Mathematical Prediction of Oil Recovery Factor for Nanoparticles Assisted Polymer Flooding through Statistical Analysis and ANN Modelling

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Abstract

Conventional Polymer flooding is a promised CEOR technique. However, there are some shortages associated with molecular architecture destruction in severe reservoir environments. The grafting of nanoparticles (NPs) toward polymer macromolecule may ameliorate the flooding performance and hence increase the oil recovery further than conventional polymer flooding. The potential of NPs assisted polymer flooding has been extensively studied in porous media through core flooding. The target of this work is to statistically scrutinize the previous core flooding experiments and investigate the parameters that affect the incremental oil recovery by NPs assisted polymer flooding. More than 350 core-flood tests were gathered to investigate the impacts of rock-oil properties, flooding conditions, polymer, and NPs characteristics on incremental oil recovery. Furthermore, an empirical model was built using an Artificial neural network (ANN) to predict the incremental oil recovery for polymeric nanofluid. The results of the investigation indicated that NPs assisted polymer flooding with optimum concentration of both polymer and NPs may result in an incremental recovery of 18% of oil-in-place. In addition, the results revealed that core-flooded viscous oil needs high permeable rock to guarantee successful flooding. Coefficient of determination (R^2) between the real and calculated incremental oil from the ANN model was established to be 0.953 and 0.952 with an error of 5.6 and 8.7% respectively for the training and testing approaches. Such statistical investigations and ANN approaches afford new insights and guidelines for preliminary assessment, designing, and execution Nanohybrid polymer upcoming projects in field scale.

Keywords: Polymer flooding; Enhanced oil recovery; Statistical analysis; and Artificial neural network (ANN).

Introduction

On the field scale, it is well-established that great quantities (~ 60%) of original oil-in-place (OOIP) remain in reservoirs after both primary and secondary recovery stages. Several techniques are pursued for recovering these trapped oil amounts These techniques comprise the inoculation of nanomaterials and metal oxide through these polymeric matrices, which in turn enhance the rheological properties and shearing action of these composites.

Improvement of oil recovery through nanoparticles-assisted polymer flooding and nanoparticles-grafted polymer flooding relies on various aspects including rock wettability alteration, mobility control enhancement to mobilize oil, and interfacial tension (IFT) reduction . Polymer nanocomposites change rock wettability to hydrophilic wetness, so reduce capillary force, control the mobility ratio, and enhance the oil recovery. Numerous core flood experiments on the application of polymeric nanofluid for purpose of enhanced oil recovery have appeared to be feasible in harsh reservoir conditions. Nanofluids serve to decrease the operating pressure for the displacing fluid and the formation damage. Nanofluids including SiO2, ZnO2, TiO2, CuO, ZrO2, graphene oxide, and Fe3O4 have been reported as oil displacement agents, in which SiO2 and graphene oxide nanoparticles are widely reported in enhanced oil recovery. This research is an attempt to statistically investigate the findings of numerous core flood tests from the literature to acquire guidelines when planning, designing, and implementing upcoming nanohybrid polymer projects on a field scale. Furthermore, an empirical correlation for the incremental recovery factor of polymeric nanofluid-EOR using ANN based on the gathered results of core flooding was also developed.

