Study on Forging and Forming, Intelligent Production Robot System for an Automotive Component

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Abstract: ***This paper describes a detailed concept of Hot Forging and forming intelligent production techniques as currently practiced in the forging and forming industry.Automobile industries has been relatively resistant to handling automation because of the severe challenges that are faced by having typically small batch sizes, extremely challenging operating conditions in terms of temperatures and pressures and lighting conditions. This paper however, discusses how aspects of these difficulties can be overcome and it is hoped that the specific solutions and methodology presented will find general applications in other aspects of manufacturing industry. The concept of the ''Automated Forging of the Future'' is also introduced in which advanced handling such as rapid tooling-change and flexibility, smart metrology, advanced sensing and intelligent gripping techniques are presented. The concurrent objective of optimizing materials performance by manipulating materials structure for example, hardness and strength by the automated forging processes is analyzed,this concept represents the distillation of work on automated forging based system.***

Keywords: Automation, Robotics, Forging, Forming,Hot, Industry, Automobile, Smart, Manufacturing

1. Introduction

The manufacturing forging industry can be grouped across several industries including Automotive, Aerospace and Medical being used by relatively high value added operation. Continual cost pressures have meant that industries needed to work smarter rather than harder, since lower costs bases attract plug or fits compatible manufacturing replication, unless there is a high skill, higher value-add differentiator[1]. Smart automation is presented as one of the factors that differentiate and the ability to quickly change over between batches, achieve higher manufacturing tolerances and overall quality, and however in many cases increasing volume have been key drivers for the implementation of advanced automation. Typical product families that have been automated include the production in the automotive industry of gears, hubs, crankshafts with the main objective of improving materials performance by manipulating materials structure for example, hardness and strength by the automated forging processes themselves[2]. The key advantages that are presented for automation include: (1) Increased Volume (capacity),(2) Improved Quality – via consistency of manufacturing and reduction in variability and [3]Costs reduction, that is the reduction in dependency on hard to find labor to work in harsh operating conditions and [4]Improved Safety Occupational health statistics implementation in order to continue to illustrate that powered presses are a major source of industrial accidents. A widely used system is based on manufacturing systems simulation allied to a cost benefit analysis in order to adopt a relatively low cost approach, which is the initial business benefits. Systems such as Witness Hocus[5], and the like can be used to explore discrete simulation approaches, especially where hard production data exist on Tact time, time in process, batch sizes and other production data can refine the investment proposition. Academic work on forging automation is relatively sparse, however case studies can be found which illustrate the public face of successful implementations according to Eleftheriou [6]. Systems simulation for automation can be applied particularly where the implementation includes data on queuing, mean time between failures (MTBF) and mean time to repair (MTTR) though the results tend to be general in nature. One possible approach when considering a large investment in forging/forming particularly due to the high cost, and longevity of press technology, is often to simulate the process in order to clarify in detail how the modified operation will work and this can then be verified in broad brush terms with a cost modeling approach in order to quantify the benefits. Forging presents a tremendous challenge to the systems integrator wishing to build in automation to the manufacturing process, combining as it does the effects of varying temperatures, immense potentially destructive forces, and accumulations of hardening lubricant. The Forging Industries Association Technology Plan [7]has identified a number of key issues that need to be addressed which prioritizes process control and modifications of the ''Hoteye'' system and other sensing data for Forging.

The key objectives of this research work are mainly the advantages that the automation of the forging process brings which include the following:

a) Increased Volume (capacity).

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b) Improved Quality – via consistency of manufacturing and
c) Reduction in variability.
d) Reduced Costs.
e) Reduced dependency on hard to find labour to work in harsh operating conditions.
f) Improved Safety Occupational health statistics continueto illustrate that powered presses are a major source of industrial accidents.

2. Methodology

The path followed for the methodology of this research paper has been to make a detailed survey the existing methods. This was though sparse academic literature, interview with Industryand machine operators and to vividly examine the related case study. The first task was to define what is meant by automationin forging process and this description is sufficiently show that a number of modular topics can be included in our findings which include:
Automated handling,

- Automated lubrication,
- Automated heating,
- Automated process control.

