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Commentary

Challenges and Strategies for Growth of Thermal Spray Markets: The Six-Pillar Plan

Thermal spraying today has become one of the leading surface technologies alongside physical vapor deposition and weld overlaying. The process, due to its high throughput, simple operation, and versatility, offers clear advantages over competing technologies. Thus, thermally sprayed coatings have been employed in many fields including aero and industrial gas turbines, automotive, oil and gas, pulp and paper, metal processing, and biomedical and electronics industries.

Today, it is estimated that the TS industry is worth approximately $6.5 billion with the majority of revenue generated in coating services (Fig. 1a) (Ref 1). Approximately two-thirds of this market is split evenly among North America and Europe/Middle East. The balance is from the rest of the world (Fig. 2). The growth rate of the industry has been the highest for Asia and South America (Ref 2-6). In particular, there has been a dramatic increase in research and development activity from China over the last 5-10 years. This is highlighted in Fig. 3 which shows the number of technical manuscripts submitted to the *Journal of Thermal Spray Technology* (JTST) during 2004-2010.

In terms of market segmentation, approximately 60% of the total TS market belongs to the turbine industry, 15% to automotive, and the remaining 25% is distributed over a large number of other industries (Fig. 1b). Future growth of the TS market will continue to depend on the growth of turbine industry which will happen either by advancement of coating technologies or by a wider penetration into new geographical regions. However, a greater growth potential exists in the ''other'' industries where currently the penetration of TS is low. One such area is energy generation using conventional or renewable resources which is the focus of this volume of the JTST. Other markets of interest include oil and gas, pulp and paper, metal processing, and biomedical and electronics industries. Many of these applications will still use traditional thermal spray (TS) technology (i.e., equipment and consumables) and use coatings in their traditional role as protective barriers against heat, mechanical wear, chemical attack, etc. Others will require a more advanced technology and material/process control to fulfill the stringent requirements associated with the new applications. Recent developments of a number of additional variations of the TS processes such as cold spraying, solution/suspension spraying, and low pressure plasma spraying hybrid technologies (Ref 7-9) have demonstrated the potential to further extend TS to a vast variety of applications. There has also been dramatic growth in online process diagnostic sensors in accordance with the need for improved process reliability and control. These technological developments are indeed required to meet the challenges of an ever-demanding market. But, are mere technological advancements enough to achieve TS market growth? What else needs to be done to achieve greater outreach and acceptance of TS technology for new markets and new applications?

In addition to technological developments, there are other critical factors that need to be addressed to achieve successful market growth. These are (1) young professional recruitment, retention, and training, (2) technology outreach, (3) role of professional and trade associations, (4) reduced time to technology transfer, (5) lowering the cost of ownership relative to competing technologies, and (6) environment, health, and safety. A ''six-pillar'' strategic plan for the successful growth of TS markets supported by these six key factors is schematically shown in Fig. 4. As will be seen in the following discussion, these elements with distinct functions for the support of TS market growth, are fairly intertwined with one another.

1. *Young professional recruitment, retention, and training*: Several university professors and students identify the need for better communication between industry and universities to promote TS technology and the potential for professional careers in the TS field. To bring the technology into the mainstream, it is suggested that TS be introduced as a subject in relevant engineering programs. Guest lectures from industry experts can be made a part of such a course. Industrial internships can provide the students an early experience for the real world and may generate interest in a professional career in TS. Government and private/industry scholarship opportunities for individuals can attract talent to the field. It has been seen that the academic institutions running large and multidisciplinary TS research and teaching programs provide the best training and have been highly successful in popularizing the technology among the students. Usually, it is also seen that large programs are further supported by funding from both academia and industry. However, the key question is what it would

