Weld Adjustment Assist Programme

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ABSTRACT
Within automated robotic welding processes minor adjustments are necessary due to allowed deviations in pre-welded component parts; the time taken to perform these adjustments is referred to as “downtime” and is none value added to the process. With processes that are heavily utilised, the downtime caused through performing weld adjustment can push production time into non-working hours, reducing the sale value of the completed product. This paper details the current progress in developing a system to reduce time taken to perform adjustments.

KEYWORDS: Mc087, OEE, Planned Production, Robot, Weld Adjustment

INTRODUCTION
As downtime due to weld adjustment is a broad subject affecting many processes in the author’s place of work, a single automated welding cell has been chosen for data acquisition and testing with the possibility of implementing this on all automated welding facilities. The chosen machinery is designated as ‘Mc087’ and will be referred to hereafter, all data gathered and displayed is in respect to this chosen facility. Mc087 is a production facility designed to produce components for the BMW MINI.

The components produced are referred to as cross car beams, which is the primary component in the cockpit of a motor vehicle used for mounting all elements of the cockpit during construction. Mc087 produces two variations of the cross car beam for different models of vehicle referred to as F54 RH and F56 RH (Figure 1). The F54 RH model comprises of 39 component parts joined together by 134 weld seams, and the F56 model comprises of 39 component parts joined together by 131 weld seams.

This document outlines the research and resulting work carried out in order to achieve the objective of this project. The objective of this project was to improve the downtime of Mc087 due to interventions referring to weld adjustments. The article will detail an overview of the process taken and the current progress of the project with key information found to date. The literature review contains information in regard to the potential benefits of the project. The methodology has been written considering a concept of a solution and information regarding the target requirements and results from the completed system. Some of the supporting research subjects and overview of findings are detailed within the research findings. Finally, the conclusion and recommendations contain information regarding the current results of the project,
with predicted overall results and future improvements to be considered.

**LITERATURE REVIEW**

Automated welding facilities are designed due to the need for high rates of production with low cycle time while maintaining a high standard of quality. The introduction of robots into welding facilities has produced benefits such as high accuracy and repeatability of weld positions. However due to component geometry fluctuations an element of human interaction is necessary to adjust co-ordinates to correct the weld positions, ‘many robotic systems, however, do not adapt to real-time changes in joint geometry’ (Nayak and Ray, 1993).

Downtime in automated processes due to any reason is time lost when the facility is unable to produce components in order to generate revenue. This lost time can be very costly in some facilities due to high requirement of production time: ‘downtime is arguably the single most significant contributor to system inefficiency in a multistage manufacturing system’ (Liu et al., 2012).

A single F54 RH component produced in Planned Production hours generates a profit of 5% of the sale value, the same component produced in none planned production hours generates a profit of 2%. A single F56 RH component produced in planned production hours generates a profit of 5% of the sale value, the same component produced in none planned production hours generates a profit of -1%. This is due to higher costs of labour during non-planned hours, consequently the profit is reduced significantly.

In conjunction with a financial benefit lies a potential Health & Safety benefit. It is stated by the United States Department of Labour in the Occupational Safety and Health Administration technical manual Section IV: Chapter 4: ‘Studies in Sweden and Japan indicate that many robot accidents do not occur under normal operating conditions but, instead during programming, program touch-up or refinement, maintenance, repair, testing, setup, or adjustment. During many of these operations the operator, programmer, or corrective maintenance worker may temporarily be within the robot's working envelope where unintended operations could result in injuries’ (Osha.gov, 2018).

By reducing the exposure and interaction time with potentially dangerous machinery the potential risk of injury will subsequently be reduced. A measure of parts produced is referred to as OEE (Overall Equipment Effectiveness), to calculate OEE running time is divided by available time, then multiplied by the sum of actual parts produced divided by the theoretical quantity, and then multiplied by the sum of acceptable parts divided by total quantity produced.

![Figure 2. OEE Representation](Edinn.com, 2018)

**METHODOLOGY**

The concept solution was to create a function to select a specific weld to adjust, allowing the machine to pause in the correct position ready for intervention from maintenance persons. Due to the machine having a total of 265 welds divided nonequally between three robots in one of multiple fixture orientations, a large
quantity of adjustment time is taken by locating and moving the machinery to the correct location in order to access the required weld.

It can be seen in Figure 3 that the highest quantity of lost time was due to adjustment of welding seams.

