Minimum Quantity Lubrication (MQL) in Machining: Benefits and Drawbacks

Nourredine Boubekri
Department of Engineering Technology, University of North Texas, Denton, Texas, USA
Email: boubekri@unt.edu

Vasim Shaikh
Department of Applied Engineering, Safety & Technology, Millersville University of Pennsylvania, Millersville, Pennsylvania, USA
Email: vasim.shaikh@millersville.edu

***Abstract*—Micro lubrication or also known as minimum quantity lubrication (MQL) serves as an alternative to flood cooling by reducing the volume of cutting fluid used in the machining process; but not without significant health concerns. Flood cooling is primarily used to cool and lubricate the cutting tool and work piece interface during machining process. The adverse health effects caused by the use of coolants and the potential economic advantages of greener machining methods are drawing manufacturer's attention to adapt and develop new methods of using lubricants. The objective of this paper is to review the state of the art literature in machining using MQL, highlight the benefits, but also stress the adverse health effects of using minimum quantity lubrication. Finally we highlight areas of relevant future research.**

***Index Terms*—minimum quantity lubrication, green machining, MQL, micro lubrication.**

I. Introduction

Shortly after the Industrial Revolution in America, Frederick Winslow Taylor flooded the tool-work interface with a heavy stream of water and discovered that the cutting speed could be increased by a factor of 2 or 3. This initial application of a "cutting fluid" inspired today's impressive variety of extremely effective fluids. These fluids provide numerous advantages which include: mechanical and chemical lubrication thereby reducing friction; cooling of the work and tool; enhancing dimensional stability; inhibiting chip welding which further stabilizes dimensions; and, flushing away chips which improves surface finish, tool efficiency and makes automated material handling practical [1]-[6]. Unfortunately, these fluids also share several negative characteristics. Many are costly to purchase; all are applied in volume; all must be periodically replaced; and, when improperly used and disposed off can lead to health and environmental issues [7], [8]. It is these negative characteristics that have prompted researchers to investigate alternative solutions to traditional cutting fluids and their method of application (flood cooling).

A. Background Information

The current trend in the metal-cutting industry is to find ways to reduce cutting fluid use; the use of coolants in machining is thought to be undesirable for economical, health, and environmental reasons [9]. Ref. [10] and [11] reported that coolant and coolant management costs are between 7.5% and 17% of the total manufacturing cost compared to only 4% for cutting tools. Ref. [12] and [13] stated that lubrication represents 16-20% of the product cost. Ref. [14] reported that the coolant cost represents about 15% of the life-cycle operational cost of a machining process. According to a survey conducted by the European Automobile Industry, the cost incurred on lubricants comprises nearly 20% of the total manufacturing cost contrasted with the cost of the cutting tool which is only 7.5% of the total cost [15], [16].

Ref. [17] reported that more than 100 million gallons of metalworking fluids are used in the U.S. each year and that 1.2 million employees are exposed to them and to their potential health hazards. The U.S. Occupational Safety and Health Administration (OSHA) [18], [19] and the U.S. National Institute for Occupational Safety and Health (NIOSH) reported that the permissible exposure level (PEL) for metal working fluid aerosol concentration is 5 mg/m^3 and 0.5 mg/m^3 respectively [20]. However, the oil mist level in the U.S. automotive parts manufacturing facilities has been estimated to be 20 – 90 mg/m^3 with the use of conventional lubrication by flood coolant [21], [22]. The exposure to such amounts of metal working fluid may contribute to adverse health effects and safety issues, including toxicity, dermatitis, respiratory disorders and cancer [23]. The mechanical infrastructure that sustains a flood coolant system is of such complexity that it hinders the rapid reconfiguration of equipment. In the conventional application of flood coolant, the chips produced are wet. They have to be dried before recycling, which incurs additional cost. MQL on the other hand, produces essentially dry chips, so the cost of drying them is reduced [24]. The savings in cutting fluid and related costs could be significant if MQL was adopted.

II. Minimum Quantity Lubrication

Manuscript received July 24, 2014; revised November 1, 2014.

doi: 10.12720/jiii.3.3.205-209

The concept of MQL was suggested a decade ago as a mean for addressing the issues of environmental intrusiveness and occupational hazard associated with airborne cutting fluid particles. The minimization of cutting fluid leads to economical benefits by saving lubricant costs. Workpiece, tool and machine cleaning time are reduced. The MQL technique consists of misting or atomizing a very small quantity of lubricant, typically of a flow rate of 50 to 500 ml/hour, in an air flow directed towards the cutting zone [25], [26]. The lubricant is sprayed by means of an external supply system consisting of one or more nozzles. The amount of coolant used in MQL is about 3-4 orders of magnitude lower than the amount commonly used in flood cooling condition [27].

