# THE EXPANDING EXPRESSION OF ENHANCED HEAT AND MASS TRANSFER, FOR "THE TIMES THEY ARE A-CHANGIN' ……"†

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Time, by its inherent definition, is dynamic. In its passage, everything transforms and changes. And just as our seasons transition and unfold new vistas (with hope, from winter to spring to summer; and with patient resilience from summer to autumn to winter), so does all else transforms in the temporal path of the cycle of life. Mr. Bob Dylan† has very eloquently given expression to change in a popular ballad when he sings, "…As the present now, Will later be past ……For the times they are a-changin'." Thus, what was past has also to give way to the now and new. And it is in this spirit that we celebrate the spring of 2014 and the $21^{st}$ year of publication of the *Journal of Enhanced Heat Transfer* (vol. 21, no. 1) with a new design of its cover. It has its own lyrics for change, rendered in the images and masthead artwork, as well as the new print format.

The old cover, or perhaps the *original cover* and its artwork has steadfastly served the *Journal of Enhanced Heat Transfer* (JEHT) very well ever since the publication of its first issue in the late 1993. Much has changed and transformed since. In its journey of growth, it changed publishing stewardship between three different houses, of which its current publisher, Begell House, has significantly expanded its readership and submission outreach to all corners of our globe. The journal's inception goals of making it "……*the place* to publish important papers on enhanced heat transfer, and to find the *pulse* of industrial application" (Webb, 1994) have not just been met to a large extent, but are also reflected in the growing impact that JEHT makes on the current scientific discourse and engineering practice (Bergles, 1999; Bergles and Manglik, 2013; Manglik, 2003; Manglik and Bergles, 2004; Manglik and Jog, 2009; Manglik et al., 2013). Moreover, the engineering principles that fundamentally describe the field of enhanced heat and mass transfer now find a prominent place not only in graduate study monographs (Bergles, 1998; Webb and Kim, 2005) but in undergraduate textbooks as well; see Kreith et al. (2011), among others.

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† Bob Dylan, *The Times They Are a-Changin'*, released January 13, 1964 (album), March 8, 1965 (single); Columbia Studios, New York, NY.

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The evolving international scientific investigations and engineering practice imperatives in this arena have brought about some taxonomical transformations too. The intrinsic objectives of enhanced heat and mass transfer, where methods and techniques are devised or employed to improve, or *augment*, or *intensify* heat (and/or mass) transfer over and above the "normal," have also come to be served by novel developments in *high performance heat exchange* devices and systems. While the traditional embodiments and their extensions endure (Bergles, 1998; Webb and Kim, 2005), the ever expanding canvas of *enhancement* now includes a much wider spectrum of problems and engineering applications. These range from devices that seek to harness convection at the micro-to-mini-to-macro-scale levels, to novel materials development that enhance thermo-physical properties with nanometer-level (or "nanoscale," as in popular idiom to denote everything "small") modifications, to extremely low- as well as high-temperature heat transfer, to name a few. At times these problems do not readily fall into the classic taxonomy (Bergles and Manglik, 2013) devised by the pioneer of this field, the Late Professor Arthur E. Bergles, and the founding advisory editor of this journal. Nevertheless, this classification continues to guide the overall explorations in this field, and is worth reiterating for the benefit of our readers; the complete listing is given in Table 1, and extended descriptions of each category can be found in (Bergles and Manglik, 2013; Bergles et al., 1983).

**TABLE 1:** Taxonomy of techniques and methods for enhancement of heat and mass transfer (Bergles and Manglik, 2013; Bergles, 1983).

| **Passive Techniques** | **Active Techniques** |
|---|---|
| Treated surfaces | Mechanical aids |
| Rough surfaces | Surface vibration |
| Extended surfaces | Fluid vibration |
| Displaced enhancement devices | Electrostatic fields |
| Swirl flow devices | Injection or suction |
| Coiled tubes | |
| Surface tension devices | |
| Additives for liquids | |
| Additives for gases | |
| **Compound Enhancement** | |
| Two or more passive and/or active techniques used together<br>*Example:* Wavy plate fins with punched-tab vortex generators | |

The notion of time and change, embraced as a philosophical guiding principle that describes their quintessential dance cycle, is very poetically and succinctly embodied in

the following *Sanskrit* verse taken from the great Hindu epic, $The\ Mahā$-$bhārata$[1]:

कालः पचति भूतानि, कालः संहरते प्रजाः ।
कालः सुप्तेषु जागर्ति, कालो हि दुरतिक्रमः ॥

kālaḥ pachati bhūtāni, kālaḥ saṃharate prajāḥ |
kālaḥ supteṣhu jāgarti, kālo hi duratikramaḥ ||

In other words, everything that is created has to change and transform with passage of time, and even in the passive (or inactive) periods of material life, time is ever "awake" and active, for it never stops and is insurmountable. Time, or $kālah$, thus represents the very nature and unfolding dynamism of change! The cover image, which displays several different swirl flow devices, in essence represents this idea of transformation due to a coupled cycle of renewal and change. They include a twisted-tape insert, twisted oval tubes, a helical wire-wrapped core insert, and a wavy-fin core piece. The phenomenological flow behavior produced by the first three devices has been characterized by the generation of helical vortices, or counter-rotating recirculation cells superimposed over the axial flow, which lend to considerable flow mixing and a consequent thinning of boundary layers to promote enhanced heat transfer (Bishara et al., 2013; Manglik and Bergles, 2013; Manglik et al., 2012; Yakovlev, 2013; Yakovlev et al., 2013). A sinusoidal corrugated-surface (or wavy-surface) plate-fin core, on the other hand, compounds the swirl flow (generated by the interplay of trough-region recirculation with axial fluid movement) with an increase in the surface are provided by the fins or extended surface (Manglik and Metwally, 2013; Zhang et al., 2004). The helical fluid recirculation of all these cases, in a mechanistic essence, articulate the enhanced forced convection equivalent of cyclical change and renewal.