take to help the growth of the smaller TS research programs to reach that critical mass. Industrial funding will generally increase only when there is a direct and short-term gain for the industry. Also, the job opportunities available for the TS engineers/technologists/scientists is proportional to size of the TS industry itself, which depends on the number of different application areas where TS is used as a leading technology which links back to the academic research. Therefore, more effort needs to be focused on attracting government funding by informing them about the mid/long-term values of the technology. Improved awareness of its value in sustainable manufacturing areas in energy, resource savings, environmental preservation, security, and other strategic areas may lead to increased government funding (seed money) for research in the field. The industry makes an investment in the recruited young professionals by training them and providing necessary experience, and hence it is necessary to retain them to get a return on the investment. Therefore, strategies should be put in place to keep the young talent continuously challenged and motivated. Management needs to invest in people and understand that it takes time, commitment, and patience. Employees need to be encouraged to fearlessly take challenging assignments and not be afraid of failure. Further development can be realized via internships, continued training, job rotations, etc. The Commonwealth Center for Advanced Manufacturing (CCAM) and the Center for Thermal Spray Research (CTSR) at Stony Brook University are just a few examples of leadership in investing in people and technology to help the markets grow. Such involvement of leaders in the overall health of the industry and not just their own company would bring profitability for everyone.

2. *Technology outreach: reliability and trust issues*: Technology outreach is one of the key factors for the growth of the TS industry. Industries outside of the traditional market of TS present a much greater opportunity for growth provided that the TS technology can attract their attention. Many industries are remotely aware of the TS technology, but are concerned about process capability, reliability, and consistency. These latter industries find the simplicity, versatility, and cost-effectiveness of the process attractive, but cannot tolerate the limitations that come along with it. The lack of trust in the capability of TS technology is one of the reasons why many industries have not embraced it. Today, TS processes have become more controlled with the implementation of in-process diagnostic sensors and controls. There have also been major developments in materials and equipment technology as a result of our improved understanding of the processes. It is critically important to demonstrate the abilities of modern TS technology through the publication of technical papers as well as presentations in important conferences

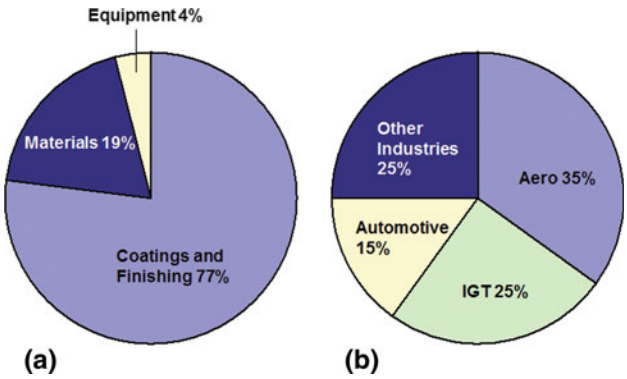

Fig. 1 TS markets: (a) breakdown by industry, (b) breakdown by supply/service type