MQL, also known as "Microlubrication," [28] and "Near-Dry Machining" [29] is the latest technique of delivering metal cutting fluid to the tool/work interface. Using this technology, a little fluid, when properly selected and applied, can make a substantial difference in how effectively a tool performs.

In conventional operations utilizing flood coolant, cutting fluids are selected mainly on the basis of their contributions to cutting performance. In MQL however, secondary characteristics are important. These include their safety properties, (environment pollution and human contact), biodegradability, oxidation and storage stability. This is important because the lubricant must be compatible with the environment and resistant to long term usage caused by low consumption [30]. In MQL, lubrication is obtained via the lubricant, while a minimum cooling action is achieved by the pressurized air that reaches the tool/work interface [31]. Further, MQL reduces induced thermal shock and helps to increase the workpiece surface integrity in situations of high tool pressure [32].

A. MQL Lubricant Characteristics

Lubricant concentration in MQL varies between 0.2 and 500 ml/hr [33]. Since very good lubrication properties are required in MQL, vegetable oil or synthetic easter oil are used instead of mineral oil [34]. Air pressure is roughly 5 bars. MQL is consumption lubrication, that is, the bulk of the lubricant applied is evaporated at the point of application. This evaporation, in concert with the compressed air stream, cools the workpiece. The remaining heat is dissipated through the tool and the chips [35]. The chips, workpiece and tool remain nearly dry in an ideally adjusted MQL system.

Ref. [30] introduced synthetic polyol esters and described their capabilities as MQL fluids. These represent a potential replacement for vegetable-based MQL oils, particularly with regard to their optimal secondary performance characteristics. All vegetable oils display high biodegradability. Synthetic esters, however, provide a wide range of biodegradability depending on their combined molecular structures of acids and alcohols. This characteristic, in conjunction with their suitable viscosities, prompted [30] to identify these lubricants for further examination.

Physical properties and biodegradability of polycol esters were compared with a vegetable oil. The viscosity, total acid number, pour point and biodegradability for polycol ester oil were 19.1 mm2/s, 0.02 mgKOH/g, 45˚C and 100% respectively. These characteristics for vegetable oil were 35.6 mm2/s, 0.04 mgKOH/g, 20˚C and 98% respectively. The molecular weights of polycol ester oil and vegetable oil were also compared. The molecular weight of the oil film increased more than 10%. The molecular weight of vegetable oil increased by 65%. In contrast, there was no significant change in the molecular weights of polyol esters. Most vegetable oils consist of a number of ester compounds mainly derived from a combination of glycerin and fatty acids. Vegetable oils are usually liquids at room temperature, due to their unsaturated bonds. Unfortunately, unsaturated bonds are chemically unstable and may cause vegetable oils molecular weight to increase. A detailed investigation of this behavior was carried out using Gel Permeation Chromatography (GPC) analysis. The results indicated that some of the molecules in vegetable oil had changed into compounds having higher molecular weights. Results of the UV analysis, which can selectively detect changes in unsaturated double bonds, indicate the unsaturated structure decreased significantly. This result supports the hypothesis that the unsaturated bond structure of vegetable oil molecules is the main cause of their easy degradation by oxidation polymerization. The polyol esters chosen as preferable biodegradable lubricants in this investigation are synthesized from a specific polyhydric alcohol rather than glycerin. Their molecules can greatly improve oxidation stability; they are free from unsaturated bonds. Regardless, they can be liquid at room temperature. Compared with vegetable oils, the synthetic polyol esters studied were optimal lubricants for MQL machining from the standpoint of maintaining a clean working environment.

III. SELECTED RECENT RESEARCH ON MQL

MQL performance using coated and uncoated HSS and Cobalt HSS drills, in a high aspect ratio operation, was examined by [36]. The workpiece material was AISI 1045. The study reported that a continuous MQL supply is beneficial in terms of tool life, whereas interrupting the MQL supply leads to a significant drop in tool life, especially in the case of heat-sensitive drills. With respect to the type of MQL lubricant, a low viscous type with high cooling capability gives rise to a notably prolonged tool life.

