USCAR LEP ESST Advanced Manufacturing

Federal Manufacturing & Technologies

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Advanced Manufacturing

Task 2 - Powertrain Components

USCAR LEP CRADA Supplement

Project Accomplishments Summary

CRADA Number 94-MULT-903-ES-4

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Abstract

The objective of this task was to provide processing information data summaries on powder metallurgy (PM) alloys that meet the partner requirements for the production of low mass, highly accurate, near-net-shape powertrain components. This required modification to existing ISO machinability test procedures and development of a new drilling test procedure. These summaries could then be presented in a web page format. When combined with information generated from the USCAR CRADA this would allow chemical, metallurgical, and machining data on PM alloys to be available to all engineering and manufacturing personnel that have access to in-house networks. The web page format also allows for the additions of other wrought materials, making this a valuable tool to the technical staffs.

Background

The automotive companies pioneered the use of powder metallurgy alloys in mass manufactured product. They have pioneered the development of new PM alloys and fabrication processes. Each manufacturing facility had developed machineability data that was unique to a particular manufacturing process and part. This made comparison of PM alloys based on machinability properties difficult. This project allows not only comparison but gives information that is needed for prediction of tool life.

Description

The objective the powertrain component task is to provide processes for the cost-effective production of low mass, highly accurate, near-net-shape, powertrain components. Components made from powder metallurgy (PM) alloys meet these requirements. PM part complexity could be increased if machining parameters for secondary operation could be developed.

The USCAR CRADA generated a significant amount of machinability data. Developing effective data summaries of the milling and drilling data presented a unique challenge. For the data to be useful to manufacturing personnel the summaries had to include tool wear, surface finish, force, and torque data. These summaries had to be compatible with the turning data that was already on the web site.

In preparing the data summaries errors were noted in the drilling horsepower data because of lack of sensitivity in the measurement system. Drilling torque tests were repeated with new and worn drills so that this data could be included in the summaries. Data summaries are included in a separate document because all CRADA information is considered confidential to the industrial partners.

A spectrum of different type machinability tests was conducted on powder metallurgy (PM) alloys to determine perishable cutting tool life and other test responses for different machining operations that are used in secondary machining operations. The results of these tests and other activities within this task produced the following benefits to the LEP partners:

- Determined the machining properties of five primary PM alloys in milling and drilling.
- Developed tests (milling and drilling) procedures, methods, and measurement techniques that will be used by the partners for near-net-shape machining.
- Evaluated the milling and drilling properties of an additional 8 PM alloys.

Expected Economic Impact

With the information generated by the CRADA, the LEP partners will be able to increase the number of secondary machining operations currently used in the production of PM components. This will allow the LEP partners to increase the complexity of the PM components used within the powertrain. This amendment permitted milling and drilling data to be put into a form that allowed machinability data to be easily obtained by manufacturing personnel.

The LEP partners reported their contribution for this task as a lump sum of \$10,000 funds-in amendment to the CRADA.

Benefits to DOE-DP

1. Setups and tooling developed under this CRADA were used directly in several weapons development programs to obtain machining data without modification of the test setup and directly avoiding the costs of development to be incurred by the programs.
2. Data reduction methods, data logging equipment, and software systems are currently being used

for an ADAPT project on the evaluation of PM stainless steel alloys.

3. Testing properties of PM alloys can apply directly to weapons programs for future databases.
4. The project developed a user-friendly design guide for properties of powder metals for process engineers. It will be directly applied and used at Federal Manufacturing & Technologies (FM&T). A further benefit of this guide is that it can be easily adapted for use or directly used for any materials, especially metals, such as wrought or cast materials. It will also be applied directly at FM&T for wrought stainless steel alloys. This design guide is user friendly and can be used across a site on an internal network. It can further be linked across the Nuclear Weapons Complex (NWC) on the complex-wide intranet, thereby contributing to enterprise integration.
5. As another side benefit, we have also been able to learn about automotive companies' transfer lines, machine tools, automatic handling equipment, and perishable cutting tools. All of these experiences are being or will be applied to improving operations within FM&T, to increase efficiency, and reduce cost while maintaining quality.
6. An improved drill test procedure was developed that will become the standard approach at FM&T and the LEP partners.
7. A near-net-shape modification to ISO 3685 test procedure was developed, tool-life testing with single-point turning tools, that will become the FM&T standard.
8. A near-net-shape modification to ISO 8688-1 test procedure was developed, tool life testing in milling, part 1 - face milling, that will become the FM&T standard.

Industrial Area

Any industry involved with performing secondary machining operations to PM components would be interested in the information contained in this report.

Project Status

This project has been completed.

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Technical Activities and Accomplishments

Under the Powertrain component task there were ten technical milestones. They are listed below:

1. Qualification of the machining laboratory by evaluating 1045 steel. The data generated was used to develop machining indices to compare PM alloys to a known wrought alloy.
 1. Machinability property testing of the primary PM alloys.
- A. Turning – Each PM alloy's tool life was evaluated at three different cutting speeds and Taylor Life

curves were constructed. In addition a speed-feed-depth of cut matrix test was performed to determine if changing machining attributes caused non-linear changes in cutting forces. The ISO test procedure was modified for near-net-shape machining.

