

Dr. Manigandan Kannan

Department of Mechanical Engineering

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EDUCATION

Doctor of Philosophy (PhD), Mechanical Engineering

December, 2014

The University of Akron

Akron, Ohio, USA

GPA: 3.51/4.00

Dissertation: “*Investigating, Characterizing and Rationalizing the Fatigue, Deformation and Fracture Behavior of Alloy Steels and Specialty Steels for Performance-Critical Applications: An Experimental Study*”.

Advisor: Dr. T.S. Srivatsan

Master of Science (MS), Mechanical Engineering

August, 2011

The University of Akron

Akron, Ohio, USA

GPA: 3.58/4.00

Thesis: “*Microstructure, Hardness, Tensile Deformation, Impact Toughness and Fracture Behavior of High Strength Steels*”

Advisor: Dr. T.S. Srivatsan

Bachelor of Technology (B.Tech), Mechanical Engineering

June, 2009

SASTRA University

Tanjore (Tamil Nadu), India

GPA: 7.6/10

Senior Design Project: “*Design and Analysis of Boiler supports*”

Industry Sponsor: Bharat Heavy Electrical Limited, Trichy India.

Research Interests:

- Materials Characterization of High Strength Steels for high performance applications
- Microstructural evolution in metals
- Stress Corrosion Cracking in Alloy Steels
- High temperature oxide & non-oxide materials
- Fiber reinforced composites
- High temperature material processing
- Ceramics matrix composites

WORK EXPERIENCE

Associate Professor of Engineering Practice

August 2019-Present

- 4900-165 “Tools for Aerospace System Engineering”
- 4600-336 “Analysis of Mechanical Components”
- 4600-484 “Mechanical Engineering Lab
- 4600-497 “Honors Project in Mechanical Engineering”

Research Assistant Professor**June 2016- August 2019****Teaching:**

- 4900-165-002 "Tools for aerospace system engineering" (Fall 2017 and 18)
- 4600-380-001 "Mechanical Metallurgy" (Summer 2016 and 18)
- 4900:380 "Aerospace Materials" (Summer 2016 and Summer 17 and 18)
- 4600-626 "Fatigue of Engineering Materials"(Fall 2016 and 18)
- 4600:484 "Mechanical Engineering Lab"- In charge of the entire lab which includes six separate experiments .(Spring 2017,18)

Research:

- Studying the properties of additive manufactured Titanium alloy built on top of conventional alloys thereby using it to repair parts and not replace the part.
- Setting up a burner rig lab capable of replicating the hot section of jet engine inside a lab.
- Foreign object damage of Ceramic Matrix Composites
- Microstructure/property relationships of ceramic matrix composites
- Acoustic emission for damage determination and general monitoring of composites, structures, and machines
- Other structural health monitoring techniques, e.g., electrical resistivity
- Fatigue failure analysis of metals using Acoustic Emission, Electrical resistivity and Digital image correlation.
- Lab manager who takes care of all testing and scheduling for the students.

Postdoctoral Research Associate**March 2015- June 2016****Teaching:**

- 4600:484-007 "Mechanical Engineering Lab- Design And Implementation Of A Motor/Centrifugal Pump Test Procedure "(Fall 2015)
4600:484 "Mechanical Engineering Lab"- In charge of the entire lab which included six experiments and also is in charge of the grades of these labs.
- 4900:380 "Aerospace Materials" (Summer 2015)
- 4600-627 : "Advanced Materials and Manufacturing Process"(Spring 2016)

Doctoral Committee(Committee Member)**May 2016**

- **Dissertation- "High Temperature Damage Characterization Of Ceramic Composites And Protective Coatings"**
Student- Matthew Appleby

- **Dissertation- "Electrical Resistance Changes of Melt Infiltrated SiC/SiC Subject to Long-Term Tensile Loading at Elevated Temperatures"**
Student- Craig Smith

May 2017

- **Dissertation- "Use of single TOW ceramic matrix minicomposites to determine fundamental room and elevated temperature properties"**
Student- Amjad S Almansour

May 2019

- Dissertation- “**Foreign Object Damage and Solid Particle Erosion Behavior of Ceramic Matrix Composites**”
Student- Michael J Presby

Master of Science Committee(Committee Member)

