CANFSA

Center for Advanced Non-Ferrous Structural Alloys
An Industry/University Cooperative Research Center

Project 28-L: Laboratory Testing to Identify Permanent PVD Coatings to Minimize Lubricant Use During Forging

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Industrial Relevance

- Utilize permanent PVD coatings to reduce the friction coefficient between die and workpiece during forging
  - Reduce the amount of lubricant required
  - Reduce lubricant overspray
  - Improve cycle times
  - Improve die life
  - Improve quality of forgings

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- Students: Trevor Kehe & Spencer Randell (Mines undergraduates)
- Advisors: Kester Clarke, Stephen Midson & Andy Korenyi-Both (Mines)

- Problem: Forging operations can use significant amounts of lubricant, which can affect component outcomes and create excessive overspray.
- Objective: Evaluate permanent PVD die coatings that can reduce the coefficient of friction between the workpiece and the die.
- Benefit: Reduced lubricant use, greater processing consistency, longer die life.

Project Duration

UG: May 2017 to July 2019

Recent Progress

- Laboratory scale dies with inserts have been designed and manufactured.
- Tests have been performed with both coated and uncoated die inserts
- Coatings have been identified that significantly reduce the coefficient of friction

Description	% Complete	Status
1. Literature review	100%	●
2. Die design	100%	●
3. Die manufacture and insert PVD coating	100%	●
4. Ring-friction testing at room and elevated temperatures	100%	●
5. Final report and project summary	100%	●

PVD Coatings for Evaluation

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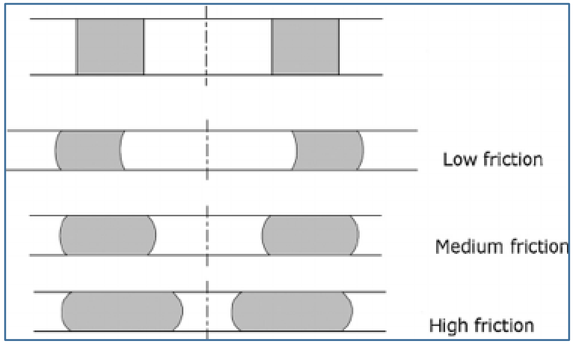
- Based on results of literature review

Type of Coating	Specifics	Supplier	Temperature
Single-layer hard coatings	TiCN	Tribologix, Dayton, Ionbond	<400°C
Multi-layer hard coatings containing lubricious particles	Super MoS_2	Tribologix	375°C
	Ti-MoS_2 (MOST)	Teer in UK, Ionbond	<350°C
	AlCrN-MoS_2	Tribologix	
	TiCN-TiMoS_2	Teer	
	CrN-DLC	Phygen	<300°C
	CrN-SiC	Phygen	
	i-Kote	Tribologix	350°C
Hard coatings containing noble metals	Hard coating plus noble metal	Voevodin, Scharf & Samir at UNT	<500°C
Highly lubricious oxide	Layered structures, similar to graphite & MoS_2	None identified	>500°C
Plasma Sprayed	PS400	NASA	
Laser Textured	Laser texture a TiCN coating	Tribologix/CSM	

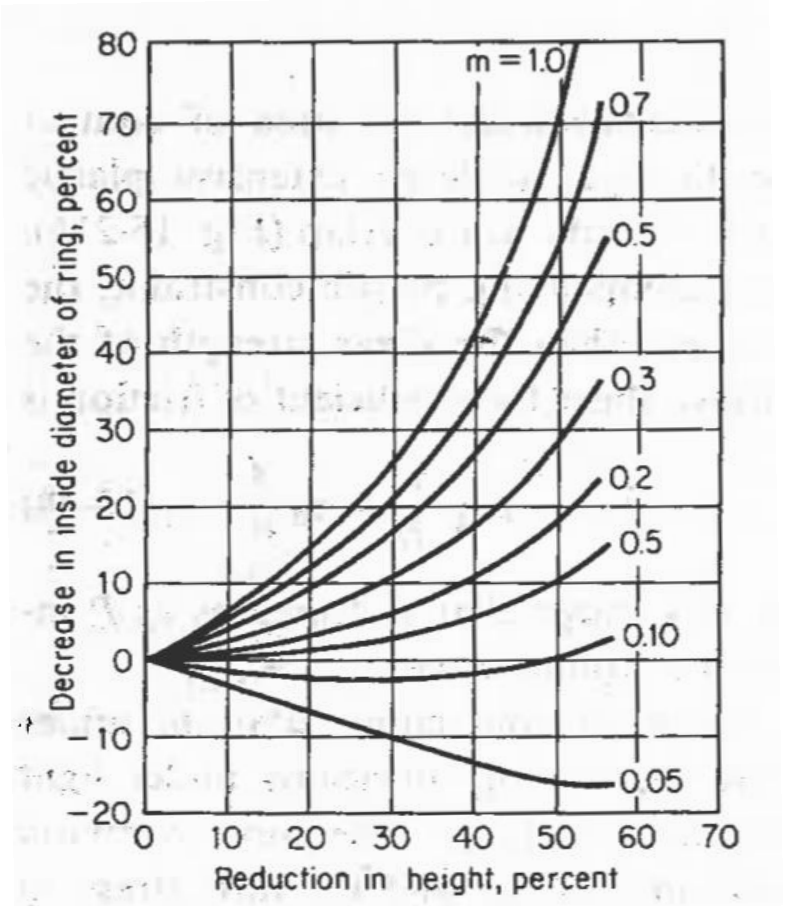
Ring Friction Test

- Test involves the compression of thin metallic rings
  - Having controlled dimensions
  - Typically OD:ID:thickness in the ratio of 6:3:1
- Coefficient of friction can easily be estimated after forging
  - Based on change in height and change in ID



