High Strength Stainless Steel Refractory Anchors: Alternative Welding Technique Feasibility

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Abstract

This paper provides a general overview of the logic, processes and theories involved in the investigation; testing and feasibility study on an alternate welding technique for Refractory Anchors to meet the client's requirements.

1.0 Project Background

Mechanical steel anchors are used to ensure retention of the refractory to equipment, most notably in the mining industry where certain equipment will contain thousands of mechanical anchors. Due to the high rate of attrition of refractory in some equipment, a high maintenance regime is required that involves removal of worn anchors and welding of new anchors prior to installation of replacement refractory. These tasks have to be conducted in an equipment shutdown environment with production loss to the manufacturer. It is of high interest to reduce the duration of the operation to minimise production loss. This project aims to investigate suitable welding techniques that have the potential to increase welding production rates for anchors and thus to minimise shutdown duration.

1.1 Project Layout

The project layout has been broken down in the following table, Figure 1.

STAGE ONE Assessment	Collect/obtain client information/knowledge
	Familiarisation of client workshop procedures
	General technology assessment
	Finalise chosen welding technology
STAGE TWO Technical	Finalise industry contact for chosen technology
	Inspect/observe procedures of chosen technology
	Technical assessment
	Present solution with modified welding technology
STAGE THREE Testing	Conduct initial test with new technology
	Determine if viable option/if anchor design needs to be altered
	Finalise design/configuration of anchor/welding
	Have test anchors and equipment ready for testing
	Conduct test welding of new anchor design
	Conduct weld integrity mechanical testing
	Finish test result summary
STAGE FOUR Thesis/Feasibility	Collation of capital, operating and maintenance costs
	Present seminars/thesis
	Client feasibility report

Figure 1 Table showing the various project stages

2.0 Welding Assessment

This stage of the project required information to be collated from the client, including being familiarised with the client's workshop procedures. Using this information, a welding technology was narrowed down for further investigation. An industry contact was also established to help with the investigation, which included site visits to observe welding procedures and processes.

2.1 Client Welding Procedures

Currently, the client uses MMAW to attach the stainless steel refractory anchors to their mild steel bases. One fit-out can have several thousand anchors and take hundreds of hours to complete the whole preparation and welding process. With many fit-outs occurring per year a lot of time and consequentially labour costs are put towards replacing refractory anchors. The important factor to consider is the production time lost while refractory anchors are installed on the plant machinery. Optimising the cost for this welding method is heavily dependant upon reducing the production time. Sacrifices in anchor cost and labour rate can occur if necessary, to reduce the overall production time.

Procedures were observed in the client workshop. The current process involves weld preparation, mark-up, tacking, two weld-outs (one on either side of anchor, allowing time to cool) followed by testing. The largest amounts of time are spent on weld preparation, tacking and the weld-outs. Weld preparation involves cleaning and grinding the weld area on the base plate. Due to the nature of the heat-affected, second-hand base material, this stage of the welding -process cannot be significantly reduced, whatever the welding technology used.

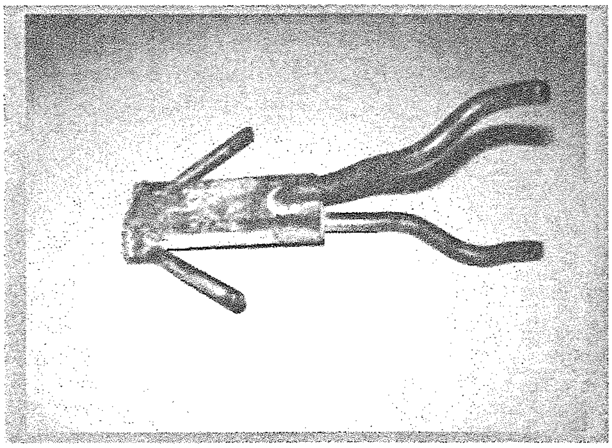

Figure 2 Photo of failed anchor

Figure 3 Photo of welding anchors in UGR workshop

The areas that can be potentially improved are the tacking and weld-out times. The tacking stage may be able to be skipped depending on the new welding process chosen, which would reduce overall time. The weld-out can also be significantly reduced if it is completed in one action; also eliminating cooling time in between runs.

2.2 New Welding Technology Assesment

A starting point was provided by the client where resistance welding technologies were named in the project description. It was established that the investigation should not be limited to this category of welding types if it is proven not to be the optimal solution. It is important that the new methods considered have the potential to provide similar or better properties than methods already used by the client. A feature of the new method would also enable the client to complete refractory anchor installation in a shorter period of time compared to current methods, consequently reducing shut down time for refinery machinery. The client had a preference that the anchor design does not change unless there is no alternative in order to accommodate the new welding technology.