2.1 Automation for forging applications

2.1.1 Automated robotic handling

A key factor in automated handling for forges is the use of robots and the following section places in this context. The British Automation and Robot Association [8]publishes an annual review on robot use based on feedback from 40 leading suppliers [4, 8]which reports that the market is dominated by automotive applications, and recent statistics suggest there are 25,000 robots in service .However the use of robotics in forging and is one that is increasing from a relatively low level depending on category definition (see Figure 1) and the non-automotive applications have continued to grow. It is estimated that 75% of installed robots are of the 6 axis type (BARA-2009) figures. An approach to adopting automation by subdividing the process (of handling) the following operations:

a) billet loading and trim press loading
b) parts transfer robot and spray robot
c) parts transfer robot
d) spray robot

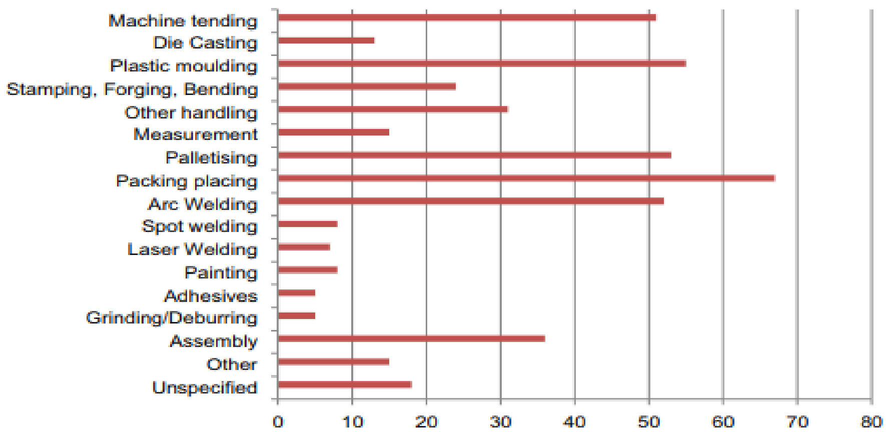

Figure 1: UK Robot application analysis for 2009[8]

This approach could be described as‘‘Robotizing the man’’[9]. A more fundamental approach which relates more to the state of the art is a system such as that promoted by Schuler Automation[10]involving a completely integrated transfer press line. This system uses a fully enclosed approach and a central drive to co-ordinate manufacture (see Figure 2). The part handling is achieved internally by using a modular lever transfer arrangement in order to handle formed panels between each individual press station. A variety of handling systems are available such as cross shuttles, robot loading with conveyors, and independently controllable feeders depending on the client automation needs. Here the robot is mounted on a rail system and it travels between sites whilst the part is still held (see Figure 3).

Figure 2 .High volume “Compact” Automotive cross bar press (Schuler Automation)

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Figure 3: "Crossbar Robot" transfers part directly from press to (Scheler Automation)

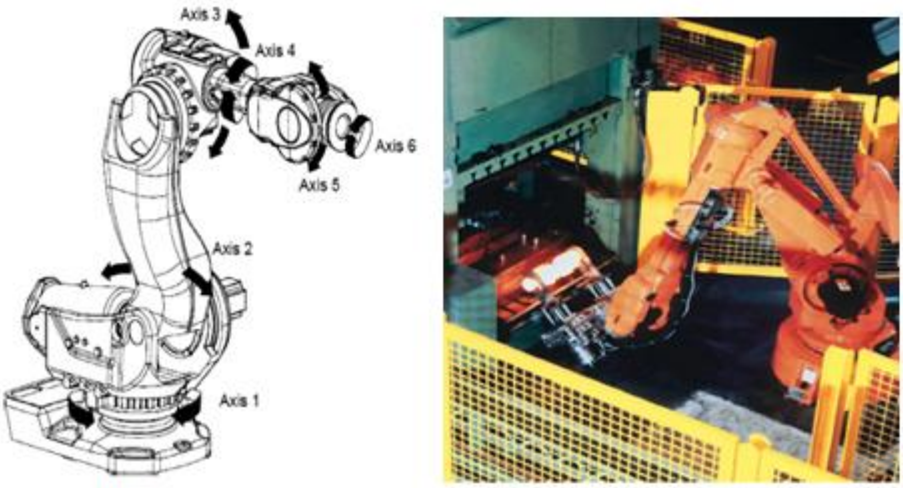
2.2 Advantages of Robotic handling

Typical advertised benefits of robotic handling include[11]:

a) Improved consistency
b) Greater production volume and reduced labor- hours
c) Safer operation, and lowered production costs
d) Improved safety and environmentally friendly through lower energy costs, typical productive life.

