National Conference in Mechanical Engineering Research and Postgraduate Students (1st NCMER 2010)
26-27 MAY 2010, FKM Conference Hall, UMP, Kuantan, Pahang, Malaysia; pp. 572-581
ISBN: 978-967-5080-9501 (CD ROM); Editors: M.M. Rahman, M.M. Noor and K. Kadirgama

ANALYSIS OF FUNCTIONAL BUILD (FB) IN ALUMINIUM EXTRUSION PROCESS INNOVATION BY USING ARENA SOFTWARE

M. D. Suziyana[1] and T. M. Yusof[2]

[1] TATI University College, Jalan Panchor, 24007 Kemaman, Terengganu.
Email: suziyana@tati.edu.my
[2] Faculty of Mechanical Engineering, University Malaysia Pahang,
26600 Pekan, Pahang
Email: myusof@ump.edu.my

ABSTRACT

Product innovation plays important role in ensuring the continuity and growth of a business. Shorter production time and less defect quantity will be the main subject in order to increase profit. Thus, development of innovation model is a need to make sure that the business is successful from time to time. Innovation model that will be discussed in this paper is related to Functional Build (FB) in aluminium extrusion process. FB is a concept that allows a certain extent of variation to process specifications whilst maintaining the overall output specification which the customer would see. A new model of innovation process was developed based on numerous literatures with the focus of improving the production ramp-up stage of the process. This paper introduced the idea of permitting the extruded sections which associated with minor surface imperfections to progress to the next operations since they were proven to be removed during the anodising operation. Both the previous and new aluminium extrusion processes were simulated by using Arena simulation software version 5.0 to analyse the expected improvement of rejection level and production time. Simulation results showed that the rejected level of extruded sections was reduced by 57.14% and total processing time was reduced by 8.04%. Hence, it is proven that the application of FB approach in innovation process of aluminium extrusion products development can help businesses to reduce the product development lead time and facilitate them to become more innovative.

INTRODUCTION

Innovation is the lifeblood of a business and crucial in determining its continuation in today's rapid changing business environment. A business which fails to react quickly to the changes of any entity in the environment is exposed to the risks of being overtaken by its competitors. A survey conducted by Deloittes in 2004 showed that the time taken by businesses to launch new product has decreased from 18.1 months in 1998 to 15.1 months in 2004. And the timeframe has been projected to be only 12.8 months in 2007 [BPIR, 2005]. From the findings, it appears that businesses have shorter time to carry out the product innovation process and therefore increases the need to develop reliable innovation model to ensure that the objectives can be achieved. Many versions of innovation models have been developed and validated by previous researchers such as Booz, Allen and Hamilton, Cooper, Walker and Trott [Walker, 1986, Trott, 2002 and Hart and Baker, 1994]. Each of which having strengths and weaknesses and have been used as guide in improving the models to produce more relevant models. New product innovation processes are resulted from the existence of various elements. A range of elements which determine the successfulness of the innovation process have been identified in previous studies. There were disagreements among the researchers about what exactly the factors that contribute to the success of innovation process. However, Walker and Trott [Walker, 1986 and Trott, 2002] have the same point of view that a successful innovation occurs through the interaction of three interdependent elements: science and technology base (I), technological developments (T) and needs of the market (D) as shown in Figure 1. The lack of one or two of the elements will cause conditions of innovation prematurity or innovation delay.

