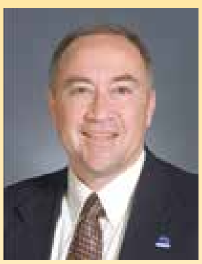
Newsletter 2016 No.2

iMAST

Institute for Manufacturing and Sustainment Technologies

IN THIS ISSUE

DIRECTOR'S CORNER



Timothy D. Bair

Running a matrix organization like iMAST means understanding everything it (ARL) does and how those capabilities and skills can be applied to meet the mission of the Navy's Manufacturing Technology program. Ten years after saying yes to this challenge I'm still learning. That is the neatest part of being a member of this very technically diverse, DoD-serving institution. This edition's main article is a good example.

Mechanical Drive Transmission (drivetrain/powertrain) technology is one of those areas I incorrectly assumed was mature when I joined ARL Penn State – nothing new to talk about or research. I obviously was wrong as I began my education. ARL Penn State's drivetrain research is very much alive and is leveraging previous Navy ManTech investment relative to sea-air-ground drive systems. With the assistance of industry, we continue to move forward with innovation that support challenges facing the Navy and

Continued on Page 2

Project Update: Laser Cladding Repair System for Production Readiness

Corrosion and pitting around submarine counter-bore surfaces within vertical launch system tubes have been repaired traditionally by a labor-intensive, manual brush electroplating procedure. This repair methodology was found to be relatively short-lived, requiring frequent rework and causing reduced combatant availability. In short, the effort was a less-than-optimal repair process.

In response to this challenge, ARL Penn State engineers, in collaboration with the Naval Warfare Center in Keyport, successfully developed a recently implemented an affordable repair solution that addresses the issue by way of ARL's unique Navy ManTech Repair Technology (RepTech) program. This effort has produced an affordable repair process, and incorporates an ARL Penn State Laser Cladding Repair System process solution. Implementation of this process on a Navy submarine at Pearl Harbor Naval Base by the Pearl Harbor Naval Shipyard & Intermediate Maintenance Facility (PHNSY & IMF) has been successful, but had to overcome some initial challenges. The new process successfully provides confidence to decision makers who are adopting, incorporating, and transitioning it into their body of repair solutions.

Navy ManTech program efforts focus on reducing both risk and life cycle cost, while both

U.S. Navy released photo

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Marine Corps team.

ARL's drivetrain engineers have been working for over 24 years to implement gear, bearing and material innovation with the support of the Office of Naval Research, Navy and Marine Corps Systems Commands, as well as repair depots and naval shipyards. ARL's Gear Research Institute (GRI), which is an industry component of ARL Penn State's Drivetrain Technology Center, provides further in-kind support to Navy- and Marine Corps-related issues when duplicate technical challenges cross our path.

The ONR ManTech program is going through a financial shift in terms of funding source, from Industrial preparedness (6.7) to Applied Research and Development (6.3) funding. This change isn't seismic, but will reflect a growing need to show innovation in our projects in FY-16 and beyond. Yes, Navy ManTech has historically been innovative. What this really means is that there will be a new category added to the qualification criteria for new projects based on the expectation that there is innovation within each. Highly innovative projects are frequently higher risk projects. That leaves the responsibility to mitigate the risk firmly in the lap of the project team. Conversely, successful efforts that are highly innovative also tend to be higher payoff, either in ROI or impact/effect terms. Therein lies some of the motive for this move to R&D funding. The investment taxpayers make every year into the manufacture of new weapons systems and platforms deserves every effort we can make to be innovative, save precious tax dollars and ensure we give our warfighters the best tools possible.

Within this issue, our cover page project update is also provided to keep you up to speed on one of our more recent successes. Our Vertical Launch System – Laser Cladding Repair System is now being used by the Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility. This is an excellent example of innovation coupled with risk mitigation. A future feature article will go into more detail on the effort, but I wanted to make note of yet another success story born out of the Office of Naval Research's Navy Manufacturing Technology program. This project was the result of successful collaborations between NUWC Keyport, Pearl Harbor Naval Shipyard & IMF, and iMAST.

