NEW PARAMETERS DISCOVERY USING AI-ARTIFICIAL-INTELLIGENCE, HIGH PERFORMANCE COMPUTING – ROBOTICS TITANIUM BI-PHASIC EXTRUSION

[1] Paul OLARU

[1]SCO-Expert Luzern, Switzerland

[1] Deutsche Materialkunde e.V., Germany, EU, polaru70@yahoo.com

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Abstract

Extrusion is a plastic deformation process in which a metal billet is forced by compression to flow through a die opening with a smaller cross-sectional area than that of the original billet. Extrusion is an indirect-compression process. The use of AI and automation, together with improvements in deployment technologies, can support a community-driven, closed-loop process. Examples include extracting, integrating, and reasoning with knowledge at scale to better respond to questions, using deep generative models to automatically propose new hypotheses, and automating testing and experimentation using robotic laboratories. Important advances in the machine representation of knowledge also enable new results to lead to new questions and hypotheses. Different modules and advanced models for assessing the hot extrusion of asymmetric aircraft profiles are presented. The accuracy of numerical predictions was demonstrated in terms of extrusion load, cooling efficiency, and die stress analysis. The AI-based numerical comparisons also showed the limitations of industrial practices, which are sometimes based on experience and/or empirical approaches. This work aims to present and describe innovative 3D numerical models for the extrusion process implemented within Multiphysics® (Mphy)that combine different modules. Several industrial case studies were discussed to show and handle some challenges for the advanced optimization of the process through numerical simulation. In particular, commercial software dedicated to the extrusion of asymmetric aircraft profiles for the new Airbus-2030 allows customized and flexible models to be implemented for analyzing the entire process from different perspectives.

Keywords: AI; Extrusion tech; Ti-Alloys, Multiphysics models, Multi-parameters Optimization

1. INTRODUCTION

Extrusion is a plastic deformation process in which a block of metal (billet) is forced to flow by compression through the die opening of a smaller cross-sectional area than that of the original billet as shown in figures 1a and 1b. Extrusion is an indirect compression process. Indirect compressive forces are developed by the reaction of the workpiece (billet) with the container and die; these forces reach high values. The reaction of the billet with the container and die results in high compressive stresses that are effective in reducing the cracking of the billet material during primary breakdown from the billet. Extrusion is the best method for breaking down the cast structure of the billet because the billet is subjected to compressive forces only. Extrusion can be cold or hot, depending on the alloy and the method used. In hot extrusion, the billet is preheated to facilitate plastic deformation.

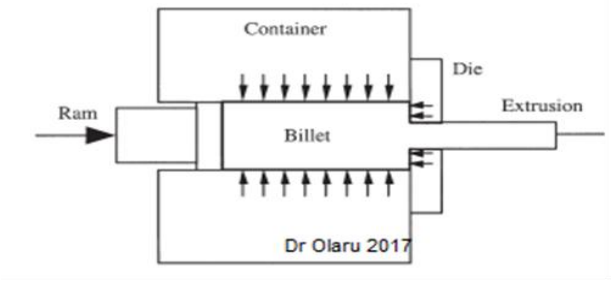


Figure 1a Definition of Extrusion

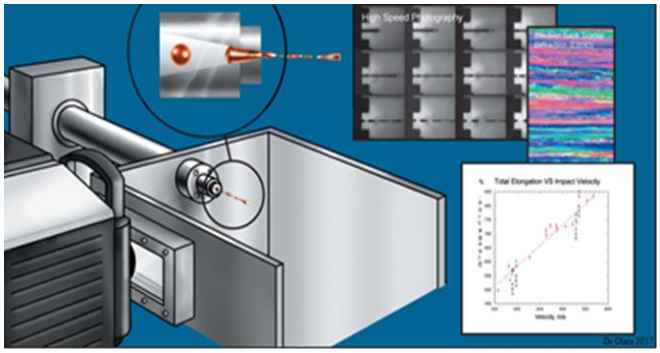


Figure 1b Al-Short Extrusion Process

What's in a name? From the Greek word Titans, the mythological *"first sons of the Earth."*

Titanium was discovered in 1791 by the Reverend William Gregor, an English pastor. Pure titanium was first produced by Matthew A. Hunter, an American metallurgist, in 1910. Titanium is the ninth most abundant element in the earth's crust and is primarily found in the **minerals rutile (TiO_2),** ilmenite ($FeTiO_3$) and sphene ($CaTiSiO_5$). Titanium makes up about 0.57 % of the earth's crust. Titanium is a strong, light metal. It is as strong as steel and twice as strong as aluminum, but is 45 % lighter than steel and only 60 % heavier than aluminum. Titanium is not easily corroded by sea water and is used in propeller shafts, rigging and other parts of boats that are exposed to sea water. Titanium and titanium alloys are used in airplanes, missiles and rockets where strength, low weight and resistance to high temperatures are important. Since titanium does not react within the human body, it is used to create artificial hips, pins for setting bones and for other biological implants. Unfortunately, the high cost of titanium has limited its widespread use. Titanium oxide (TiO_2) is used as a pigment to create white paint and accounts for the largest use of the element. Pure titanium oxide is relatively clear and is used to create titania, an artificial gemstone. Titanium tetrachloride ($TiCl_4$), another titanium compound, has been used to make smoke screens.