One resistance method that, in theory, could be tested was rotational friction welding. Several issues were presented with this type of welding and therefore this method did not warrant further detailed investigation. The method that proved to show potential was stud welding. This technology was found through researching resistance welding technologies; however it is in fact a form of arc welding. This type of welding already has established methods for attaching refractory anchors and showed potential for retaining the current weld design. It is a developed and proven form of welding that is growing in popularity, with established companies already operating in Western Australia. It has the potential to weld dissimilar metals accurately with short cycle times. It also has the potential to retain the current weld design.

2.3 Arc Stud Welding Workshop Procedures

Arc Stud Welding procedures where observed on site with Stud Weld International. This allowed a first hand insight into how the technology works. One aspect especially highlighted in this site visit was the very high cycle time of the welds.

3.0 Arc Stud Welding Technical Assessment

Arc-drawn stud welding is a variation of manual shielded metal arc welding. The process is used without filler metal and has the options of both external gas and flux shielding. Partial shielding can be achieved from the use of various types of ferrule. This process is reliable and widely used in many different applications and is proven for many different environments and joining materials.

Studs are attachments in application-oriented configurations that can be welded to an assembly or structure to serve as anchoring, spacing or fastening devices. There is a large range of design for a stud depending on the application. Most of these studs can be rapidly applied by portable equipment. The stud gun is the key to moving the stud the required distance in the correct sequence. The end of the stud and the work piece are heated by the arc drawn in the air gap between the two. Once the required temperature has been achieved and a weld pool is established, the stud is plunged with low pressure into the work piece forming the bond. Like manual metal arc welding, the heat for the weld is drawn from the arc created between the electrode (the stud) and the work piece (base plate). The current for the weld is supplied by a dc transformer very similar to those used in the manual process.

Aside from manually placing the stud in the gun, the arc drawn welding process is automated. All components of the process such as; welding time, arc gap, plunging pressure and holding time are controlled automatically. The control unit is usually integrated into the power source.

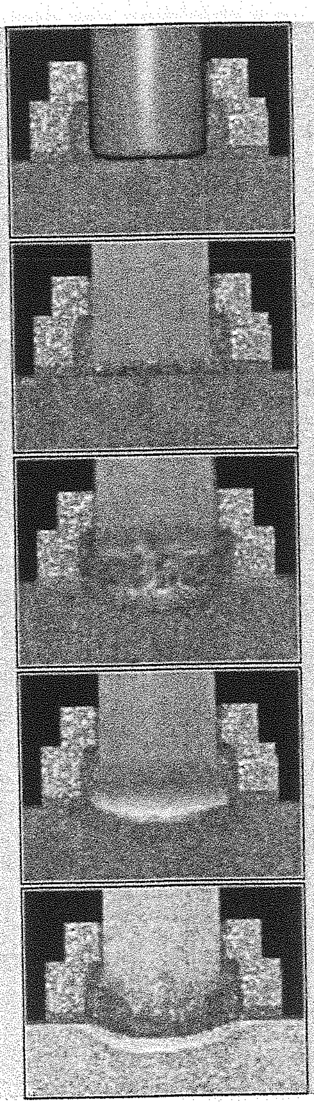

Figure 4 Process diagram of Arc Stud Welding *(www.stiftlassen.nl/images/fotoboek/proces.jpg)*

Advantages

- Because of short cycle times, there is very little heat input to the base metal compared to conventional arc welding. This results in minimal distortions of the base metal in the weld locations. This also results in the weld affected zone and the heat effected zone remaining very narrow.
- A full penetration weld is achieved, compared to restricted penetration using the manual arc welding technique.
- Studs are able to be welded without access to the backside of base member. No drilling, tapping or riveting is required in this process.
- Designs can be lighter in weight; not only can material be saved, but the amount of welding and machining required to join the components can be reduced.
- This method has the ability to weld many combinations of dissimilar metals with ease.
- After initial setup welds are fast, repetitive and uniform.

Limitations

- The stud size and weld shape is limited to the chuck size of the gun and the design of the ferrule (if used in the weld).
- The stud base diameter is limited for thin base materials.
- In large applications a disposable ceramic ferrule is required for the weld. In these cases a flux is also usually needed in the stud design and sometimes even a shielding gas during the weld to achieve a sound joint.
- 230 volt or 460 volt alternating current is required to operate the direct current DC welding source. The limitations arising from this are almost identical to conventional manual drawn arc welding methods.

3.2 Anchor Redesign

After the investigation and initial testing of the technology, it was decided that to obtain consistent and reliable welds with this method; round bar would need to be used for the base of the anchor instead of flat bar. This would allow a more even heat distribution during the welding process. This would also potentially eliminate the need for the use of a shielding gas.

