38-L ON DEMAND CASTING OF NET-SHAPE TITANIUM COMPONENTS FOR IMPROVED WEAPON SYSTEM RELIABILITY

Under graduate student TBD (CSM)
Faculty: Stephen Midson (CSM)
Industrial Mentor: Paul Brancaleon (NADCA)

38.1 Project Overview and Industrial Relevance

Titanium is a desirable material for the production of lightweight components because of its high specific strength, good corrosion resistance, and high temperature properties. The supply chain for near net-shape titanium components can be expanded by the development of high volume casting methods such as die casting. However, due to the high melting temperature of titanium, conventional die materials will have extremely short lives. In addition, titanium is a difficult material to melt and process.

This project is part of a three university effort to address the feasibility of titanium die casting. The specific tasks for each university are as follows:

- Improve the production of titanium components by leveraging the latest on-demand melting technology (University of Alabama, Birmingham)
- Expand the die casting process to high melting temperature casting alloys (CSM)
- Explore alloy modifications to improve castability (CSM)
- Evaluate/develop degassing technology for molten titanium alloys (Purdue University)

The project at CSM will focus on (1) the identification of candidate high temperature resistant die materials and coatings for titanium casting, (2) provide a coated tool for the demonstration of on-demand casting of titanium, and (3) provide an improved titanium alloy composition for die castability and high performance properties.

38.2 Previous Work

There have been previous attempts to die cast titanium, most notably by Howmet in the late 1990s. This project will leverage those efforts.

38.3 Recent Progress

This project has just started, and initial efforts have focused on identifying the best approach for fabricating a die casting die that will last for at least 1,000 shots. The concern regarding the die is that the surface of a steel die will be heated to a temperature close to that of molten titanium, so the expansion of the die's surface will greatly exceed the plastic limit of the steel, and thermal fatigue and heat checking will quickly destroy the integrity of the die. Therefore, an approach is being considered is to utilize a coating on the surface of a metallic die, to reduce the maximum temperature experienced by the metallic die.

Initial calculations have been performed to determine the type and thickness of such a coating, utilizing the simple model shown in Figure 38.1. This represents a coating or lining of thickness δ_c applied to a metallic die of thickness δ_s. The liquid titanium is cast against the surface of the coating (and so this interface in the model is maintained at 1650ºC), and heat is extracted through the coating and die, to a water line maintained at 50ºC. Steady state calculations have been performed using the equations listed below, to calculate the impact of coating thickness and coating material (i.e., thermal conductivity) on the surface temperature of the metallic die (T_i in Figure 38.1).

$$k_c \frac{T_M - T_i}{\delta_c} = k_s \frac{T_i - T_w}{\delta_s} \Rightarrow$$

$$\frac{k_c}{\delta_c} T_M + \frac{k_s}{\delta_s} T_w = \left(\frac{k_s}{\delta_s} + \frac{k_c}{\delta_c} \right) T_i$$

where:

- T_m = constant titanium temperature
- T_w = constant water temperature
- δ_c = coating thickness
- δ_s thickness of die material (distance to water line)
- K_c = thermal conductivity of coating
- K_s = thermal conductivity of die

Two coatings conditions have been examined, a 12 mm thick graphite liner and a 1.5 mm thick yttria coating. The impact of three die materials have been examined, H13 steel (the conventional steel for die casting dies), Anviloy (a tungsten-based alloy), and copper beryllium. The impact of the coatings on the maximum temperature of the die (T_i in Figure 38.1) are listed in Tables 38.1 and 38.2, which indicate that both the graphite liner and the yttria coating significantly reduce the maximum temperature of the metallic dies.

37.4 Plans for Next Reporting Period

The calculated die temperatures shown in Table 38.1 and 38.2 suggest that the approach of using a coating or liner may be suitable for minimizing the maximum temperature of the die material. However, many more questions need to be addresses before this approach can be tested, including how the liners and coatings would be fabricated, and whether they would survive the aggressive die casting process. These questions will be address in up-coming months.

37.6 Figures and Tables

Table 38.1: Impact of graphite liner and die materials on the maximum temperature of the metallic die

Sleeve		Die Material		Temperature at Interface	
Material	Thickness	Material	Thickness	Deg-C	Deg-F
Graphite	12 mm	H13 steel	12 mm	845	1553
Graphite	12 mm	Anviloy	12 mm	459	858
Graphite	12 mm	Cu-Be	12 mm	337	639

Table 38.2: Impact of yttria coating and die materials on the maximum temperature of the metallic die

Coating		Die Material		Temperature at Interface	
Material	Thickness	Material	Thickness	Deg-C	Deg-F
Yttria	1.5 mm	H13 steel	12 mm	1045	1913
Yttria	1.5 mm	Anviloy	12 mm	632	1170
Yttria	1.5 mm	Cu-Be	12 mm	447	837

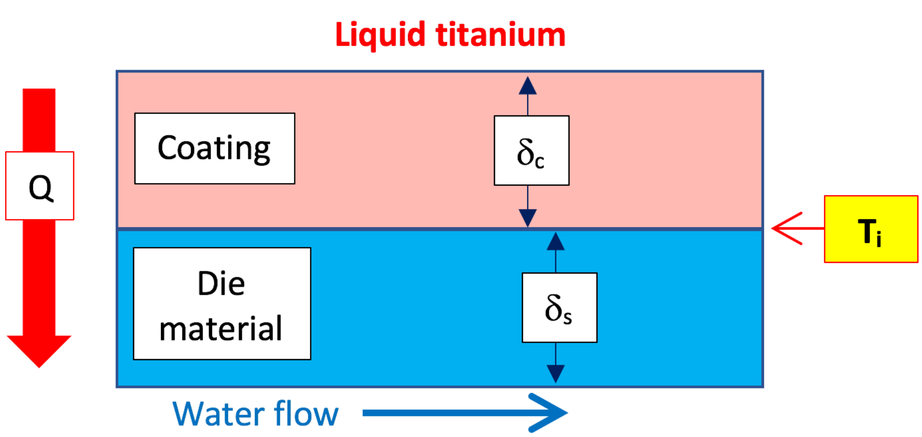

Figure 38.1: Schematic drawing of the coating/liner and the metallic mold