A similar study [37] was conducted to compare MQL and wet drilling using tooling prepared with thin perfluoropolyether (PFPE) lubricant films. The main findings indicate that the PFPE surface treatment reduced the cutting torque, increased tool life and improved the surface finish of the machined part. Also, drilling with pecking showed some improvement with the number of holes produced being more consistent.

Ref. [38] also reported on MQL and drilling operations. The workpiece material investigated was titanium alloy Ti6Al4V (300 BHN). They analyzed the temperature during drilling while using class K10 carbide drills with and without hard coating (TiAlN, CrCN or TiCN). It was concluded that the measured temperature with application of MQL internally through the tool was 50% lower than that obtained with MQL applied with an external nozzle.

A similar study [39] was conducted to compare MQL at different flow rates with emulsion and compressed air cooling in the drilling of gear wheel steel. The main findings indicate that the highest wear was observed for emulsion, followed by air and MQL assisted machining. In terms of surface finish, MQL (15 ml/h) and emulsion drilling gave the best result followed by air, MQL (5 ml/h) and MQL (23 ml/h).

In a comparative study between flood and MQL [28] showed the following results:

In a drilling test using AISI 4340 Steel (32-34 HRC), there was no significant differences in tool life (number of holes to reach end of life criteria) between MQL and flood cooling. Average thrust forces were 570 lbs and 447 lbs for flood and MQL cooling respectively.

In a milling test using AISI 4140 Steel (24-26 HRC),the analysis showed little differences in tool life between flood and MQL cooling. Sixty-six passes were milled for the flood tests and 80 were milled for the MQL tests. The average resultant forces observed were 46 lbs for flood and 36 lbs for MQL cooling.

A similar study [40] was conducted to shows the technological developments and implementation of MQL at the Ford Motor Company. The main findings indicate that a 10 year per machine life cycle comparison with flood cooling showed a 15% reduction of operating cost with the implementation of MQL.

A study involving the intermittent turning of aluminum alloy on a CNC lathe was undertaken by [41]. Rapeseed oil and synthetic esters (mono carboxylic acid with polyalcohol) were employed as lubricants. MQL with rapeseed oil had a small lubricating effect in light loaded machining conditions. Results showed MQL with water droplets, specifically an oil film on a water droplet, provided good lubrication performance if an appropriate lubricant, such as synthetic ester, was used. When MQL with synthetic ester but without water was used, it showed a lubrication effect. However, tool damage was evident as was chip welding.

A similar study [42] was conducted to develop an understanding of mechanical and environmental effects of MQL in machining and characterize MQL performance as a function of machining and fluid application parameters. The main findings indicate that MQL showed a significant reduction in the cutting temperature over a wide range of speeds, and resulted in lower cutting tool wear rate as compared to dry machining.

Ref. [43] conducted an experiment to evaluate the performance of MQL by vegetable oil in terms of cutting force, cutting zone temperature, tool wear, job dimension and surface finish in turning AISI-1060 steel. The main findings indicate that the cutting force, cutting zone temperature, tool wear and surface roughness were reduced by the application of MQL as compared to dry cutting. Application of MQL also improved the dimensional accuracy as compared to dry cutting.

Ref. [26] conducted a study where they compared the mechanical performance of MQL with completely dry lubrication when turning hardened, bearing-grade steel using CBN cutters. The fluid tested was a triglyceride and propylene glycol ester solution vegetable based cutting fluid at a flow rate of 50 ml/hour at a nozzle pressure of 20 psi.

The findings indicated that regarding surface roughness, no noticeable difference was found with the use of MQL over dry turning.

Ref. [44] investigated the influence of burr formation using MQL in up-milling, down-milling and face milling. The main findings indicate that variation in cutting speed showed no influence on burr formation. But, varying feed per tooth increased the burr value in dry machining and MQL. The supply of the fluid through an external nozzle proved to be disadvantageous.

A similar study [45] was conducted to investigate the effect of the MQL in high-speed end-milling of AISI D2 cold worked die steel. The tool performances of Ti0.75Al0.25N and Ti0.69Al0.23Si0.08N coated carbides end-mills were compared using wet, dry and MQL conditions. The main findings indicate that MQL conditions showed maximum cutting length with minimum flank wear followed by dry cutting and wet cutting. Ti0.69Al0.23Si0.08N coating was better than Ti0.75Al0.25N coating.

Ref. [46] conducted an experiment to investigate the mechanism of MQL in high speed milling of hardened steel and compared with dry cutting. The main findings indicate that cutting force and surface roughness under MQL was less than dry cutting. Tool performance under MQL was enhanced under all cutting speeds.