As always, we appreciate your support and look forward to hearing from you.

Tim Bair

MARK YOUR CALENDAR

Don't miss Defense Manufacturing Conference 2016 (DMC 2016).
28 November - 1 December 2016 in Denver, Colorado.
Be sure to visit our iMAST exhibit booth.
Details at dmcmeeting.com.

PROFILE

Aaron Isaacson is head of the Drivetrain Technology Center at The Pennsylvania State University's Applied Research Laboratory where he is managing director of the ASME- and AGMA-affiliated Gear Research Institute, a not-for-profit research activity that contracts all research to ARL Penn State. Mr. Isaacson holds B.S. and M. S. degrees in mechanical engineering from Penn State and is currently pursuing his doctorate in Materials Science and Engineering. Mr. Isaacson began conducting gear and roller testing as an undergraduate student working at the Applied Research Laboratory in the summer of 1997. He became a full-time engineer in January of 1999. Mr. Isaacson has over 19 years of experience conducting gear performance testing. His research interests include gear performance characterization, failure analysis, gear tooth friction and efficiency, ferrous metallurgy, high strength aluminum alloys and aluminum matrix composites, sintering of metal and ceramic matrix composites, and control system design. Aaron Isaacson can be reached at (814) 865-5832, or by email at aci101@arl.psu.edu

MATERIALS PROCESSING TECHNOLOGIES · MECHANICAL DRIVE TRANSMISSION TECHNOLOGIES · LASER PROCESSING TECHNOLOGIES · COMPLEX SYSTEMS MONITORING TECHNOLOGIES · COMPOSITES MATERIALS TECHNOLOGIES · NAVY/MARINE CORPS REPAIR TECHNOLOGIES · MANUFACTURING SYSTEMS TECHNOLOGIES

Focus on Mechanical Drive Transmission Technologies

The Impact of Surface Condition and Lubricant on Gear Tooth Friction

by Aaron Isaacson, Suren Rao, Lane Winkelmann, and Gary J. Sroka

Frictional losses in gear boxes transform into heat, which makes them significant to gear box designers and will result in a fuel efficiency reduction for the vehicle involved. This effort is to measure and document the comparative friction losses in a gear mesh due to gear tooth surface condition and lubricant.

Editor's Note: *A core resource in support of U.S. Navy ManTech efforts within ARL Penn State's Applied Research Laboratory is the Drivetrain Technology Center. Key research efforts within the Office of Naval Research have addressed improvements to powertrain systems. The Navy has relied on iMAST to address manufacturing-related issues such as ausform finishing, gear metrology, tribology and advanced materials – as they relate to Navy and Marine Corps sea-air-land power systems. The ability to minimize drive system power losses is a hot topic for many cutting edge industries; from improving the efficiency of wind power generation to increasing the range of electric vehicles. This topic is particularly relevant to Navy and Marine rotorcraft as well. Improving gearbox efficiency in helicopters reduce the heat generated in the drivetrain. Reduced heat leads to smaller and lighter cooling systems which, in turn, increase operational range and/or accommodate increased payload capacities. All of this enhances the warfighter's ability to successfully accomplish the various assigned missions. Measurement of power losses (friction) due to gear tooth surface condition, lubricant and operating condition has recently been an area of research within ARL's Drivetrain Technology Center. The work recounted within the following article was sponsored by the Gear Research Institute Aerospace Consortium and was presented at a recent American Gear Manufacturers Association (AGMA) meeting. Working with DoD, industry and academia, iMAST continues to provide support on powertrain-related technologies that provide leading-edge support on a variety of manufacturing issues that can, and will, support pending manufacturing challenges presented to iMAST via the Navy and Marine Corps systems commands.*

INTRODUCTION

The impact of gear tooth surface quality treatments on frictional losses in a gear mesh is of significant interest to the aerospace gear community as these losses are converted to heat that has to be dealt with.