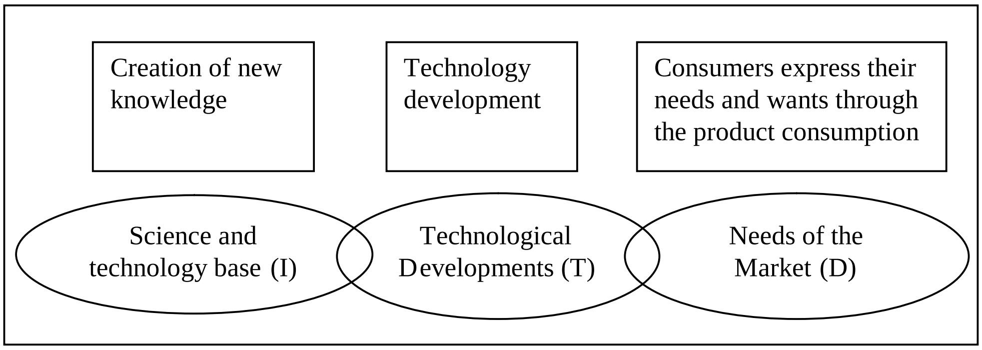


Figure 1: Elements of successful innovation

Functional Build (FB) approach to manufacturing validation is one of the technology elements which can be applied to improve the innovation process. According to Hammett, Wahl and Baron [Hart and Baker, 1994], FB approach can help to reduce validation time and costs while meeting the end product quality requirements through the use of flexible criteria in validating the products. It concerns more on meeting the final build specifications than the design specifications of components which constitute the product.

The process and shapes flexibility of aluminium extrusion has resulted its widespread use in various areas such as the building, shipping and offshore, furniture and automotive industries [Reiso, 2004]. The average annual progression rate of total production of aluminium extrusion products in Western Europe countries has been reported to be 4.7% from 2002 to 2005 [AFFG, 2007]. However the occurrence of minor surface imperfections on the extruded aluminium such as die lines, scratches and blemishes due to process variations has limited the extrusion productivity and quality. The intense competition of the industry and the critical importance of surface finish to certain types of product have forced the extruders to find ways to minimise the product rejection and product development lead time. This paper attempts to identify the opportunity of using FB approach to overcome the rejection problem and help the aluminium extruders to become more productive and innovative.

Numerous studies have been implemented on the application of FB in the automotive industries, mainly in the development of vehicle body such as by Gerth and Baron [2003], Vasilash [2000], Auto/Steel Partnership [1999], Kobe [2003] and Glenn [2001]. The studies have proven that FB is capable of causing a great improvement in the assembly process of vehicle body. However, the applicability of FB in other manufacturing processes has not yet been extensively studied. The fact makes this research of particular interest with its focus on the application of FB concept in the aluminium extrusion process. This research addresses the applicability of FB in improving the innovation process of aluminium extrusion in terms of reducing the production time. It is motivated by the need to produce and validate a model which can improve the innovation process and help businesses to become more innovative.

Aluminium Extrusion

Aluminium extrusion process is a plastic deformation process in which billet (block) of aluminium is pushed by compression through a shaped die having a small cross-sectional area than the extruded cross-sectional area of the billet and acquiring the shape of the die. In general, a hot aluminium extrusion process involves several basic steps such as depicted in Figure 2 [AEC, 2006].

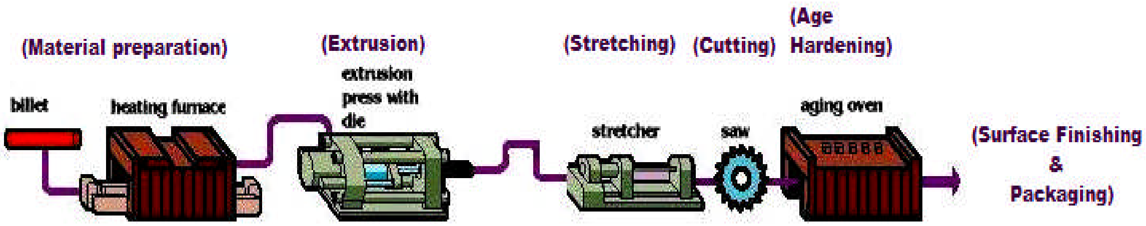


Figure 2: Basic steps involved in extruding an aluminium profile

Hendess [2002] studied the effect of extrusion die design on extruded product quality and classified the defects into two categories: visual defects and physical defects. Reiso [Reiso, 2004] identified surface defects that are caused by the extrusion speed such as die lines, pick-ups, tearing or hot shortness and spalling. Besides that, [Qamar, Arif and Sheikh 2004] had presented the classification of extruded product defects for decorative purpose such as press (extrusion) area defects, anodising area defects and painting area defects. The production process of aluminium extrusion products for decorative purpose can be portrayed as shown in Figure 3.

