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Understanding the effect of soil particle size on corrosion behavior of natural gas pipeline via modelling and corrosion micromorphology

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ABSTRACT

The effect of particle size on the electrochemical corrosion behavior of natural gas pipeline steel in a 1.5 wt% NaCl sandy soil corrosive environment was investigated by standard quartz sand. A mathematical model of gas/liquid/solid three-phase boundary (TPB) zone and the soil particle size was developed, and then the theoretical calculation indicated that a critical particle size corresponded to 1.2 mm radius. The laboratory experiments indicated that the corrosion rate of natural gas pipeline steel increased with decreasing soil particle size to < 1.0 mm and was mainly determined by a cathodic reaction. Whereas the corrosion rate of pipeline steel increased with increasing soil particle size exceeding 1.0 mm and the dominant reaction was metal dissolution in the bulk zone and the corrosion rate was determined by anodic reaction. The modelling result is in good agreement with experimental data.

1. Background

The No.1 West-East Gas Pipeline (1-WEGPL) Project was developed to transmit natural gas from the western part of China to the east, travelling about 4000 km. Furthermore, two thirds of the pipeline is buried in the desert of saline soil in Northwest China [1], as shown in Fig. 1(a). The integrity of gas pipeline is maintained by a three-layer PE coating and cathodic protection (CP). The 1-WEGPL serviced well during the early period, however, soil corrosion problem became increasingly serious with the service time increased [2]. Fig. 1(b), (c) and (d) shows the severity of in-situ pipeline corrosion from the Lunnan, Hami and Liuyuan stations, respectively. Fig. 1(b1), (c1) and (d1) are close snapshots of the corrosion products. Fig. 1(b2), (c2) and (d2) are the close-ups of corroded surface. Obviously, the pipe steel suffered more serious corrosion in Liuyuan and Lunnan stations than that in Hami station, evidencing by the corrosion morphologies of pipe steel and the large number and depth of corrosion pits on the metal surface. According to the analysis of the physical and chemical properties of soil around these stations, the water content, salinity and chemical composition of soil samples in Liuyuan, Lunnan and Hami stations are different. The details are includes in appendix. Moreover, it is worth noting that the particle sizes of the soil in Lunnan station is the smallest, and in Liuyuan station is the biggest, while in Hami station is the medium size. This is resulted from the more serious wind erosion in Lunnan which is in the vicinity of the Taklimakan Deseret.

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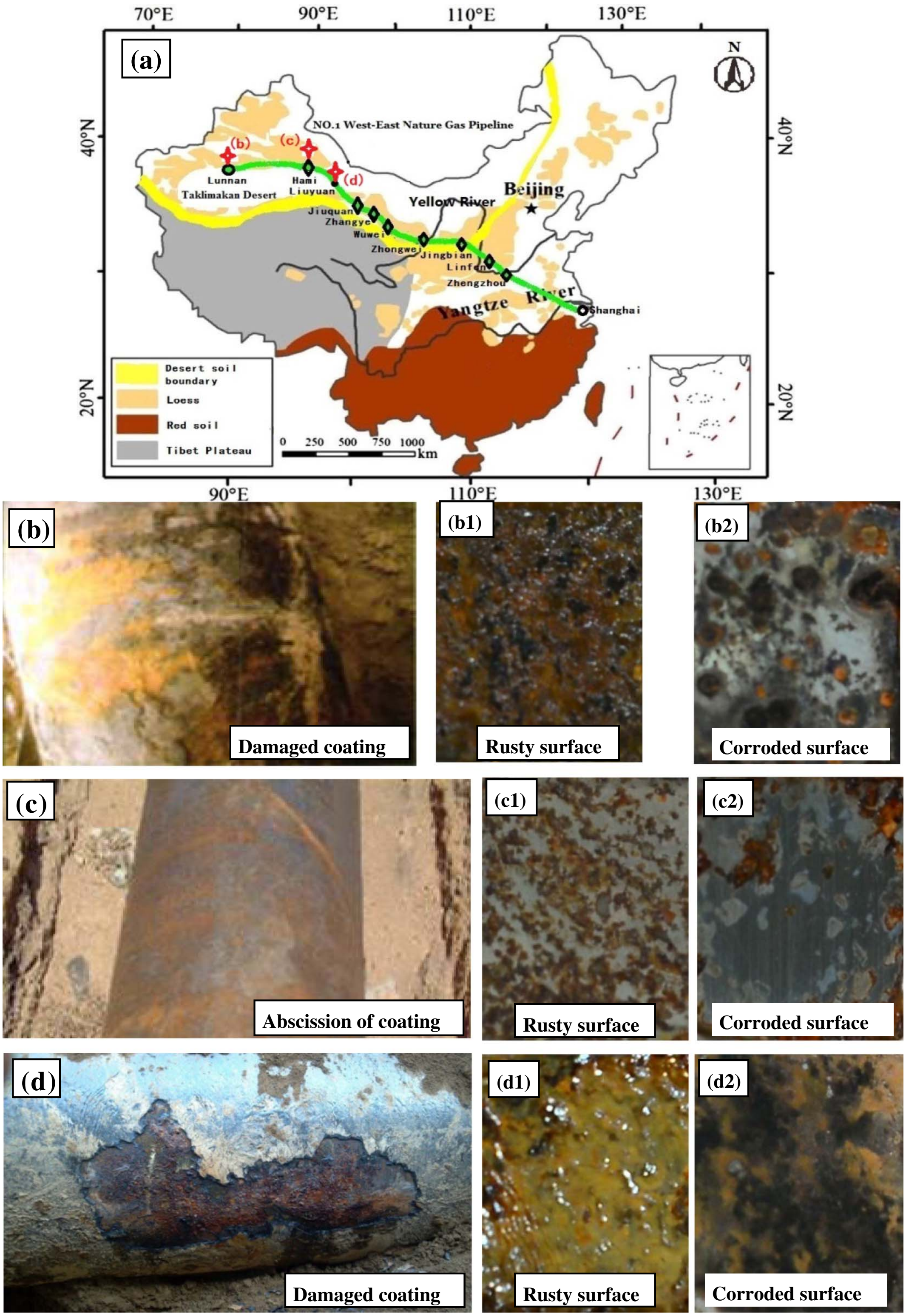

Fig. 1. The 1-WEGPL of China (green line): (a) the desert regions of China (north of the yellow line); (b) A view of coating failure and the corroded pipeline in Lunnan station; (b1) and (b2) is the close-up of the corroded gas pipeline of rusty and corroded surface in Lunnan station, respectively; (c) A view of coating failure and the corroded pipeline in Hami station; (c1) and (c2) is the close-up of the corroded gas pipeline rusty and corroded surface in Hami station; (d) A view of coating failure and the corroded pipeline in Liuyuan station; (d1) and (d2) is the close-up of the corroded gas pipeline rusty and corroded surface in Liuyuan station, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)