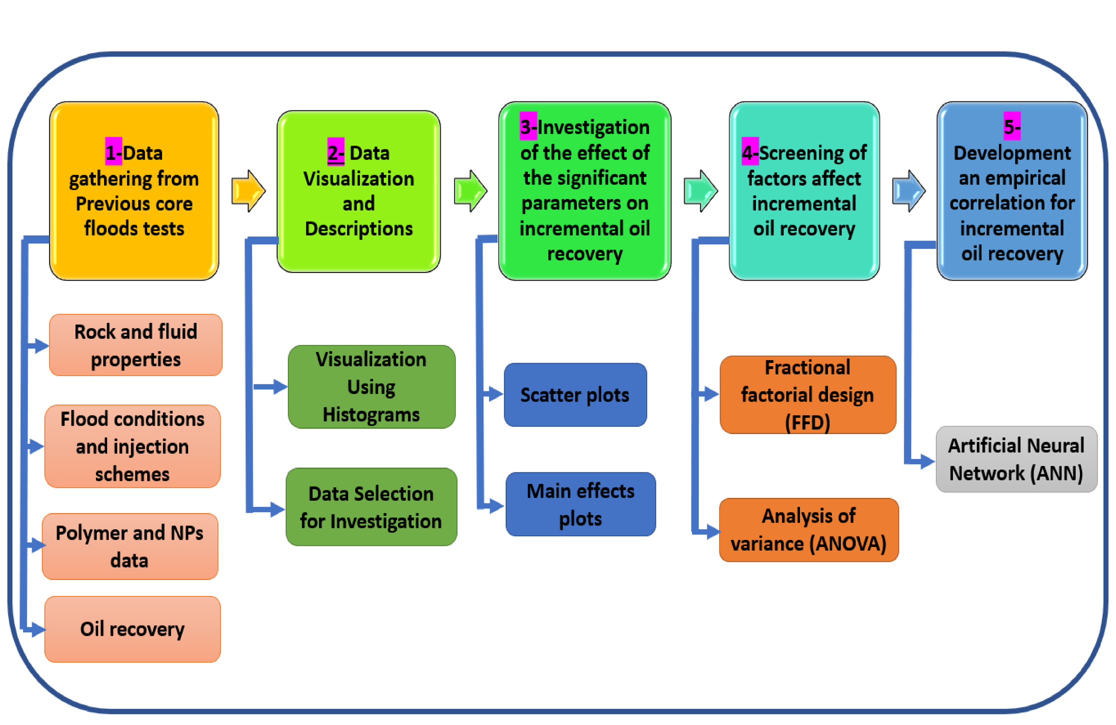
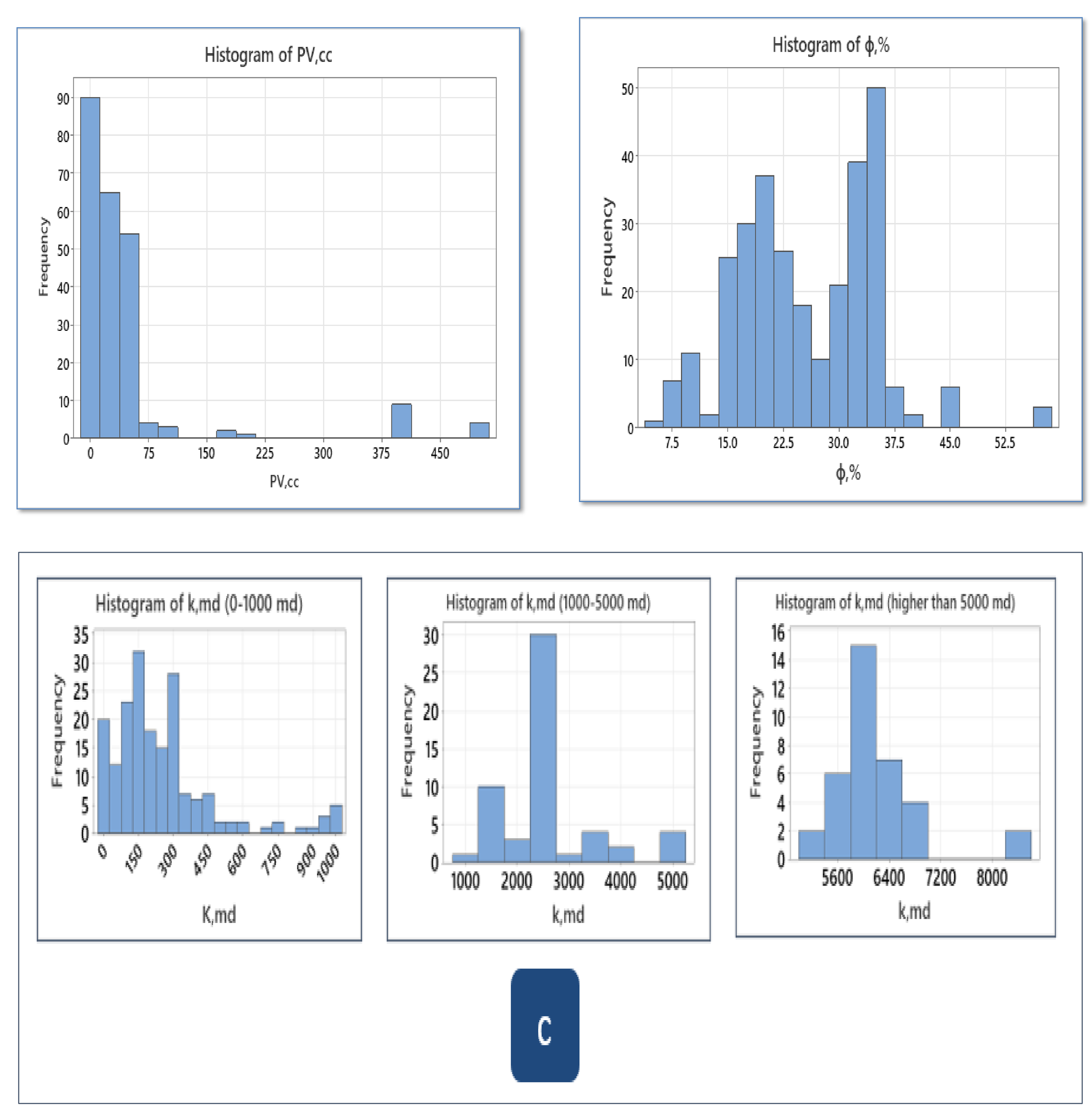