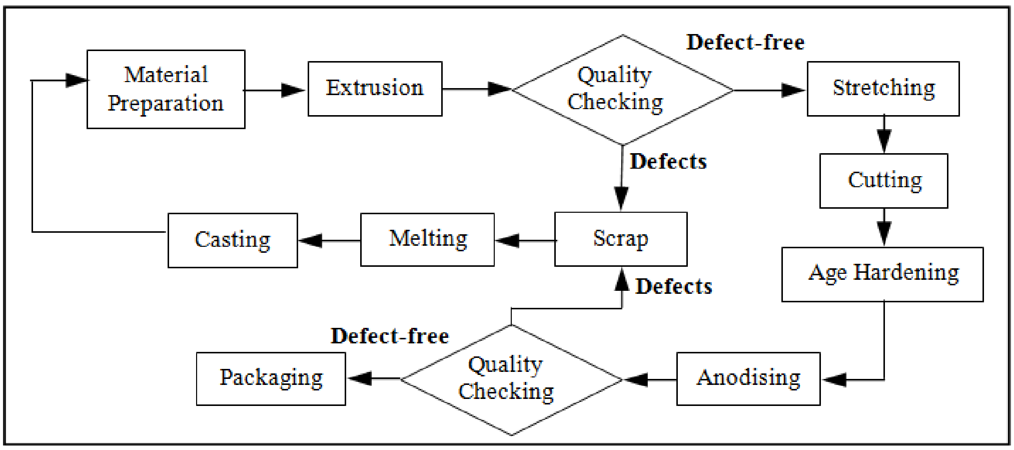


Figure 3: Production process of aluminium extrusion by [Qamar, Arif and Sheikh, 2004]

According to their study on the total production of aluminium extrusion and defects for decorative purpose, the die lines defect contributed the largest product rejections at the press area and followed by the scratches defect. The die lines defect were included the finer and shallower die lines known as micro die lines. The extruded sections which were found to have the surface imperfections have been rejected and cost the business a huge amount due to the material and labour processing loss. Figure 4 shows total production (in tons) and percentage of reject for aluminium extrusion for 9 years.

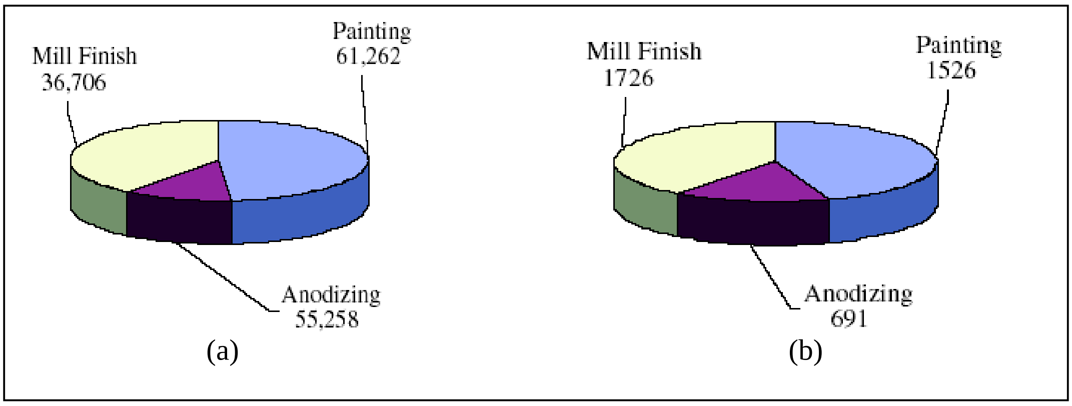


Figure 4: (a) Total production of extruded aluminium and (b) Total rejection for 9 years

The defects that cause the rejection have been classified in the paperwork. The minor surface imperfections such as light die lines and scratches, and fine blemishes can be removed by the etching process of anodising operation. In this research, the rejection breakdown data at the press centre presented by Qamar, Arif and Sheikh was referred to get the data on minor surface defects. The black or white lines (B/WL) (i.e. the die lines) and scratches (S) defects which were reported to be the largest percentage of defects at press centre of the studied facility were considered to be the minor surface defects in this research. The B/WL defect contributes 39.76 percent and S contributes 15.38 percent of the total defect in mill finish. Thus, it was assumed that all (hundred percent) of both defects (B/WL and S) can be removed by the anodising operation.