- B. Milling – Tool life was determined, at specific machining attributes, for comparison purposes. The ISO test procedure was modified for near-net-shape machining.
 - C. Drilling – Drill life was determined, at specific machining attributes, for comparison purposes. A drilling test procedure was developed for this testing program that will be used by the LEP partners for PM materials.
-
- 1. Optimize cutting tool geometry. The effect on cutting tool life was determined while varying the side rake angle of the turning tool for all primary PM alloys.
 - 2. Determine the thermal conductivity of the sample materials. Cut-bar specimens were fabricated and tests run to determine the thermal conductivity over the range of 200 to 800° C.
 - 3. Determine the metallographic properties; evaluate density and hardness of the sample materials. Metallurgical specimens were prepared from both the pucks and rings used for the machinability testing.
-
- A. Both metallographic and SEM photographs were generated to differentiate microstructure.
 - B. Percent of different structures was determined.
 - C. Macro and micro hardness of the specimen were determined.
 - D. Density of the PM alloys was determined.
-
- 1. Optimized material for machinability. With the addition of item 10 below the evaluation was made using the samples provided.
 - 2. Green machining (deprioritized when item 10 was added). Samples were received from the vendor and metallurgically evaluated. Flaws were found in the structure and tests could not be performed safely. These minor flaws usually are healed in the sintering process.
 - 3. Texture measurement device (deprioritized when item 10 was added).
 - 4. Machining with lubricants. The primary PM alloys were drilled with a metal removal fluid (MRF) and the drill life determined. Tool life increased significantly.
 - 5. Determine the variation in drilling and milling properties of PM alloys used previously in the NCEMT test program for MANTEC. Added in a SOW revision. Eight PM alloys were evaluated. Their drilling and milling tool lives established and compared to the six primary PM alloys.

Under supplement 4, a funds-in addition, General Motors Corp. and the Ford Motor Co., Inc. contributed additional funding for the creation of the data summaries presented below.

History of Statement of Work Changes and Reasons

There were three amendments to the Statement of Work (SOW) during the life of the CRADA. The first in 1996 added item 10 to the SOW. The second in FY98 was a no-cost extension of the completion date of this CRADA. The 1999 extension was an agreement between some of the partners (GM and Ford) and FM&T to complete the data summaries to be compatible with the web page presentation format. An example of the Milling Summary is included in Figure 1 and the Drilling Summary in Figure 2. Figure 3 shows the drill down steps of the data presentation.

In addition copies of the Milling and Drilling test specifications are included. These specifications outline the activities and requirements of the testing activities.

Meeting of objectives as outlined in the original SOW:

1. Completed as planned
2. Completed as planned
3. Completed as planned
4. Completed as planned
5. Completed as planned
6. Deprioritized in favor of CTC materials (Milestone 10)
7. Deprioritized due to material problems
8. Deprioritized due to lack of funds [and priority?]
9. Completed as planned
10. Data summaries were completed and are attached in this report.

Figure 1

Example of a Milling Summary

Material: HSS (M7)

Length: Jobber Length

Type: General Purpose

Coating: Surface Treated (Oxide)

Point: 118 Degree

Drill selected for the test: Precision Twist Drill; Type 2AB; Stock No. 29090

Inspection: Drills to be measured by FM&T cutting tool inspection and met FM&T Specification CTS1454800.

Machine Type:

Monarch Cortland Machining Center

HP Available: 15 HP

Max Spindle Thrust: 2000 lbs

Max Speed: > 3,500 RPM

Max Feed: > 40 IPM

Tooling Setup:

Tool Holder: 9 mm end mill holder or

9 mm collet holder

Concentricity: Drill concentricity in machine spindle will be 0.0018 TIR max.

Coolant: None

Drilling Pattern: Random

Spacing: A 4-inch diameter puck will yield 37 holes when the 9-mm holes are on 13.5-mm centers. The outside edges of four holes are within 1.5 mm of the specimen side. The 4.25 squares will yield 52 holes with the same spacing. No hole closer than 4 mm from the edge.

Machining Parameters:

Speed: 1265 RPM (116.5 SFM)

Feed: 11.4 in/min (0.009 in/rev)

Stainless Steel

Speed: 407 RPM (37.8 SFM)

Feed: 1.9 in/min (0.0047 in/rev)

Equipment Used:

KIAG SWISS (Kistler) Force Table, CE# 51078

KIAG SWISS (Kistler), Charge Amplifiers, Model 5001, CE# 51078 (A, B, C)

Kistler Type 9275 Torque Dynamometer (S/N 974144)

Kistler Model 5841B1 3-Channel Charge Amplifier CE#201756 (Model 5010)

Kistler Model 5350 Transducer Simulator with Model 5371A Calibration Capacitors

ROI Measuring Microscope, CE67517, with rotary mounting stage with attached 3-jaw chuck.

Mast extensions (4-inch extension when using solid tool holder. 9-inch extension when using

collet holder. When using collect holder a Monarch Cortland Tooling Fixture is mounted on the 3-jaw chuck on the rotary stage.