IV. Conclusions and Future Research

Findings from the forgoing research indicate that MQL applications generate a significant amount of mist compared to flood cooling. This later must be effectively controlled to realize the benefits of MQL. Mist collection or filtering equipments are generally required to manage this fine mist particularly in ferrous machining, where sparking and smoking is often observed. Whenever possible the use of vegetable or synthetic oils is to be used instead of mineral oil

MQL has been shown to work well in short term tests over a range of processes. Long term capability and robustness remain still unanswered tough MQL applications have indicated favorable cost reduction due to the reduced cost of managing the cutting fluids .Theses issues may be sorted out when more extensive MQL experience is accumulated from large-scale production applications. More material specific issues may require additional testing. The processes of lubrication and cooling in MQL are yet to be well understood. The process of metal working fluids mist particles generation and their physical characteristics are yet to be determined for a whole class of machining processes and machining conditions.

References

[1] V. T. G. Naves, M. B. Da Silva, and F. J. Da Silva, "Evaluation of the effect of application of cutting fluid at high pressure on tool wear during turning operation of AISI 316 austenitic stainless steel," *Wear*, vol. 302, pp. 1201-1208, 2013.

[2] S. A. Lawal, I. A. Choudhury, and Y. Nukman, "Developments in the formulation and application of vegetable oil-based metalworking fluids in turning process," *International Journal of Advanced Manufacturing Technology*, vol. 67, pp. 1765-1776, 2013.

[3] J. A. Ghani, C. H. C. Haron, S. H. Hamdan, A. Y. Md Said, and S. H. Tomadi, "Failure mode analysis of carbide cutting tools used for machining titanium alloy," *Ceramics International*, vol. 39, no. 1, pp. 4449-4456, 2013.

[4] R. B. Da Silva, A. R. Machado, E. O. Ezugwu, J. Bonney, and W. f. Sales, "Tool life and wear mechanisms in high speed machining of Ti–6Al–4V alloy with PCD tools under various coolant pressures," *Journal of Materials Processing Technology*, vol. 213, no. 8, pp. 1459-1464, 2013.

[5] S. Wang and A. F. Clarens, "Analytical model of metalworking fluid penetration into the flank contact zone in orthogonal cutting," *Journal of Manufacturing Processes*, vol. 15, no. 1, pp. 41-50, 2013.

[6] K. Leo Dev Wins and A. S. Varadarajan, "Simulation of surface milling of hardened AISI4340 steel with minimal fluid application using artificial neural network," *Advances in Production Engineering & Management*, vol. 7, no. 1, pp. 51-60, 2012.

[7] J. Z. Rozzi, J. K. Sanders, and W. Chen, "The experimental and theoretical evaluation of an indirect cooling system for machining," *J. Heat Transfer*, vol. 133, no. 3, pp. 1-10, 2010.

[8] H. Wichmann, H. Stache, C. Schmidt, M. Winter, R. Bock, C. Herrmann, and M. Bahadir, "Ecological and economic evaluation of a novel glycerol based biocide-free metalworking fluid," *Journal of Cleaner Production*, vol. 43, pp. 12-19, 2013.

[9] H. Caliskan, C. Kurbanoglu, P. Panjan, M. Cekad, and D. Kramar, "Wear behavior and cutting performance of nanostructured hard coatings on cemented carbide cutting tools in hard milling," *Tribology International*, vol. 62, pp. 215-222, 2013.

[10] F. Koné, C. Czarnota, B. Haddag, and M. Nouari, "Modeling of velocity-dependent chip flow angle and experimental analysis when machining 304L austenitic stainless steel with groove coated-carbide tools," *Journal of Materials Processing Technology*, vol. 213, no. 7, pp. 1166-1178, 2013.

[11] H. J. Heins, "Dry machining-A promising option," *American Machinist*, vol. 126, no. 8, pp. 92-93, 1997.

[12] S. Zhang, J. F. Li, and Y. W. Wang, "Tool life and cutting forces in end milling Inconel 718 under dry and minimum quantity cooling lubrication cutting conditions," *Journal of Cleaner Production*, vol. 32, pp. 81-87, 2012.

[13] B. K. A. Ngoi and P. S. Sreejith, "Dry machining: Machining of the future," *Journal of Materials Processing Technology*, vol. 101, pp. 287-291, 2000.

