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REVIEW OF WELLBORE INSTABILITY CASES IN DRILLING THROUGH CASE BASE REASONING (CBR) METHOD

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ABSTRACT:

No well is drill without problem. Oil companies spend about $ 25 billion annually on drilling. Unfortunately, not all of that money is well spent. A significant portion, around 15% is attributed to losses. These include loss of materials & drilling process continuity.

The objectives of this paper is to shortly review of CBR approach as in the petroleum industry , a new level of active computerized support for information handling, decision – making and diagnosis, repair with explanation of the wellbore stability problem cases in drilling. It is our plan to analyse pased wellbore instability data in terms of lessen learned and specific cases, which lead to improved knowledge that can help to avoid the same problem occurring in the future. A Tool named TROLL CREEK" has been used to serve as explanatory support for case retrieval and reuse through CBR data Base. It is shown how the combined reasoning method enables focused decision support for wellbore instability cases and prediction of potential unwanted events in the drilling engineering domain.

KEYWORDS: CBR, Wellbore Instability and Drilling

1. INTRODUCTION

Main wellbore instabilities are pack off, stuck pipe, lost circulation, pore hole cleaning and Downhole equipment failure[3]. These unwanted things are repeatedly occurring but still so complex that are not easily solved. In our daily drilling operation, most practical problems need to be solved fast. Since most practical problems have occurred before, the solution to the problem is hidden in past experience, experience which either is identical or just similar to the new problem. If the solution is not found immediately, discussion with a colleague, a phone call to an expert, study of textbooks/project reports or a search on the internet is the way to handle the new problem. If the new problem or a similar one has been solved previously, the above described method is often a waste of time, having to solve the problem all over again. Such problems can be solved much more efficiently by storing and then reusing similar experience, i.e. CBR. A similar, previous experience is a good initial approach to solving the problem.

We focus on the capturing of useful experiences; stability related unused case data aim to produce valuable information in terms of knowledge and on their reuse within future similar contents. The expert user can exert necessary information from CBR data base in his planning phase. The CBR technique is applied to derive new scenarios (alternate drilling plans) based on

Previous "cases". Similar work is under way through number of oil companies collaborating to form a "Drilling Club including bank of previous immense amount of experience data" from many wells but busy engineers would prefer to see just the relevant information. Relevant information have to be presented so that the system assists by extracting an intelligent summary and structuring information to highlight key factors that will result in the greatest cost savings on a proposed drilling operation.

2. METHODOLOGIES

2.1 CBR

CBR as a technology has now reached a certain degree of maturity, but the current dominating methods are heavily syntax-based, i.e. they rely on identical matching through the toll, TrollCreek. Figure-1 shows how can construct a case through TROLL CREEK. The CBR approach (see figure -2)[4] followed certain commend path when diagnosis a case; these are:

Retrieve –The most similar case or cases
Reuse- The information and knowledge in that case to solve the problem
Revise- The proposed solution
Retain- The parts of this experience likely to be useful for future problem solving

An initial description of a problem (top of the figure-2) Define a new case (in this paper lost circulation) which we have discussed in section -5. This new case is used to RETRIEVE a case from the collection of previous cases. The retrieved cases is combined with the new case through REUSE- into a solve case i.e. a proposed solution to the initial problem. Through the REVISE process this solution is tested for success, e.g. by being applied to the real world environment or evaluated by a expert and repaired if failed. During retain, useful experience is retained for future reuse, and the case base is updated by a new learned case, or by modification of some existing cases.

Based on above discussion the CBR approach success is deepens on quality cases structure in knowledge model .Cases fully depend on data quality, because data finally converted to knowledge. Figure- 3 shows how data reaching become knowledge following loop **data- information- knowledge** cycle [4]. Although there is a variety of knowledge modelling methodologies to diagnosis a case but most of them start the following three types of component structures:

Tasks- what are the goals of the system, what should it do?

Problem solving methods – by what methods will the system accomplish its tasks?

Domain Knowledge – What knowledge is needed by the methods in order to accomplish these tasks?