- Thesis- “Damage Monitoring Of MI SiC/SiC CMCs With Stress Concentrations Utilizing Acoustic Emission And Electrical Resistance”
Student- Ryan Maxwell
- Thesis- “Extrinsic Influence Of Coating And Surface Treatment On The Tensile Response And Fracture Behavior Of Three High Strength Metals”
Student- Arindam Paul
- Thesis- “Study of Fatigue crack propagation on metals using acoustic emission and electric resistivity in correlation with digital image correlation”.
Student- Sulochana Shreshta
- Thesis- “Simulation and prediction of wear using finite element analysis with experimental validation”
Student- Saikrishna Enabothula

Book Edited

Manufacturing Techniques for Materials: Engineering and Engineered provides a cohesive and comprehensive overview of the following: (i) prevailing and emerging trends, (ii) emerging developments and related technology, and (iii) potential for the commercialization of techniques specific to manufacturing of materials. The first half of the book provides the interested reader with detailed chapters specific to the manufacturing of emerging materials, such as additive manufacturing, with a valued emphasis on the science, technology, and potentially viable practices specific to the manufacturing technique used. This section also attempts to discuss in a lucid and easily understandable manner the specific advantages and limitations of each technique and goes on to highlight all of the potentially viable and emerging technological applications. The second half of this archival volume focuses on a wide spectrum of conventional techniques currently available and being used in the manufacturing of both materials and resultant products. **Manufacturing Techniques for Materials** is an invaluable tool for a cross-section of readers including engineers, researchers, technologists, students at both the graduate level and undergraduate level, and even entrepreneurs. CRC Press 2018 , ISBN-13: 978-1138099265 **Edited by T. S. Srivatsan ,T. S. Sudarshan and K. Manigandan**

BOOK CHAPTER

T. S. Srivatsan, K. Manigandan, and T. S. Sudarshan ,”Additive Manufacturing of Materials: Viable Techniques, Metals, Advances, Advantages, and Applications” Additive Manufacturing Innovations, Advances, and Applications, Edited by T. S. Srivatsan and T. S. Sudarshan CRC Press 2015 Print ISBN: 978-1-4987-1477-8 eBook ISBN: 978-1-4987-1478-5. Sep 2015 , pp 1 -48

T. S. Srivatsan, K. Manigandan, and T. S. Sudarshan , “Use of Conventional Manufacturing Techniques for Materials: A Few Highlights” Manufacturing Techniques for Materials: Engineering and Engineered, Edited By T.S. Srivatsan, T.S. Sudarshan, K. Manigandan, CRC Press 2018 ISBN-13: 978-1138099265 , pp 435 -510

JOURNAL PAPERS

- 1) T.S. Srivatsan, K. Manigandan and Thomas Quick: "The Impact Toughness and Fracture Behavior of Four High Strength Steels: Role of Processing," International Journal of Engineering Sciences and Management, Vol. 1, Issue 2, pp. 23-36, 2011.
- 2) T.S. Srivatsan, K. Manigandan and Thomas Quick: "The Tensile Deformation and Fracture Behavior of Four High Strength Steels," Steel Research International, Vol. 82, Issue 12, pp. 1385-1393, 2011.
- 3) T.S. Srivatsan, K. Manigandan and T. Quick: "Influence of Silicon Carbide Particulates on Tensile Fracture Behavior of an Aluminum Alloy," Materials Science and Engineering, Vol. 534 A, 2012, pp. 711-715.
- 4) T.S. Srivatsan, K. Manigandan, T. Quick and M.L. Schmidt: "Investigating and Understanding the Cyclic Fatigue Fracture Behavior of Two High Strength Specialty Steels," International Journal of Engineering Sciences and Management, Vol II. Issue 1, pp. 15-28, 2012.
- 5) T.S. Srivatsan, K. Manigandan, Chinmay Godbole, Muralidharan Paramsothy and Manoj Gupta: "Influence of Nickel Particle Reinforcement on Cyclic Fatigue and Final Fracture Behavior of Magnesium Alloy Composite," Journal Metals, 2012, 2, pp. 143-169; doi: 10.3390/met 2020143
- 6) T.S. Srivatsan, K. Manigandan, C. Godbole, M. Paramsothy and M. Gupta: "The Tensile Deformation and Fracture Behavior of a Magnesium Alloy Nanocomposite Reinforced with Nickel," Advanced Materials Research, Vol. 1, No. 3, 2012, pp. 169-182.
- 7) Therese Hurtuk, C. C. Menzemer, A. Patnaik, T. S. Srivatsan, K. Manigandan and T. Quick: "The Quasi Static Deformation, Failure and Fracture Behavior of Titanium Alloy Gusset Plates Containing Bolt Holes," Journal of Materials Engineering and Performance, Vol. 21, No. 11, Nov. 2012, pp. 2363-2374.
- 8) T.S. Srivatsan, K. Manigandan, T. Quick and M. L. Schmidt: "Mechanisms Governing the Fracture Behavior of Two High Strength Steels: Role of Composition and Microstructure", Emerging Materials Research, Volume 1, Issue 4, pages 170-184 , 2012
- 9) T.S. Srivatsan, K. Manigandan, A. Freborg and T. Quick: "The Quasi Static Deformation and cyclic Fracture Behavior of a Novel High Strength Steel for Emerging Applications," Emerging Materials Research, Vol. 2, pp. 17-26, 2013, pp. 17-26.
- 10) K. Manigandan , T.S. Srivatsan, , A. Freborg and T. Quick: "Investigating and Understanding the Cyclic Fatigue, Deformation, and Fracture Behavior of a Novel High Strength Alloy Steel: Influence of Orientation" Steel Research International, Volume 84, Issue 3, pages 218–228, March 2013
- 11) T.S. Srivatsan, K. Manigandan, M. Petraroli, Rosa M. Trejo and T. S. Sudarshan: "Influence of Size of Nanopowder Particles and Plasma Pressure Compaction on Microstructural Development and Hardness of Tungsten Samples" Advanced Powder Technology, Vol. 24, 2013, pp. 190-199.
- 12) Troy D. Topping, Tao Hu, K. Manigandan, T. S. Srivatsan ad E. J. Lavernia: "Quasi Static Deformation and Final Fracture Behavior of Aluminum Alloy 5083: Influence of Cryomilling, Philosophical Magazine, Vol. 93, Issue 8, 2013, pp. 899-921.