[14] R. Quaile, "Understanding MQL: machining with minimum quantity lubricant can save money and improve both tool life and part finish," *Modern Machine Shop*, 2000.

[15] J. Jurko and A. Panda, "Application of vegetable oil-based metalworking fluids in machining ferrous metals-A review," *International Journal of Machine Tools and Manufacture*, vol. 52, no. 1, pp. 1-12, 2012.

[16] T. Brockhoff and A. Walter, ''Fluid minimization in cutting and grinding," *Abrasives*, pp. 38-92, October 1998.

[17] R. E. Chalmers, "Global flavor highlights NAMRC XXVII," *Manufacturing Engineering*, vol. 123, no. 1, pp. 80-88, 1999.

[18] D. Park, "The occupational exposure limit for fluid aerosol generated in metalworking operations: Limitations and recommendations," *Safety and Health at Work*, vol. 3, pp. 1-10, 2012.

[19] R. B. Aronson, "Why dry machining," *Manufacturing Engineering*, vol. 114, no. 1, pp. 33-36, 1995.

[20] U.S. Department of Health and Human Services, "Occupational exposure to metal working fluid," *NIOSH Publication No.* pp. 98-102, 1998.

[21] N. Fazli and M. B. Hamdi, "New technique of mechanical pulse jet coolant delivery system for minimal quantity lubricant (MQL) operation," in *Proc. AIP Conference Proceedings*, vol. 1315, pp. 1071-1076, 2007.

[22] E. O. Bennett and D. L. Bennett, "Occupational Airways Diseases in the Metal Working Industries," *Tribology International*, vol. 18/3, pp. 169-176, 1985.

[23] H. S. Abdalla, W. Baines, G. McIntyre, and C. Slade, "Development of novel sustainable neat-oil metalworking fluids for stainless steel and titanium alloy machining - Part 1 - Formulation development," *Journal of Advanced Manufacturing Technology*, vol. 34, pp. 21-33, 2007.

[24] M. Siniawski and C. Bowman, "Metal working fluids: finding green in the manufacturing process," *Industrial Lubrication and Tribology*, vol. 61, no. 2, pp. 60-66, 2009.

[25] A. D. Jayal and A. K. Balaji, "Effects of cutting fluid application on tool wear in machining: Interactions with tool-coatings and tool surface features," *Wear*, vol. 267, no. 9/10, pp. 1723-1730, 2009.

[26] R. Autret and S. Y. Liang, "Minimum quantity lubrication in finish hard turning," in *Proc. International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management*, March 26-28, 2003.

[27] S. Kurgin, G. Barber, and Q. Zou, "Cutting insert and work piece materials for minimum quantity lubrication," in *Proc. SPIE - The International Society for Optical Engineering, Fourth International Seminar on Modern Cutting and Measurement Engineering*, 2011, vol. 7997, pp. 1-10.

[28] T. F. MaClure, R. Adams, M. D. Gugger, and M. G. Gressel. (2007). Comparison of Flood vs. Microlubrication on Machining Performance. [Online]. Available: http://www.unist.com/pdfs/articles/AR_flood_v_micro.pdf

[29] F. Klocke and G. Eisenblatter, "Dry cutting," *Annals of the CIRP*, vol. 46, no. 2, pp. 519-526, 1997.

[30] T. Wakabayashi, I. Inasaki, and S. Suda, "Tribological action and optimal performance: Research activities regarding MQL machining fluids," *Machining Science and Technology*, vol. 10, pp. 59-85, 2006.

[31] U. Irfan, A. Kubilay, and B. Fevzi, "An experimental investigation of the effect of coating material on tool wear in micro milling of Inconel 718 super alloy," *Wear*, vol. 300, no. (1/2), pp. 8-19, 2013.

[32] A. Attanasio, M. Gelfi, C. Giardini, and C. Remino, "Minimum quantity lubrication in turning," *Wear*, vol. 260, pp. 333-338, 2006.

[33] M. H. Sadeghi, M. J. Hadad, T. Tawakoli, A. Vesali, and M. Emami, "An investigation on surface grinding of AISI 4140 hardened steel using minimum quantity lubrication-MQL technique," *International Journal of Material Forming*, vol. 3, pp. 241-251, 2010.

[34] S. Woods, "Going green," *Cutting Tool Engineering*, vol. 57, no. 2, 2005.