Titanium can burn in an atmosphere of pure nitrogen. Estimated Crustal Abundance: 5.65 × 10^3 mg/kg

Estimated Oceanic Abundance: 1 × 10^{-3} mg/dm^3

Number of Stable Isotopes: 5

Most common isotopes: Titanium-46, Titanium-47, Titanium-48, Titanium-49;

Electron Shell Configuration [4]:

$1s^2$
$2s^2$ $2p^6$
$3s^2$ $3p^6$ $3d^2$
$4s^2$

Ionization Energy: 6.828 eV;
Oxidation States: +4, +3, +2

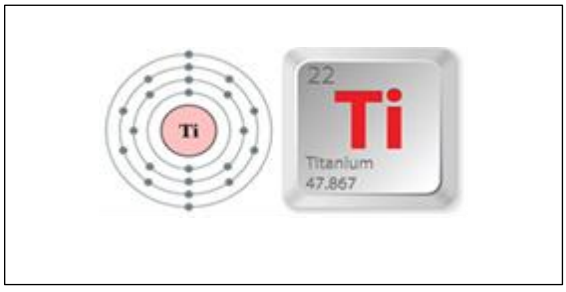


Figure 1c Electron Shell Configuration

TITANIUM ALLOYS, (Figure 1d), offer an attractive combination of high specific mechanical properties, such as modulus/density and strength/density, because of their relatively low density. Titanium alloys also have high toughness and corrosion resistance, making them useful materials for precision mechanism gears, turbine engine components, and biomedical prosthesis devices. However, these alloys have poor fretting fatigue

resistance and poor tribological properties. From theoretical calculations, metals with low theoretical tensile and shear strengths exhibit higher coefficients of friction (**μ**) than higher-strength materials. Within the class of hexagonal close-packed (HCP) structures, titanium has relatively low values for these properties. Consequently, it is expected that titanium would exhibit high frictional values, which has been demonstrated for titanium sliding against itself in air (**μ ≤ 60**), and vacuum. Lower-tensile-strength materials, including titanium, also exhibit greater material transfer to nonmetallic counterfaces than higher-strength metals. The great affinity of titanium for oxygen (**Figure 1d**), results in the formation of an oxide surface layer, which is transferred to and adheres to nonmetallic materials, such as polymers, resulting in severe adhesive wear. Addition of a lubricant, such as polyperfluoroalkylether (PFPE), or kerosene oil, reduces the coefficient of friction and wear damage somewhat, compared with unlubricated conditions, although reaction of titanium surfaces with these lubricants (generally under high-temperature conditions) can reduce lubricant performance. Although titanium alloys offer attractive mechanical and physical properties, their surface properties are deficient, thus restricting the use of uncoated titanium alloys to non-tribological applications. To realize the full benefit of titanium alloys in friction and wear applications, surface modification treatments are required to effectively increase near-surface strength, thereby reducing the coefficient of friction and lowering the tendency for material transfer and adhesive wear [3].

- Atomic number (number of protons in the nucleus): 22; Atomic symbol: Ti
- Atomic weight (average mass of the atom): 47.867; Density: 4.5 g/cm³
- Phase room temperature : Solid; Melting point: 1,668 °C); Boiling point: 3,287 °C.