The most exhaustive experimental study quantifying gear tooth friction is by Yoshizaki[1], in which spur gears with various geometries were operated in a power re-circulating test rig and frictional losses were measured. Various lubricants and additives were also evaluated and tooth surface finishes (Rmax) ranging from 0.5 to 4 μm were considered. In Britton[2], another experimental study, that specifically evaluated the effect of superfinishing on gear tooth friction on a power re-circulating gear test rig is described. A 30 percent reduction in frictional losses is measured and documented. In another experimental study on gear tooth friction, Petry-Johnson[3] measured frictional losses in a power re-circulating test rig operating ground and chemically polished gears with two different tooth sizes in three different lubricants. This data was further utilized to define guide lines for the design of gear meshes and transmissions. Martins[4] experimentally measured the friction coefficient in FZG (ground) gears utilizing two lubricants. Several attempts to model and predict the friction losses[5, 6, 7] are also evident in literature, where the experimental effort is utilized to correlate to analytical results.

Based on the available literature, a comprehensive experimental study to compare gear mesh friction losses with different tooth surface conditions, different lubricants and under various operating conditions was considered a worthwhile effort. In this study, the special variables being evaluated include superfinishing and a W-DLC coating compared to a ground base line. Two lubricants are also evaluated.

EXPERIMENTAL SET-UP

A high-speed, power re-circulating (four-square) gear test rig was utilized for the purpose of this experimental study. This rig consists of a test gear box connected to a reversing gear box, as shown in Figure 1. An electrohydraulic torque applicator establishes and measures the torque within the four-square loop and consequently the load on the gear teeth. The motor driving the four-square kinematic loop is only supplying the power to overcome the frictional losses in the test gear box mesh and the reversing gear box mesh. This input torque, outside the four-square loop, was measured with a

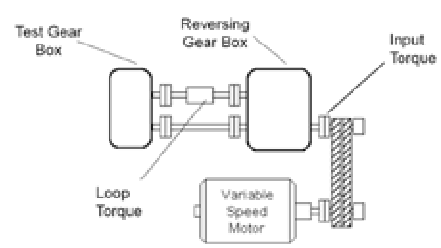

Figure 1. Four-Square Gear Test Rig Schematic

Figure 2. Test gears in gear box with oil inlet nozzles.

precision, bearing-less, digital torque-meter, under different experimental conditions to establish a comparative measure of the frictional losses in the test gear mesh under those experimental conditions.

As stated above the four-square gear test rig consists of a test gear box and a reversing gear box. The reversing gear box consists of very high accuracy helical gears with a face width of 100 mm. The gears in the test gear box are 28 teeth, 3.175 module, 20 degree pressure angle, 6.25 mm face width, spur gears fabricated from AMS 6308 steel, carburized and hardened to 60-64 on the Rockwell C scale. Due to the significant difference in face widths between the gears in the test gear box and the reversing gear box, gear failure in fatigue testing is restricted to the test gear box only. Figure 2 illustrates the test gears mounted in the test gear box with the direction of rotation illustrated by the arrow. Oil jet lubrication was employed in the tests and the “oil into the mesh” nozzle is at the bottom and the “oil out of the mesh” nozzle is at the top in the figure.

As the test gear box and the reversing gear box are dissimilar, the total frictional losses cannot be precisely assigned to either of the two gear boxes. However, a comparative estimate of changes in gear tooth frictional losses due to surface condition or lubricant change can be assessed. Further, an arbitrary assignment of frictional losses attributable to the two gear boxes allows an approximate assessment of the changes of frictional losses due to the variables of surface and lubricant.