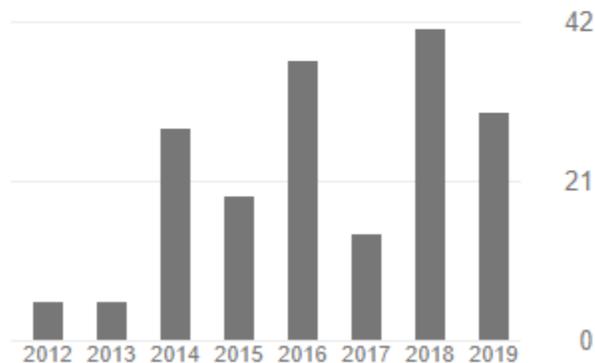
- 13) K. Manigandan, T. S. Srivatsan and A. M. Freborg: "Influence of Surface Finish and Notch on Flexural Strength and Fracture of Steel, Emerging Materials Research, Volume 2, Issue 4, 2013, pp. 198-206.
- 14) K. Manigandan, T. S. Srivatsan, T. Quick, M. L. Schmidt and S. Sastry: "Mechanical Behavior of Two High Strength Steels under Conditions of Cyclic Tension," Journal of Materials Engineering and Performance, January 2014, Volume 23, Issue 1, pp 198-212
- 15) K. Manigandan, T. S. Srivatsan and T. Sudarshan: "Synthesis and Characterization of Ultrafine Tungsten Samples Produced by Plasma Activated Sintering, , Emerging Materials Research, Volume 3, Issue 1, November 2013 pages 19 –30
- 16) K. Manigandan, T. S. Srivatsan, T. Quick, S. Sastry and M. L. Schmidt: "Influence of Microstructure and Load Ratio On cyclic Fatigue and Final Fracture Behavior of Two High Strength Steels," Materials & Design, Volume 55, March 2014, Pages 727–739.
- 17) N. Tini, C. C. Menzemer, K. Manigandan and T. S. Srivatsan: "The Bearing Strength and Fracture Behavior of Bolted Connections in Two Aluminum Alloys," Journal of Materials Engineering and Performance, November 2013, Volume 22, Issue 11, pp 3430-3438
- 18) K. Manigandan, T. S. Srivatsan, T. Quick, A.M. Freborg and S. Sastry: "The Microstructure and Mechanical Behavior of High Strength Alloy Steel X2M" Advances in Materials Research, An International Journal, 2014, Volume. 3, No.1, pp. 47-59
- 19) K. Manigandan, T. S. Srivatsan and G. Morscher: "Quasi Static and Cyclic Fatigue Fracture Behavior of an Emerging Titanium Alloy , Emerging Materials Research, Volume 2, Issue 6, June 2013 pages 348 –355
- 20) R.R. McCullough, J.B. Jordon, A.T. Brammer, K. Manigandan, T. S. Srivatsan, P.G. Allison and T. W. Rushing: "A Fatigue Model for Discontinuous Particulate-Reinforced Aluminum Alloy Composite: Influence of Microstructure," Journal of Materials Engineering and Performance, January 2014, Volume 23, Issue 1, pp 65-76
- 21) K. Manigandan, T. S. Srivatsan, D. Tammana, P. Behrang and V. K. Vasudevan: "Cyclic Strain Resistance, Stress Response, Fatigue Life, and Fracture Behavior of High Strength Low Alloy Steel 300 M," Journal of Materials Engineering and Performance, 2013 May 2014, Volume 23, Issue 5, pp 1799-1814
- 22) K. Manigandan , T.S. Srivatsan, and T. Quick: "Investigating and Understanding the Bending Fatigue Response and Fracture Behavior of Two High Strength Steels," Journal of Materials Performance and Characterization, Vol. 2, No. 1, 2013, pp. 420-439
- 23) K. Manigandan, T. S. Srivatsan, D. Tammana, P. Behrang and V. K. Vasudevan: "Influence Of Microstructure On Strain-Controlled Fatigue And Fracture Behavior Of Ultra High Strength Alloy Steel Aermet 100" Materials Science and Engineering A, 2014 Volume 601, 17 April 2014, Pages 29–39
- 24) K. Manigandan, Srivatsan, T. S., Tammana, D., Poorganji, B., and Vasudevan, V. K. "The Cyclic Strain Resistance, Stress Response, Fatigue Life, and Fracture Behavior of a High Performance Alloy Steel," Materials Performance and Characterization, Vol. 3, No. 1, 2014, pp. 127-146,