2.2 Tool

Troll Creek is a novel & flexible system architecture tool where case base component and model base component might be combined as per case merit but different ways [4]. A case can be presented as symbolically using by entities. Entities which are related to cases can be divided in to four ways: Casual model, Relation types & entities for the wellbore instability domain, and Case matching routine.

Over a period of two decades a method for building knowledge intensive applications (ki-CBR) has been developed and formalized through the software called TrollCreek (http://trollhetta.tripod.com) [3, 7,9] .This methodology well is applied in these studies as a tool for testing out on Knowledge Model and Cases related to wellbore instability problem.

Three major components of a drilling case base system must be implemented to allow case based planning of a new well to avoid the previous instability problems are:

- A representative set of stored wells and associated drilling knowledge
- Methods for retrieving similar or partially similar wells stability problem
- Techniques for adaptation of retrieved information to suit the new planned well avoiding risk
- Store new stability cases to rich knowledge model data base.

The purpose of the software system, TrollCreek, employed in this task is to automatically capture drilling data and knowledge insert by the expert and to extract key information required for drilling of new wells by the skilled user.

3. MODELING A CASE FROM RAW DATA:

The manually developed knowledge structure will gradually consist of relatively stable objects. At the simplest level, the Troll Creek general domain model can be seen as a labelled, bi-directional graph. It consists of nodes, representing concepts, connected by links, representing relations. Relation types also have their semantic definition, i.e. they are concepts. The uppermost ontology of the Troll Creek model is illustrated in Fig. 4

Different relations have different numerical strength, i.e. a value in the range 0-1. Attributes or parameters in the knowledge model are interconnected through structural relationships (has subclass, has part, has instance, has value), caused and other kinds of influence relations. Properties are inherited along the relation lines. The parameters, i,e the outmost " leaves" on all "branches" in the class hierarchy , are inter- linked through the following relationships (where a relation's explanatory strength is shown in parenthesis): Structural (1.0), Causes(0.9), leads to(0.85),enables (0.80), influences(0.75),implies(0.70),involves(0.65),indicate(0 .60), describes(0.55) and occurs in(0.50) etc. Relation always has an inverse relation, e.g. "caused-by". In addition to numerical values a quantifier/modifier can be introduced to each relation (multiplication weight shown in parenthesis): always/strongly (1.1), typically (0.95=default), sometimes/moderately (0.7), or seldom/weakly (0.3). A few examples from the Relationship list are:

Relationship 1 : i) High mud filter loss increase of mud filter loss,ii) High mud filter loss enables clogged BHA
iii) Clogged BHA leads to stuck downhole equipment

Relationship-2: i) High mud gas content causes low Downhole mud viscosity, ii) Low downhole mud viscosity causes hole clean problem iii) Bad hole clean concerns to causes stuck pipe iv) Stuck pipe leads to non productive time vii) Non productive time responsible for high well cost

Relationship -3: i) High pump rate cause high pump pressure, ii) High pump pressure may occurs in lost circulation iii) Lost circulation causes wellbore stability problem iv) lost circulation in reservoir zone hamper reservoir quality iv) Reservoir quality related to ultimate recovery vii) less ultimate recover differed income viii) lost circulation also responsible for non productive time for high well cost

We got the case data quantitative basis and need to be transforming it into qualitative concepts for our CBR system. Let proposed as exemplified in table-1: The entity "Weight On Bit" (WOB) & Rate of Penetration (ROP) are taken as an example. WOB & ROP are a subclass of operational parameters which is subclass of Observable parameter in our ontology model. Table -2 shows relation between some concepts. Currently, the oil drilling domain model contains about 1500 concepts related through 35 different relation types.