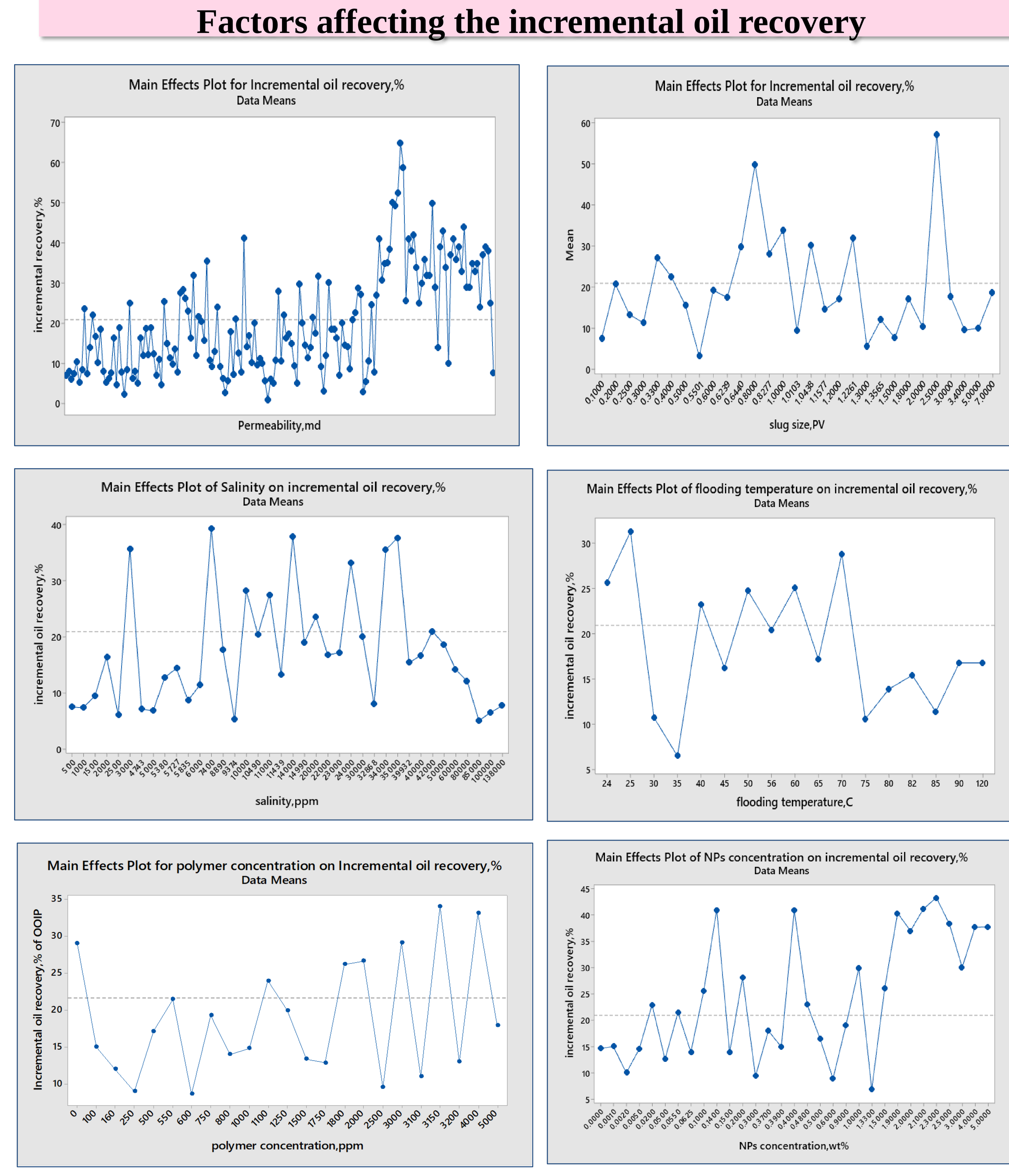
Figure (1): Framework of research methodology

