DEVELOPMENT OF A NEURAL NETWORK SYSTEM FOR THE ANALYSIS OF PRODUCTION OUTPUT CURVES

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Abstract

The structure of a neural network system for the analysis of production output curves (POC) in geothermal wells is described. From the interpretation of the output curves it is possible to obtain qualitative information about reservoir properties (such as: relative pressure values, temperature, amount of gases, permeability, type of fluid, etc.), effects of scaling in the well and, in some cases, it is possible to define feed zones in wells.

1.0 INTRODUCTION.

Production output curves are routinely determined for most geothermal wells. Once the well has been drilled and after the heating stage is completed, the fluids flow through orifices of different diameter. At the completion of a successful output test the stable or quasi-stable flow has been measured at different wellhead pressures. From the way in which mass flow, enthalpy and chemistry vary with wellhead pressure some deductions can be made about the reservoir. Common applications include gathering qualitative information about the reservoir properties (e.g. relative pressure values, temperature, amount of gases, reservoir permeability and type of fluids in the reservoir), scaling effects in the wellbore and, of course, for a given wellhead pressure it is possible to predict the mass flow (Grant et al., 1982). Figure 1 and Figure 2 show some possible variations of the output curves of mass flow and enthalpy versus wellhead pressure.

An artificial neural network is an information processing system, which simulates a biological neural network. Some of its main characteristics are: its capacity to analyze a large amount of data in a short period of time, its usefulness in handling ambiguous data, and its capacity to "self learning" when proper data is provided. It is well known that these systems have been successfully applied to solve problems related to the classification and recognition of patterns (Lippmann, 1989).

In order to evaluate the application of neural networks to the understanding of geothermal reservoirs we have developed a system to analyze the POC of wells. The present work has been divided in four sections. The first one describes the structure of the system, in the second one comments on handling the network are made, in the third one application examples shown and finally, conclusions and proposal of future work are presented.

2.0 NEURAL SYSTEM

2.1 Analysis of characteristic production curves.

For the analysis of characteristic production curves a neural system has been designed, it is shown in Figure 3. This system was developed using the technique of holographic neural networks (Sutherland, 1993).

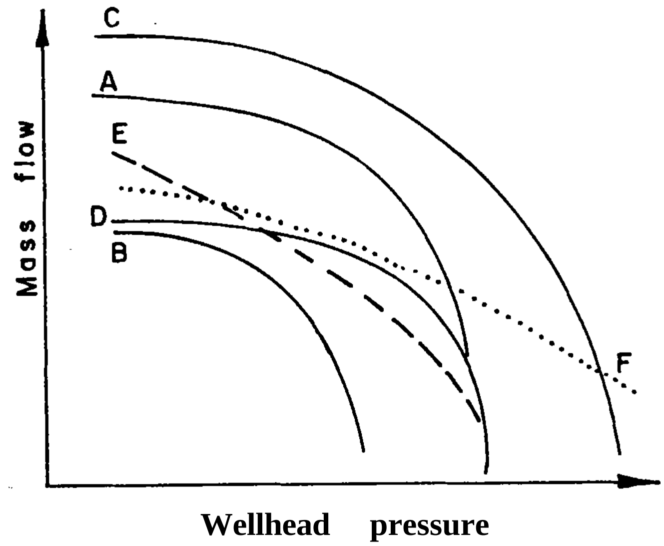

Fig. 1 Output curves: Variation of mass flow with wellhead pressure (After Grant et al., 1982).