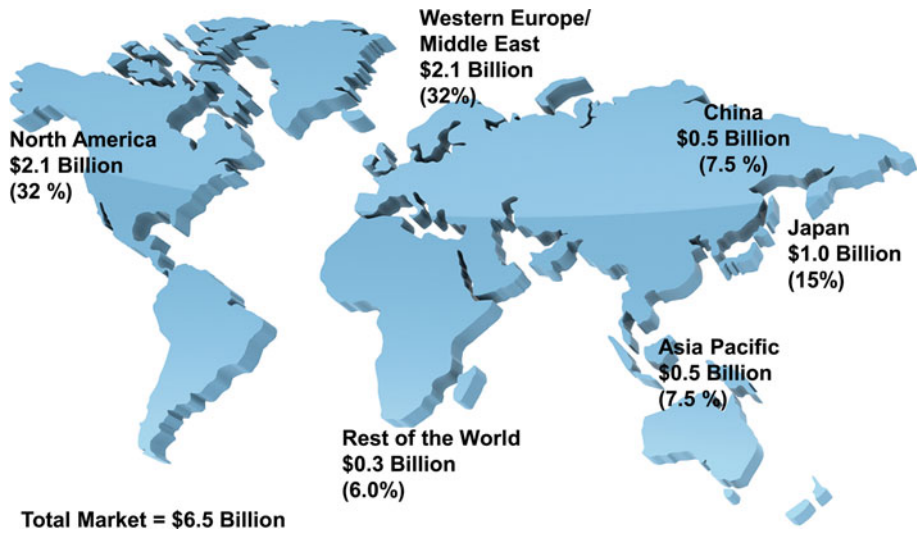

Fig. 2 TS markets: regional breakdown

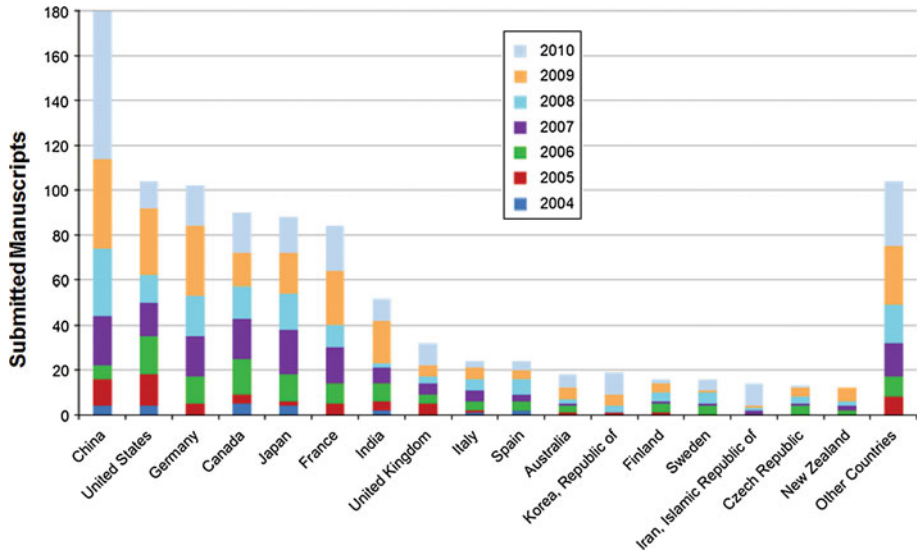

Fig. 3 Number of technical papers submitted to the *Journal of Thermal Spray Technology* in 2010

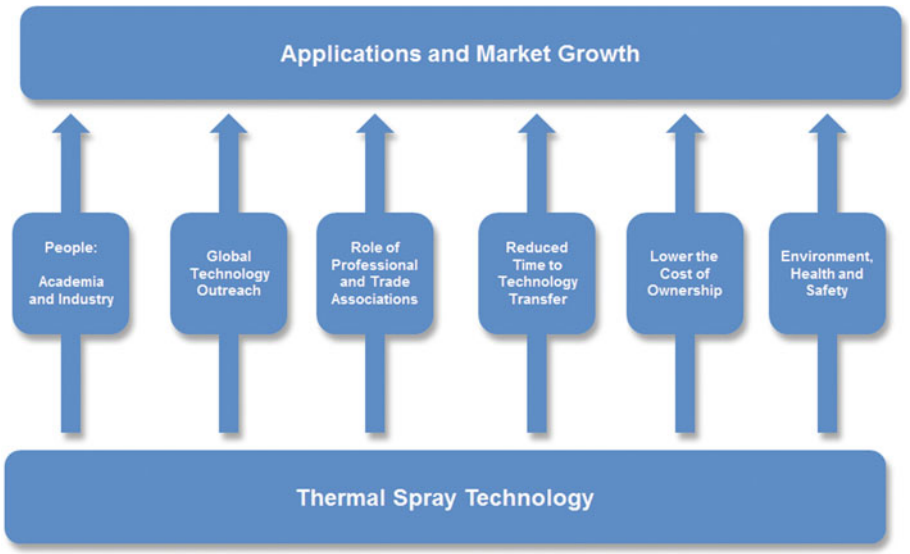

Fig. 4 Thematic representation the ''six-pillar'' plan

outside the boundaries of TS where prospective customers from other industries may be present. Such information can also be presented to customers on a one-on-one basis. Well-structured information supported by scientific data would be very helpful in addressing the trust issue. One important factor realizing this effort would be to provide proper operation-level knowledge and hands-on training to TS operators.

3. *Role of professional societies and trade associations*: The principal role professional societies and trade associations play is to be the resource for technical information related to TS and help to develop people via education and training. Publication of books and journals, classroom training, and online seminars are some of the primary ways for professional societies to disseminate knowledge and educate individuals about the field. One way in which professional societies can potentially help the growth of the market is by providing information to the government about the possible applications of TS technology in the areas of critical importance. This can help generate funding from government grants for further research at academic and/or commercial institutions. Another way in which societies can support market growth is through education classes, technical papers, and networking at

conferences outside of the traditional TS area. For this type of outreach to happen, increased cooperation is needed between societies with potentially reciprocal memberships. In addition, professional societies can help the development and growth of markets by promoting technical conferences and expositions in emerging markets. Collaborative programs with professional societies outside of the TS field can be of great value in allowing outreach to new people and industries. Participants from universities, industry, and government can exchange information to solve their day-to-day problems. An efficient website with a fast search engine is critical for the visibility of an organization and its resources to internet users. Furthermore, the societies should find ways to take advantage of social networking media to promote themselves and raise awareness of TS among the populace. Greater promotion of case studies where TS has been the technology behind the success stories might inspire others to learn about it and possibly adopt it as a technical solution.