Test Pair	S/N	Surface	Ra Avg	Ra Std Dev	Rz Avg	Rz Std Dev
1	006	As Ground	0.241	0.008	1.26	0.11
1	008	As Ground	0.257	0.028	1.33	0.22
2	064 (R)	REM ISF	0.084	0.010	0.56	0.16
2	057	REM ISF	0.081	0.015	0.53	0.11
3	054	W-DLC Coating	0.084	0.015	0.62	0.12
3	064 (L)	REM ISF	0.084	0.010	0.56	0.16

Notes:
1. Surface roughness measurements are reported in micrometers.
2. Measurements reported here are directional, taken orthogonal to grinding direction.
3. Averages are computed based upon 4 measurements at 6 similar locations for each sample.

Table 1. Surface Roughness Data of Test Gears.

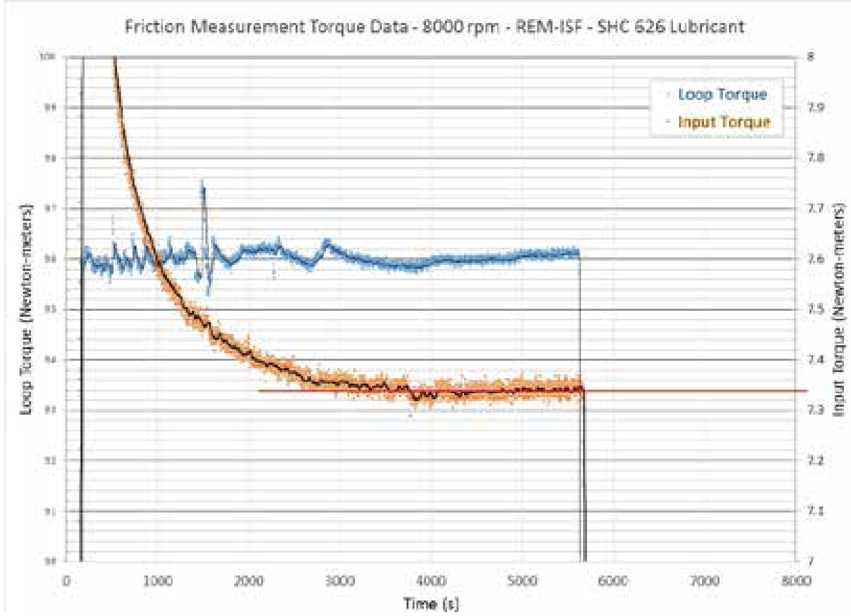

Figure 3. Record of measured torques.

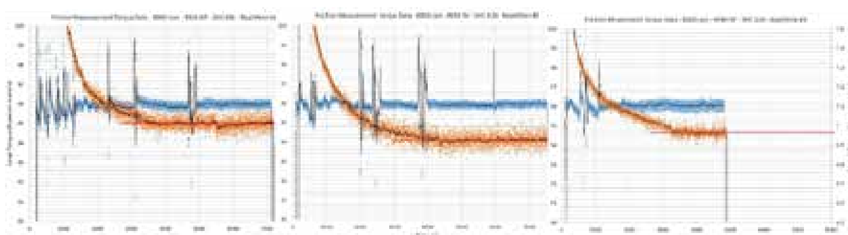

Figure 4. Three repetitive torque measurements.

TEST EFFORT

The initial effort focused on characterization of the surface of the test gears. Negatives of the tooth surface were first fabricated using surface replication epoxy (accuracy experimentally verified to be better than 0.1 micron). These replicas were analyzed utilizing optical interferometry to obtain surface characteristics of ground, superfinished and coated gears. The results of the surface characterizations are summarized in Table 1 and are considered to be consistent with what is normally obtained in industry.

A typical data output from one test run is illustrated in Figure 3. The blue line represents the measured loop torque within the four-square test rig and the orange line represents the input torque as measured by the torque transducer on the power input shaft. This particular figure shows the input and loop torques while operating with superfinished gears at 8,000 rpm in SHC 626 lubricant. Depending on the test conditions and the thermal inertia of this test rig, the set up requires up to an hour of operation before the input torque stabilizes for measurement purposes.