2.3 Type of Robot used in Automobile and Forging Industry

The introduction of Automation in forging clearly has a number of specific challenges, because of the prevalence of high temperatures (up to 1100 C for some materials) and airborne detritus means those exceptionally robust robots are used, often incorporating specially adapted grippers [12]. This system has been installed by DIC Engineering as part of a crankshaft line for General Motors incorporating an NKMZ 7000T forging press, with piezoelectric load cells to protect against overload. It should be possible using a robot spray technique to generate a relatively sophisticated dag spray pattern that only operates where it is absolutely needed using a modified lance rather than in the general area of the part and tooling see Fig.4 (a and b) below. Automatic lubrication systems are often a part of the forming process – usually named ''dagging.'' This will result in less dag being applied together with reduction in the associated cooling effects; fig .5 reveals the use of dagging in extrusion and heading.



(a) (b)

Figure 4 (a and b) Standard 6 axis Robot model IRB 7600for handling crankshaft for Auto-Industry [12]

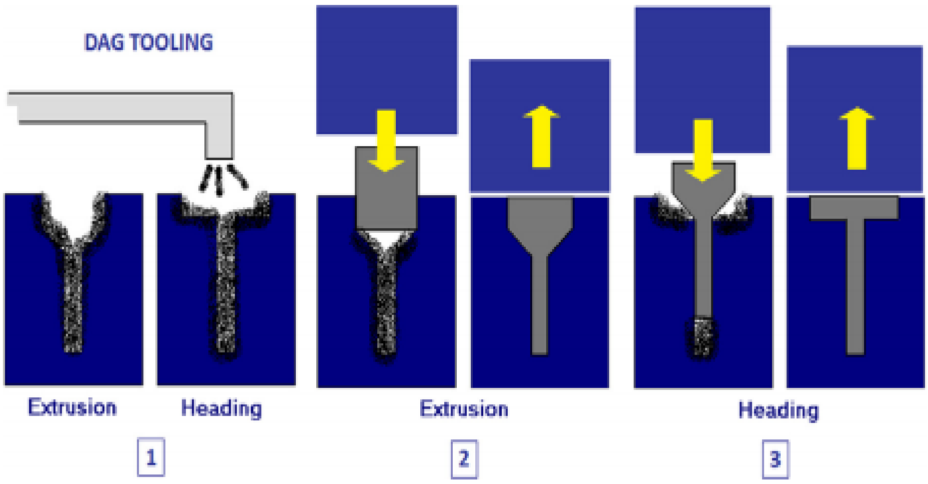


Figure 5: Dag application in Extrusion and Heading (Mc.Intosh)

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3. Research Challenges in Forging Automation

3.1 Non-specific automation process challenges

It is important to have a high understanding of the detailed nature of the task that requires automation in order to be able to specify and implement an automated system. Barriers to implementation can include fear of redundancy [3] and labor displacement – though in practice robotic automation tends to mean that existing staff are redeployed into other areas after an increase in volume and quality has been achieved, though some of those who leave voluntarily may not be replaced. Automation in general has a range of challenges but forging presents some that rare relatively uncommon. There is a market led desire to move towards small smaller batch sizes[13] and the case for automation may mean that the technical aspects of implementation cannot easily be demonstrated ,therefore technical achievability influences the benefits. The major long term strategic challenge involved is that of worker substitution[14]. The original source of the word robot [15], particularly applicable in a hostile environment such as a forge or foundry operations involving high temperatures, levels of contamination, and extremely powerful machinery.

3.2 Process specific challenges

Hot Forging in particular means that handling equipment must be designed to cope with metallic materials at up to 1100 C, so replaceable, robust handling systems such as gripper jaws are one possible solution for long term use. Cold and warm forging often means a commensurate increase in forging forces. The idea that fragile dexterous robot hands can be used is not one that finds implementation in practice. Hence smart techniques for advanced handling or sensing must be sufficiently robust as to cope with locally high temperatures.

3.2.1. Handling flash/excess material

Forging and forming processes often produce small but important amounts of waste or excess flash material either after clipping or as part of the extrusion process. One objective of the forming process is to improve the material parameters by using the deformation process and thus the idea is to do the minimum possible machining.

