Automation of Post-Fabrication Processes

P. A. Fuller
Alvis Ltd
Coventry
UK

ABSTRACT

Shot peening is an important post-fabrication process at Alvis. The methods used for shot peening aluminium armour welded assemblies have not previously attracted significant attention in the area of improved processing techniques. Alvis has commenced a work programme using micro-processor based controls and robotics to provide for a productionised automated system. The objective of this paper is to outline the requirements necessary to create a facility for the automated shot peening of aluminium armour plate assemblies.

INTRODUCTION

General Background

Alvis manufacture a range of fast, highly manoeuvrable combat and reconnaissance tracked vehicles (see Figure 1). These comprise the Scorpion and Stormer vehicle families.

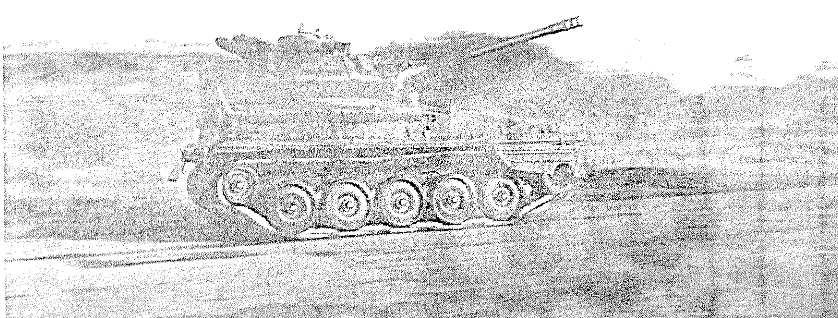

Figure 1 View of a typical Alvis vehicle

All hulls are made from Al-Zn-Mg light armour alloy. The general method of production is the manufacture of a basic hull welded assembly from machined plate. This is selectively shot-peened followed by painting. The assembly then passes along the 'track' to have all other items fitted e.g engine, gearbox, turret, instrumentation, seating etc. This is followed by final checking and painting at the test track.

Shot peening is carried out on specific areas of aluminium armour assemblies after welding.

This process was initially selected for automation due to the labour intensive nature of the work which is carried out in a hostile environment. Peening quality and cycle time depend on process parameters under direct operator control. As a result there are potentially significant benefits to be gained in the areas of improved standards and reduced process-time/labour.

CURRENT SITUATION

Facilities

The facilities within the Company consist of two booths for shot peening and a third booth for both shot peening and metal spraying. The first two have a multi-hopper underfloor gravity system for re-cycling the used shot. The third has the latest waffle-floor pneumatic full recovery system. All three systems were supplied by Vacu-Blast Ltd.

The controls consist of an operator on/off valve at the nozzle inside the booth and externally a gate valve controlling the mass of shot with a pressure valve to regulate the airflow carrying the shot to the nozzle.

