A cognition-based human–machine interaction approach for thermal spraying

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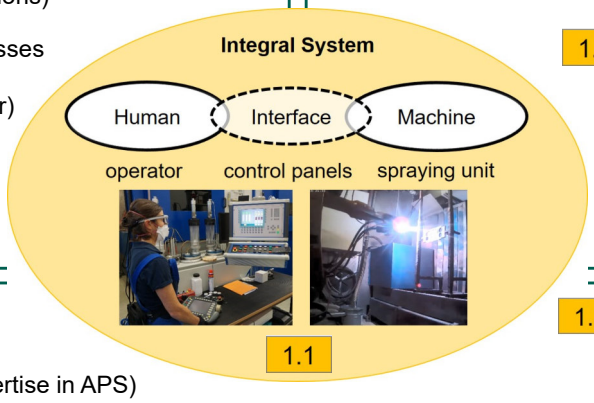
The development of cyber-physical production systems and industry 4.0 is a central goal of the German research initiative (High-Tech Strategy 2025). Complementary to this aim, we propose a cognition-based human–machine interaction approach and apply it in the context of manufacturing (coating technology). To analyze technical and cognitive processing, operator's glance behavior was tracked and matched to expert knowledge. This combined data- and expert-driven method reveals insights into the operator's attention and information search processes. These processes are central to an understanding of human monitoring and control of the thermal spraying process and are the basis for the development of technical assistant systems.

Cognition-based human–machine interaction (Co-HMI)

Co-HMI aims to enhance transparency and comprehensibility of HMI in complex technical processes by:

1. Holistic analysis
   - 1.1 Systems analysis (e.g., components of the integral system, technical process, influencing factors)
   - 1.2 Psychological task analysis (e.g., process stages, tasks and subtasks, operations)
   - 1.3 Analysis of cognitive processes (e.g., visual attention and information search behavior)
2. (Cognitive) Modeling
3. Model test and evaluation
4. Engineering results assessment

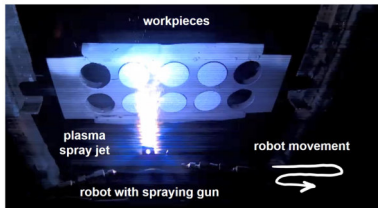


Thermal spraying: atmospheric plasma spraying (APS)

- Complex manufacturing technique for instance for wear and corrosion resistance and thermal barrier coatings
- Many influencing factors (e.g., process/substrate conditions, spray jet and spray particles) ➔ expert knowledge is crucial for process control
- Process stages:

1.2 Manufacturing order: Part drawing ➡ Preparation → Coating → Control → Postprocessing; Control → Coating (loop); Control → Delivery of final result

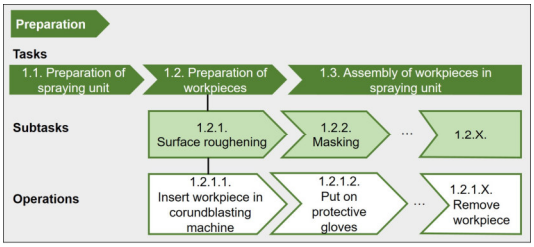
1.1 Technical components of the spraying process

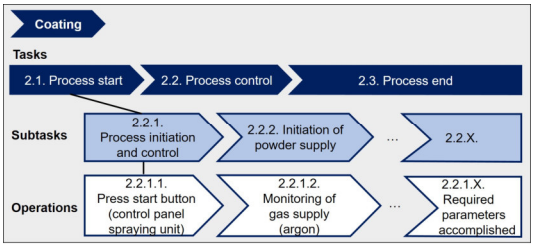


1.2 Interview and observation

Subject: expert operator (10 years expertise in APS)
Task: coating of workpieces with APS

Psychological task analysis:



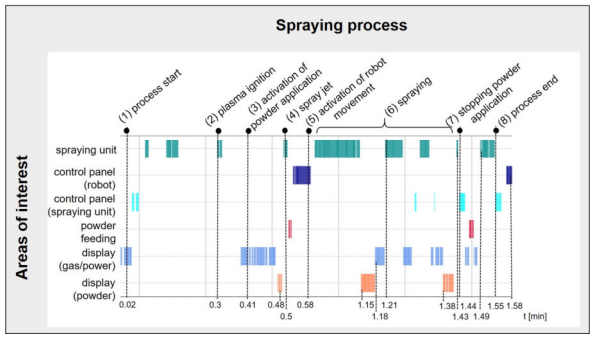


1.3 Eye-tracking study and retrospective think-aloud technique

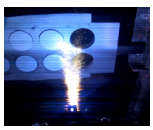
- longest dwelling times for areas of interest (AOI) „spraying unit" (20.8%) and „display gas/power" (20.7%)
- more and shorter fixations for „display gas/power" (96; 305.5 ms) than for „spraying unit" (63; 497.6 ms)

➔ control of process parameters is easier than control of spray spot
➔ information about plasma spray jet should be included in control displays

Operator's visual attention and information search behavior matched to expert knowledge



AOI „spraying unit"



„display gas/power"

Future prospects

- Cognitive modeling of eye-tracking data and expert knowledge using (adaptive) fuzzy pattern classification [1], [2]
- Development of advanced interaction displays and cognitive assistance systems to support the operator (e.g., depending on level of expertise)
- Implementation of cognitive processes and human issues in cyber-physical production systems [3]

References

[1] Bocklisch, F., & Hausmann, D. (2018). Multidimensional Fuzzy Pattern Classifier Sequences for Medical Diagnostic Reasoning. *Applied Soft Computing*. DOI: 10.1016/j.asoc.2018.02.041
[2] Bocklisch, F., Bocklisch, S.F., Beggiato, M. & Krems, J.F. (2017). Adaptive Fuzzy Pattern Classification for the Online Detection of Driver Lane Change Intention. *Neurocomputing*, DOI: 10.1016/j.neucom.2017.02.089
[3] Bocklisch, F., Drehmann, R., & Lampke, T. (in press). Kognitionsbasierte Mensch-Technik-Interaktion in Cyber-Physischen Systemen am Applikationsbeispiel Thermisches Spritzen, MONARCH TU Chemnitz https://monarch.qucosa.de/

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