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Alternate Processes for In-service Welding
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Conducting weld deposition repairs and attaching hot-tapping sleeves to in-service pipelines has the incentive of avoiding loss of service and revenues. However, welding procedures must be applied with precise control of many variables to avoid burn-through and hydrogen induced cold cracking. Recently, procedures have been investigated and developed for the application of Shielded Metal Arc Welding to in-service pipeline repair, however the consistency of welding cannot be easily controlled with this process due to its manual application. Therefore, alternate processes need to be investigated that can be applied with mechanized travel and torch control to minimize the variability in applying repair procedures. The Gas Metal Arc Welding, Gas Shielded and Self Shielded Flux Cored Arc Welding, and Metal Cored Arc Welding processes are wire fed processes that have the advantage and ability to be applied with mechanized travel and torch control, and are therefore the focus of this study.

The tasks involved in developing welding procedures for in-service pipeline repair with the aforementioned processes on X52 and X80 pipeline grade materials, are:

1. Review the literature from industry and available pipeline research reports, and summarize the elements of currently recommended procedures for welding on in-service pipelines. Select pipe grades and welding electrodes for investigation.
2. Establish practical welding parameter ranges for direct deposition and fillet welding with each process / electrode combination.
3. Examine the critical thickness for burn-through to occur with each process.
4. Characterize the 800 to 500ºC cooling rate's vs. heat input and arc efficiency of each process. Evaluate productivity characteristics of each process / electrode combination by performing deposition rate tests.
5. Establish diffusible hydrogen characteristics for each consumable / process combination.
6. Establish inspection and delay time requirements to inspect for hydrogen induced cold cracking with each welding process and material, using BMT's hydrogen diffusion and cracking model software. This software is described below:

BMT and Graville Associates have developed an engineering tool for multi-pass weld hydrogen management which predicts the effects of welding procedure parameters on weldment thermal history and hydrogen diffusion. The BMT Hydrogen Diffusion and Cracking Model considers a wide range of welding parameters, ambient environmental conditions and material parameters which influence the hydrogen diffusion process and hence the time to peak hydrogen in a weldment.

The current model considers a wide range of welding, environmental and material parameters influencing the risk of hydrogen cracking. These parameters include:

- Welding Procedure Parameters
  - weld pass deposition timing
  - weld pass heat input
  - idealized weld pass geometry
  - weld metal initial hydrogen conc.
  - weldment pre- and post-heating
    - temperature and width of heating
    - heating duration and timing
- Material Parameters
  - hydrogen diffusivity
  - thermal conductivity
  - chemical composition
- Environmental Factors
  - ambient temperature and weather
  - external heat source or sink history
  - external hydrogen source history
  - applied load history.

7. Characterize and compare the cooling rates of each process on the BMT flow loop, using still air, flowing air, water-mist-spray, and flowing water to simulate a range of operating conditions.
8. Validate procedures by performing sleeve fillet welds with mechanized equipment and qualify by applying the test matrix and requirements of API 1104 specification.

To-date Tasks 1A, 2A, 3A, 4A, 5A, and 6A have been completed for the GMAW and SS-FCAW processes, as well as the benchmark SMAW process. Task 7A has also been partially completed for the aforementioned processes that examine static air, flowing air, and water mist spray variables. Task 2B, 3B, and 4B have been completed for the GS-FCAW and MCAW processes and Tasks 5B and 6B are partially completed with the exception of sleeve fillet weld modeling which will be reported later in the project as required.

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