The new production process of aluminium extrusion as illustrated in Figure 5 improves the previous process by adopting the functional build approach whereby the extruded aluminium which has minor surface defects resulted from the extrusion operation is allowed to progress to the next operations. This means that certain degree of flexibility is introduced in validating the quality of extruded sections since the associated minor surface defects do not affect their functionality. The extruded sections are rejected only when they are found to have other types of defects (i.e. excluding the minor surface imperfections). The quality checking that is done after the anodising operation is to ensure that the products that are delivered to the customers free from any defects including the minor surface defects.

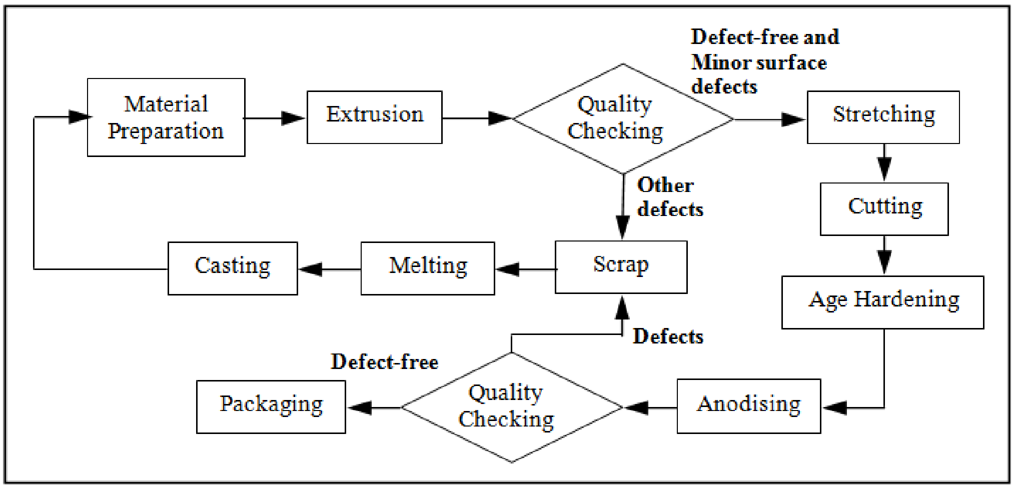


Figure 5: Improved production process of aluminium extrusion

FB Model Development

From Figure 4(a), the following calculation was made to calculate the total production per day, assuming that the total operation days per month is 26 days.

Total production per day = (Total Production in 9 Years) / (Total Operation Days in 9 Years)

$$= \frac{(36706 + 55258 + 61262)}{(9 \times 12 \times 26)}$$

= 54.57 tons or 54570 kg

The operation hours per day was assumed to be approximately 16 hours and the total production per day (54570 kg) was entered at the aluminium billet arrive module.

The product rejection data such as depicted in Figure 4(b) was used to set the parameters at the extrusion quality checking and anodising quality checking (i.e. the decide modules). The data was used to make the following calculations:

Percentage of mill finish reject = (Total Mill Finish Reject / Total Production) × 100

$$= \frac{1726}{153226}(100)$$

$$= 1.13\ \%$$

The data was entered at the true output of the extrusion quality checking in the model that was run to simulate the previous aluminium extrusion process.

Percentage of anodising reject = (Total Anodising Reject / Total Production) × 100

$$= \frac{691}{153226}(100) = 0.45\ \%$$

The data was entered at the true output of the anodising quality checking in the model that was run to simulate both the previous and improved aluminium extrusion process.

The data presented by Qamar, Arif and Sheikh [63] was used to make the following calculations:

Percentage of minor surface defects = % B/WL + % S
= 39.76 + 15.38
= 55.14

Improved extruded aluminium reject
= [Total Percentage of Reject – Percentage of Minor Surface Defects/100] × Total Mill Finish Reject
= [(100 – 54.14) / 100] × 1726
= 774.28 tons

Percentage of improved extruded aluminium rejects;
= (Improved Extruded Aluminium Reject / Total Production) × 100
= (774.28 / 153226) × 100
= 0.505

The data was entered at the true output of the extrusion quality checking in the model that was run to simulate the improved aluminium extrusion process. **Figure 6** shows the complete innovation model by using ARENA Software to simulate effectiveness of the FB in aluminium extrusion.

