Classification of Main Faults in the Production Process of Extruded Aluminium Profiles

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Abstract- Aluminium use has been rising steadily in recent decades. Several different industries are adapting it since its light weight, doable structure and robustness. Aluminium manufacturing runs in three ways; namely: (1) cascading, (2) extrusion and (3) drawing. Extrusion process is used to form aluminium in profiles which is one of the main semi/final-products for many industries. Although profiles production runs smoothly and easily most often, there are a number of repeated faults which might occurs during the extrusion process and some distinct patterns of faults and defects can be seen on the surface of the produced profiles. This paper describes the main types of these faults and defects and suggested solutions to avoid them based on 24 months of observations for the production process at three different extrusion machines in two different aluminium profiles manufacturing plants. The main aim of this study is to classify these faults and defects to help manufacturer to control and to avoid them or at least to minimize their occurrences by optimising quality control systems.

Keywords: Aluminium Extruded Profiles, Defects, Scratches, Faults, Aluminium Production

I. INTRODUCTION

Extrusion is the process of pushing or drawing through a die of the desired cross-section to create very complex cross-sections and work materials that are brittle [1]. This process can be done using aluminium or some other materials and it can be hot, cold or warm types.

The extrusion process (Fig. 1), which can be direct or indirect [2], has been likened to "squeezing toothpaste" out of a tube. When pressure is applied at the closed end, complex shapes can be produced by complex openings (Fig. 2 shows the Definition and principle of extrusion). The aluminium extrusion process begins with heating aluminium billets in a furnace up to 750 or 900 degrees Fahrenheit (398- 482Celsius) [3]. The form of aluminium can be classified as not liquid, but rather a malleable solid at the time of extrusion.

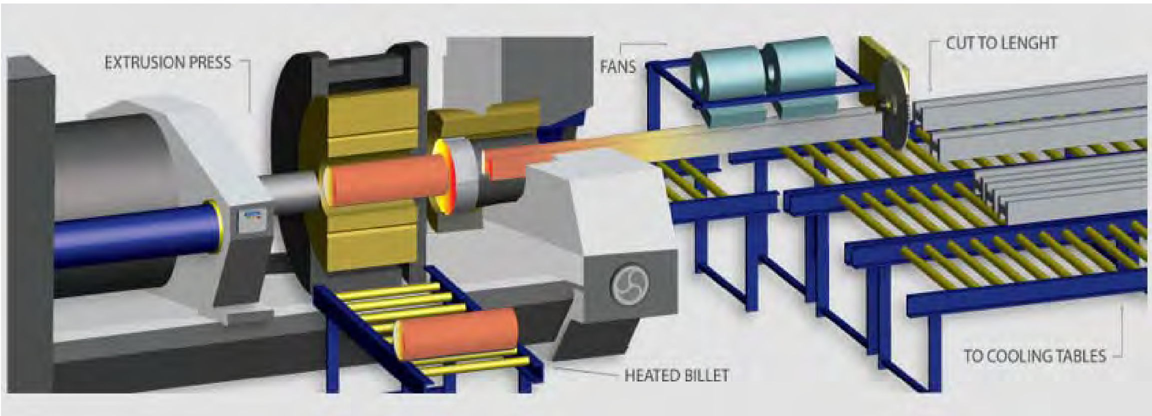

Fig. 1. Extrusion process [4]

Once a billet reaches the wanted temperature, it is moved to the loader and a ram applies pressure to the dummy block which, in turn, pushes the billet inside the container. Under pressure the billet is crushed against the die, becoming shorter and wider until it has full contact with the container walls [5].

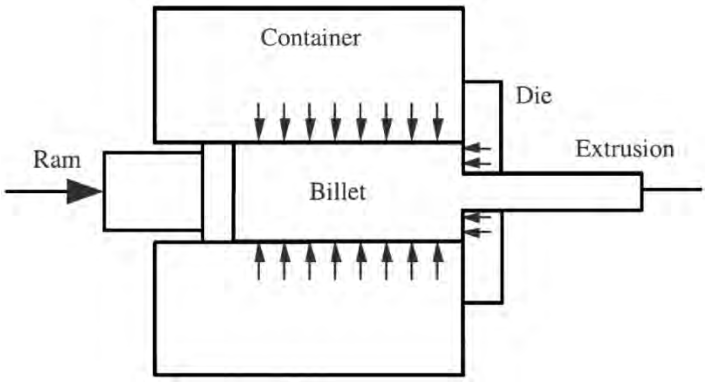

Fig. 2. Definition and principle of extrusion [2]

Extrusions are pushed out of the die to the lead-out table and the puller, which guides metal down the run-out table during extrusion. While being pulled, the extrusion is cooled using fans along the entire length of the run-out and cooling table. Then profiles are cut into desired length and pulled from both sides to be straightened as well as to improve the structure of aluminium. This is mainly how extrusion process goes on from billets to make ready profiles[2].