- 25) K. Manigandan, T.S.Srivatsan, Andrew Freborg: “Cyclic Strain Resistance, “The Strain-Controlled Fatigue And Fracture Behavior Of A High Alloy Steel: Influence Of Microstructure And Orientation”” Materials Science and Engineering A, 2015 (in review).
- 26) Eric B. Hilty, Craig C. Menzemer, K. Manigandan, and T.S. Srivatsan: “Influence Of Welding And Heat Treatment On Microstructure, Properties And Fracture Behavior Of A Wrought Aluminum Alloy”. Emerging Materials Research. Volume 3, Issue 5, June 2014 pages 230 –242
- 27) Srikanth Bajaj, Anil Patnaik, J. Payer, R. L. Liang K. Manigandan and T. S. Srivatsan : Extrinsic Influence Of Environment On The Corrosion Behavior Of Enamel-Coated STEEL Dowel Bars” , Emerging Materials Research Volume 3, Issue 4, June 2014 pages 158 –168
- 28) K. Manigandan , T. S. Srivatsan: On the Specific Role of Microstructure in Governing Cyclic Fatigue, Deformation, and Fracture Behavior of a High-Strength Alloy Steel, June 2015, Journal of Materials Engineering and Performance , Volume 24, Issue 6, pp 2451-2463
- 29) K. Manigandan ,T. S. Srivatsan, V. K. Vasudevan, P. Behrang, D. Tammana: “Influence of Cyclic Straining on Fatigue, Deformation, and Fracture Behavior of High-Strength Alloy Steel,” Journal of Materials Engineering and Performance, January 2016, Volume 25, Issue 1, pp 138–150
- 30) Sunil Gowda, Carl Hotz, K. Manigandan, Anil Patnaik and T. S. Srivatsan: “The Microstructure, Tensile Response and Fracture Behavior of a High Performance Structural Steel: Influence of Orientation,” Emerging Materials Research, Volume 4 Issue 2, December, 2015, pp. 255-264
- 31) Gowda, S., Hotz, C., K. Manigandan, Srivatsan, T. S., Patnaik, A., and Payer, J. "Quasi-Static, Cyclic Fatigue and Fracture Behavior of Alloy Steel for Structural Applications: Influence of Orientation," Materials Performance and Characterization, Vol. 5, No. 1, 2016, pp. 148-163
- 32) T Srivatsan, K Manigandan, A Patnaik, TS Srivatsan ,“Influence of Exposure to an Aggressive Environment on Cyclic Fatigue Response and Life of an Alloy Steel”, The Journal of Engineering Research [TJER] 14 (2), 124-136
- 33) Singh, Y. P., Presby, M. J., Kannan, M., and Morscher, G. N. (October 4, 2018). "Multi-Lead Direct Current Potential Drop Method for In Situ Health Monitoring of Ceramic Matrix Composites." ASME. J. Eng. Gas Turbines Power. March 2019; 141(3): 031301. doi: <https://doi.org/10.1115/1.4041271>
- 34) D Quade, S Jana, G Morscher, M Kannan, L McCorkle, “Effect of Thin-Film Adhesives on Mode I Interlaminar Fracture Toughness in Carbon Fiber Composites With Shape Memory Alloy Inserts” NASA/TM—2018-219883
- 35) Derek Quade, Sadhan Jana, Gregory Morscher, Manigandan Kannan, Linda McCorkle, The effects of fiber orientation and adhesives on tensile properties of carbon fiber reinforced polymer matrix composite with embedded nickel-titanium shape memory alloys, Composites Part A: Applied Science and Manufacturing, Volume 114, 2018, Pages 269-277, ISSN 1359-835X, <https://doi.org/10.1016/j.compositesa.2018.08.019>.