ROI 2x objective accessory lens installed

Cutting Force Monitoring Equipment (Dell PC, Running Labview with National Instruments Data Acquisition Board with National Instruments Signal Conditioning Modules.

Measurement Interval and Dwell Time:

Measure wear of the drill point after the first hole is drilled. Then measure the drill wear every 10th hole until failure. If it is obvious that the drill is wearing at a slow rate, measurement interval can be increased to 20 holes. This may be further increased to 34 holes if the drills are not wearing. During this program this has happened infrequently with only a few materials. Allow the drill to cool for 1 minute between holes. (We have found this waiting period to influence the life of the drill greatly.) Care must be given to getting this interval correct because we are not drilling with coolant that would remove the heat from the tool. Take breaks only after a run of ten holes. Interrupting a run of ten holes will change the wear rate. Make sure to obtain wear measurements after the first hole and again at 0.0075, 0.0110, and 0.015 in corner wear. It is not unusual for a drill to wear linearly at a low rate and then very quickly fail. Make every attempt to determine any other reason for failure other than fatigue. "D" designates a failed drill computer run in the last digit of the file name.

Measurement of Drilled Holes:

Measure diameter of the drilled holes that correspond to wear measurements at the top center and bottom of hole and record on data sheet.

Drilling Loads:

Record the axial force for each hole drilled on the data sheet.

Save the digital torque data for the initial hole and the last hole before a drill measurement is made. Retain data files until the 50%, 75%, and failure points are determined. The initial file will be designated as the A run. Runs at the 50% (B), 75% (C) additional runs will be designated alphabetically starting with E and noted on the data sheet.

Controlling Document:

No formal standard exists for drill testing from a recognized standards organization. The FM&T procedure is based on test procedure supplied by Precision Twist Drill and modified by the CRADA partners. The main difference is we are drilling dry.

Milling Test Specification

Specimen: Disk 4-inch diameter x 1.125 thick

Square 4.25 inch x 1.072 thick

Cutting Tool:

Face Mill: Valenite Model No.: B(5)10R15P

Axial Rake: 5 Deg Positive

Radial Rake: 0 Deg

Lead: 15 Deg

Insert: Valenite, SPKN 1203 EDER 35M, with 11 Deg Relief

Grade 35M (Grade C5-6)

Machine Type:

Monarch Cortland Machining Center

HP Available: 15 HP

Max Spindle Thrust: 2000 lbs

Max Speed: > 3,500 RPM

Max Feed: > 40 IPM

Tooling Setup:

Tool Holder: Monarch Cortland 2.00-inch Dia Face Mill Holder (Cat No. MMSA-45-24).

Milling Pattern:

Feed cutter centerline down the centerline of the test specimen.

Machining Parameters:

Speed: 169 RPM (225 SFM)

Feed: 0.5 in/min (0.005 in/rev)

Depth of Cut: 0.040 in

Equipment Used:

KIAG SWISS (Kistler) Force Table, CE# 51078

KIAG SWISS (Kistler), Charge Amplifiers, Model 5001, CE# 51078 (A, B, C)

Kistler Type 9275 Torque Dynamometer (S/N 974144)

Kistler Model 5841B1 3-Channel Charge Amplifier CE#201756 (Model 5010)

Kistler Model 5350 Transducer Simulator with Model 5371A Calibration Capacitors

ROI Measuring Microscope, CE67517, with rotary mounting stage with attached 3-jaw chuck.

Mast extensions (4-inch extension when using solid tool holder)

Cutting Force Monitoring Equipment (Dell PC, Running Labview with National Instruments Data Acquisition Board with National Instruments Signal Conditioning Modules.

Measurement Interval:

Measure wear of the insert after the first milling pass. Then measure the insert wear after every pass until failure. If it is obvious that the insert is wearing at a slow rate, measurement interval can be increased to every other pass. This may be further increased to 4 passes if the insert is not wearing. During this program this has happened infrequently with only a few materials. Take breaks only after a completed pass. Make sure to obtain wear measurements after the first pass and again at 0.0075, 0.0110, and 0.015 in flank wear. Make every attempt to determine any other reason for failure other than fatigue. D designates a failed insert computer run in the last digit of the file name. Designate wear patterns per the ISO procedure. Failure criteria are also defined by the ISO procedure.

Milling Loads:

Record the X, Y, and Z force for each milling pass. Save the digital data for the initial pass and the last pass before a wear measurement is made. Retain data files until the 50%, 75%, and failure points are determined. The initial file will be designated as the A run. Runs at the 50% (B), 75% (C) additional runs will be designated alphabetically starting with E and noted on the data sheet.

Controlling Document:

ISO Procedure 8688-2; Tool life testing in milling – Part 1: Face Milling

Inventions

No inventions were created under this task.

Future Collaborations

This work was part of the basis of the new Funds-in-CRADA (two years in duration) between FM&T and Management and Engineering Technologies.

Conclusions

The project proved to be a win-win project for all parties involved. The customer obtained information they required. Honeywell FM&T increased and refined its machinability testing capabilities in milling and drilling and developed new testing and data reduction procedures. The DOE gained increased testing capabilities and information that can be utilized in future programs.