TABLE I- Properties of Used Machines

Feature	**1st Machine**	**2nd Machine**	**3rd Machine**
Type	1400 Tones	1400 Tones	2000 Tones
Age	10 years	6 years	7 years
Avg. Working time	600 hour per month	600 hour per month	600 hour per month
Number of workers	Min:5, Max:7	Min:5, Max:7	Min:5, Max:7
Working Load	1112 meters per hour	554 meters per hour	770 meters per hour
Produced profile	0.421 (KG/Meter)	0.881 (KG/Meter)	0.869 (KG/Meter)

II. MAIN PRODUCTION FAULTS AND DEFECTS

During the extrusion process, some faults and some certain defects might be caused because of different reasons and these might extend for long distances along the produced item. This can cause a significant loss in terms of money, work and time, sometimes forcing large amounts of profiles to be scrapped. There is no well-known statistic about the amount of scraped aluminium, but in general more than a third of all the aluminium globally produced comes from aluminium scrap [6].

To be able to understand these faults and defects, the production line of three manufacturing machines in two different plants in Turkey were monitored for 24 months; all faults and defects were recorded in a dataset. The main features of monitored machines are listed in Table I.

Table II describes the occurred faults and defects which were classified into 17 different types; their level of acceptance by customer and the main reasons for their occurrence. A set of photos of these faults and defects were collected in a semi-controlled environment and are listed in Table III.

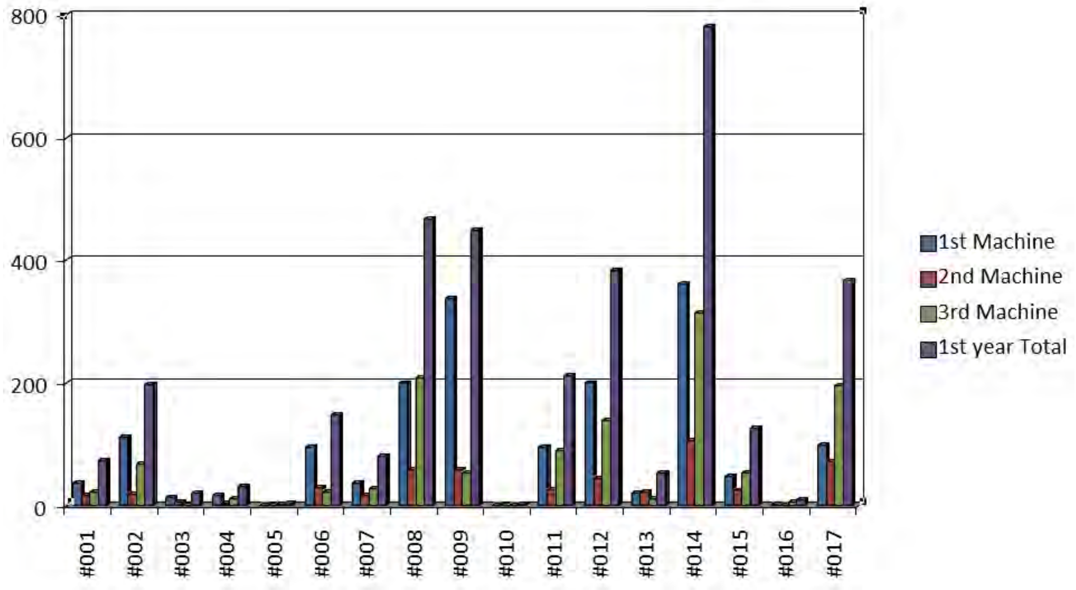

Fig. 3. The number of occurrences of faults during 24 Months for each machine

To maintain a degree of consistency throughout the dataset, the same physical setup was used in each photography session. Because the equipment had to be reassembled for each session, there was some minor variation in images collected on different dates. The photos dataset (Table III) contains (34) images that includes (17) detected defects and (17) unharmed profiles of images.