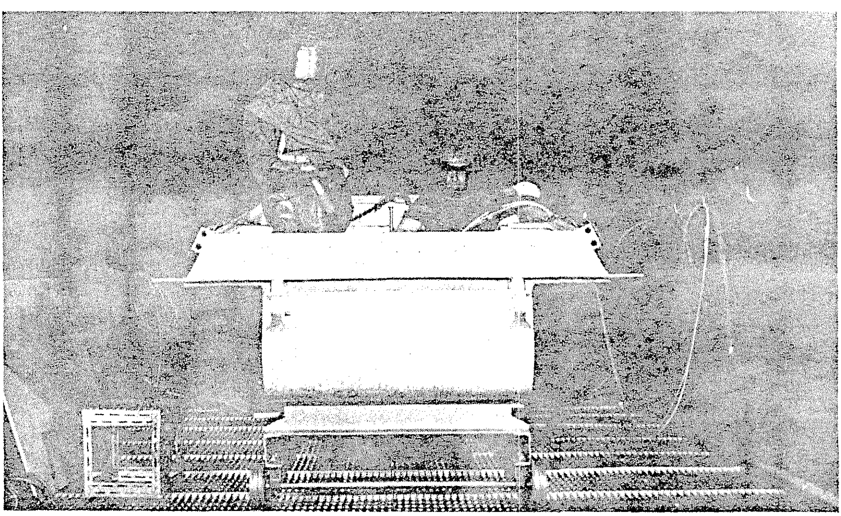

Figure 2 View inside a shot-peening booth

Current Method

The components requiring peening range in size from small sub-assemblies .5m cube approx to vehicle hulls 5.5 x 2.5 x 2.5m approx. Areas not to be peened are masked off using plates and slave bolts. Components are loaded onto a platform mounted on bogies which is then wheeled into the booth on rails.

All components are processed in a similar manner regardless of size. There are no positional aids such as turntables or manipulators for use inside the booths. The operator has to position himself so that he can present the nozzle at the correct impinging angle.

The operator requires protective clothing and an air-fed helmet. There is a significant fatigue allowance with the two operators per booth. The process parameters are directly controlled by the operator with reference to established standards.

The operators' ability to satisfactorily peen is totally dependent upon training and experience. The results of his work may be checked at various positions using Almen strips. This does not, however, guarantee that the parameters are correct throughout the process. To this end there is a tendency to overpeen i.e increase the coverage rate. This is acceptable as there is little detrimental effect due to an excessive surface layer of compressive stress once saturation has been reached up to 400% coverage [1]. Coverage is a measure of the time taken to completely cover the surface such that the 'dimples' visible on the surface just overlap when viewed at x10 magnification.

Quality Requirements

Alvis Ltd, in association with MODUK organisations, set the standards for a variety of peening processes e.g shot-peening, needle peening, flail peening. This led to the first operational shot-peening booths designed specifically for processing aluminium armour welded assemblies to be installed at the Company.

The processes were validated by the hole drilling method of stress analysis using manually peened samples [2]. Standard Almen intensity strips are used to control the process based on the results of the stress analysis.

In-house documentation and MODUK specifications provide detailed definition of the standards which must be maintained and the quality checks used to verify them.

Limitations

The work is exacting and carried out in a physically demanding environment. During peening the atmosphere is contaminated by fine aluminium and shot debris. This reduces visibility and makes it necessary to provide a separate air supply for breathing. The noise level is considerable due to the impacts of the steel shot on the aluminium plate.

The protective clothing worn is made from a rubber material in order to withstand the reflected shot. An air-fed helmet incorporating eardefenders acts as protection against shot impacts as well as providing a dust-free air supply. The bulky nature of this apparel restricts the movements of the operator considerably.

The interface of the peening system with the operator is provided by a 12ft length of 4" dia rubber hose to which a range of different nozzle assemblies can be fitted enabling the operator to direct the shot at the required area. The equipment is particularly unwieldy as the flexibility of the hose is restricted due to air pressure, and the mass which the operator has to move is increased due to the flow of shot through the hose.

The process depends on the operator for maintaining the standard of the process as sample Almen strips are only applied to one place on one component per shift. This is an area where automation of the process will have a major effect. Better control over the process parameters will lead to more consistent quality and repeatability.

PROPOSALS FOR AUTOMATION

Choice of Components

The components requiring peening may be divided into three types: sub-assemblies; turrets; vehicle hulls. As part of the Alvis/Robotic Development Programme it is intended to work on these in the order stated. The Company intends that this technology be available on the latest Stormer family of vehicles. Therefore, it is intended to start with these, then apply the technology to new products and finally to the longstanding Scorpion family of vehicles.

There are no particular advantages to be gained from choosing any one of the three types of component. However, there are obviously greater cycle-time savings the longer the original cycle-times and these are usually related to the size of the component. Therefore, the overall objective is for a production installation to process vehicle hulls in order to obtain the maximum benefits from automation.

Nozzle Manipulator (Robot) Specification

a. Number of Axes
For this application the nozzle manipulator must be capable of accessing external and internal features of the hull. This means that a minimum of five axes would be required in order to simplify the programming and minimise the component manipulation. The use of six axes is not considered to make a significant difference in this case as some means of manipulating the components would be necessary due to their size.

b. Configuration
This feature is linked to the number of axes as it would affect the manipulator's ability to reach the areas specified. The areas to be peened would be moved into range using a component manipulator. It is considered that an arm and elbow type would provide the best articulation for its size and therefore simplify the programming task.

