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GRADO EN INGENIERIA MECANICA

Specification sheet

Repair of ductile cast iron frames for heavy trucks
used in quarries and mining

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1 DEFINITION AND SCOPE

The objective of this TFG, is to provide the best welding process to repair cracks on ductile cast iron frames of haul trucks, the welding process can be supported by heat treatment. The idea is to study the needs of haul truck frames, their ability to support big loads and hard operating conditions, then to take into account the origins of the cracks and failures that may occur and to study the ductile cast iron. At the end, it is asked to provide and describe a complete repairing process on a 100mm crack, the crack may change direction and not be planar (around a shaft following the rounded curve for example). This specification document is dedicated to a supposed haul truck manufacturer such as Caterpillar which needs a process to repair their Cat 797F haul truck frames in ductile cast iron.

Haul truck frames work in difficult conditions, they face variations of temperature, variation of loads depending on the road or if they are loaded or not. All this conditions may lead to stress and strain on the frame, this frame in ductile cast iron may crack because of fatigue or because of one-time strong load. Ductile cast iron can be repaired by welding, however welding process generally lead to the weak the structure of the welded zone and its surroundings, in that way other failures may occur, costing again time and money to the truck company owner.

The goal is to achieve a welding process for a 100mm long crack, the repaired zone must be tough and resistant to the loads. Too hard and brittle structured must be avoided, the repair must have a resistance as close as possible to the parent material, regarding to the filler material, the heat affected zone and the interface. The process development can use different welding methods and also pre or post-treatment such as heat treatment. The process should take into consideration the variation of the microstructure and try to keep the most tough and ductile one. The process can also use different welding passes and different types of filler material. In all of the cases, the material and process used must be described and justified.

As it is simply a theoretical study because no experimental work could have been applied since we are in confinement, it is important to describe the process using schemas and to justify the results we are hoping to have. A cost study is needed, in order to estimate the cost of the repairing of a crack.

2 CONDITIONS AND NORMES

2.1 STANDARDIZATION AND NORMES

The general conditions and standards that must be complied corresponding to the legislation of both the Spanish UNE standards and the European ISO standards, in reference to the machine tools that form part of a manufacturing line that consists of moving and lifting elements, as well as their requirements for materials, manufacture, finishes and resistance directly focused on safety.

The technical standardization committees mainly involved are, they must be respected in order to provide an efficient and secured work :

CTN 15 - MACHINE TOOLS

CTN 15/SC 1-MACHINE VERIFICATION

CTN 15/SC 2-MACHINE SAFETY

CTN 17 - FASTENERS

CTN 18 - TRANSMISSIONS, BEARINGS AND GEARS

CTN 23 - FIRE SAFETY

CTN 23/SC1/GT2 - SYMBOLS AND SIGNS

CTN 23/GT2/AHG1 - MAINTENANCE

CTN 23/SC4/GT4 - LIFTING EQUIPMENT

And the coordination of international regulations:

IEC/TC 65 - Industrial-process measurement, control and automation

IEC/SC 65A - System aspects

IEC/TC 72 - Automatic electrical control

IEC/TC 79 - Alarm and electronic security systems

IEC/TC 95 - Measuring relays and protection equipment

THE GENERAL REQUIRED CONDITIONS ARE:

- Performance aspects

- Description and specification of repairing processes.

-Description of the repair and the materials used

- Reference of all constituent materials, specifying their material description
- Reference of all the finishes and surface treatments of the different pieces.

- Delivery

- All those aspects related to the delivery of the repair and articles necessary for its execution and production are described.
- They include the operation, assembly, installation and use of each subsystem and the process including all details. And also costs and prices of each item used and the workforce.

2.2 REGULATIONS AND NORMES

BOE-A-2011-17887

Royal Legislative Decree 3/2011 of 14 November, approving the revised text of the Public Sector Contracts Act.

BOE-A-1997-17824

Royal Decree 1215/1997 of 18 July 1997, establishing the minimum health and safety requirements for the use of work equipment by worker.

BOE-A-2008-16387

Royal Decree 1644/2008 of 10 October 2008, establishing the rules for the marketing and commissioning of machinery.