Experimental Work

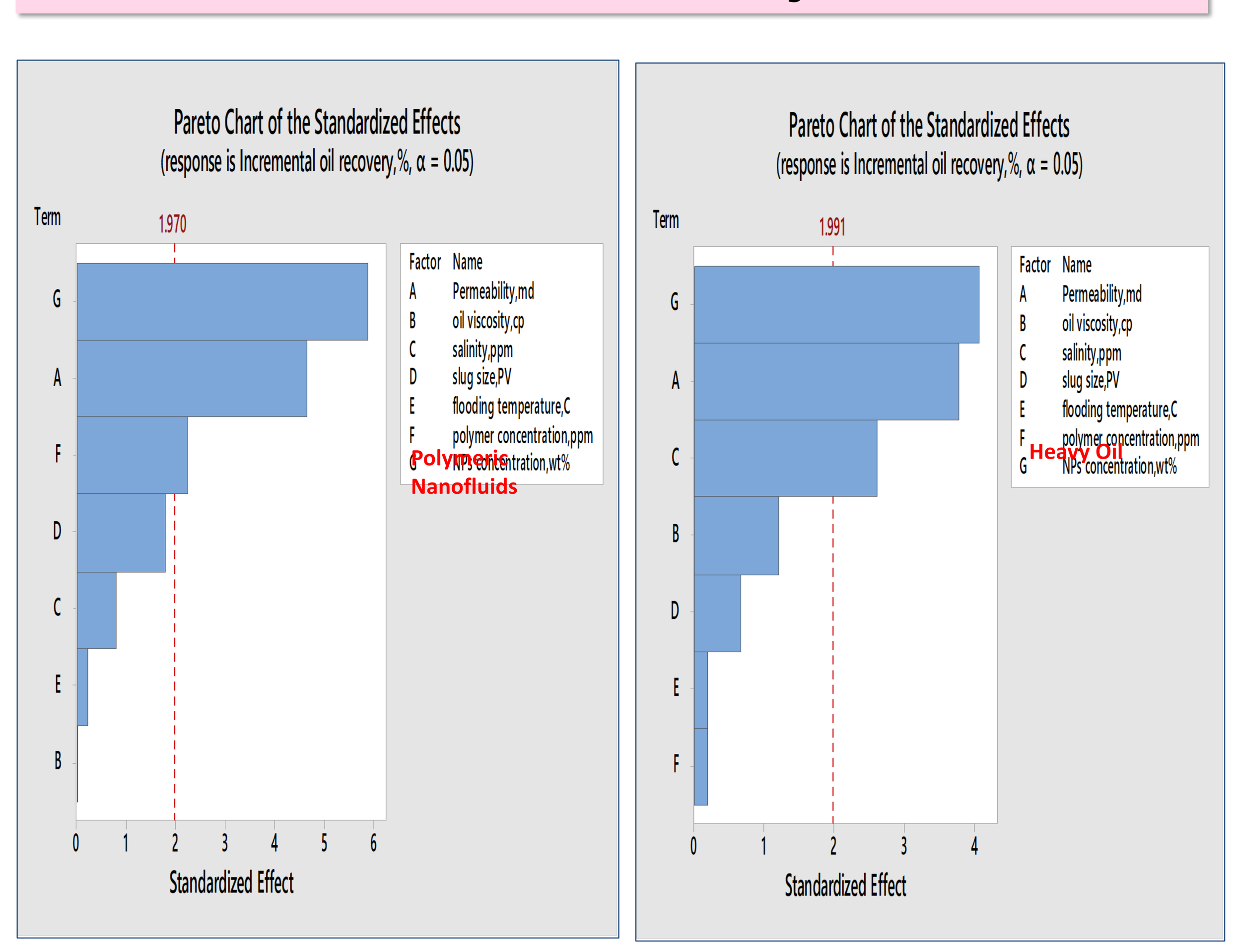
Datasets were compiled from the core flood experiments of nanoparticle-assisted polymer flooding published in the literature. This work gathered data from 60 publications with more than 350 experiments conducted in laboratory core flooding/displacement tests in sandstone and carbonate cores that used nanoparticle-assisted polymer flooding.