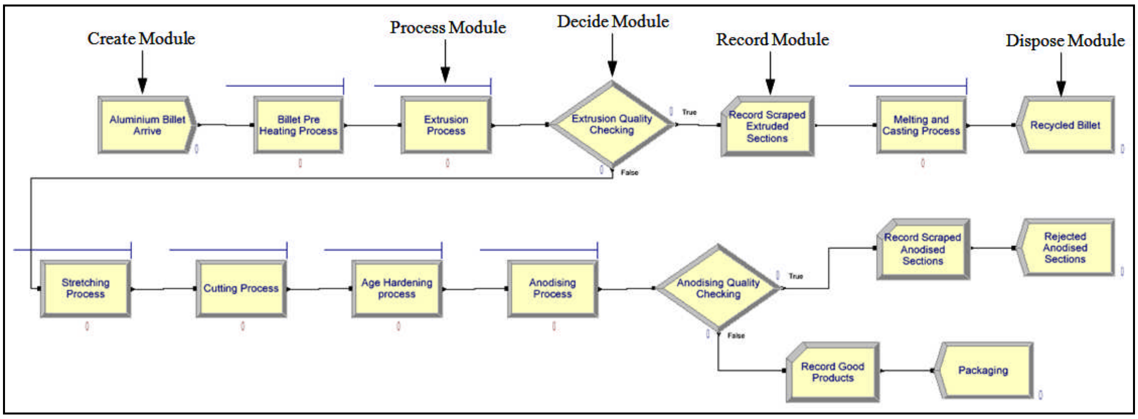
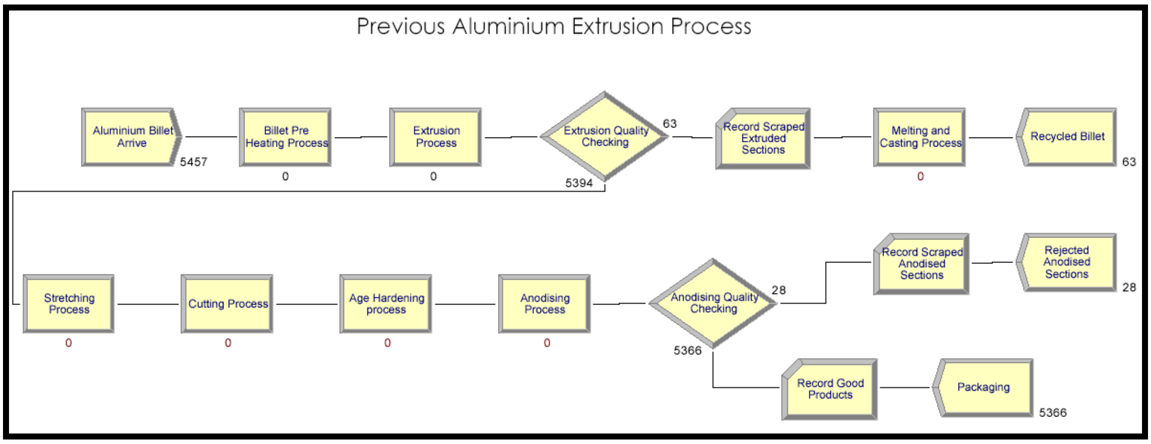


Figure 6: Innovation Model of Aluminium Extrusion by Using ARENA Software

RESULTS AND DISCUSSION

Figure 7 shows the simulation result of previous aluminium extrusion process. The aluminium billet arrive module (i.e. 5457×10 kg) represents the materials to be processed within one day approximately 16 hours of operation. The 5457 was set instead of 54570 in order to minimise the entity in the simulation. The quality checking performed after the extrusion process resulted that 53940 kg (or 53.94 tons) of the extruded sections were accepted and progressed to the next processes. The amount represented good products which were free from any defects including the minor surface defects. Besides that, the checking has also resulted that 630 kg of extruded sections which were discovered to associate with any kind of defects were rejected and recorded as scraped for further reprocessed. Another quality checking which was implemented on the anodised sections revealed that 53660 kg of inspected products were not having any defects and recorded as the good products. The accepted products were packaged and prepared for delivery to the customers. Apart from that, 280 kg of anodised sections were recorded to have defects and sent the scrap area. The time taken to complete the whole processes was 16 hours and 7.8 minutes.