A gantry mounted system was considered but was rejected on the grounds that it would be difficult to protect, installation in the existing facilities would be problematic due to floor load limitations and component manipulation would still be required making the overall system costly.

c. Type of Drive
This feature is important as the ability to function in a dust filled environment is paramount. Electric drives are considered the most suitable providing protection against the ingress of shot and debris could be achieved through shrouding, improved seals, or a combination of both.

d. Type of Control
Point-to-point control would make the peening of 3-dimensional features difficult. Continuous path systems would be the best choice, particularly as there are some repetitive circular features on every hull. This would also simplify the programming task and hence reduce the memory requirements.

e. Accuracy/Repeatability
This is not critical for this application as the current manual positioning is adequate i.e plus or minus 13mm.

f. Load Capacity
The actual load that would be exerted is difficult to determine as it would be a function of the nozzle reaction, the peening hose mass, tooling mass and the constraint of any external shrouding. The first item has been measured at 4kg, the remainder are estimated at 30kg total. Therefore, the required capacity is 50kg in order to give a margin of safety.

g. Memory Capacity
This is difficult to ascertain at this stage but as a minimum 500 positions would be specified. This should allow for several different programmes to be stored simultaneously. In addition, there should be provision for extending this by some mass storage device i.e floppy disk unit.

h. Programming Method
Manual teaching by physically moving the robot into the required position is not considered practical due to the size of both the robot and the component. Remote teaching via a pendant would be the preferred option. This would be particularly useful during editing. Off-line programming would be a future option which could be carried out as a continuation of the computer graphic simulation work.

i. External Input/Outputs
A minimum of 8 in and 8 out could be required. This would ensure that external devices could be controlled i.e safety interlocks, process equipment etc. The interfacing of all the equipment in this project is important to provide control over the complete system.

j. Control of External Axes
A means of controlling the hull manipulator may be required so that the nozzle movements can be integrated with the manipulator movements. Initially, it is intended to keep the manipulation simple and therefore independent of the robot. However, this option must be available.

k. Environmental Protection
This is an important requirement as the robot would be subjected to both debris in the atmosphere and rebounding shot. The seals on the drives

must be dustproof as a minimum requirement. Protection from rebounding shot will be provided by an external shroud of rubber material.

Supplier Appraisal

During this phase of the project a considerable amount of time was spent discussing our requirements with suppliers. The following factors were taken into consideration during the appraisal:

a. Product Features
This should be taken as an overall assessment of each company's ability to meet the specification. In particular the attitudes of the suppliers to the problem of protection.

b. Experience
This reflects the level of experience the suppliers have had in the installation of robot systems into similar process type areas.

c. Delivery
This is relatively unimportant providing that delivery dates are met.

d. Price
The prices were virtually identical.

e. Application Support
This was considered an important factor. In particular, the ability of ASEA/ESAB to provide support for both peening and welding applications from separate sources was considered to be an advantage.

f. Further Requirements
This refers to the welding application and the results reflect the assessments of the company's abilities.

To summarise the findings:

ASEA/ESAB are the preferred choice as they could fully meet the specification and offer the best support for both peening and welding applications. The provision of an ASEA IRb60 to an existing foundry standard could give basic dust protection. From this base ASEA were confident that full shot protection could be developed at low cost. By using the ASEA robot, applications support would be available from ASEA for the shot peening and ESAB for the welding. An ASEA IRb60 robot is shown in Figure 4.

Hull Manipulator Required Features

a. Ability to fit into existing facilities.
b. Ability to withstand environmental conditions.
c. Ability to link with robot control system.
d. Load capability 10,000kg minimum.
e. Capability to adjust to different hull sizes.
f. Accuracy +/- 13mm (0.5in).

A decision on the specification of this equipment and its supplier will be made after a computer simulation has been completed.