Table 1: Qualitative values and their definitions (data North Sea)

Relation Between Qualitative & Quantitative value		
Qualitative value	Quantitative value	Quantitative definition
Normal WOB	WOB-30	Average value over last 30 m of drilling
High WOB	WOB-1/WOB- 30> 1.2	Wob-1 = average value over last 1 m of drilling
Low WOB	WOB-1/WOB- 30< 0.8	
Normal average ROP	3-10 m /hr (north sea)	Not bad
Moderate ROP	5-20 m/ hr	Relatively good, in upper drilling section
High average ROP	> 10 m/hr	Intermediate hole section mixed formation
Very high ROP	20-30 m/h	Reservoir section
Increasing ROP	10-30 m/h	Intermediate section, sand formation
Decreasing ROP	5-. 0.5 m/h	Shale section , hard formation

Table 2: Relation between some concepts:

Node/Concept	Relation	Explanatory strength	Target Node
Background gas from shale	Implies	0.70	Increasing poor pressure
Back reaming	Leads to	0.85	Negative ECD
Riper trip	Leads to	0.85	Lost casing shoe
Balled bit	Occurs in	0.50	WBM
Blowout	Enabled by	0.80	kick
Blowout through BOP/annulus	Caused by	0.90	Failed to close BOP
Faulted formation	Implies	0.70	Mud loss
Naturally fracture formation	Causes	0.90	Lost circulation
Induced fracture formation	Causes	0.90	Lost circulation
Big cutting	Occurs in	0.50	Poor hole cleaning
Complex well trajectory	Lead to	0.85	Pack off problem
ROP very low	implies	0.70	Harder formation
ROP very high	Implies	0.70	Week formation

4. CASE STRUCTURE FIELD EXAMPLES

4.1 Case Structure

A case structure may consist following six components about the problem: 1) Summary- general overview, 2) problem- what happened 3) general information- about the circumstances 4) observation- while occurs problem 5) Explanation problem in symbolically- responsible to causes the problem 6) Solution- (solving immediate problem and better plan to avoid next time),

4.2 Field Case Example:

How to make a case from drilling operational data [2]:

In October 2003, development drilling of the ConocoPhilips Indonesia Inc.Ltd operated Belank field commenced when the platform rig was rigged up over a previously installed twenty- four slot platform. Drilling commenced with the objective of drilling and completing ten slant directional wells and six horizontal wells. The 9-7/8” hole & 7-5/8” casing sections were batch set in ten wells. Most well objectives were met and the performance was exceptional in some wells, but this section was plagued by surface and downhole equipment failures.

9-7/8” Hole section/7-5/8” Casing : on the majority of wells the 9-7/8” hole was a long tangent section (8000-12000ft) in 45 to 60 degree inclination. A PDM bit was used to drill the section in all of these wells, with an objective of no more than 10% oriented drilling. Two PDC bit runs was the initial plan to drill this section. The objective is to maximize ROP, with 5 blades-steel body PDC bit, in the softer upper section and use heavier set of PDC bit to drill lower hard, abrasive section. In order to keep the PDC bit durable and have a change to drill the section with one bit, low speed high torque motor was used. The specification of this motor was tied to recommend drilling parameters to achieve optimum ROP and durability, high WOB and low RPM.

A synthetic mud system was used in this section. Wellbore stability studies carried out in the design phase indicated the need for mud weight of 11.0-11.5 ppg, depending on the hole angle, to keep the Barat shale stable. In practice, it was found that this required density could be safely reduced by 0.4 ppg. This minimized differential sticking in permeable zones while keeping the wellbore stable. Maintaining the mud 6 RPM reading at a high level appeared to give effective cuttings removal. Once confidence in the hole condition had been gained it was possible to dispense with wiper trips and after circulating clean at TD, the assembly was pulled out of the hole to run casing. Hole cleaning also achieved by pumped high flow rates at 900 gpm when drilling out from surface casing. Optimal hydraulics was assisted by the use of 5-1/2” drill pipe.

PDM failures, mainly due to the elastomer chunking, occurred several times on this section. From ten wells (plus one sidetrack) drilled, only four wells were drilled without a motor problem. An attempt to solve the problem was made by change in the elastomer type and by increasing the clearance between the stator and rotor (i.e. a loose fit). This resulted in no measurable increase in success. It was felt that the combination of synthetic mud, high motor differential and high temperature environment were all possible causes of this problem. Logging tool also failed frequently in this high temperature environment.