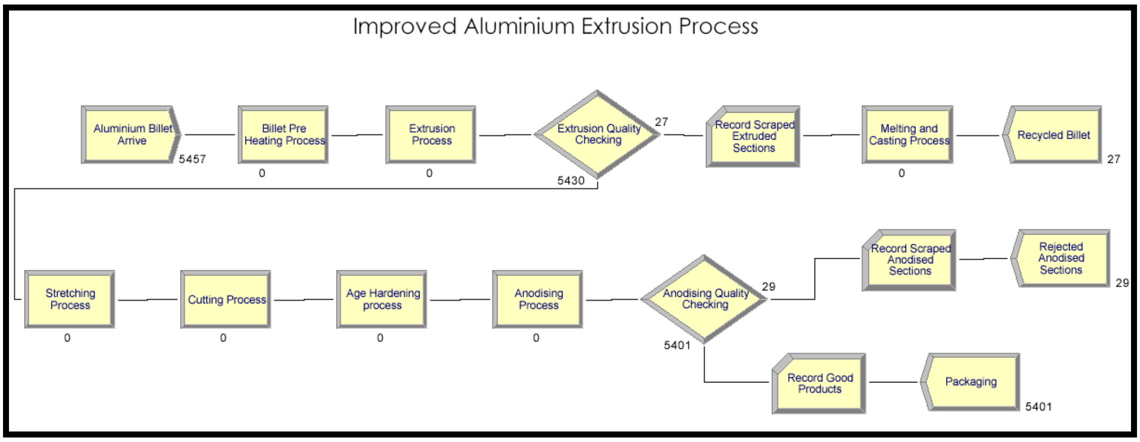


Note: All figures shown must be multiplied by 10kg (e.g. 5457×10 kg)

Figure 7: Simulation result of previous aluminium extrusion process

The simulation result of improved aluminium extrusion process is presented in Figure 8. The model was set to process the same amount of aluminium billet as the previous process, which was 54570 kg. The result clearly showed that only 270 kg extruded sections were rejected and sent to the scarp area. The amount does not represent the extruded products which were found to have minor surface defects as they were accepted and passed to the next processes. The accepted products were resulted to be 54300 kg at this stage. Other than that, 54010 kg of outputs of anodising process were accepted since they were not having any defects and 290 kg were rejected due to associated with defects. The time taken to complete the whole processes was 14.83 hours and 49.8 minutes.

Table 1 shows the comparison of result for previous and improved aluminium extrusion process for one day operation. The new process has shown an improvement in terms of amount of accepted and rejected products at the extrusion quality checking compared to the previous process. An increment of 360 kg per day in the amount of accepted extruded sections was achieved and resulted in the increase of final good products (packaged products) and reduction of the scrap (at extrusion and anodising quality checking) by 350 kg. This was resulted from the application of FB approach whereby any extruded sections which were found to have the black or white lines and scratches or damages (i.e. the minor surface defects) were permitted to progress to the next processes since the defects could be recovered through the etching process of anodising operation. Meanwhile, the amount of rejected products at the anodising quality checking for the improved process increased by 10 kg as the number of anodised sections increased. However, the total rejection of extrusion was decreased from 630 kg to only 270 kg for one day. In the same time, the total processing time for one day has reduced by 8.04 percent from 967.72 minutes to 889.88 minutes.



Note: All figures shown must be multiplied by 10kg (e.g. 5457×10 kg)

Figure 8: Simulation result of improved aluminium extrusion process

Table 1: Comparison of Result for Previous and Improved Aluminium Extrusion Process for One Day Operation

No.	Processes	Result for Previous Aluminium Process	Result for Improved Aluminium Process
1	Pre Heating (×10 kg)	5457	5457
2	Extrusion (×10 kg)	5457	5457
3	Stretching (×10 kg)	5394	5430
4	Furnace (melting and casting process) (×10 kg)	63	27
5	Cutting (×10 kg)	5394	5430
6	Age Hardening (×10 kg)	5394	5430
7	Anodizing (×10 kg)	5394	5430
8	Record Scraped Anodizing Section (×10 kg)	28	29
9	Record Scraped Extrusion Section (×10 kg)	63	27
10	Record Good Product (×10 kg)	5366	5401
11	Time Consume (minutes)	967.72	889.88