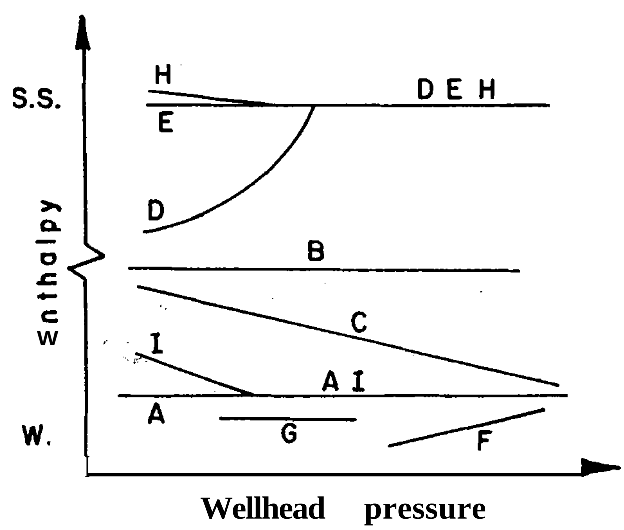

Fig. 2 Output curves: Variation of enthalpy with wellhead pressure (After Grant et al., 1982). S.S. = Saturated steam, W = Water

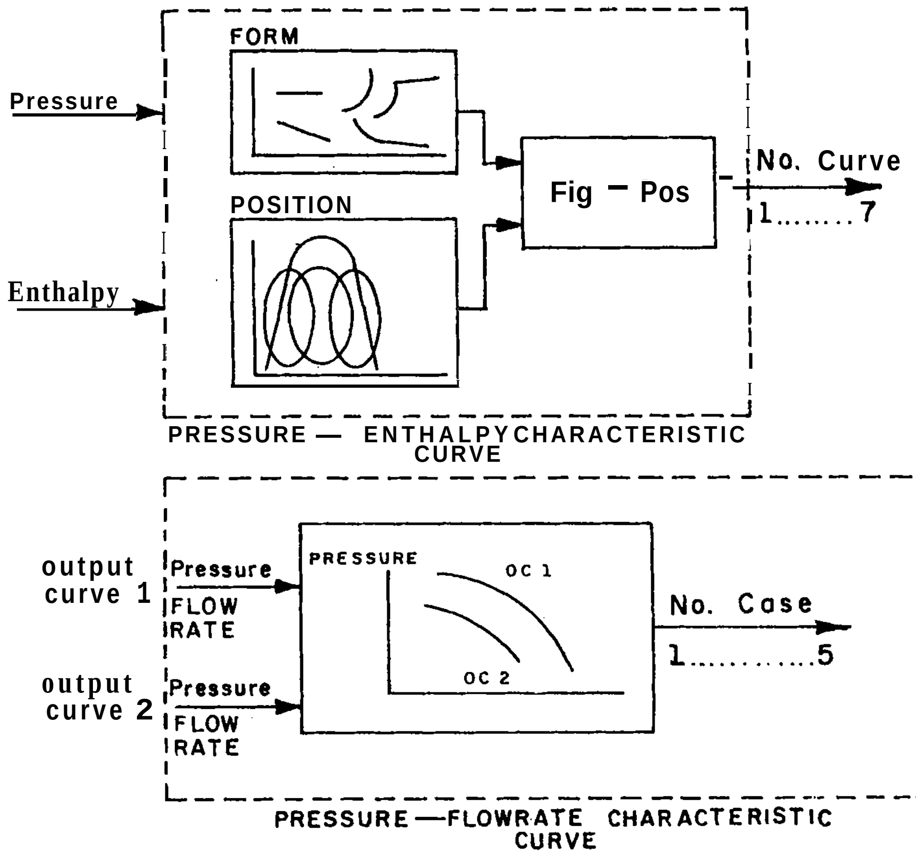

Fig. 3 Diagram of a neural system for the analysis of POC.

The interpretation of the pressureenthalpy plots is based on their shape and position. As it can be seen in Figure 2 , its shape can be. a straight line (positive, negative or zero slop), curve (concave or convex) or a combination of both. The position depends on the thermodynamic region where the data are located (liquid water, saturated liquid, two phase, saturated steam and superheated steam). On the other hand, the interpretation of the pressure-mass flow plots is based on the comparison of two curves between each other.

To improve the structure and the training of the system an holographic neural commercial package (HNETpro II) was used. The system runs on a personal computer under Windows. Holographic neural networks, as well as other artificial neural networks have two fundamental stages in their development: structure design (number of neurons and inter-connections) and handling.