9-7/8 “ Section Result : this section was completed 15 days longer than the plan due to additional wireline work that was not in the original plan and the need to geological sidetrack a well. On this section the Non-Productive-Time (NPT) was 25% of the total time. The NPT was due to logging tools hung up, failure on Steerable motors, MWD, rig equipment and logging tools. Despite this NPT,the overall performance was satisfactory, generally speaking , without problems the typical well could be finished within 8 days.

4.3 Filtering Data To Build A Case To Use In Cbr Method:

Name of Case: Downhole Equipment Failure

1. Case with repair failure:

a. **Initial headings**:

Has status	: solved case
Has failure	: equipment failure
Has task	: repair failure

b. **Administrative relation**:

Has time stamp	October 2003
Has case characteristics	Conoco Phillips
“	Belanak Field
“	Indonesia

c. **Static parameters:-** 7-5/8” casing section, 9 7/8” bit size, PDM, Synthetic based mud, drilling activities

d. **Observable parameters:-** Very high downhole temperature, deep well high inclination, high WOB, Low RPM, high mud viscosity

e. **has initial repair :** changed elastomer type

f. **has solution :** changed PDM

g. **has outcome :** broke down after short time

h. **has explanation:** poor PDM design vs given strain

i. **has experience :**Select a completely different PDM for those conditions

2. Store in the case base as a case and what purpose can this case are used: During execution:

User can retrieve this case if a similar failure occurs in a similar circumstance. for planning: user can, in case the well will be drilled in similar environment, select i) Different drilling parameters (simulate what – if): mud, WOB, RPM, Different PDM

How to use it in a stepwise fashion: it goes like this:

1. A new case is reported with e.g. equipment failure,
2. Should describe the case as detailed as possible including all observations),
3. Insert in TrollCreek and Match (see case match model – lost circulation for example in this paper in section 5.0)
4. Evaluate the best matching case and re-use it if the matching degree is high enough,

3. Entities involved are : 9 7/8 Bit Size belonak field, broke down, ,PDM,poor PDM design,,Solved case,ConocoPhillip, deep well, equipment failure, high inclination, Indonesia, low RPM, ,change elastomer, changed PDM, SBM, repair failure, ,high WOB, low RPM, high mud viscosity, Very high downhole T, all the case relation, October 2003, New entities are high mech. Friction, high Torque, elastomer weakening, elastomer chunking

Structure- All entities are to be placed here in one, two, three or 10 level below the last time. See figure-9

Relations / Explanation- 1) Very high DT and SBM leads to elastomer weakening, 2) Elastomer wakening and high WOB causes elastomer chunking 3) Elastomer chunking causes PDM failure, 4) deep well AND high inclination causes high mechanical friction, 5) high mechanical friction and low ROP causes high Torque, 6) High torque causes PDM failure

Solution: change PDM and use completely different PDM

The above data/information has to be formulated as per Troll CREEK version which has been shown in Fig. 1 & Fig. 5

4.4 Case Matching:

Case Matching Routine: **-**Within a completed case an expert will evaluate the importance of each attribute, and designate a proper level of relevance, four level were chosen; Sufficiently indicative (1), Strongly indicative (2), Indicative (3), Spurious(4)

There, shortly descried the procedure how to construct a case from raw data and how this data convert to knowledge as a model and used accordingly. Due to space limitation others cases i.e., lost circulation, stuck pipe related problem could not presented in this papers but followed procedure is same as like as presented downhole equipment failure case.

5. DISCUSSION

We discussed in this paper how to construct a case (downhole equipment failure) from raw case data as per CBR approach and fit to this case in Troll CREEK along with other cases. CBR is an on going research in our project where we have constructed several wellbore stability cases and tested as well. Due to space limitation of this paper we were not able to discuss all cases. But just for better understanding, a case example (lost Circulation) [3, 5] was presented its diagnosis & how to get solution using Troll Creek.