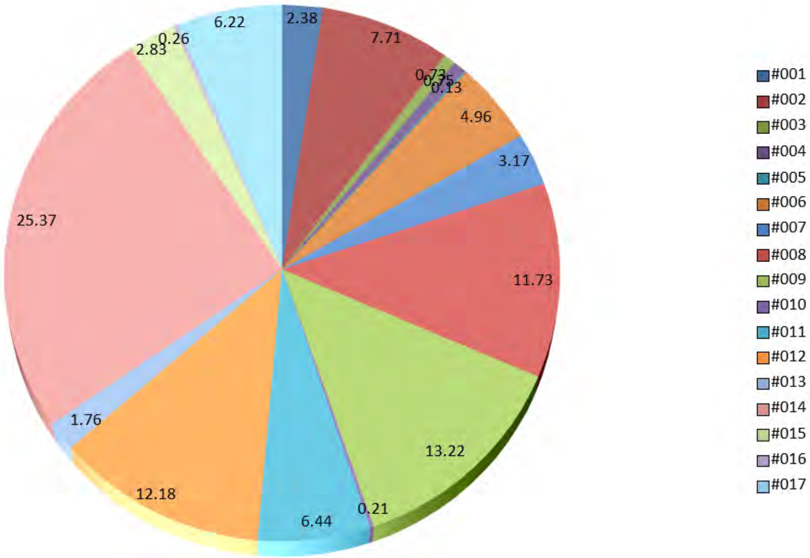

Fig. 4. The percentage of occurred faults during 24 Months

Photos were captured in a special illumination and photography environment that includes a reasonable illumination light source and a 1.3 Mega Pixels digital microscopic video camera of the following specifications: (Still capture resolution: 1600*1200, Focus range: 10mm to 500mm, Magnification ratio: 20x – 400x). A set of 24-bit RGB images of size 516 (height) x 716 (width) pixels were produced. The aspect ratio of the pixels was roughly 1.04 (height/width).

Frequencies of the occurrence of these faults and defects for each machine during monitoring period are shown in Fig. 3. While Fig. 4 shows the percentages of these faults and defects.

III. Discussion and Conclusion

Fig. 5 shows the percentage of occurred faults according to customer satisfaction and according to their type. As can be seen, not all faults are critical for marketing side. Some faults can be acceptable for some customers; also some faults can be corrected in the post-extrusion processes like painting or anodizing.

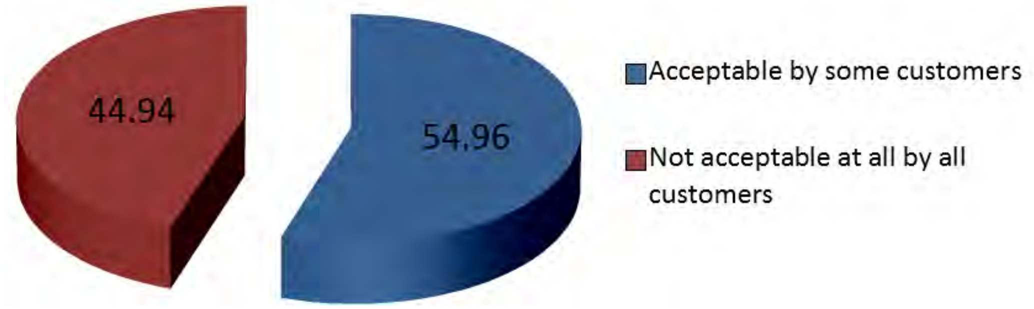

Fig. 5. The percentage of occurred faults according to their acceptance by customer

In Fig. 6, the percentage of occurred faults according to their types is presented. Faults can be classified into two sets since profiles are designed in cross-sections and extruded to create a surface. Defects occur on surface and measurement problems occur on cross-sections; other problems are also related to these two sets but cannot be classified under these groups because of their different shapes and reasons of occurrence.

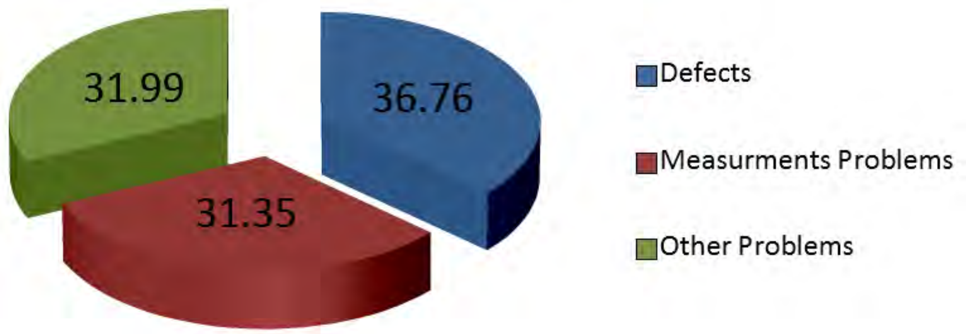

Fig. 6. The percentage of occurred faults according to their types

Defects and measurements problems have high percentage of occurrence. This can be explained due the lack of using automated detection techniques and because of the reliance on human detection all the time with poor training for workers. It is strongly recommended to use machine vision technology to detect these defects online at early time, to increase the training for workers especially about the faults mentioned in Table II and to be sure of applying regular maintenance for machines with clear regulations.