Computer Graphic Simulation

This work is being carried out in conjunction with IBM Warwick using CATIA and CADAM software. A copy of the 3D wire frame model is shown in Figure 3. This was constructed at an earlier stage when a Computervision system was being used at Warwick University. The following work is being carried out using the model of an ASEA IRb60 available on the IBM system:

a. Evaluation of reach and collision detection.
b. Alternative layouts and methods of manipulation.
c. Nozzle geometry will be analysed for the alternatives in b.
d. Process times will be assessed.
e. Cost estimates of alternative methods of manipulation.

The overall benefits of the simulation work will be a better planned installation, with improved tooling and manipulation methods at reduced cost. The lead times to introduce the complete system will also be reduced. The programming task should be easier due to the visualisation of the system in operation. There is also the possibility of off-line programming in the future.

This work will enable a confident approach to be made to the overall project by determining the level of accessibility of the chosen robot prior to installation in production. The objective at the outset is to notionally peen 90% of the areas required for the major operations. Therefore it should be possible to gear the manipulation costs to suit the overall benefits anticipated from the production system by altering the sophistication of the system accordingly.

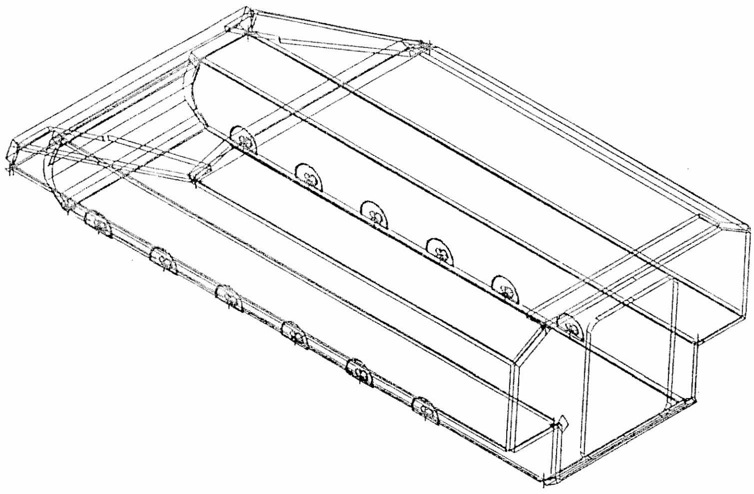

Figure 3 3D Wire frame model of a typical Alvis vehicle

Tooling

There are two areas that will require specific tooling to be designed and manufactured. Firstly, the peening nozzle and feed hose must be attached to the robot arm. This should be fairly straightforward as this application is similar to the well established attachment of welding torches and associated wire feed units to robots. Secondly, the various hulls must be accommmodated by the manipulator. The tooling requirements will not be known until after the computer simulation has been concluded. Whatever the configuration of the manipulator the tooling is likely to be expensive due to the size and weight of the vehicle hulls.

Shot Peening Equipment

The existing Vacu-Blast Waffle Floor Blast Room used for metal spraying and shot peening is of a suitable specification for use as a development unit.

A separate unit specifically for carrying out the validation work was considered. This option was discounted for a number of reasons: cost; floorspace; not fully representative of production system. The latter is an important factor and reflects the empirical nature of the process. In effect each system is unique as the process is dependent upon the flow of air through the booth.

Revised calibration procedures will need to be established to meet the requirements of the various inspection authorities concerned.

Proposed Development Trials

The trials will be carried out in two phases. The first will be aimed at validation of the process and will involve the processing of test pieces with Almen strips which will then undergo stress analysis to enable the process to be approved to the same standards as have been used in previous validation exercises.

The second phase will be the writing of programmes to carry out the satisfactory peening of sub-assemblies, turrets and hulls, the latter being carried out in the modified production facility.

While the development unit is in use limited trials will be carried out on metal spraying and welding. This work will be scheduled into the inevitable gaps that will arise in the main programme of work.