4. *Reduced time to technology transfer*: Many R&D managers in government and University laboratories recognize that the time from an idea to actual commercialization is too long. It is not uncommon for some products to take ten or more years from inception to commercialization. There are many factors that contribute to the lead time such as the technology drivers, level of collaboration, and people involved. It is often seen that the speed of technology research, development, and acceptance is much faster when it is driven by market needs compared to when a new concept developed in academic research is introduced in the market. The growth of traditional TS technology and processes with the needs of the aerospace industry is a clear example of the same. The level of collaboration among industry, government, and universities for a given technology is another factor affecting the lead time. A greater collaboration will definitely help the technology to grow faster. CCAM is an example of an organization the purpose of which is to bridge the gap between research and commercialization. A goal of the collaboration is to accelerate technology into the market with a secondary goal to demonstrate technological solutions for real problems. The cost of R&D will be reduced because it will be shared between partners. If successful, the program will train the next generation of technology leaders and give marketable experience to young professionals. More information on the CCAM initiative is available at http://www.ccam-va.com/.
   Yet another challenge is the difference in the primary focus of various collaborators and associated timescales. The timescales for academic institutes with interest in the scientific understanding of the problem may be longer than that of an industrial collaborator interested in a marketable product. Therefore, effort needs to be invested in project planning with proper workload distribution and resource allocation in order to reduce the overall lead time.
5. *Reduced cost of ownership relative to competing technologies:* The implications of reduced cost of ownership are lower production costs which translate into improved financial returns for the end user. For example, higher efficiency power turbines with longer service lives will potentially reduce the cost of electricity for consumers. In the short term, cost reduction can be realized through measures including forward or backward integration, diversification into related processes, and consolidation and expansion into emerging markets. In the long run, investments in technological innovation and process development research are required to enhance the capabilities and manufacture more reliable and consistent products (coating solutions) at a reduced cost. Some examples where the cost of ownership may be reduced through innovation are new equipment technology and processes such as plasma spray-physical vapor deposition (PS-PVD) and suspension spray which may result in significant cost savings compared to traditional electron beam-physical vapor deposition (EB-PVD) technology where capital costs are significantly higher. Again, although these new TS technologies are in their infancy, effort must be made for market development by communicating their capabilities to prospective customers.
6. *Environment, health, and safety*: Like many other engineering industries, TS and related operations pose a number of potential environmental, health, and safety (EH&S) issues (Ref 10). EH&S is an important issue for all areas of the TS community and is absolutely critical for its successful growth. This topic is further complicated by today's globalized nature of the business. Thus, in many cases, it is no longer sufficient to comply with just the local, state, and national regulations of any one country, but across international borders as well. In the United States, the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) are two federal regulatory agencies relevant to the TS industry. In Europe, the EU regulations called REACH (Registration Evaluation Authorization and Registration of Chemicals) impact all chemical substances manufactured or imported into Europe since it was established in 2007. To meet these challenges, the TS community needs to establish standard operating instructions, personal protective equipment and procedures for the proper handling of harmful waste, and improved training programs on EH&S. Many professional societies have safety committees to address many of these issues. For example, ASM-TSS has ''Thermal Spray Safety Guidelines'' as a free, nonmember community service on (1) risk assessment, (2) personal protective equipment, (3) OSHA standards for hexavalent chrome, (4) spray booth design, (5) gas handling, etc. (Ref 11). Future standardization should be on more consistent documentation on Material Safety Data Sheets (MSDS) and packaging and labeling. While training and standardization are necessary for any industrial process, it is worth mentioning here

that in some cases, TS has already been shown to be a more environmentally friendly and sustainable technology (Ref 12). At present, HVOF sprayed carbide coatings are being used as a replacement for chromium electroplatings for aircraft landing gears and hydraulic rods in industrial applications (Ref 13-15). Such examples of environment friendly, sustainable manufacturing are desirable for gaining support for market growth.