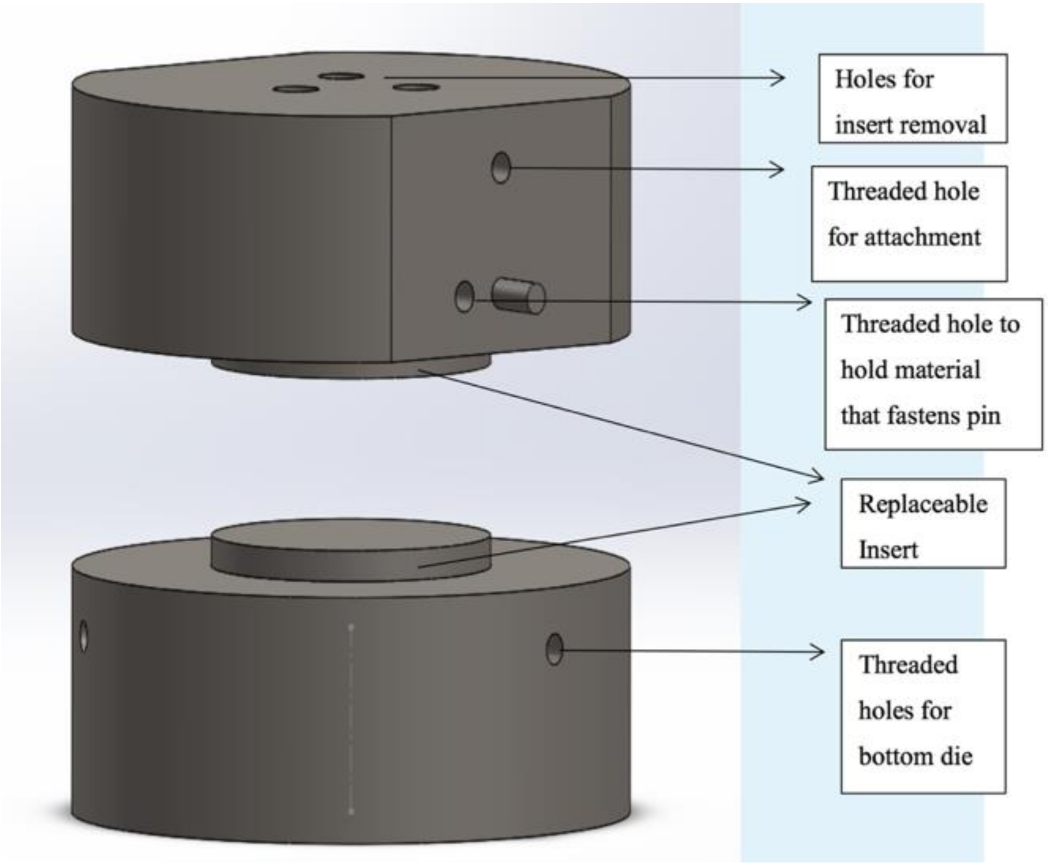
Measurement of Friction Factor

- Friction factor (m) can be estimated from calibration curve
- Based on change in shape of ring
  - Increase/decrease in internal diameter
  - Reduction in height



Test Equipment

- Modified conventional ring compression test equipment
  - Ability to quickly switch die inserts
  - Capability to fit the test equipment onto the 100 kip hydraulic press at CSM
  - Measure both load and displacement during testing



Aluminum Forging Samples

- Rod of 6061 aluminum was purchased for the testing
  - OD of 1.0-inches
  - ID of 0.50-inches
- Samples 0.33-inches long were cut from the rod
- After saw-cutting
  - Saw cut surfaces were ground flat
- Final dimensions measured using digital calipers

Summary of Results

Coating	Lubricant	Temperature (°C)	No. of Samples Tested	Ave. Friction Coefficient
None	None	RT	8	0.8
i-Kote	None	RT	18	0.35
Super MoS_2	None	RT	5	0.60
TICN	None	RT	8	0.87
AlCrTiN	None	RT	1	0.80
SiC	None	RT	3	1.00
DLC	None	RT	3	1.00

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DLC	None	RT	3	1.00

Summary & Conclusions

- In the unlubricated condition
  - Lowest friction factors were obtained with two PVD coatings
  - i-Kote and Super MoS_2
- These are hard, thin-film coatings containing lubricious particles
  - Graphite and/or molybdenum disulfide (MoS_2)
- Based on the results of this study
  - Identified coatings that provide low levels of friction during unlubricated forging
  - May allow a reduction in the use of conventional lubricants
  - Or possibly total elimination of conventional lubricants

Future Work

- Seeking additional funding to continue research
- Focus on testing of PVD coatings that contain lubricious particles
  - Identify coatings with lower friction factors than i-Kote or Super MoS_2
- Specific targets
  - Optimize the structure of the hard thin-film coating
  - Identify which lubricious particles provide the lowest friction factors
  - Identify the optimum concentration of lubricious particles
  - Determine the optimum distribution of the lubricious particles in the thin-film coating
  - Examine the thermal stability of these types of coatings
  - Perform extended forging series at elevated temperatures

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Questions?

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