COMPUTER-ASSISTED PROBLEM ANALYSIS VIA SEMANTICALLY EXTRACTED EXPERIENCE

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Abstract:

To identify the right problem and solve it quickly, or to invent at the highest level of creativity, engineers need to leverage scientific and technical knowledge, often beyond their immediate personal experience or field of expertise. Engineers must be able to find appropriate concepts from among thousands of scientific effects and from tens of millions of articles, patents, and other sources of information. Although Altshuller identified this "informational fund" as an essential component of the TRIZ methodology, little could be done until the sources became digitized and readily accessible. Still, their promise remained unfulfilled due to ineffective retrieval technologies. Traditional keyword search methods return documents rather than concepts, and lack the precision needed to navigate right to the passage that addresses the engineer's functional requirement.

Through new breakthroughs in computational linguistics, it is now possible to generate, from virtually any digitized information source, a Cause-Effect Experience Base of semantically extracted concepts that aggregates and generalizes patterns of effects, or failure signatures, and their causes. Over 15 million patents have already been analyzed. When integrated into a Root Cause or FMEA workflow, such an Experience Base enhances and accelerates problem understanding by acting as a virtual subject matter expert.

Using the improvement of artificial bone scaffolds as a case study, this presentation illustrates how such a Cause-Effect Experience Base can be easily generated and then tapped to leverage technical insights. Altshuller's information fund is now a usable reality.

Introduction

Statistics show that during problem solving situations, individuals will unconsciously limit their options, their field of search, their repertoire of moves to those most practiced, comfortable and conditioned. Athletes, artists, and businessmen alike share this common proclivity to operate using only 10-15% of the total number of potential resolution maneuvers, techniques or strategies. For challenges requiring creative problem solving, TRIZ has gained popularity as a systematic and repeatable method for breaking through this inertia by broadening the field of thinking and enhancing one's creative options.

TRIZ achieves these benefits though a number of tools and disciplines. Its greatest success has been in helping engineers, inventors, and problem solvers to express their problem in an abstract functional language, to identify the underlying system constraints and contradictions revealed through the abstract problem statement, and to then leverage libraries of abstract rules, principles and patterns from which corresponding analogues can be found that provide fruitful avenues for researching concrete solutions.

Unfortunately, 'researching concrete solutions' has remained a most difficult task, and arguably constitutes one of the obstacles to greater TRIZ adoption. Success in applying TRIZ requires that we make that final leap from an abstract or analogous solution to a concrete physical capability. And, as Harold Buhl [1] states, "The only raw material available for solving problems is past knowledge." Yet how does one effectively and rapidly search past knowledge for a viable concrete implementation of an abstract strategy? As an alternative to reading millions of pages from patents, journals and reference texts, Altshuller proposes the use of a specialized Information Fund as a means of looking across disciplines and branches of science.

A similar challenge exists during the problem analysis and definition phase. Not only does finding a solution require broad access to knowledge, so too the predecessor step of problem definition often requires reaching beyond one's current expertise and personal experience. Peter Drucker [2], noted author, business analyst, professor, and management authority has said, "I much prefer to arrive at the wrong solution to the right problem than find the right solution for the wrong problem." His rather extreme statement illustrates the importance of achieving a thorough understanding of the situation and its root causes. Here again, an effective Information Fund could supplement traditional brainstorming efforts during Root-Cause Analysis.

The TRIZ Information Fund

TRIZ literature describes the Information Fund as "concentrated experience" of problem solutions that can be applied in a concrete way to produce a desired outcome or effect. The Information Fund is a key component of the TRIZ methodology, occupying a prominent position as one of the main categories of the UDC taxonomy scheme for TRIZ [3]. In its most concise form, the Information Fund is a set of examples each illustrating the physical instantiation of an abstract inventive principle or evolutionary pattern, along with a searchable encyclopedia of cross-disciplinary scientific effects. In its broader definition, the Fund is nothing less than the entire realm of published literature comprising patents, text books, journals, etc.