The repeatability of the measurements was evaluated. Figure 4 illustrates torque recordings of three different repetitions of superfinished gears operating at 8,000 rpm in SHC 626 lubricant. The range of the stabilized input torque in the three repetitions was 0.09 N-m. This computes to less than +/-1% of the measured torque of 6.95 N-m and was considered acceptable. The tests conducted are detailed in Table 2 (next page) with their respective pitch line velocities.

RESULTS AND DISCUSSIONS

In order to provide an adequate tribological basis for the collected data it was

MIL-PRF-23699	4000 RPM (18.62 m/s)	8000 RPM (37.24 m/s)	10000 RPM (37.24 m/s)
96 N-m	1,2,3	1,2,3	1,2,3
192 N-m	1,2,3	1,2,3	1,2,3
Mobil SHC 626	**4000 RPM (18.62 m/s)**	**8000 RPM (37.24 m/s)**	**10000 RPM (37.24 m/s)**
96 N-m	1,2,3	1,2,3	2,3*
192 N-m	1,2,3	1,2,3	2,3*

1 – Both Gears are As Ground
2 – Both Gears are REM/ISF
3 – Specimen Gear is W-DLC coated, mate Gear is REM/ISF
* Tests 2 and 3 were not conducted as excessive vibration and scoring damage occurred during ground gear testing at prior 10K rpm test

Table 2. Test details.

decided to compute and document the range of specific film thickness λ for the experimental effort[8]. The bulk temperature of the gear tooth in mesh was interpolated from an earlier experimental effort[9] in order to obtain the lubricant parameter that is required for the computation of the ratio. Based on an oil inlet temperature of 40.5ºC, the range of computed λ ratios for the MIL-PRF 23699 lubricant ranged from 0.31 to 2.5. For the SHC 626 lubricant the computed λ ratios ranged from 0.50 to 4.3. The lowest λ ratios are associated with ground gears at high torques and low speeds while the highest λ ratios are associated with superfinished gears at low torques and high speeds. The λ ratios for the coated gears could not be determined due to lack of experimental data on tooth bulk temperature and lack of coefficient of friction data to compute the same.

Tests were conducted with the various gear pairs in the test gear box and under load, speed and lubricants as defined in Table 2. One typical set of results is shown in Figure 5. As can be seen in the figure, the ground gears had the highest measured input torque at all speeds at 192 N-m with MIL-PRF-23699 lubricant.

The results of all the tests conducted are summarized in Table 3. To examine these results analytically, the measured input torque for the ground gear pair was subtracted from the measured input torques for the superfinished and coated gear pairs, under the same load,

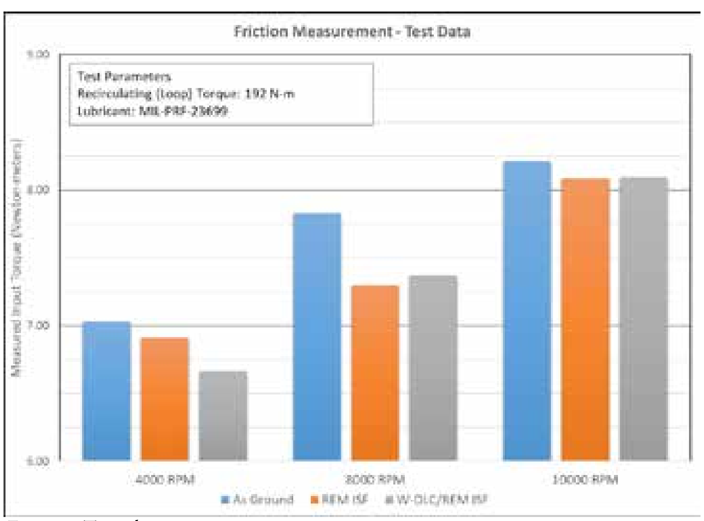

Figure 5. Typical input torque measurements.

speed and with the same lubricant. These changes in input torques can be entirely attributed to the change in the surface condition of the gear pair under test and the change in frictional losses at the tooth flank, as all test conditions are otherwise identical. The frictional loss changes range from -0.72 N-m (ID No. 6) to +0.08 N-m (ID No. 2), as shown in Table 3 (next page).