References

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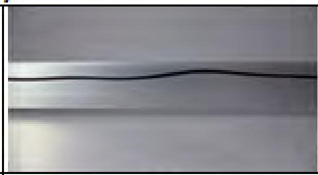
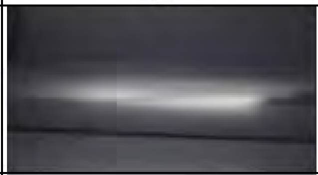
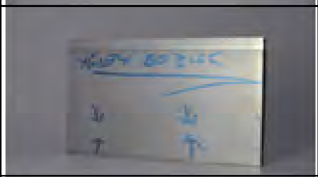
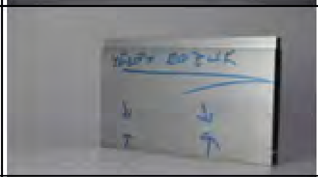
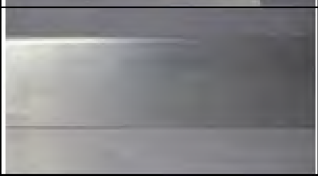
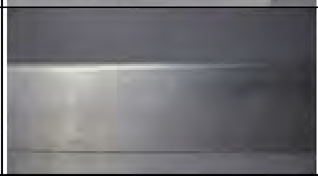
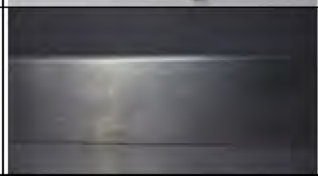
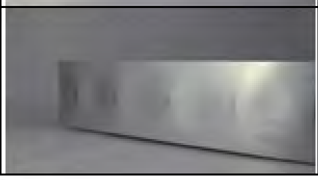
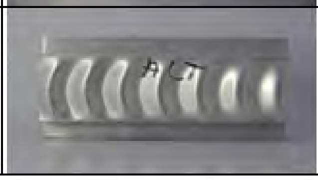
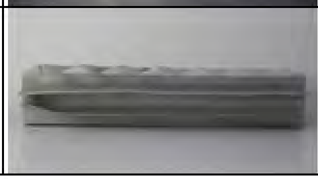
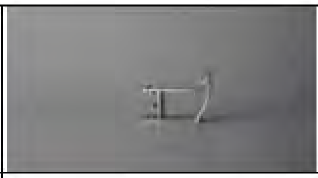
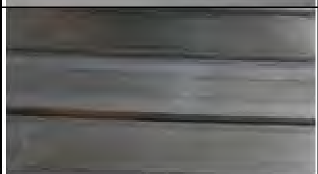
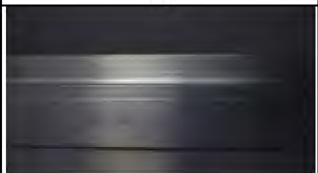
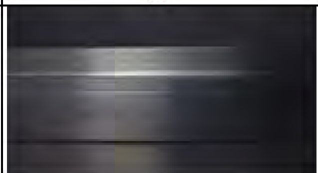
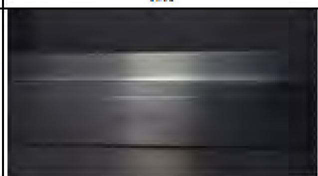
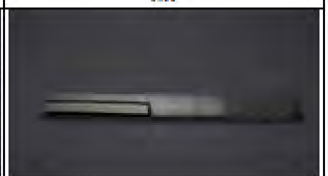
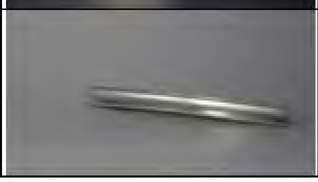
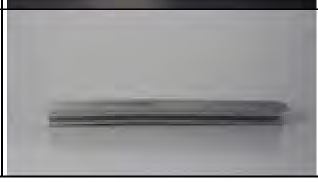
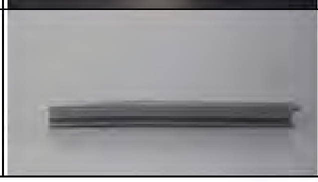
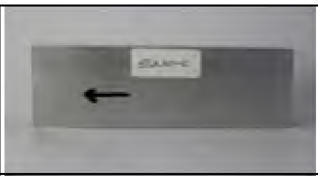
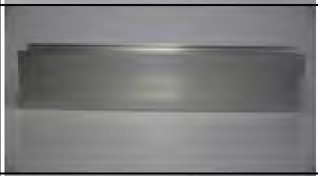
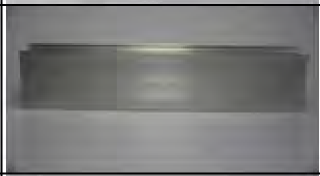
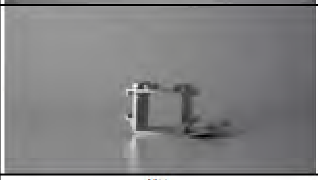
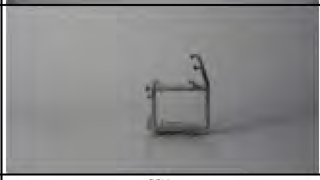
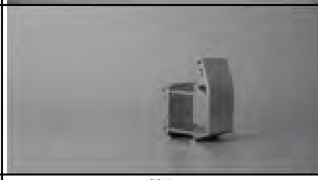
TABLE II - The Most Occurred Faults and Defects (NA: Not Acceptable, MbA: Might be Acceptable)