Consider that we are in a position where drilling fluid losses are observed, and the situation turns into a problem (lost circulation, LC). See the problem case description to the left in Fig. 6; TROLL CREEK produces first of all a list of similar cases for review of the user from domain knowledge Fig. 7 bottom row, testing of case LC 22 suggests that case LC 40 is the best match, with case 25 as the second best. Inspecting case 25 shows a matching degree of 45 % and a display of directly matched, indirectly (Partly) matched, and non-matched features. Examination of the best – matched cases reveals that Case LC 40 and 25 are both of the failure type Natural Fracture (an uncommon failure in our case base). By studying case LC 40 and 25 the optimal treatment of the new problem is devised (the “has –solution” slot, see right part of Fig. 6 and the new case is stored in the case base.

Fig. 8 shows parts of the explanation structure explaining why case LC 22 is a problem of the type Natural fracture. It is seen that non observable parameter which is not directly measurable (annular flow restriction, increasing annular pressure, decreasing fracture pressure, leaking Fm, LCD, pressure surge, high annular pressure) are related to conditions down in the well.

The user can choose to accept the delivered results, or construct a solution by combining several matched cases.

The user may also trigger a new matching process, after having added (or deleted) information in the problem case. The user can also browse the case base, for example by asking for cases containing one specific or a combination of attributes.

6. CONCLUSION

CBR is a quite new method for building, diagnosis and repair of wellbore instability cases in drilling by using TROLL CREEK. The CBR approach we presented in this paper is a methodology for constructing any wellbore instability case using operational data and diagnosis problem cases based on similar previous successful solve cases.

This CBR method will be more applicable in the oil industry if the followings research task are over come and impleted.

- Prediction of unwanted events before they occur- in the oil drilling domain, incorporating time-dependent cases and temporal reasoning [8]
- How to automatically update the general domain model based on data, where we study probabilistic network as a data mining method [2,9]
- Improve the knowledge acquisition and modelling methodologies for both general and case specific knowledge[10] automatically generated past case descriptions from text reports, and to facilitate this type of decision support in a mobile computing environment.
- Integrate a knowledge –based decision support tool smoothly into the other computer- based systems in an operational environment.
- Integrate computerized decision support into the daily organizational and human communication structure on- board a platform or onshore.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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9. PHRASE DICTIONARY:

CBR =Case Base Reasoning	GPM =Gallon Per Min
BHA =Bottom Hole Assembly	PPG = Pound Per Gallon
PDM=Positive displacement mud motor	PDC = Diamond Bit
ROP=Rate of Penetration	TD = True Depth
WOB =Wait On Bit	LC = Lost Circulation
RPM 6 Revolutions Per Minute of Bit	Chunking = Pressed Together

RPM = Viscosity Measurement Concerning Cuttings Removal
Ontology: data may be executed and make it informative with logical, networking and modeling approach.
Case base : incident or accident in drilling domain
Model Base : general domain knowledge serve as explanatory support for case retrival and reuse processes through a model
Entity : its character of the object

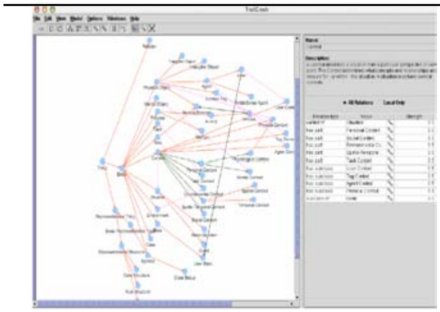


Fig 1:how can make case structure through Troll Creek

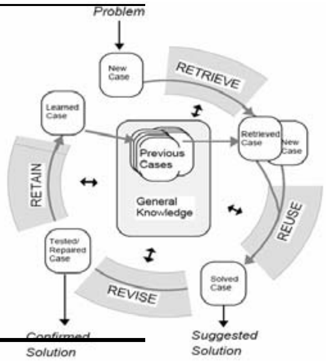
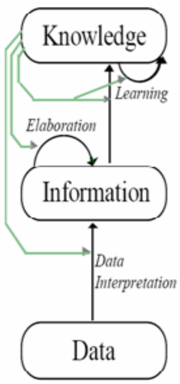