The superfinished and coated gears generally required lower input torques (compared to ground) except for one instance where the coated gear had a higher input torque (ID No. 2) than the ground gear set. As this experiment was the first test conducted with the coated gear, some "breaking in" of the coating may have influenced the measurement. If time and budget allowed, the test would be repeated with new gears for better characterization of the break in process or to confirm an anomaly in the data. The ground and superfinished gears were also new at the start of testing. No data was observed that would indicate a similar break in characteristic.

A comparison between superfinished and coated gears was inconsistent. In some instances the superfinished gears had a lower or the same input torque as the coated gear. In some instances the coated gear performed better with a lower loss measurement. The more viscous SHC 626 oil appears to play a greater role in reducing frictional losses at lower speeds and higher loads at the same speeds. The MIL-PRF-23699 appears to more effective at reducing losses at higher speeds and lower loads. As all other conditions are maintained the same, this difference in input torques at each speed, each loop torque and utilizing the same lubricant is entirely due to the changes in frictional losses in the meshing gear teeth mesh.

As the input torque measurement includes the losses in the reversing gear box, which is very dissimilar to the test gear box, an assumption on the amount of losses in the reversing gear box was necessary in order to compute the input loss change as a percentage of the loss with a pair of ground gears. Splits of 50% split and 67% in the losses between the test gear box and reversing gear box were assumed, with the 67% split being more appropriate (large face width, helical gears in the reversing gear box). The percentage reductions in losses are listed in %%0615_REM_Tab2%% based on the loss split assumption model. Based on a 67% split model, superfinishing alone provided a reduction in frictional losses of up to 26% (ID No. 5) while the addition of this coating increase this reduction to 28% (ID No. 6).

The test tooth surfaces were characterized after testing with the same tooth negative optical interferometry technique that was used for pre-test inspection. A reduction in surface finish (Ra) of approximately 0.005 to 0.010 microns was observed for both the superfinished and the W-DLC coated gears. A similar reduction was measured for the corresponding superfinished mate gears. The ground gears were damaged during the 10,000 RPM testing. As expected, the post-test surface characterizations of the ground gears showed an increase in roughness of 0.02 to 0.07 microns (Ra).

CONCLUSIONS

The impact of surface treatments such as superfinishing and coating on frictional losses is of significant interest since this loss is converted into heat that has to be accounted for. This experimental effort described above demonstrates that these surface treatments can reduce frictional losses by as much as 28% over ground gears, based on an assumption of the loss split between the two gear boxes on the four-square test rig. Considering that this reduction can be obtained at each gear pair and most gear boxes have many gear meshes, the total impact on the heat generated by the gear box can be significant. It is difficult to state, based on this study if W-DLC coating has any added benefit on frictional losses, though it may improve contact fatigue life and oil out performance of the gear pair.

In order to obtain a more precise estimate of the impact of the surface treatments on gear losses it is necessary to obtain an accurate measure of the losses in the reversing gear box. It would then be possible to isolate the actual losses in the test gear box. From a measurement of total losses a more precise estimate of changes in frictional losses due to surface treatments could be estimated. Identifying the losses solely in the test gear box and eliminating other losses would also lead to an estimate of the effective coefficient of friction at the tooth flank and the impact of the surface treatment on this parameter.