CONCLUSION

An increment of 360 kg in the amount of accepted extruded sections was achieved and resulted in the increase of final good products (packaged products) and reduction of the scrap (at extrusion and anodising quality checking) by 350 kg. This was because any extruded sections which were found to have the black or white lines and scratches or damages (i.e. the minor surface defects) were permitted to progress to the next processes since the defects could be recovered through the etching process of anodising operation. The reduction in the amount of rejected products was resulted in the increase of accepted products. The increment of good product at 360 kg was resulted the reduction in the processing time of about 77.84 minutes. This means that the reduction of rejected extruded sections by 57.14% has caused a reduction in the total processing time by 8.04%. It is proven that the application of FB approach to manufacturing validation is capable of improving the production process of aluminium extrusion products in terms of reducing the total processing time. In other words, the extruders can become more innovative since the extruded aluminium products development lead time is reduced by the shorter production time.

ACKNOLEDGEMENT

I would like to thank to project supervisor, Malcolm Willis from University of Northumbria at Newcastle upon Tyne, for his guidance, encouragement and constructive criticism in completing this project.

REFERENCES

sAluminium Extruders Council (AEC). *Extrusion process*. Available at: http://www.aec.org/techinfo/expro.html. 2006. (Accessed: 19 August 2007).

Aluminium For Future Generations (AFFG). *Sustainability of the European aluminium industry 2006.* http://www.alufuture.org/affg/pdf/EAA_SDI_brochure Competitiveness_10.pdf. 2007. (Accessed: 18 July 2007).

Auto/Steel Partnership. *Event-based functional build: an integrated approach to body development*, Michigan: Auto/Steel Partnership, (A/SP-9030-1). Available at: http://www.a-sp.org/database/custom/bsa/bodydevexec.pdf. 1999. (Accessed: 20 March 2007).

BPIR.Com. *New product development – innovation strategy.* Available at: http://www.bpir.com/index.php?option=com_content&task=view&id=82&Itemid=71. 2005. (Accessed: 5 February 2007).

Gerth, R. J. and Baron, J. 'Integrated build: a new approach to building automotive bodies', *International Journal of Automotive Technology and Managemet*, 3(3/4), 2003, pp. 185-201.

Glenn, D. W. 'The functional build approach to die tryout in the automobile industry', *IIE Transacions*, 35, pp. 357-367 *EBSCO* [Online]. Available at: http://web.ebscohost.com/ehost/results?vid=3&hid=107&sid=0a03af3c-bd93-42c5-83a8-713978a19e95%40sessionmgr102. 2003. (Accessed: 20 June 2007).

Hammett, P. C.; Wahl, S. M. and Baron, J. S. *Using flexible criteria to improve manufacturing validation during product development*. Available at: http://www-personal.umich.edu/~phammett/Papers/fb-cera-journal.PDF, 1999 (Accessed: 20 March 2007).

Hart, S. J. and Baker, M. J. 'The multiple convergent processing model of new product development', *International marketing review*, 11(1), 1994, pp. 77-92.

Hendess, P. M. *The effect of die design on extruded product quality*. Available at: http://www.streamlineextrusion.com/paper1.pdf.2002. (Accessed: 20 August 2007).

Kobe, G. 'Manufacturing 2010', *Automotive Industries*. August [Online]. Available at: http://web.ebscohost.com/ehost/results?vid=4&hid=107&sid=0a03af3c-bd93-42c5-83a8-713978a19e95%40sessionmgr102. 2001. (Accessed: 20 June 2007).

Qamar, S. Z.; Arif, A. F. M. and Sheikh, A. K. 'Analysis of product defects in a typical aluminium extrusion facility', *Materials and Manufacturing Processes*, 19(3), 2004, pp.391-405.

Reiso, O. 'Extrusion of AlMgSi alloys' *Materials Forum*, 28, 2004, pp. 32-46.

Trott, P. *Innovation management and new product development*. 2nd edn. Essex: Prentice Hall, 2002.

Vasilash, G. S. *Building better vehicles via functional build.* Available at: http://www.autofieldguide.com/articles/020002.html. 2000. (Accessed: 24 March 2007).

Walker, D. *Design and innovation: an introduction*. Milton Keynes: Open University Press, 1986.