Fault ID	Status	Fault Description	Reason
#001	NA	Some bins or holes can be seen on the profile surface	Arrival of foreign material to the mold which means that the row material is not clean
#002	NA	No output out of the mold	Die or aluminum ingot is not heated enough or the extrusion machine is not working in a good way (may be broken or no electric)
#003	NA	Parallel lines on profile surface	Something is scratching the surface of the profile
#004	NA	White and black line color (could not be seen before Anodizing)	There is a high temperature in both of the profile and the die
#005	MbA	There is some color change on the surface of the profile (gray color like a line) which is unseen before Anodizing.	Temperature problem: there is a difference in temperature of some areas on the profile surface.
#006	NA	Wavy Profile Shape.	Very high pressure (profile is going very fast) and there is a problem in the flowing of aluminum through the die.
#007	NA	Inaccurate outputs, some parts of the desired profile are filled with extra aluminum or are missing aluminum.	Aluminium flowing is not good through the die or the die is broken
#008	NA	The whole surface is curved.	Die is not accurate, the die should be replaced.
#009	NA	Some sides of the output profile are coming out of the die faster than others	The flowing of material throw the die is not good.
#010	NA	Producing rotated profiles	The bolster which holds the die is not fixed properly or the flowing of material throw the die is not good
#011	MbA	Vessels, Pulling (like a barrier) or Tearing on the profile surface	Bad row material, bad die coating or bad polishing for the die surface
#012	MbA	Profile dimensions are incorrect (out of tolerance), Edges are wider or thicker compared to the wanted design in some areas (not accurate)	The flow of aluminum varies in the different sides of the profile or the die bridge is not located correctly or Die design problem or wrong centering of extrusion system (die, punch and exit hole) by Machine operator or applying high pressure
#013	NA	Horizontal line across the profile	The die is moving and not fixed correctly or the mold has deflected
#014	MbA	Damaged surface which is like a tiny scratch along the surface.	Die coating is not correct or has finished
#015	MbA	Some edge parts of the profile are raised up or fallen down in some cross sections.	Die design problem or wrong centering of extrusion system (die, punch and exit hole) by Machine operator or applying high pressure
#016	NA	incorrect Profile (different output compared to the design - sometimes upside down)	The wrong combination of a set of molds by operator
#017	MbA	Post-extrusion mistakes (not related to machine)	Handling Error due to bad cutting or pulling problem or dirtiness

TABLE III – Defects Photos

FID	Samples			
#001				
#002	N/A	N/A	N/A	N/A
#003				
#004				
#005				
#006				N/A
#007				N/A
#008		N/A	N/A	N/A
#009			N/A	N/A
#010	N/A	N/A	N/A	N/A
#011				
#012				N/A

#013			N/A	N/A
#014				
#015				N/A
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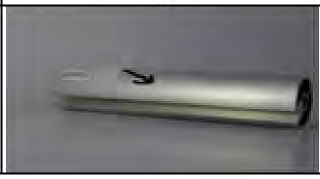
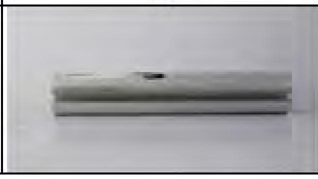
#017				N/A