3.2.2. Press integration

Integrating with existing manufacturers presses presents major challenges and one approach is to go back to the original manufacturer, or specifically the press controller. Presses have long lives typically 50 years+ but much longer are not unusual – with upgrades in controllers in order to interface with advanced metrology. Fortunately we have skilled expertise that can deal with this, skills which are often employed by the systems integrator, including the critical safety elements, safety interlocks, guarding as required [16-18]. Often once the press project moves forwards snags occur, such as dealing with the waste product (flash) created when parts are reduced in volume – failure to do this will jam the tools, as well as how parts that stick in the tool are to be removed.

4. Vision for Automation

This is to achieve the following:

- To generate a stable repeatable platform for forging and forming trials/experiments.
- To generate and prove out automation forming techniques which have a 5–10 year technical benefits lead on existing industrial practice.

4.1 Design considerations

As part of the implementation of the Automation Capability a Forge working processfor example in a typical robotic orientated cell a pick and place robot would be positioned front and center (or slightly offset due to the geometry of the robot joints) in a permanent floor position, meaning difficulties for both access and interoperability as shown in Fig. 6.

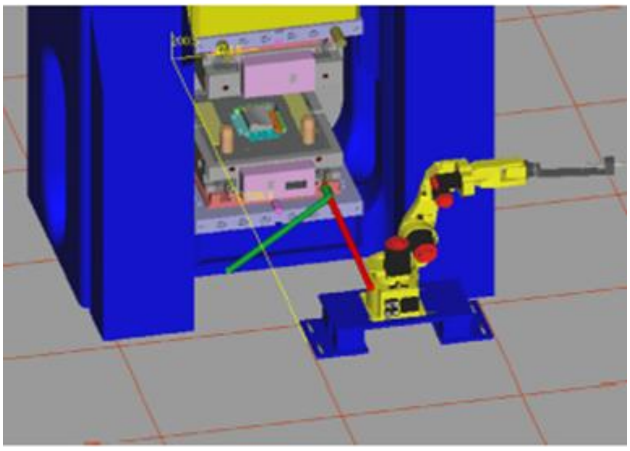

Figure 6: Design of Special Intelligent Manufacturing Robot Tool- Layout checking

5. Types of Automation in Intelligent Forming and Forging

5.1.1. Furnace heating – automation

The AFRC rotary furnace device includes an incrementing hearth which can be moved round to the next position for presentation to the operator or robot.

5.2. Screw press – automation

Here the screw press needs to be controlled remotely by a master PLC in order to execute pre-programmed load conditions and press stroke. Some thought needed to be put into what would happen if a part is stuck in the tooling, as well as into making sure that appropriate communications protocols are put into place and thatfacilities exist to interact with the master PLC, see Fig. 7 and Fig.8.

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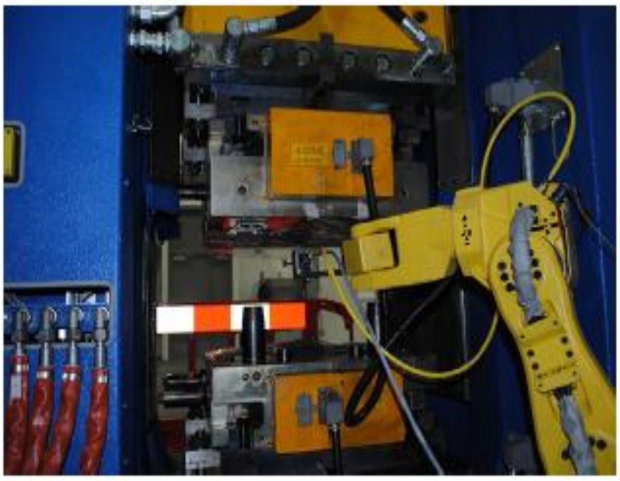