[35] For Minimum Costs and Maximum Protection of the Environment. (2007). *Topic of the Month*. [Online]. Available at: www.schunk-usa.com

[36] R. Heinemann, S. Hinduja, G. Barrow, and G. Petuelli, "Effect of MQL on the tool life of small twist drills in deep-hole drilling," *International Journal of Machine Tool and Manufacture*, vol. 46, pp. 1-6, 2006.

[37] J. Dosbaeva, J. Fox-Rabinovich, Dasch, and S. Veldhuis, "Enhancement of wet- and MQL-based machining of automotive alloys using cutting tools with DLC/polymer surface treatments," *Journal of Materials Engineering and Performance*, vol. 17, no. 3, pp. 346-351, 2008.

[38] R. P. Zeilman and W. L. Weingaertner, "Analysis of temperature during drilling of Ti6Al4V with minimal quantity of lubricant," *Journal of Materials Processing and Technology*, vol. 179, pp. 124-127, 2006.

[39] B. Tasdelen, H. Thordenberg, and D. Olofsson, "An experimental investigation on contact length during minimum quantity lubrication (MQL) machining," *Journal of Materials Processing Technology*, vol. 203, no. 1-3, pp. 221-231, 2008.

[40] R. Furness, A. Stoll, G. Nordstrom, G. Martini, J. Johnson, T. Loch, and R. Klosinski, "Minimum quantity lubrication (MQL) machining for complex components," in *Proc. International Conference on Manufacturing Science and Engineering*, 2006.

[41] F. Itoigawa, T. H. C. Childs, T. Nakamura, and W. Belluco, "Effects and mechanisms in minimal quantity lubrication machining of an aluminum alloy," *Wear*, vol. 260, pp.339-344, 2006.

[42] K. Li and S. Y. Liang, "Performance profiling of minimum quantity lubrication in machining," *International Journal of*

Advanced Manufacturing Technology, vol. 35, no. 3-4, pp. 226-233, 2007.

[43] M. M. A. Khan and N. R. Dhar, "Performance evaluation of minimum quantity lubrication by vegetable oil in terms of cutting force, cutting zone temperature, tool wear, job dimension and surface finish in turning AISI-1060 steel," *Journal of Zhejiang University (Science)*, vol. 7, no. 11, pp. 1790-1799, 2006.

[44] U. Heisel, M. Schaal, and G. Wolf, "Burr formation in short hole drilling with minimum quantity lubrication," *Production Engineering*, vol. 3, no. 2, pp. 157-163, 2009.

[45] M. Kang, K. Kim, S. Shin, S. Jang, J. Park, and C. Kim, "Effect of the minimum quantity lubrication in high-speed end-milling of AISI D2 cold-worked die steel (62 HRC) by coated carbide tools," *Surface and Coatings Technology*,vol. 202, no. 22-23, pp. 5621-5624, 2008.

[46] Y. S. Liao and H. M. Lin, "Mechanism of minimum quantity lubrication in high-speed milling of hardened steel," *International Journal of Machine Tools and Manufacture*, vol. 47, no. 11, pp. 1660-1666, 2007.

[47] C. Y. Lin, M. Wu, J. A. Bloom, I. J. Cox, and M. Miller, "Rotation, scale, and translation resilient public watermarking for images," *IEEE Trans. Image Process.*, vol. 10, no. 5, pp. 767-782, 2001.

Nourredine Boubekri received his Ph.D. in 1983 from the University of Nebraska in Industrial and Management Systems Engineering. He received both his Master and Bachelor of Science degree in 1980 from Boston University in Manufacturing Engineering. His experience and tenure started at the University of Miami where he began as an assistant professor and founded the Industrial Assessment Center. His Management experiences include his role as department chair/Director of Research at NIU (2002-2006), Department chair at UNT (2006-2010), Director of UNT SACSCOC reaffirmation (2012-Present). He directed more than thirty Master and Ph.D. Students and published more than 100 journal papers in the areas of machining and product development. His research support exceeds five million dollars in grants and contracts.

Vasim Shaikh received his Ph.D. degree in Materials Science and Engineering, in 2013 and the M.S. degree in Mechanical Engineering Systems, in 2008 from the University of North Texas, Denton. He received both his B.S. degree and Diploma in Production Engineering from the University of Mumbai, India, in 2005 and 2002, respectively. He is currently an Assistant Professor with the Department of Applied Engineering, Safety & Technology at Millersville University of Pennsylvania. His research areas include mist and microstructure characterization during machining using minimum quantity lubrication. He is performing research to develop green and sustainable machining processes, which are environmentally friendly and harmless to the machining operators.