Fig 2: CBR Cycle [4]



Interpreted symbol structures:
Used to interprets data, elaborate on information, and learn

Used within

Interpreted symbol and symbol structures:
Input to a decision step
Output from a decision

)bserved,
ninterrupted
ymbols:
igns, character

Fig 3: how data transform to knowledge [2]

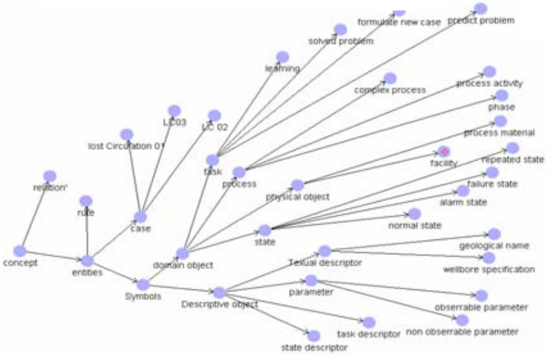


Fig 4: A part of the top-level ontology, showing concepts linked together with structural relations of type has subclass, each relation has its inverse (here sub class of, not shown)

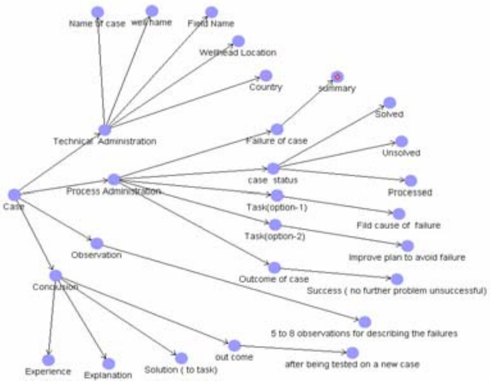
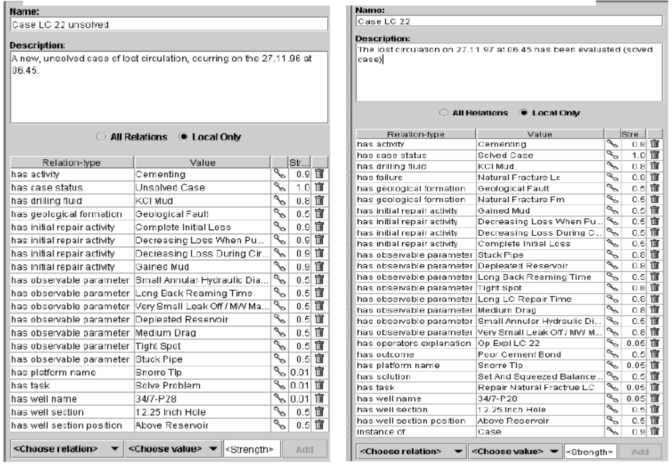


Fig 5: a part of the top level ontology, showing concepts linked to make of



Name:
Case LC 22 unsolved

Description:
A new, unsolved case of lost circulation, ocurring on the 27.11.96 at 06.45.

○ **All Relations** ● **Local Only**

Relation-type	Value	Str...
has activity	Cementing	0.9
has case status	Unsolved Case	1.0
has drilling fluid	KCl Mud	0.8
has geological formation	Geological Fault	0.5
has initial repair activity	Complete Initial Loss	0.9
has initial repair activity	Decreasing Loss When Pu...	0.9
has initial repair activity	Decreasing Loss During Cir...	0.9
has initial repair activity	Gained Mud	0.9
has observable parameter	Small Annular Hydraulic Dia...	0.5
has observable parameter	Long Back Reaming Time	0.5
has observable parameter	Very Small Leak Off / MW Ma...	0.5
has observable parameter	Depleated Reservoir	0.5
has observable parameter	Medium Drag	0.5
has observable parameter	Tight Spot	0.5
has observable parameter	Stuck Pipe	0.5
has platform name	Snorre Tlp	0.01
has task	Solve Problem	0.01
has well name	34/7-P28	0.01
has well section	12.25 Inch Hole	0.5
has well section position	Above Reservoir	0.5