BOE-A-2017-12902

Law 9/2017, of 8 November, on Public Sector Contracts, which transposes into Spanish law the Directives of the European Parliament and Council 2014/23/EU and 2014/24/EU, of 26 February 2014.

Pliego de condiciones

BOE-A-2003-22510

Judgment of 27 October 2003, of the Third Chamber of the Supreme Court, annulling Royal Decree 786/2001, of 6 July, approving the Fire Safety Regulations for industrial establishments.

BOE-A-1997-15712

Royal Decree 941/1997 of 20 June 1997, establishing the certificate of professionalism of the occupation of installer of industrial machinery and equipment

BOE-A-2000-21837

Royal Decree 1849/2000 of November 10, 2000, repealing various provisions on the standardization and approval of industrial products.

BOE-A-1995-5650

Royal Decree 154/1995 of 3 February 1995, amending Royal Decree 7/1988 of 8 January 1988, regulating safety requirements for electrical equipment intended for use within certain voltage limits

BOE-A-1971-380

Order of 9 March 1971 approving the General Ordinance on Safety and Health at Work.

UNE-EN ISO 12100:2012

Safety of the machines. General principles for design. Risk assessment and risk reduction (ISO 12100:2010)

UNE-EN ISO 13849-1:2016

Safety of the machines. Safety-related parts of control systems Part 1: General principles for design (ISO 13849-1:2015)

UNE-EN 60204-1:2007

Safety of the machines. Electrical equipment of the machines. Electrical equipment of machines - Part 1: General requirements (IEC 60204-1:2005, modified).

Pliego de condiciones

UNE-EN ISO 13850:2016

Safety of the machines. Emergency stop function. Principles for design. (ISO 13850:2015).

UNE-EN ISO 13857:2008

Safety of the machines. Safety of machinery - Safety distances to prevent hazard zones being reached by upper and lower limbs (ISO 13857:2008)

UNE-EN ISO 4414:2011

Pneumatic transmissions. General rules and safety requirements for systems and their components (ISO 4414:2010).

UNE-EN ISO 11161:2009

Safety of the machines. Integrated manufacturing systems. Fundamental requirements - Safety of machinery (ISO 11161:2007)

UNE-EN ISO 4413:2011

Hydraulic transmissions. General rules and safety requirements for systems and their components (ISO 4413:2010)

UNE-EN 62402:2011

Management of obsolescence. Application guide.

UNE-EN ISO 14159:2008

Safety of the machines. Safety of machinery - Hygiene requirements for the design of machinery (ISO 14159:2002)

DOUE-L-2006-81063

Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)

Pliego de condiciones

UNE-EN 1011-8

Welding. Recommendations for welding metallic materials. Part 8: Welding of cast iron.

ISO/TC 44/SC 11

Qualification requirements for welding and allied processes personnel.

ISO/TC 44/SC 10

Quality management in the field of welding.

UNE-EN 287-6

Qualification of welders. Fusion welding. Part 6: Cast iron.

UNE-EN ISO 1071

Welding consumables. Coated electrodes, wires, rods and tubular electrodes for fusion welding of cast iron. Classification.

UNE-EN 1563

Foundry. Spheroidal graphite cast iron.

EN 22401

Covered electrodes — Determination of the efficiency, metal recovery and deposition coefficient (ISO 2401:1972).

EN 439

Welding consumables — Shielding gases for arc welding and cutting.

3 TECHNICAL CONDITIONS

The technical specification is the document which describes in detail how the work needs to be carried out to ensure that the repair is performed properly. For this reason, the aim of this specification is to complete and improve the data that appear in the report, budget and plans.

3.1 MATERIAL CONDITIONS

This section specifies the materials that will be used for the repair, as well as the treatments and machining processes that will be carried out on them.

The characteristics described are the minimum required, and some higher ones may be admitted, but never lower than those specified.

Ductile cast iron

It is a type of cast iron which is an iron alloy composed from 3.2 to 3.6% of carbon, 1.2 to 2.3% silicon, 1% of nickel, and other components in lower quantities. There are lot of types of ductile cast iron, and their properties may change from one to another depending on the composition.