2. TITANIUM BINARY PHASE DIAGRAMS

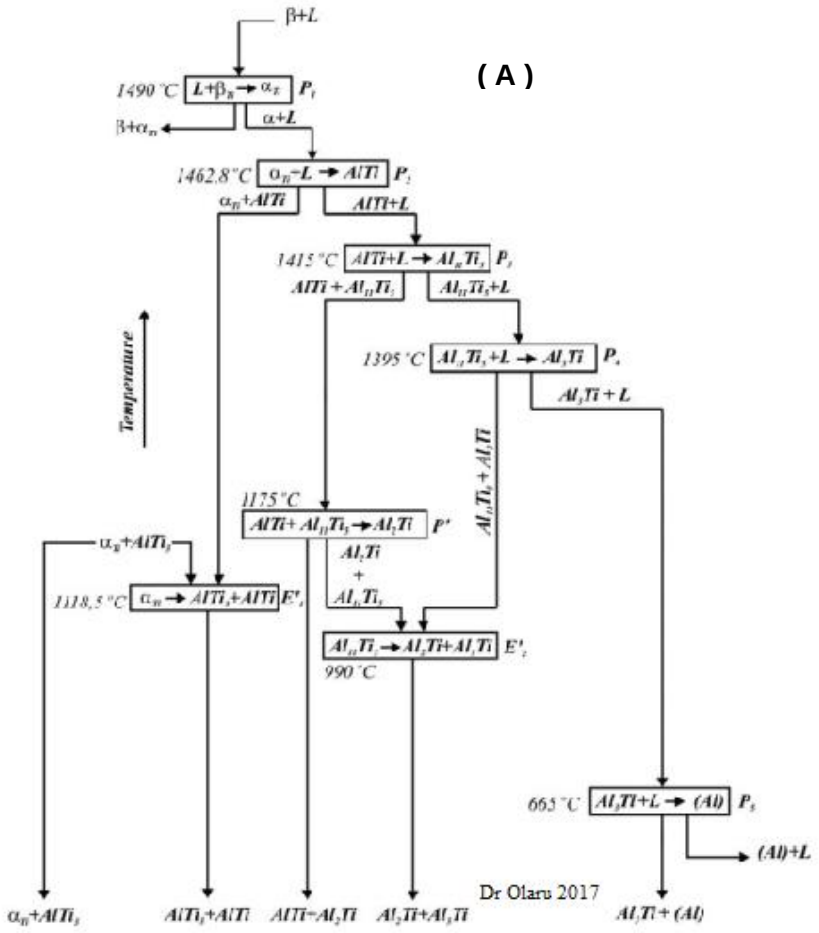


Figure 1d. Intermetallic compounds (A): $AlTi_3$ (α_2) and AlTi (γ) have variable compositions, whereas Al_2Ti and Al_3Ti have constant compositions. Al_2Ti is considered stable up to 1216 °C, compared with 1199.4 °C reported in other studies. Differences are also reported for the peritectic transformations of Al_3Ti (1387 °C versus 1392.5 °C) and AlTi (1460 °C versus 1462.6 °C)

3. BILLET EXTRUSION AI PROCESS

Billet extrusion is also a viable process for producing coiled semifinished products for further processing (**Figure 2**), such as rod and tube drawing. **Figure 3** illustrates the billet welding arrangement in the container. **Figure 4** shows the high-speed direct-extrusion AI process (Ti-Multiphysics zooming process).