The applications for these and other enhancement techniques, whether addressed by those classified in Table 1 or emerging ones that may need an addition to the taxonomy, continue to expand and find usage in multifarious systems. Be it the development of renewable and clean energy production systems, high temperature heat-recovery as well as primary energy-transfer systems, devices that accommodate two-phase transport with boiling or condensation, and compact heat exchangers for tackling energy-water nexus challenges and energy storage systems, among many others, the present-day requirements for viable integration of heat and mass transfer enhancement in their engineering

[1]Verse 2.22, this *shloka* or *Sanskrit* couplet or two-line verse is uttered by *Vidura* to the king $Dhṛtarāṣhṭra$; see the following for additional reference and extended commentary on the verse: http://blog.practicalsanskrit.com/2010/12/time-is-insurmountable.html

design cannot be overstated. The research reported in JEHT, which tackle both the underlying fundamental science as well as their design applications, is expected to address most of these compelling needs. Needless to reiterate that my editorial-board colleagues and I surely intend to embrace the spirit of "The Times They Are a-Changin' . . . . . " and provide a dynamic forum for exchange of scientific information on current advancements in heat and mass transfer enhancement, along with the latest technological developments that engage its practical usage.

## REFERENCES

Bergles, A. E., Techniques to enhance heat transfer, in *Handbook of Heat Transfer*, Rohsenow, W. M., Hartnett, J. P., and Cho, Y. I., Eds., pp. 11.11-11.76, McGraw-Hill, New York, NY, 1998.

Bergles, A. E., Enhanced heat transfer: Endless frontier, or mature and routine?, *J. Enhanced Heat Transf.*, vol. **6**, no. 2–4, pp. 79–88, 1999.

Bergles, A. E. and Manglik, R. M., Current progress and new developments in enhanced heat and mass transfer, *J. Enhanced Heat Transf.*, vol. **20**, no. 1, pp. 1–15, 2013.

Bergles, A. E., Nirmalan, V., Junkhan, G. H., and Webb, R. L., Bibliography on augmentation of convective heat and mass transfer – II, Heat Transfer Laboratory Report No. HTL-31, ISU-ERI-Ames-84221, Iowa State University, Ames, IA, 1983.

Bishara, F., Jog, M. A., and Manglik, R. M., Heat transfer enhancement due to swirl effects in oval tubes twisted about their longitudinal axis, *J. Enhanced Heat Transf.*, vol. **20**, no. 4, pp. 289–304, 2013.

Kreith, F., Manglik, R. M., and Bohn, M. S., *Principles of Heat Transfer*, Cengage Learning, Stamford, CT, 2011.

Manglik, R. M., Heat transfer enhancement, in *Heat Transfer Handbook*, Bejan, A. and Kraus, A. D., Eds., pp. Ch. 14, Wiley, Hoboken, NJ, 2003.

Manglik, R. M. and Bergles, A. E., Enhanced heat and mass transfer in the new millennium: A review of the 2001 literature, *J. Enhanced Heat Transf.*, vol. **11**, no. 2, pp. 87–118, 2004.

Manglik, R. M. and Bergles, A. E., Characterization of twisted-tape-induced helical swirl flows for enhancement of forced convective heat transfer in single-phase and two-phase flows, *J. Thermal Sci. Eng. Appl.*, vol. **5**, no. 2, pp. 021010 (1–12), 2013.

Manglik, R. M. and Jog, M. A., Molecular-to-large-scale heat transfer with multiphase interfaces: Current status and new directions, *J. Heat Transf.*, vol. **131**, no. 12, article 121001 (1–11), 2009.

Manglik, R. M. and Metwally, H. M., Enhanced heat transfer in corrugated-plate channels with non-Newtonian power-law fluid flows, *J. Enhanced Heat Transf.*, vol. **20**, no. 4, pp. 361–377, 2013.

Manglik, R. M., Patel, P., and Jog, M. A., Swirl-enhanced forced convection through axially

twisted rectangular ducts – Part 2, Heat transfer, *J. Enhanced Heat Transf.*, vol. **19**, no. 5, pp. 437–450, 2012.

Manglik, R. M., Bergles, A. E., Dongaonkar, A. J., and Rajendran, S., Limitations of compiling the global literature on enhanced heat and mass transfer, *J. Enhanced Heat Transf.*, vol. **20**, no. 1, pp. 83–92, 2013.

Webb, R. L., Editor's Comments, *J. Enhanced Heat Transf.*, vol. **1**, no. 3, p. i, 1994.

Webb, R. L. and Kim, N.-H., *Principles of Enhanced Heat Transfer*, 2nd Ed., Taylor & Francis, Boca Raton, FL, 2005.

Yakovlev, A. B., Heat transfer and hydraulic resistance in single-phase forced convection in annular channels with twisting wire inserts, *J. Enhanced Heat Transf.*, vol. **20**, no. 6, pp. 519–525, 2013.

Yakovlev, A. B., Tarasevich, S. E., Giniyatullin, A. A., and Shishkin, A. V., Hydrodynamics and heat transfer in tubes with smooth and ribbed twisted tape inserts, *J. Enhanced Heat Transf.*, vol. **20**, no. 6, pp. 511–518, 2013.

Zhang, J., Kundu, J., and Manglik, R. M., Effect of fin waviness and spacing on the lateral vortex structure and laminar heat transfer in wavy-plate-fin cores, *Int. J. Heat Mass Transf.*, vol. **47**, no. 8–9, pp. 1719–1730, 2004.