Name:
Case LC 22

Description:
The lost circulation on 27.11.97 at 06.45 has been evaluated (soved case)

○ **All Relations** ● **Local Only**

Relation-type	Value	Stre...
has activity	Cementing	0.8
has case status	Solved Case	1.0
has drilling fluid	KCl Mud	0.8
has failure	Natural Fracture Lc	0.8
has geological formation	Geological Fault	0.5
has geological formation	Natural Fracture Fm	0.5
has initial repair activity	Gained Mud	0.5
has initial repair activity	Decreasing Loss When Pu...	0.5
has initial repair activity	Decreasing Loss During C...	0.5
has initial repair activity	Complete Initial Loss	0.5
has observable parameter	Stuck Pipe	0.8
has observable parameter	Depleated Reservoir	0.8
has observable parameter	Long Back Reaming Time	0.5
has observable parameter	Tight Spot	0.8
has observable parameter	Long LC Repair Time	0.8
has observable parameter	Medium Drag	0.8
has observable parameter	Small Annular Hydraulic Di...	0.5
has observable parameter	Very Small Leak Off / MW M...	0.8
has operators explanation	Op Expl LC 22	0.05
has outcome	Poor Cement Bond	0.5
has platform name	Snorre Tlp	0.05
has solution	Set And Squeezed Balance...	0.5
has task	Repair Natural Fractrue LC	0.05
has well name	34/7-P28	0.05
has well section	12.25 Inch Hole	0.5
has well section position	Above Reservoir	0.5
instance of	Case	0.9

Fig 6: unsolved case (left) and the corresponding solved case (right) of Case Lost Circulation 22

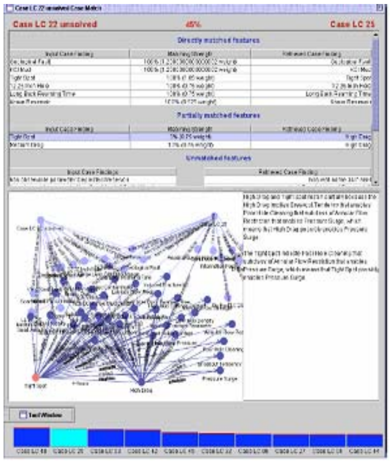


Fig 7: Result of matching a new case (case LC 22 unsolved) with case base of Case

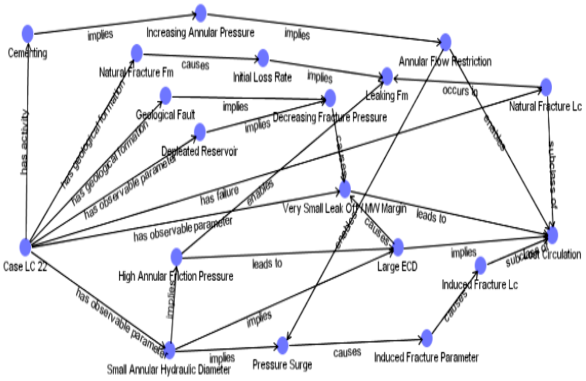


Fig 8: some of the explanations paths behind the failure in Case Lost Circulation Case 22 [3]

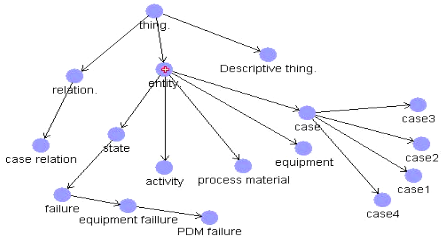


Fig 9: Case structure of downhole equipment failure; PDM; All entities are to be placed here in one, two, three or 10 level below the last time,