ID No.	Surface Condition	Loop Torque (N-m)	Speed (RPM)	Lubricant	Input Torque Change (N-m) Relative to As Ground at Same Condition	Reduction Compared to As Ground (50% Model)	Reduction Compared to As Ground (67% Model)
1	REM/ISF	96	4000	MIL-PRF-23699	-0.03	98.8%	98.2%
2	W-DLC	96	4000	MIL-PRF-23699	0.08	102.7%	104.1%
3	REM/ISF	96	8000	MIL-PRF-23699	-0.19	94.3%	91.4%
4	W-DLC	96	8000	MIL-PRF-23699	-0.32	90.7%	85.9%
5	REM/ISF	96	10000	MIL-PRF-23699	-0.67	82.9%	74.1%
6	W-DLC	96	10000	MIL-PRF-23699	-0.72	81.4%	71.9%
7	REM/ISF	192	4000	MIL-PRF-23699	-0.11	96.8%	95.1%
8	W-DLC	192	4000	MIL-PRF-23699	-0.36	89.7%	84.4%
9	REM/ISF	192	8000	MIL-PRF-23699	-0.53	86.4%	79.4%
10	W-DLC	192	8000	MIL-PRF-23699	-0.46	88.2%	82.1%
11	REM/ISF	192	10000	MIL-PRF-23699	-0.13	96.8%	95.2%
12	W-DLC	192	10000	MIL-PRF-23699	-0.12	97.1%	95.6%
13	REM/ISF	96	4000	Mobil SHC 626	-0.18	94.1%	91.1%
14	W-DLC	96	4000	Mobil SHC 626	-0.14	95.6%	93.3%
15	REM/ISF	96	8000	Mobil SHC 626	-0.27	92.5%	88.6%
16	W-DLC	96	8000	Mobil SHC 626	-0.31	91.6%	87.2%
17	REM/ISF	192	4000	Mobil SHC 626	-0.28	92.4%	88.5%
18	W-DLC	192	4000	Mobil SHC 626	-0.29	92.1%	88.0%
19	REM/ISF	192	8000	Mobil SHC 626	-0.38	90.6%	85.7%
20	W-DLC	192	8000	Mobil SHC 626	-0.37	91.0%	86.4%

Table 3. Test data summary showing changes in input torque.

This effort, to measure the actual losses in the reversing gear box of the four-square test rig and estimate the effective coefficient of friction at the test gear tooth flank, is currently underway.

ACKNOWLEDGEMENT

The authors wish to express appreciation for the support of ARL Penn State's Institute for Manufacturing and Sustainment and Technologies (iMAST), a U.S. Navy Manufacturing Technology (ManTech) Program under contract by the Office of Naval Research. The authors would also like to express appreciation to the American Gear Manufacturers Association, the Gear Research Institute, and REM Surface Engineering Inc.. Any opinions, findings, conclusions and recommendations expressed in this article are those of the authors and do not necessarily reflect those of the United States Navy or the American Gear Manufacturers Association.

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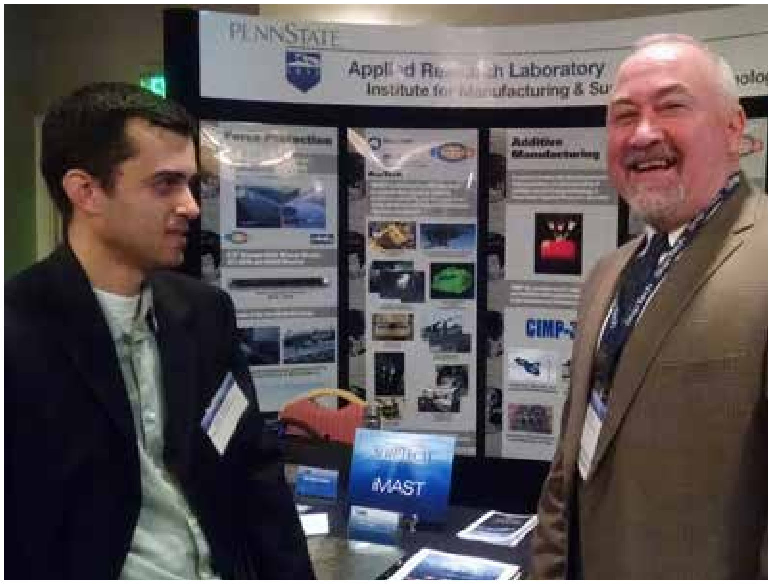
INSTITUTE NOTES