Assessment of Rheological properties and Factors affecting the incremental oil recovery

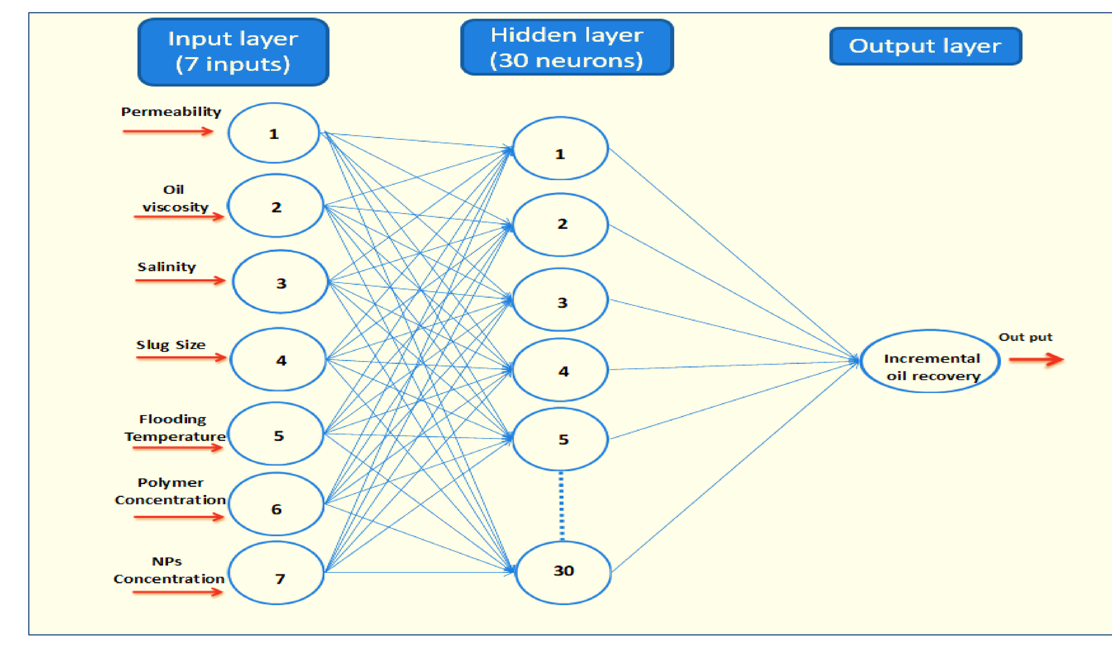


Statistical Analysis



Results& Discussion

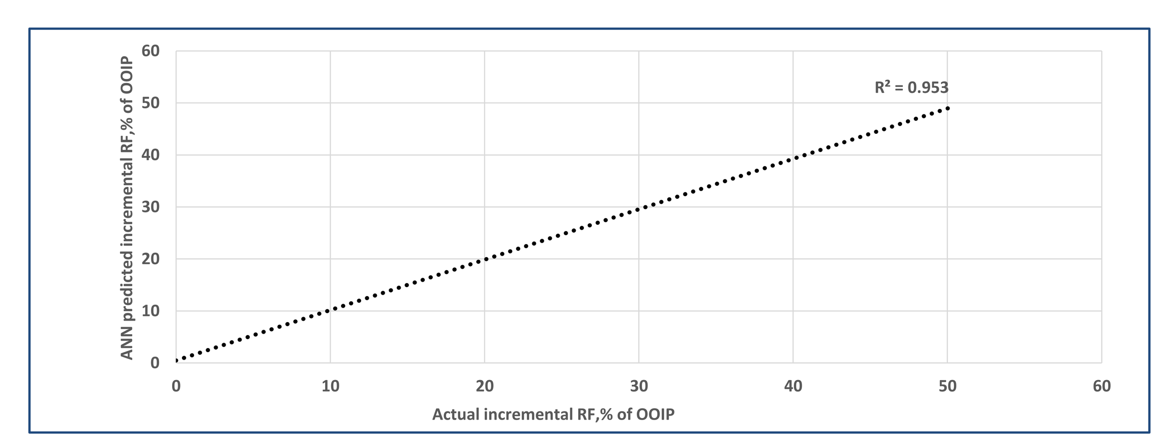
Machine Learning & Development of ANN Model

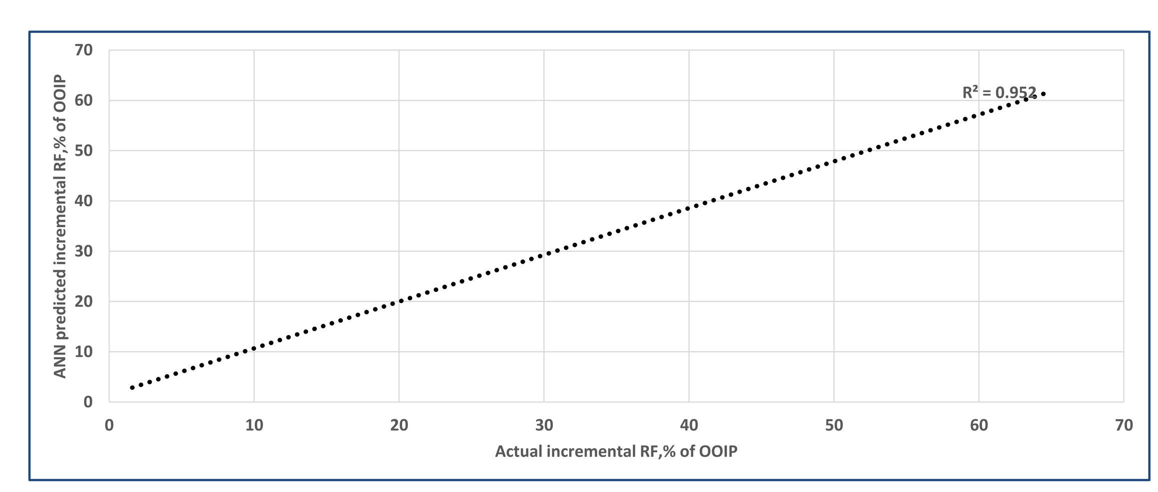


ANN Model Results

ANN was applied to 329 datasets to train and verify the model. Before ANN construction, the gathered dataset is randomly split into two categories (training and testing). 75% of the data (245 points) is dedicated to the training process, while 25% of the data (82 points) is assigned to testing and verification of the proposed ANN model.

$$RF_{\text{incr.}} = \left[\sum_{i=1}^{N} W_{2i} \left[\frac{1}{1+e^{-\left(W_{1i,1}A+W_{1i,2}B+W_{1i,3}C+W_{1i,4}D+W_{1i,5}E+W_{1i,6}F+W_{1i,7}G+b_{1i}\right)^{\wedge}2}}\right]\right]+b_2$$





Conclusions

A robust investigation was conducted and data from the literature were analyzed to develop new findings for NPs assisted polymer flooding. Additionally, a new empirical correlation was developed using ANN to predict the incremental oil recovery. The following conclusions can be depicted:

- There is an optimum NP concentration, optimum polymer concentration, and optimum injected slug size for each reservoir rock.
- Experimentally, polymeric nanofluid can result in a mean incremental RF of 18% of OOIP.
- An empirical correlation was developed to calculate the incremental oil recovery factor of polymeric nanofluid EOR.
- The coefficient of determination (R^2) of ANN-based correlation between the actual and calculated incremental recovery factor from the ANN model was established to be 0.955 and 0.952 with AAPE of 5.6 and 8.7% respectively during the training and testing processes.

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