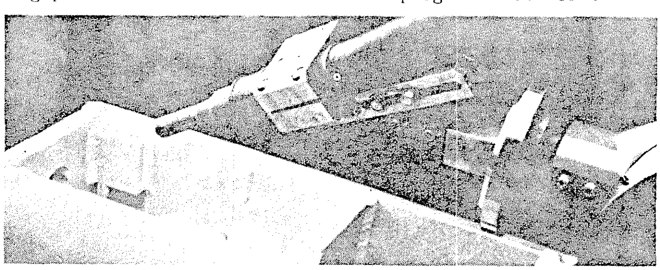

Figure 4A View of robot peening

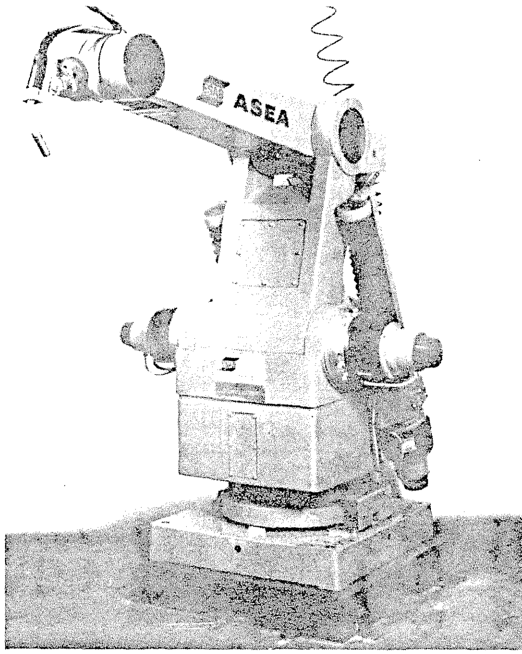

Figure 4B View of robot welding

Total Facility Specification

a. Shot blast booth equipped to the basic specification for metallic abrasive media. Additional features required are: Process controls for shot mass flow capable of integration with the robot controller; Armoured glass viewing ports and improved internal lighting; Safety interlocks on all doors.

b. Robot manipulator for the nozzle based on the specification for an ASEA IRb60 with foundry standard protection. Controller must be capable of integration with external equipment e.g process controls, manipulators, safety equipment.

c. Hull manipulator mounted on bogies capable of accommodating the present and future range of vehicle hulls. Controls must be integrated into the robot controller.

d. Turret manipulator to the same specification as in c.

The specification above is for a totally new facility.

At present, it is intended that following development of the process the system be incorporated into the existing production facilities which have a gravity type of shot recovery system instead of the 'waffle-floor' type. This, however, will not cause any significant problems as the tyoe of floor does not affect the process. The Tealgate peening control system can be applied to the existing booth. See Figure 5 for a schematic layout of the likely production facility.