iMAST director Tim Bair discusses program developments at ShipTech with Pearl Harbor Naval Shipyard electrical engineer Eric Petran, a recent recipient of a National Society of Professional Engineer (NSPE) Federal Engineer of the Year Award, whom iMAST highlighted in our previous newsletter.

Members of the RepTech Working group, along with principal investigators and facility staff, tour the Albany Maintenance Center's work center production lines.

ShipTech 2016

After a short hiatus, the annual ShipTech forum, hosted by the Office of Naval Research and supported by the National Shipbuilding Research Program (NSRP) as well as the Navy Metalworking Center, resumed on course in Charleston, South Carolina.

This year's featured theme, "Transitioning Advanced Manufacturing Technology for an Affordable Fleet," brought together the domestic shipbuilding industry, as well as domestic industrial-base suppliers, Navy program offices, and U.S. Navy-sponsored research organizations for the purpose of exchanging information on technical shipbuilding developments.

Advances generated by NSRP, U.S. Navy ManTech Program Centers of Excellence, and related shipbuilding initiatives, culminated in a productive event. The objective of ShipTech continues to be providing a robust forum focused on reducing the total ownership costs of naval ships, while also enhancing the competitiveness of America's domestic shipbuilding industry. More information on next year's event will be noted in future iMAST newsletters.

RepTech Working Group Meeting

As previously noted, the Institute for Manufacturing and Sustainment Technologies is leading the Navy-Marine Corps team's repair, overhaul, and sustainment initiative as established by the Office of Naval Research. As part of the execution process, a RepTech Working Group (RWG) meeting regularly convenes to review current projects, as well as to identify and evaluate potential new projects. The working group solicits "issues" from systems command representatives before submitting them for consideration to the Navy Manufacturing Science and Technology director at the office of Naval Research.

A recent RWG meeting took place on the grounds of the Marine Corps Maintenance Center at Marine Corps Logistics Base Albany (Georgia). Following program updates and reviews, a tour of facilities was conducted as a follow-up to a Production Plan Albany (PPA) briefing presented by Navy ManTech representative Greg Russell. Following the tour of facilities and final programmatic discussions, the meeting was adjourned.

COVER STORY

Continued from Page 1

enhancing performance and increasing affordability (both in operation and maintenance). ARL Penn State's Navy ManTech Repair Technology effort is currently leading the Navy-Marine Corps' repair, overhaul, and sustainment initiative by closing the gap between the capability of the repair process and the sustainment requirements of the various weapons systems. iMAST's RepTech program implementation efforts are carried out through the various shipyards, depots, logistics supply centers, and Original Equipment Manufacturer (OEM) contractor facilities.

Application of the Laser Cladding Repair System in the repair of vertical launch systems aboard U.S. Navy vessels has been successfully implemented. More on this issue will appear in a future informational article about the process written by our principal investigator, Steve Brown.

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The impossible is often the untried.
—Jim Goodwin

CALENDAR of EVENTS

		2016
2-3 Nov	Letterkenny Technology Showcase	Chambersburg, PA
8 Nov	NDIA Aircarft Survivability Symposium	Monterrey, CA
28 Nov - 1 Dec	Defense Manufacturing Conference	**Denver, CO
5-8 Dec	DoD Maintenance Symposium	Albuguerque, NM
		2017
10-12 Jan	Surface Navy Association	**Crystal City, VA
3-5 Apr	Navy League Sea-Air-Space Expo	**National Harbor, MD
9-11 May	AHS Forum 73	Ft. Worth, TX
4-8 June	45th North American Manufacturing Research Conference	Los Angeles, CA

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