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# Tribological Characterization of Surface-Engineered Tool Steels and Lubricants for Hot Metal Gas Forming of Aluminum AA6063

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## Abstract

High-strength aluminium alloys are receiving increasing attention in various sectors where strength-to-weight ratio is of paramount importance. Within the automotive industry, weight reduction is a high priority in the strive towards reduced fuel consumption and thereby emissions. It becomes especially vital in e-mobility in order to compensate for added weight that vehicles now incorporate due to additional components like batteries. Hot forming appears as a key technique in harnessing the potential of high-strength aluminium alloys and overcome challenges associated with their limited formability at room temperature.

Hot metal gas forming (HMGF) is a die forming process in which a metal tube is heated to a ductile state, just below its melting point. Internally pressurized with room-temperature gas, the material is forced outward into a shape defined by an enclosing die cavity. The aluminium tube can be heated in a furnace, or by induction to the desired temperature, while the forming tools are also preheated. As in any hot forming process involving aluminium, material transfer and friction control are challenging in the HMGF process. The current solution involves lubricating both the workpiece and dies; however, issues still persist and a comprehensive understanding of their precise tribological action is still lacking.

In this work, the tribological properties of two tempered martensitic hot work tool steels and two PVD coatings (CrWON and AlCrN) during sliding against AA6063 have been characterized. Two different graphite water-based lubricants were evaluated. The friction and wear tests were performed using a hot strip drawing test setup in a flat-on-flat configuration during linear-unidirectional sliding. The test conditions were set as follows: contact pressure of 5 MPa, strip and tool temperature at 500°C, sliding speed of 100 mm/s, and a sliding distance of 50 mm.

The results have shown that, for CrWON coated tool steel, one of the graphite water-based lubricants was more effective, exhibiting the lowest and most stable friction. Conversely, the other graphite water-based lubricant showed superior performance in the case of an uncoated tool steel. It has also been seen that the method of applying the lubricant onto the aluminium strip ensured sufficient availability of lubricant at the contacting interface, effectively preventing direct contact of tool-workpiece surfaces and thus minimizing material transfer. The lubrication mechanism is similar for all tool steels, regardless of coating, and for both lubricants. During sliding, the lubricant accumulates at the leading edge and gradually spreads across the tool pin surface.

## 1 Introduction

Utilising high-strength materials for structural components in many applications is a well-known approach to reduce weight and improve performance. Due to ever increasing demands on improved energy efficiency and reduced environmental footprint in all aspects of machine design, the need for material solutions with high strength-to-weight ratio is continuously increasing. High-strength aluminium alloys provide very good strength-to-weight ratio and within the automotive industry, weight reduction is a high priority in the strive towards reduced fuel consumption and thereby emissions. It becomes especially vital in e-mobility in order to compensate for added weight that vehicles now incorporate due to additional components like batteries and also new safety components such as battery enclosures. Hot forming is a key technique to harness the potential of high-strength aluminium alloys and overcome challenges associated with their limited formability at room temperature. Hot metal gas forming (HMGF) is a die forming process in which a metal tube is heated to a ductile state, just below its melting point [1]. Internally pressurized with room-temperature gas, the material is forced outward into a shape defined by an enclosing die cavity. The