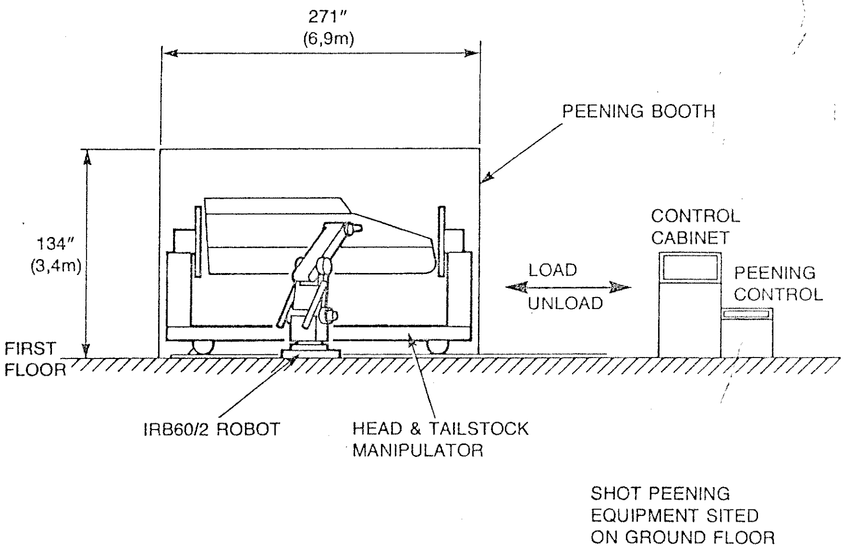

Figure 5 Schematic diagram of production unit

Limitations of the Proposed Facility

The main limitation would be the continued requirement for an operator to monitor the process. In the event of a malfunction the shot stream could cause considerable damage in a short space of time. The operator would still be required to peen areas not accessible to the robot and also to retrieve shot not recovered automatically. The latter is carried out using a vacuum system and it may be possible to automate this in the future. However, this will be dependent upon the regularity of shot distribution in the hull after peening.

Increased maintenance would be required with a greater bias towards electronics. The systems would be more sophisticated and require more routine maintenance. The current electro-mechanical equipment has lttle preventative maintenance and generally has work carried out as a result of a breakdown. This change is in keeping with the maintenance task developing with the increase in CNC machine tools and would not be a large addition to the activity.

Greater production engineering support would be necessary due to the increased sophistication of the equipment, in terms of programming, calibration, tooling and setting-up.

Project Justification

The economic justification of such a project is very complex due to the in-house development work necessary. The scale of the benefits will not be known accurately until after the development phase. Similarly the final cost of the production system is not known at this stage. The areas where savings will accrue are summarised below:

a. Manpower
Due to the hostile working environment the current method has a 100% fatigue allowance i.e two operators per booth. With automation only one man would be required to work, outside the booth, for that portion of the work successfully automated.

b. Cycle Time Reduction
The cycle time for the major peening operation is a significant number of hours, excluding masking and preparation. It is hoped to achieve a reduction of 30%. This should be possible due to elimination of changeover time, consistent operation at maximum speeds, no time lost in repositioning due to a programmed cycle and a reduction in time lost due to 'over peening'. Labour will still be required to carry out any remaining peening.

c. Risk
A major factor which has reduced the 'risk' level of the project is a successful application to the Department of Trade and Industry for grant aid. This will amount to 20% of total project costs.

Implementation

A work programme has been drawn up to cover the period from raising the initial capital expenditure proposals to further development after the system has been successfully installed in production. From this programme a network analysis has been carried out using PERT software on an ACT Sirius microcomputer to determine the 'critical' events. This system is being used as a project management tool to monitor the project.

During the life of the project regular consultations are planned to inform the relevant people of the progress of the project and any effects it may have in their area i.e production control, trades unions, design, production engineering, supervision, etc.

A future project related to shot peening is the development of metal spraying. For this operation the same facilities would be employed. In this process the total surface area of the vehicle requires spraying therefore the benefits would be greater.

CONCLUSIONS

Current methods used for shot peening require an operator to carry out demanding tasks in a harsh environment whilst maintaining adequate quality standards. The existing fatigue allowance doubles the cost of this operation.

The use of Almen strips to control the process does not guarantee that the parameters are maintained throughout an operation. This leads to excessive process times in order to ensure that quality standards are maintained.

Automation of the shot peening of vehicle hulls will be implemented at Alvis Ltd. The following are required:

a. A nozzle manipulator based on a 5 axis 'arm and elbow' type robot protected against the environment i.e an ASEA IRb60/2.
b. Component manipulators protected against the environment.
c. A shot peening booth (existing).
d. A micro-processor controlled shot peening system.
e. Validation of the new process to meet quality requirements.
f. Overall integration of the various control systems.

The result of this work will be a unique system providing control over the following peening parameters during processing: Nozzle stand-off distance; Impinging angle; Time of exposure; Shot mass flow.

The limitations of the system are that an operator will still be required to monitor the process and peen areas not accessible to the robot nozzle manipulator. Increased maintenance and production engineering support would be necessary due to the greater sophistication of the systems.

The benefits are reduced manufacturing costs, better working conditions and an improved standard of peening. In addition, there would be inventory savings dependent on output levels in the first year of production operation.

ACKNOWLEDGEMENTS

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