device can be attached to any kind of machine tool, which is providing a relative movement between the workpiece and the peening tool. A main application for the surface smoothening ability of Machine Hammer Peening can be found in finishing of pressing dies used in the automotive industry. The technology of Machine Hammer Peening opens up new opportunities for the modification of materials surfaces in the field of production engineering and further meets the requirements of the original process application of surface smoothening [15].

Common Crack Repair Techniques in Metals

Fracture is defined as rupture in tension or rapid extension of a crack which leads to gross deformation, loss of function or serviceability, or complete separation of the component. When fracture critical cracks are detected in mechanical components and structures, several methods are employed to arrest or stop them from further growth or propagation. The choice of the repair technique or a combination to be used depends on many factors which include the nature of the crack, crack position, crack orientation, crack size, crack accessibility, component application, expected repair precision, availability of tools, metal type, component thickness and the required expertise. The commonly employed techniques will be reviewed in this section [16–18].

CONCLUSION

Repair of cracks in metals was reviewed and various repair methods that are currently in use at both general practical purpose and high value and critical application levels have been discussed. It has been noted that computational studies are playing a key role in improving understanding of the effect of most crack repair techniques on the mechanical performance of repaired components. The recent introduction and use of laser additive technology for crack repairs has also been studied as it shows significant potential for crack repair. Limited recent works on this Technique have been published and therefore is an interesting research area.

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