H2Pipe JIP – Development of guidelines for design of offshore hydrogen pipelines

Erling Østby1, Ramgopal Thodla2, Jan Fredrik Helgaker2, Leif Collberg3, Agnes Marie Horn3

1DNV
Havik, Norway
2DNV
Columbus, Ohio, USA

ABSTRACT
The potential role of hydrogen as an important energy carrier in the new energy mix is receiving a lot of attention. The option of transporting hydrogen in pipelines is highly relevant in this respect. At the same time, it is known that hydrogen may have a detrimental effect on steel properties, which could pose restrictions in design of such pipelines. Currently, some experience exists when it comes to transporting hydrogen in onshore pipelines, and some codes (e.g. ASME B31.12) have been developed to provide guidelines on design. There is an interest to also develop projects including offshore pipelines for H2 transport. Offshore pipelines pose some new design challenges, e.g. higher axial loads (both cyclic and static) and typically higher pressures. As a response to these challenges DNV has launched the H2Pipe Joint Industry Project with an objective to develop a guideline for design and potential re-purposing of offshore pipelines for H2 transport. This paper gives a status summary of the guideline work in the JIP and presents results from mechanical testing performed in Phase 1 of the JIP.

KEY WORDS: Hydrogen, Pipelines, Environmental Effects

INTRODUCTION
Hydrogen is assumed to be an important part of tomorrow’s energy mix. C-Mn pipelines are considered a highly relevant means of transporting H2 gas in this respect. The recently increased interest is likely due to that it in addition to transporting energy may also be used for storing energy. Both design of new and re-purposing of existing pipelines are relevant scenarios. At the same time, it is well known that hydrogen may have a detrimental effect on the properties of steels, resulting in what is often termed “hydrogen embrittlement” (HE). HE might lead to significantly reduced ductility in steels. In addition to reduction in ductility, it is also likely that hydrogen leads to increased susceptibility under fatigue loading as well as a decrease in fracture resistance. It is necessary to have a sufficiently detailed knowledge on the magnitude of these effects in order to allow for safe yet cost-effective pipeline solution for transport of H2. Despite having been known for about 150 years, there are still significant uncertainties regarding the actual mechanisms controlling HE. There is already some experience with H2 transport on onshore pipelines. Further, guidance regarding design of such can be found in ASME B31.12 and IGEM/TD/1. However, offshore transport of H2 is also a relevant scenario, and no experience exists in this respect. Offshore pipelines offer some additional challenges like more cyclic loading, larger operational loads, and special accidental loading scenarios. In order to address these challenges DNV has launched the H2Pipe JIP with the ambition to provide guidelines for design and re-purposing of C-Mn pipelines for offshore H2 transport. The focus of the paper will be towards structural integrity issues of H2 pipelines while flow and transport capacity issues will not be addressed. First limit states and special challenges for offshore pipelines are discussed. Then a brief outline of HE is presented together with a short summary of existing codes for design of H2 pipelines. This is followed by a presentation of key experimental findings from Phase 1 of the JIP and an outline of the current status of the Guideline document. The paper is concluded with a general discussion and key conclusions. Phase 1 of the JIP was concluded early in 2023 and a Phase 2 of the JIP was kicked off in early 2023 with the objective to close some of the main gaps identified in this paper.

LIMIT STATES FOR OFFSHORE PIPELINES
The design of a pipeline requires that the utilization of the pipeline is checked against a set of limit states to establish that the probability of any of these being exceeded is sufficiently low (see e.g. DNV-ST-F101 for an overview of applicable limit states to be checked for offshore pipelines). Checking the different limit states will typically require information about the pipe geometry, pipe material properties (including welds), functional loads, environmental loads and both internal and external environment (this latter being of particular importance for possible influence of hydrogen). The key different general categories of limit states are; SLS (serviceability limit states) and ULS (ultimate limit state), with the sub-groups fatigue limit state (FLS), and ALS (accidental limit states). As a part of these special limit states, like the fracture mechanics-based fatigue and fracture limits state and recently introduced concepts like the LLS (leak limit state), may be defined. The physical state for which the different limit states is checked against varies. Some are considering structural load carrying capacity (several of the ULS, e.g. maximum bending moment or