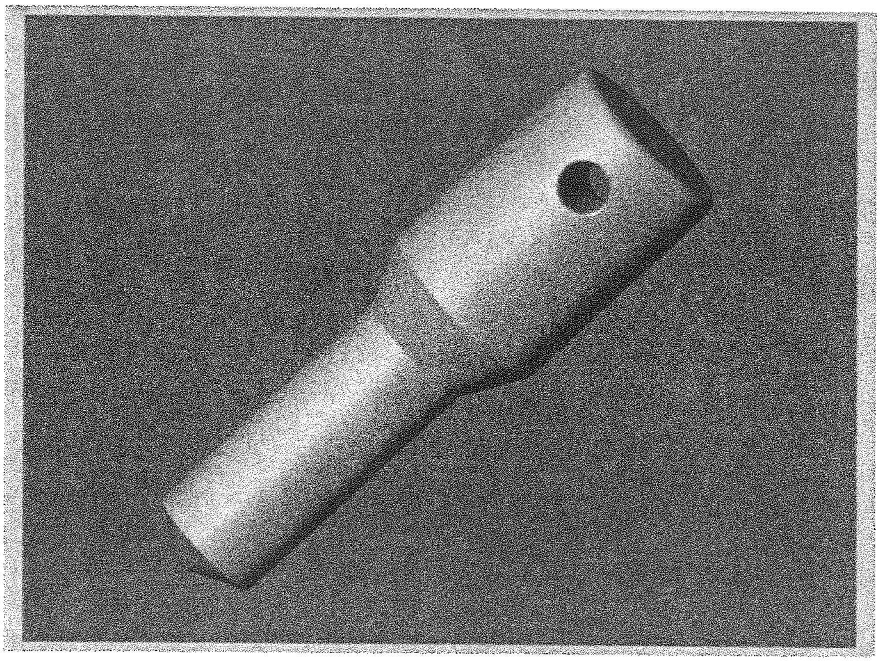

Figure 5 CAD of altered base anchor design

Although there were many potential design options for the anchor configuration, it was not seen important to focus on the top configuration at this stage of the investigation. Therefore the test design of the anchor is not necessarily the most economical design possible, however for testing purposes the fundamental feature was that the base of the anchor was round and still had the same geometrical surface weld area. It may be the case after testing that this base size can be reduced because of superior weld characteristics due to the new technology allowing full weld penetration.

3.3 Anchor Manufacture

The project required industry contact and negotiation with engineering firms to discuss and develop a manufacture plan for the test anchors. Due to the unique nature of the anchor material, which meant it had be order from eastern states if not overseas, precise timetabling with plenty of leeway was arranged for the proceeding welding, testing and analysis to be completed within the time limits of the project.

One aspect raised with the engineering firm manufacturing the anchors was that several anchors will need to be test welded with varying amounts of flux in order to find out the optimum amount necessary to create the ideal welding conditions. There is also a possibility that no flux at all with be needed due to the high nickel content of the stainless steel used for the anchors. This situation will be test welded as well.

4.0 Testing

The testing part of the project involves test welding the new anchor design using the arc stud method. The test welding will be followed by detailed weld integrity testing that includes mechanical and metallurgical testing of selected test welds.

4.1 Test Welding

This was carried out with the help of Stud Weld International. They offered the use of their welding expertise and equipment as well as workshop area. Test welding will help determine calibration requirements of the arc stud welding machine. It will also determine what sort of chuck is required to hold the size and configuration of the anchor. From the test welding the best weld results will be used for the mechanical and metallurgical testing stage.

4.2 Weld Integridy Mechanical and Metalurgical Testing

The chosen welded anchors will be professionally tested to specified criteria. The testing has to be conducted at a private laboratory due to the size of the weld and the nature of the welded material. The testing laboratory offers weld integrity testing packages for industry; however their testing procedures will be modified to meet the criteria required by the client and the university.

This stage of the project will provide a detailed analysis of the Arc Stud Welds, where the test welds are prepared to a specified configuration and subject to tensile testing to the Australian Standard and then to destruction. The failed weld is then subject to a failure analysis. Prepared test pieces are also subject to a detailed metallographic examination, where the microstructure and microhardness of the welds are analysed.

As well as being present during the testing process, test reports, failure analysis and various weld images produced by the laboratories will then be analysed and conclusions drawn to determine the mechanical feasibility of the welded anchors.

5.0 Feasibility and Cost Analysis

Upon completion of testing of the welding technology, a cost analysis will be conducted using information obtained from the client and contacts established during the project. This will add a financial aspect (from an engineering perspective) to the feasibility of the new technology as the economics of the welding process is an integral aspect of the potential in-service trials.

6.0 References

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