Figure 7: Robot operating inside press tooling

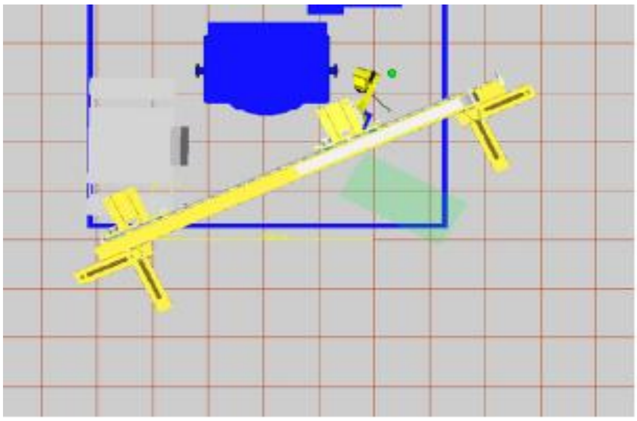

Figure 8: Checking clearance of robot and park position

5.2.3. Safety protocols/guarding

Legislative requirements and basic consideration for staff safety dictated at an early stage that safety guarding had to be included. Since even the smaller robot (overall mass 140 kg) is capable of moving at up to 600 per second it does have the potential to cause some damage both to staff and itself and auxiliary equipment. Guards were therefore procures and installed Final layout is also important upon placement of the multi-forge/horizontal up-setter and integration of the guarding to cope with both the position of that in the one manufacturing cell.

Advantages

The standard workspace is clear and the robot could be parked safely well away from the press when not in use. The robot could be repeatedly placed in a centralized position when required. The working envelope of the robot and its flexibility would be enhanced considerably.

Disadvantages

Due to the increase in the cost and increased complexity in programming of (7th axis), however these disadvantages were greatly enhanced by the increased flexibility – especially important in an R&D environment where the ability to change over from task to another and to implement small batch sizes is critically important. Fig.9 illustrates how the location and handling arrangement is to be checked so that the robot could be placed in an ideal park position, and deployed in front of the Programmable furnace, screw press and clipping press.

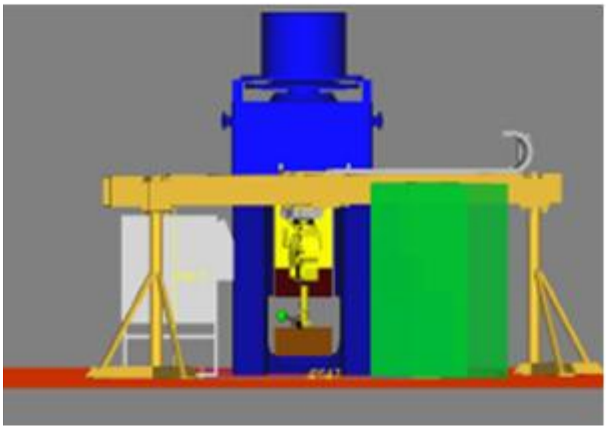

Figure 9: Show Robot interactions with press

5.2.1. Trimming/clipping press

At the output side of the screw press, a clipping press has been placed which removes any final waste from the final stamped part. From the Automation engineers view both presses can be regarded as similar devices – in which program control is handed over to the individual press controller, which then has load displacement parameters required for a particular part sequence as seen in Fig. 10 below

Figure 10: Funuc M710 Robot mounted inverted on Gantry for Trimming /clipping press

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5.2.2. Automation in practice

As the development of the automation work is progressing it became imperative that the experimental interest and benefits from highly repeatable trials of particular forging situations excited research interest,. Although, more project of opportunity arose, pertaining to quenching where the advantage of repeatedly quenching an object under programmable control emerged. With the fact that the automated handling system was not designed for this from the outset a brief model in Roboguide and clarified that it would be possible to repeatedly quench objects, thus improving the consistency of the experimental procedures. This has been a trend that has been observed elsewhere, robots tend to be redeployed to other factory/R&D functions rather than be replaced. As part of this work it was decided to add automation capability to a larger furnace presently used for quenching trails based on a forklift. This means that it would be possible to routinely and repeated quench the relatively large (up to 25 kg) objects in a systematic way, since the time to go from the furnace to quenchant by the existing manual (forklift) method was very variable.It is also important to have an extremely complete understanding of the detailed nature of the task that requires automation in order to be able to specify and implement an automated system. Barriers to implementation can include fear of redundancy[14] and labour displacement due to practice robotic automation implies that existing staff are redeployed into other areas after an increasein volume and quality has been achieved, though some of those who leave voluntarily may not be replaced.

6. Conclusions

This paper has described the process of intelligentmanufacturing and smart automation as related to forging and an outline of a process to design and implementation of an automated robotic forging cell, based on a large press. The process requires clear management support from the beginning as well as a realization that for certain applications smart design can accommodate both manual forging and automated forging operation using the same installation. A micro-management approach to the process is required that includes all the corrective actions that intelligent operators do in order to produce smart forgings and the process of laying out the cell has been described, using CAD tools including Robo-guide, and Pro-Engineer. This serves as a basic structure for flexible technology development in the manufacturing industries.

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