![Figure 3. Mc087 Downtime reasons February 2018](image)

When analysing individual occurrences, it can be seen that for a single weld adjustment the intervention time needed can differ significantly. For example, a selection of eight jobs from the downtime incurred in February 2018 (Figure 4) shows the difference in time taken. It can be seen from the gathered data that the difference from the highest to lowest time is 28 minutes.

![Figure 4. Sample weld adjustment time](image)

The average time taken was 15 minutes. If all weld adjustments could be limited to the average time a saving of 27 minutes would be seen.

The longer times are due to the location of the required weld lying later in the robot program and the maintenance person stopping the process prematurely, this results in manual progression through the program at a reduced speed. Using a function to pause the process in the correct position could potentially reduce downtime by one quarter.

**RESEARCH FINDINGS**

Research has investigated naming definitions of weld seams across all machinery in regard to standards and common practices within the automotive industry. This is to identify a program structure that will be applicable for all facilities. Results have shown no existing naming standards or guidelines in regard to welding locations. From research into different customer specifications, it was found that all customer drawings rely on either a numerical based system or do not have uniquely identified weld numbers only detailing position and length.

![Figure 5. Customer part drawing showing weld references](image)

The research shows that a numerical based standard can be implemented on all new machinery and added to existing machinery.
communication between the maintenance personnel and the machine in order to have the ability to pause in the necessary program location.

The communication means for Mc087 is through an industrial network protocol referred to as “Profinet”. The network enables communication between all elements of the machinery. The research is focused on the communication between the robotic element and the human interface, both elements are connected via the PLC (Programmable Logic Controller) making research into the three elements individually a requirement. Research into memory sizes within Siemens systems has shown the relative size of slave device is determined by options contained in the devices GSD file.

GSD is an acronym for General Station Description, the file is provided by the device manufacturer and contains a description of the PROFIBUS DP/PA or PROFINET device. The GSD file provide a way for an open configuration tool to automatically get the device characteristics.

Once the GSD file is loaded it is possible to select memory sizes for input and outputs from and to the device. The GSD file for the robot interface has optional sizes from 8 bytes to 128 bytes for both inputs and outputs independently, giving a potential maximum input and output combined quantity of 2048 editable bits.

Currently Mc087 is configured to use 32 byte input and outputs, giving 256 bits of communication between both inputs and outputs. The machine uses 40% of available inputs and twenty percent of available outputs. The binary coding of weld numbers on larger machines should be considered for future projects because, when compared to direct output communication, 8 bits can generate a number sequence from 0 to 127. This shows that by utilising 1 byte of data it is possible to communicate between a number of devices, whereas direction communication requires 16 bytes of information.

This finding of communication between devices using binary coding rather than direct input-output communication has been crucial when considering the feasibility of the programs fruition. This is due to the limited available memory and the quantity that will be required for the programs integration.

Research into virtual simulation software provided by the robot supplier will be
continuous until project end. This has enabled a simulated copy of Mc087 to be created in order to test programs and the virtual environment will be a key factor in testing in order to prove the functionality of the system.

Figure 8. Screen shot of current simulation status

Further research is currently focused around human machine interface and robot programme structure for selecting weld numbers. Additional research is needed regarding PLC program structure, from weld selection through to the desired output of the robot’s motion pausing.

CONCLUSION AND RECOMMENDATIONS
The results from the project at this stage of progress suggests the proposed solution can be successful. From the data gathered benefits will be seen in regard to reduction in time taken for weld adjustment, leading to an improvement in machine safety because of the reduced interaction and translating into financial benefit. On reflection it can be seen future improvements are needed, using the research data provided by the current system only a single weld number can be chosen when each component part is joined by at least two welds.

When benefits are seen following integration, data will be gathered into quantity of welds that require adjustment in conjunction. This data will ultimately lead to modification of the system for expansion. During development a larger amount of memory will be reserved in order to provide the functionality of multiple weld numbers being entered in a future revision.

Pending the conclusion of that future research a virtual simulation will be completed prior to software integration. After that integration training with be delivered to maintenance personnel. The resulting data will be gathered in order to demonstrate results and benefits in both quantity of reclaimed lost time over a specified period and avoidance of potential profit over the same period.

Once all data has been gathered and reviewed potential modifications will be identified following a period of use. Eventually the procedure will be completed on other machines in a systematic nature tracking the savings from all equipment within the system one implemented. As part of the main report all findings will be documented, and the results made available.

REFERENCES