- 36) Panakarajupally, R.P.; Presby, M.J.; Manigandan, K.; Zhou, J.; Chase, G.G.; Morscher, G.N. Thermomechanical Characterization of SiC/SiC Ceramic Matrix Composites in a Combustion Facility. *Ceramics* 2019, 2, 407-425
- 37) Derek J. Quade, Sadhan C. Jana, Gregory N. Morscher, Manigandan Kannan, Linda McCorkle, The effect of thin film adhesives on mode II interlaminar fracture toughness in carbon fiber composites with shape memory alloy inserts, *Mechanics of Materials*, Volume 131, 2019, Pages 22-32, ISSN 0167-6636, <https://doi.org/10.1016/j.mechmat.2019.01.002>.

Google Scholar Citation Index (Aug 23 2019)

Citations	182	169
h-index	8	8
i10-index	5	4



CONFERENCE PAPERS

- 1) K. Manigandan, T. S. Srivatsan, M. Petraroli, M. Schmidt and T. Quick: "Influence of Alloy Chemistry and Processing on Impact Toughness and Fracture Behavior of Four High Strength Steels," *Processing and Fabrication of Advanced Materials XIX: Volume 1, Proceedings of the Nineteenth International Symposium*, (Editors: D. Bhattacharyya, R.J.T. Lin, T. S. Srivatsan) Auckland, New Zealand, January 2011, pp. 3-20.
- 2) K. Manigandan, T. S. Srivatsan, M. Petraroli, M. Schmidt and T. Quick: "Influence of Alloy Chemistry and Processing on Tensile Deformation and Fracture Behavior of Four High Strength Steels," *Processing and Fabrication of Advanced Materials XIX: Volume 1, Proceedings of the Nineteenth International Symposium*, (Editors: D. Bhattacharyya, R.J.T. Lin, and T. S. Srivatsan) Auckland, New Zealand, January 2011, pp. 21-34.
- 3) Troy D. Topping, Ying Li, Enrique J. Lavernia, K. Manigandan and T. S. Srivatsan: "The Influence of Processing on Microstructure, Tensile Deformation and Fracture Behavior of Aluminum Alloy 5083," in *Advanced Materials Research Vol. 410, Processing and Fabrication of Advanced Materials XX, Proceedings of the Twentieth International Symposium*, (Editors: Alan Kin-tak Lau, T. S. Srivatsan and Debes Bhattacharyya, Ming Zhang and Mabel M.P. Ho) Hong Kong, Hong Kong, 2011, pp. 175-186.