2.2 Network structure

In Figure 3 each block represents a sub-network composed of, in the simplest case, 5 holographic cells. The inter-connection between the cells corresponds to the minimal configuration which can be improved in the commercial package used.

The structure of the system separates the problem in sub-problems, diminishing the degree of complexity, generating an efficient solution of the problem. For example, because of the wide range of data values in the pressure-enthalpy plot, it is sometime difficult to define the trend and position of data. For this reason, the pressure-enthalpy plot was divided into several thermodynamic zones (liquid water, saturated liquid, two-phase, saturated steam and superheated steam).

3.0 KNOWLEDGE OF THE SYSTEM

The knowledge of a neural network in its simplest way consists in presenting a set of data as input and to obtain output values which will be compared to the correct answer. The difference between the output and the correct value is used to adjust network weights, which are used as memory. This iterative process is repeated as far as the difference between values would be within a previously determined value.

The network learning was carried out using production output data from wells from two Mexican geothermal fields: Los Azufres and Cerro Prieto.

The used input data correspond to the parameters shown in Figure 3. The best values used as input data where obtained analyzing each case by a human expert.

4.0 APPLICATION EXAMPLE

At the time of writing this manuscript, the system has been validated against a number of published and unpublished problems with known solutions. As an example the analysis of two sets of production output curves from well E-1 (Cerro Prieto geothermal field) are presented. Figure 4 shows the production output curves for this well. The first one was carried out in 1980 and the second one in 1981. The system compares the two sets of output curves and concludes that they are similar to case D in Figure 1. That means that scaling occurs inside the wellbore. This conclusion is right, since in December 1983 well E-1 was repaired after scaling inside the conducting pipeline.

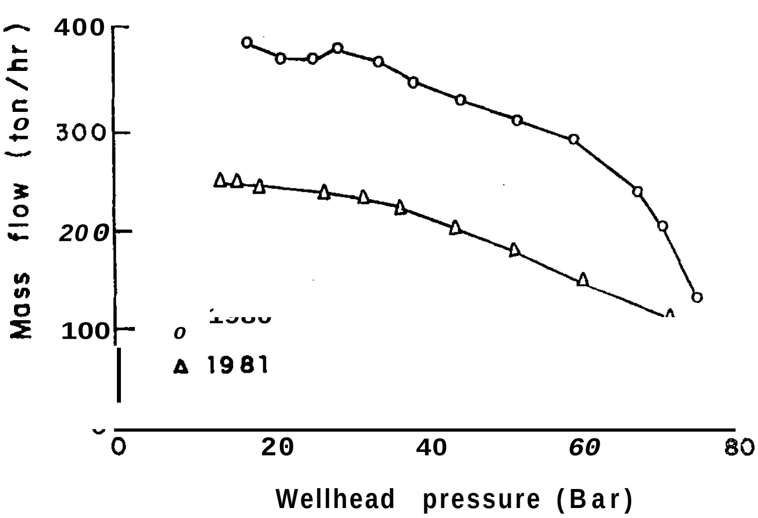

Fig. 4 Output curves of well E1 from Cerro Prieto geothermal field, Mexico.

5.0 CONCLUSIONS

The first version of a neural system for the analysis of production output curves from geothermal wells was developed and validated.

We have successfully validated this system against a sample set of field data from two Mexican geothed fields: Cerro Prieto and Los Azufres.

For prototyping, developing and training the system we chose an holographic neural commercial package (HNET pro II). The system runs on a personal computer under Windows.

Though still in a rapid stage of evolution, the system already provides a convenient and useful tool for the analysis of production output curves. The main advantages of this system are: it is user friendly, requires essentially no experience on the part of the analyst, can handle complex cases and is significantly faster than a human expert.

The development of this system allows to evaluate the possible application of neural networks to the study of geothermal systems. At the moment we are working on the development of an intelligent system for the evaluation and management of geothermal reservoirs. This system will be integrated by a data base, a graphic section and an intelligent module; the last one will be formed by a series of expert systems and neural networks (Arellano, et al. 1990, 1992, 1995).

6.0 REFERENCES

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