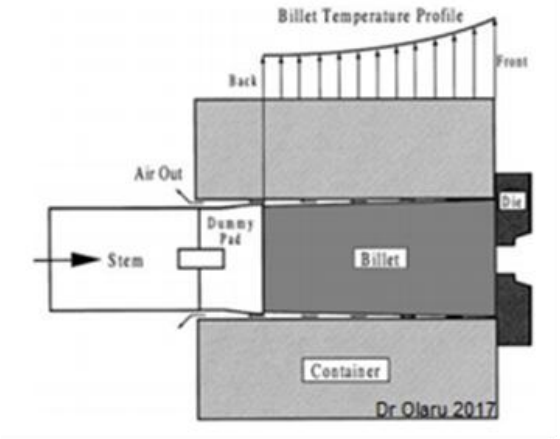


Figure 2 Bleeding out air during upsetting

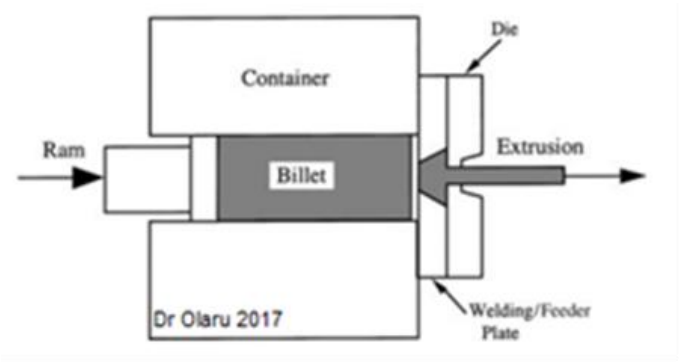


Figure 3 The extrusion welding plate in front of the die

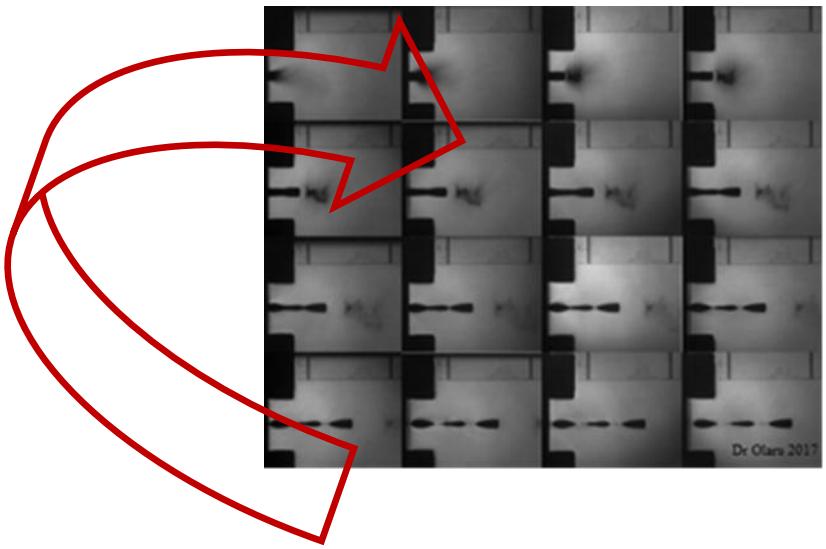


Figure 4 High-speed direct-extrusion AI process (Ti-Multiphysics zooming) [2]

4. AI COMPUTING ROBOTIC TITANIUM BI-PHASIC EXTRUSION PROCESSES



Figure 5 Installations (1), AI processes (2), and final profile component (3) – Airbus A321 XLR

5. RESULTS

The work samples were fabricated using an Arcam A2X electron beam melting (EBM) machine and standard Arcam Ti-6Al-4V material (50 µm) [2]. Billet sample fabrication involved eight separate bulk billets, with the material divided into two lots for testing. The bulk billets were AI-fabricated oversized to allow for machining. The bulk-billet bars were fabricated vertically, but a small batch of horizontal cylindrical samples was also fabricated to check for orientation effects.

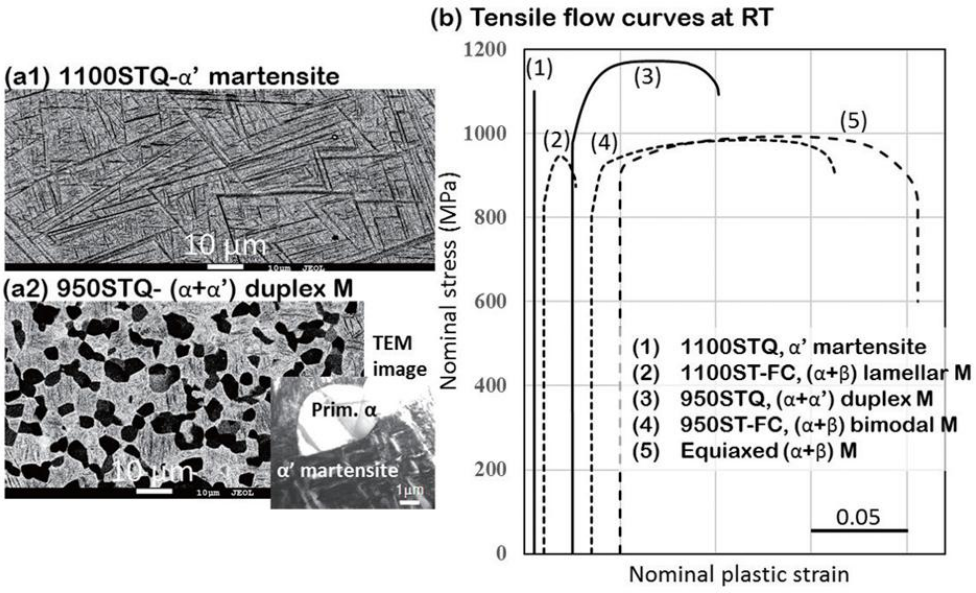


Figure 6 Microstructures of Ti-6Al-4V after quenching: (a1) 1100STQ and (a2) 950STQ; (b) nominal stress–nominal plastic strain curves of heat-treated Ti-6Al-4V alloys at room temperature (RT). Morphology has a pronounced intergranular effect on the crystal plasticity mechanism

6. CONCLUSIONS - ADVANTAGES

The Arcam EBM process (AMS 4999) incorporates the principles of electron beam machining. Instead of using the electron beam to shape the final dimensions of a part or to melt an alloy for refinement, the process uses it to melt and solidify material into a near-net-shape part intended for subsequent extrusion. The test results for the billet samples were satisfactory. Based on these data, the final alloy profile component (Figure 5) produced by extrusion in this study appears to generally meet or exceed the required mechanical properties of titanium alloys.

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