We use it for its mechanical properties, because it gives the resistance of cast iron in a more ductile way. Ductile cast iron is different than other cast irons thanks to the alloy elements, in fact the presence of magnesium, magnesium-ferrosilicon and magnesium-nickel provides the formation of graphite nodules which gives to the microstructure a better ductility and toughness and without losing the ease of moulding cast irons. In fact, it is useful in the automotive industry, for example to manufacture truck frames, especially haul truck frames. We are going to focus on repairing ductile cast iron frames by welding the cracks.

3.2 TECHNICAL CONDITIONS OF THE REPAIRING AND ASSEMBLY

The execution process will be mainly focused on the repairing of the parts that require a specific process, and to carry out the process.

The process to be followed for the manufacture of the different elements will be carried out as described below. Additionally, the following instructions must be followed:

- The safety of the operators must be taken into account at all times.

Pliego de condiciones

- Care must be taken to ensure that the operators responsible for carrying out the various tasks are qualified and capable of performing them.
- It must be ensured that the materials and machinery to be used do not suffer any kind of defect or damage.
- Knocks on the elements must be avoided both when transporting the materials and after the parts have been produced.

3.3 MACHINES SERVICE

Below are some of the safety rules the machine must pass before being tested in service. These tests are included in the UNE regulations, as they affect safety.

- The UNE-EN ISO 12100:2012 standard specifies the terminology, principles and methodology for achieving risk assessment and risk reduction.
- The UNE-EN ISO 13849-1:2016 standard provides safety requirements and guidelines for control and safety systems.
- The standard UNE-EN 60204-1:2007 establishes the safety requirements for electrical and electronic systems that work together in a coordinated manner.
- UNE-EN ISO 13850:2016 specifies the functional requirements and principles for the design and emergency stop function of machines.
- The UNE-EN ISO 13857:2008 standard establishes values for safety distances so that hazardous areas of machinery are not reached.
- The standard UNE-EN ISO 4414:2011 specifies the general rules and safety requirements for pneumatic transmission systems and components.
- The standard UNE-EN ISO 11161:2009 specifies the safety requirements for manufacturing systems incorporating two or more interconnected machines for applications such as the manufacture and assembly of components.

Pliego de condiciones

- The standard UNE-EN ISO 4413:2011 indicates the general rules and safety requirements for hydraulic transmission systems and components.

Additionally and after the installation in the plant, another service test must be carried out, by which the following sections must be fulfilled in order to ensure the correct installation of the machine:

- Verification of the functionality, quality and integrity of the installation, by means of a global verification process.
- Verify extremely important documents such as manuals, instructions, plans, diagrams and instrumentation.
- Guarantee that the equipment works as expected according to the foreseeable conditions, including misuse and error.
- Overall integrity checks.
- Examination of functionality by means of conventional functional tests or simulation.
- Verification of contractual requirements.
- Verification of the availability and quality of documents
- Final inspection

4 ECONOMIC STUDY

These terms are those that affect the cost and form of payment of the work contracted, the guarantees or for the fulfilment of what has been agreed, the compensation in the event of non-compliance and, in general, the obligation contracted by the owner to pay the amount of the work carried out.

They may be eliminated and included in the particular contract between the developer and the contractor.

The following points should be taken into account in the economic conditions:

All those involved in the repairing process are entitled to receive the contracted amounts on time for their correct performance, in accordance with the contractually established conditions. The owner, the contractor and, if applicable, the technicians can demand from each other adequate guarantees for the punctual fulfilment of their payment obligations.

Composition of unit prices

The calculation of the prices of the different work units is the result of adding up the direct costs, indirect costs, material or immaterial.

Direct costs

- The labor force, with its bonuses and social security charges and insurance, which is directly involved in the execution of the unit of work.
- The materials, at the resulting prices, which are integrated into the unit in question or which are necessary for its execution.
- Technical health and safety equipment and systems for the prevention and protection of accidents and occupational diseases
- The costs of personnel, fuel, energy, etc., incurred in the operation of the machinery and installations used in the execution.

Indirect costs

The costs of installation of offices, communications, building of warehouses, workshops, temporary halls for workers, laboratories, insurance, etc., those of the technical and administrative staff assigned exclusively and unforeseen costs.