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Original Research Article

Inspection method of aluminium extrusion process

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ABSTRACT

The paper presents the method for the monitoring of aluminium extrusion processes. The developed hybrid method combines the advantages of computer based, simultaneous infrared and visible image analysis for surface inspection of the profile directly after leaving the die. Thermograms present the temperature distribution on the surface of the extruded profile and contain information about the extrusion process. The proposed inspection system can be applied in industry for on-line monitoring of aluminium extrusion processes and the inspection of defects arising in extruded products.

1. Introduction

A hot aluminium extrusion is a plastic deformation process in which a preheated aluminium billet, placed in a heated container, is forced to flow by compression through the die opening to obtain the desired shape. Compression is caused by a moving ram pushing the billet. Typically, the hot aluminium extrusion process is carried out at temperature between 450 °C and 580 °C, and at a profile exit speed between 5 m/min and 100 m/min. Parameters of extrusion process are dependent on the shape and size of the profile and the alloy used to produce the profile [1]. After leaving the die, the extruded profile is cooled using an air or water quench. The average cooling rate is determined by the exit speed, the quench temperature, and the shape of the profile and, in general, its value is lower than 20 °C/s. One of the main issues in the production of aluminium profiles with use of hot hydrostatic extrusion technology is constant monitoring process parameters and an on-line inspection of products just after they leave the extruder. In the aspect of quality of products, due to different use of aluminium profiles as construction elements that often require high aesthetics, it is essential to control the state of their surface. The quality of the produced aluminium directly depends on the basic parameters of the extrusion process such as strength and extrusion speed, temperature in the working area, and other factors like the type of material, the size of the billet, the billet preparation, profile shape, matrix design, wear of the die, and the phenomenon of occurring in the process of friction and lubrication [1]. Some aspects of the extrusion process and forging process, like tool temperature, press settings, process speed, lubrication, and tool wear condition are very similar [2]. The abrasive wear and thermo-mechanical cracking are dominant mechanisms in the degradation process of the dies [3]. High-tech, highly automated production lines are equipped with control systems to ensure the monitoring of the desired parameters of extrusion process. Measurements of the surface temperature of the finished product are usually performed by non-contact infrared pyrometers [4,5]. In paper [6], the method for local temperature

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measurement with use of a long-wave infrared sensor was presented. Temperature control in the areas of the container and die is carried out by contact methods using thermocouples [7] and non-contact methods where infrared methods pyrometers are applied [8]. The temperature value is used for optimization in the feedback control system of the press extrusion process [1,9]. A limitation of the method of temperature control by means of a pyrometer is a local measurement, performed in a fixed location on the surface of the product. Local measurement method does not allow for tracking of the temperature distribution on the surface of the selected sections in a direction transverse to the direction of movement and the detection of anomalies that may indicate a disturbance in the extrusion process. In current practice, regardless of the automation process control, the extrusion press operator verifies the basic parameters of product. Manual control includes a visual assessment of the quality of the manufactured profiles, in particular, the surface condition and measurements of the main dimensions of the cross-sectional geometry are performed. The main quality testing of products takes place at a separate station where the defective sections of the profiles are identified and rejected.

Analysis of scientific publications and technical studies on the problem of quality assurance in the process of hot hydrostatic extrusion confirmed the lack of advanced solutions with the use of combined infrared and visible light techniques for surface inspection of manufactured products. The development progress of methods and systems for on-line monitoring processes of hot hydrostatic extrusion and quality assurance of manufactured products is, therefore, a current and important research topic with a significant economic importance for aluminium profiles manufacturing companies.

2. Product defects in aluminium extrusion

A review of publications on the subject of hot hydrostatic extrusion concludes that the classification of defects of aluminium profiles in a manufacturing process have not been developed or organized. Therefore, there is flexibility in the naming of identified defects of the products that hinder proper communication between specialists in the same research area. The main difficulty in comparative studies of extrusion defects is the lack of quantifiable data, mainly by giving shapes and sizes of geometric representations of defects and histograms of the captured images with reference to the manufacturing process parameters. An analysis of selected scientific publications relating to various types of defects occurring in the process of hot hydrostatic extrusion is presented in [10]. The results indicate a lack of a systemic defect identification method in current engineering practice. Based on the analysis of available publications [1,10–13] and the authors' research carried out in a light alloys manufacturing company, the following major defects can be identified that occur most often in practice.

Streak defects are defects that manifest themselves only after anodizing or painting in the form of elongated streaks that differ from the surrounding surface brightness and colour shade (Fig. 1). The lack of the possibility of direct visual detection of these defects on the processing line is a major problem in quality control.

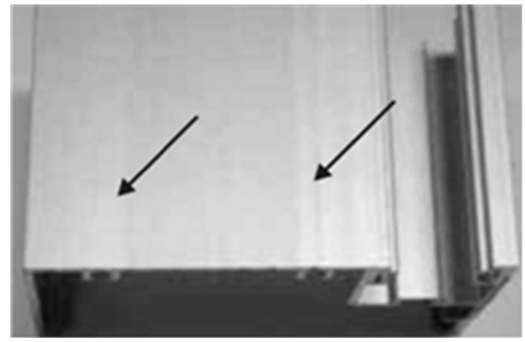

Fig. 1 – Surface defects in the form of bright streaks (pointed by arrows) [12].

The study indicates that the cause of defects is increased friction between the surface of the die and material [14]. The result of the uneven wear of the working surface of the matrix may be uncontrolled local increase of temperature and thermal energy in the top layer of the surface of extruded material. This phenomenon is associated with dynamic uneven recrystallization that causes inhomogeneous distribution of grain boundary grooves and the formation of regions with large grain microstructure shapes elongated in the extrusion direction [12]. As a result, anodized or painted profiles in the areas of the change in the microstructure have different reflectivity and colour. The key effect of the heat generated in the material that affects the growth of the grains of the microstructure was identified in the works [13,15]. The theoretical work with use of computer simulation methods have confirmed that changes in the coefficient of friction between the die and the material of the billet have a substantial effect on the variations in the microstructure of the material surface layer [16].

Die lines are one of the often-described defects in the aluminium extrusion process is a die line. It is defined as longitudinal depressions or protrusions formed on the surface of the extruded material due to imperfections on the die surface (Fig. 2). However, in practice, there are cases in which the high-quality surface of the die and the optimal parameters of the extrusion process still did not guarantee avoiding this defect.

Weld defects are defects resulting from the nature of the extrusion process, resulting from the merger of the faces of two consecutive extruded profiles (Fig. 3). The formation of defects contributes to a large oxide layer located on the surfaces of faces and contamination by the lubricant.

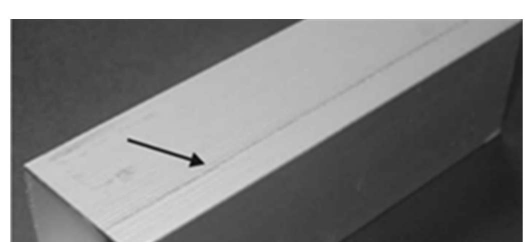

Fig. 2 – Die lines defect [10].