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References

1. P. Hanneforth, The Global Thermal Spray Industry—100 Years of Success: So What's Next?, *iTTSe*, Vol 1, No 1, ASM International, Materials Park, May 2006, p 14-16
2. M. Fukumoto, The Current Status of Thermal Spraying in Asia, *J. Therm. Spray Technol.*, 2008, **17**(1), p 5-13
3. G. Sundararajan, Y.R. Mahajan, and S.V. Joshi, Thermal Spraying in India: Status and Prospects, *Thermal Spray 2009: Proceedings of the International Thermal Spray Conference*, B.R. Marple, M.M. Hyland, Y.-C. Lau, C.-J. Li, R.S. Lima, and G. Montavon, Eds., ASM International, Materials Park, 2009, p 511-516
4. C. Lee, Market Direction and Application Opportunities for T/S Growth in Korea, *Thermal Spray 2009: Proceedings of the International Thermal Spray Conference*, B.R. Marple, M.M. Hyland, Y.-C. Lau, C.-J. Li, R.S. Lima, and G. Montavon, Eds., ASM International, Materials Park, 2009, p 505-510
5. A. Nakahira, Current Status and Future Prospect of Thermal Spray Coating Applications and Coating Service Market of Job Shops in Japan, *Thermal Spray 2009: Proceedings of the International Thermal Spray Conference*, B.R. Marple, M.M. Hyland, Y.-C. Lau, C.-J. Li, R.S. Lima, and G. Montavon, Eds., ASM International, Materials Park, 2009, p 499-504
6. A. Valarezo, Latin America: An Emerging and Growing Market for Thermal Spray, Oral presentation, *International Thermal Spray Conference 2012*, Houston, TX, 2012
7. E. Irissou, J.-G. Legoux, A.N. Ryabinin, B. Jodoin, and C. Moreau, Review on Cold Spray Process and Technology: Part I—Intellectual Property, *J. Therm. Spray Technol.*, 2008, **17**(4), p 495-516
8. A. Killinger, R. Gadow, G. Mauer, A. Guinard, R. Vaßen, and D. Stöver, Review of New Developments in Suspension and Solution Precursor Thermal Spray Processes, *J. Therm. Spray Technol.*, 2011, **20**(4), p 677
9. M. Gindrat and R. Damani, LPPS Hybrid Technologies for Emerging Energy Applications—Recent Developments, *International Thermal Spray Conference & Exhibition ITSC 2011*, DVS-ASM, Hamburg, 2011, p 387-393
10. H. Hériaud-Kraemer, G. Montavon, C. Coddet, S. Hertert, and H. Robin, Harmful Risks for Workers in Thermal Spraying: A Review Completed by a Survey in a French Company, *J. Therm. Spray Technol.*, 2003, **12**(4), p 542-554
11. http://tss.asminternational.org/portal/site/tss/SafetyGuidelines. Accessed 30 Jan 2013
12. N. Krishnan, A. Vardelle, and J.G. Legoux, A Life Cycle Comparison of Hard Chrome and Thermal Sprayed Coatings: Case Example of Aircraft Landing Gears, *International Thermal Spray Conference 2008: "Crossing Borders"*, DVS-ASM, Hamburg, 2008, p 212-216
13. M.C. Nestler, G. Prenzel, and T. Seitz, HVOF-Spraying vs. Hard Chrome Plating—Coating Characteristics and Aircraft Applications, *Thermal Spray 1998: Meeting the Challenges of the 21st Century*, ASM International, Materials Park, 1998, p 1073-1078
14. D.S. Parker, Case Study: Application of HVOF Sprayed Coatings for Replacement of Chrome Plating on Navy P-3 Aircraft Hydraulic Components and Landing Gear, *Thermal Spray 1998: Meeting the Challenges of the 21st Century*, ASM International, Materials Park, 1998, p 243-248
15. B. Evans, R. Panza-Giosa, E. Cochien Brikaras, and S. Maitland, HVOF-Applied WC-Co-Cr as a Hard Chrome Replacement for Landing Gear, *Thermal Spray 2006: Science, Innovation, and Application*, ASM International, Materials Park, 2006, p 615-617