The problem with the latter is that it is too big to work with – an engineer has only minutes, maybe hours, to research a problem, not the years that would be required with conventional search technologies. The problem with the former is that it is too small – the common complaint is that we need more examples and more effects. Obviously, we need an Information Fund that is both big in terms of comprehensiveness, and yet small in terms of speed and utility.

But focusing on “more” examples or effects as a means of improving the utility of problem analysis and the abstract Principles and System of Standards is inefficient because it only incrementally addresses a symptom rather than permanently resolving a root cause. First, there will never be “enough” examples. And, second, examples will never be “good enough” since the real challenge is getting from an abstraction to a domain specific instantiation that is relevant to the user’s current situation.

Altshuller himself highlights the conundrum. In the procedural roadmap for problem solving he identifies numerous critical steps where the inventor must “investigate the possibility of applying physical phenomena and effects,” “investigate how principles can be used” and ask “how similar problems are solved.”[4] But how are these investigations to be performed, these questions to be answered? He also extols the virtues of patent information – recommending that it be studied both after a problem is defined – as a means of finding a solution, and prior to beginning work on a problem – to increase an inventor’s creative potential.[5] In practice, neither strategy is viable. A survey of senior design engineers across several dozen global manufacturers revealed that patent literature, even though technically accessible, is virtually never used as a resource for problem analysis or problem resolution. The reason – insufficient time. It’s simply too cumbersome to wade through hundreds or thousands of potentially relevant patents, particularly when you need a fast yet precise answer to a specific functional requirement. And how would you know what’s a relevant patent when TRIZ teaches us that solutions often exist in different fields of science and engineering? Who can read, and remember, millions of patents?

This is a travesty – the world’s greatest resource for problem solving virtually unused by problem solvers! As stated by the European Patent Office, “Patents reveal solutions to technical problems, and they represent an inexhaustible source of information: more than 80 percent of man’s technical knowledge is described in patent literature.”[6]

Natural language processing and computational linguistics can overcome these challenges. The following case study will show a repeatable process that can create and leverage an Information Fund for retrieving the right piece of information for the right defined problem in a timely manner with trivial user effort.

Case-Study – The improvement of artificial bone scaffolds

The need for better biomaterials is underscored by the growing demand for artificial joints and artificial bone scaffolds. More than 150,000 hip replacement and nearly 300,000 knee replacements were performed in last year, according to the National Center for Health Statistics. These numbers are expected to swell in the future as baby boomers age.

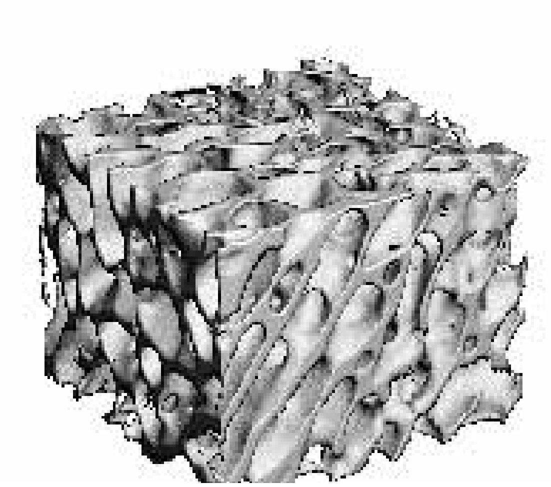


Figure 1. Synthetic Bone Scaffold Structure; www.tcd.ie/bioengineering/researchers/conor_buckley.htm

The modern scaffolding is a fundamental building block in tissue engineering that provides a platform on which healthy cells can inhabit and proliferate. This material, when thinly coated onto an implant, facilitates the all-important bond between the implant and surrounding tissue. Over time, as more and more cells inhabit the scaffolding, the implant becomes as enmeshed into the body as any bone.

When a scaffolding-coated implant is inserted into the body, bone cells incrementally invade the scaffolding -- first occupying the outer layer, then the next layer, and the next -- until the implant slowly becomes a part of the body.