- 4) K. Manigandan, T. S. Srivatsan, T. Quick and A. M. Freborg: “The High Cycle Fatigue and Final Fracture Behavior of Alloy Steel 9310 for Use in Performance Sensitive Applications”, International Symposium on Fatigue Behavior of Materials: Advances and Emergences in Understanding, (Editors: T.S. Srivatsan, Ashraf M. Imam and R. Srinivasan), WILEY and The Minerals, Metals and Materials Society (TMS), Warrendale, PA, USA, October 2012, pp. 211-232.
- 5) T. S. Srivatsan, S. Vasudevan and K. Manigandan: “The High Cycle Fatigue, Damage Initiation and Growth and Final Fracture Behavior of Aluminum Alloy 2024,” International Symposium on Fatigue Behavior of Materials: Advances and Emergences in Understanding, (Editors: T.S. Srivatsan, Ashraf M. Imam and R. Srinivasan), WILEY and The Minerals, Metals and Materials Society (TMS), Warrendale, PA, USA, October 2012, pp. 119-138.
- 6) K Manigandan, TS Srivatsan, VK Vasudevan, D Tammana, B Poorbangi: “Cyclic Strain Resistance, Deformation and Fracture Behavior of a Novel Alloy Steel”, International Symposium on Fatigue of Materials III: Advances and Emergences in Understanding, (Editors: T.S. Srivatsan, Ashraf M. Imam and R. Srinivasan), WILEY and The Minerals, Metals and Materials Society (TMS), 2014, pp. 127-146.
- 7) Presby, M. J., Mansour, R., Kannan, M., Morscher, G. N., Abdi, F., Godines, C., and Choi, S. (2016). “Damage Characterization of High Velocity Impact in Curved SiC/SiC Composites.” HTCMC-9 & GFMAT 2016 Proceedings.
- 8) Presby, M. J., Mansour, R., Kannan, M., Smith, R. K., Morscher, G. N., Abdi, F., Godines, C., and Choi, S. (2016). “Influence of Curvature on High Velocity Impact of SiC/SiC Composites.” Mechanical Properties and Performance of Engineering Ceramics and Composites XI: Ceramic Engineering and Science Proceedings, Volume 37, Issue 2, 2016. DOI: 10.1002/9781119320104.ch12.
- 9) Han Z, Morscher GN, Maillet E, Kannan M, Choi SR, Abdi F. Electrical Resistance and Acoustic Emission During Fatigue Testing of Pristine and High Velocity Impact SiC/SiC Composites at Room and Elevated Temperature. ASME. Turbo Expo: Power for Land, Sea, and Air, Volume 6: Ceramics; Controls, Diagnostics and Instrumentation; Education; Manufacturing Materials and Metallurgy DOI:10.1115/GT2016-56507.
- 10) Mansour R, Singh YP, Kannan M, et al. Study of Interlaminar Fracture Properties of Ceramic Matrix Composites at Room and Elevated Temperatures. ASME. Turbo Expo: Power for Land, Sea, and Air, Volume 6: Ceramics; Controls, Diagnostics and Instrumentation; Education; Manufacturing Materials and Metallurgy. DOI:10.1115/GT2017-65168.
- 11) Quade Derek J, Jana, Sadhan C, Morscher Gregory N, Manigandan Kannan, McCorkle Linda S, The Effects of Fiber Orientation and Adhesives on Tensile Properties of Carbon Fiber Reinforced Polymer Matrix Composite with Embedded Nickel-Titanium Shape Memory Alloys, NASA/TM—2017-219703
- 12) Yogesh P Singh, Michael J Presby, K Manigandan, Gregory N Morscher ; “ Use Of Electrical Resistance As A Non-Destructive Evaluation Tool In Health Monitoring And Damage Evaluation Of Ceramic Matrix Composites. Proceedings of the 41st International Conference on Advanced Ceramics and Composites, Volume 613, John Wiley & Sons

- 13) Z Han, Gregory N Morscher, Manigandan Kannan, Emmanuel Maillet;(2018) Use Of Electrical Resistance And Acoustic Emission During Fatigue Of Wovensic/Sic Composites Under Different Conditions, Proceedings of the 41st International Conference on Advanced Ceramics and Composites, Volume 613,John Wiley & Sons
- 14) Srivatsan T.S., Lin Y., Chen F., Manigandan K., Lavernia E.J. (2018) Synthesis and Microstructural Development of Particulate Reinforced Metal-Matrix Composites Using the Technique of Spray Atomization and Deposition. In. Metal-Matrix Composites Innovations, Advances and Applications. TMS 2018. The Minerals, Metals & Materials Series. Springer. https://doi.org/10.1007/978-3-319-72853-7_11
- 15) Singh YP, Presby MJ, Manigandan K, Morscher GN. Multi-Lead Direct Current Potential Drop (DCPD) for In-Situ Health Monitoring of Ceramic Matrix Composites. ASME. Turbo Expo: Power for Land, Sea, and Air, Volume 6: Ceramics; Controls, Diagnostics, and Instrumentation; Education; Manufacturing Materials and Metallurgy DOI:10.1115/GT2018-75803