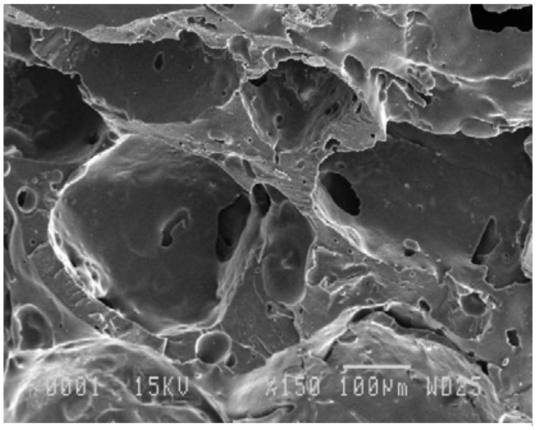


Figure 2. Porous Scaffold for Bone Tissue; www.msm.cam.ac.uk/ccmm/projects/vam27.html

Initial Problem Statement or Undesirable Event

A fundamental problem needs to be understood and resolved - namely, the initial strength of the scaffold structure. How can we maintain or increase the mechanical strength of artificial bone scaffold while its porous rate is also increased? There is a requirement to produce a scaffold structure which has more pores and more strength. A TRIZ practitioner would recognize the obvious technical conflict, and might be tempted to immediately apply the Contradiction Matrix to identify inventive principles that, by analogy and abstraction, could potentially lead to a creative resolution.

Yet experience shows that engineers, operating under intense time pressures and the ever-present psychological inertia, may accept at face value the initial problem statement, and fail to look beyond the first level of obvious cause-effect relationships. This can result in solving the problem at a surface or symptomatic level, which may produce a less than optimal business result, or worse, result in reworking the problem again at a later time.

Project Roadmap & Methodology

To achieve the TRIZ goal of lowing the problem's complexity, we will apply a root cause analysis, assisted by semantic access to a world-wide informational fund, to rapidly develop a comprehensive understanding of the potential etiology of the situation. Figure 3 shows the roadmap. Through a series of successive iterations the computer is called upon to "walk the causality chain" while a fault-tree diagram is dynamically developed. At each step in the process, the engineer's existing skill and expertise is both stimulated and extended by suggestions retrieved from patents, web sites and shared corporate information sources.

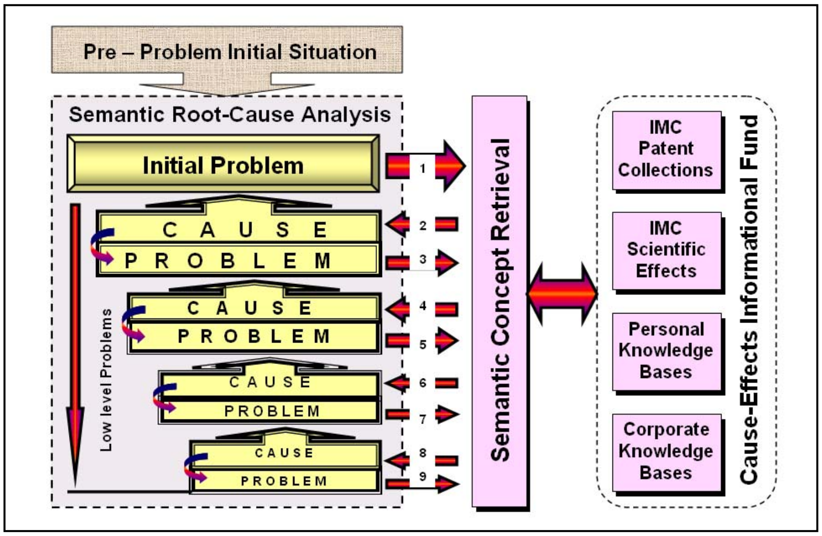


Figure 3. Roadmap for Knowledge Enable Root Cause Analysis

Creating the Semantic Information Fund

In this case study, the Semantic Information Fund consists of concepts that are related pairs of Cause & Effect events extracted from over fifteen million patents and the IMC Scientific Effects database. These concepts are extracted from a semantic analysis of natural language text and stored, with reference links, in an Experience Base. The analysis and extraction is handled by a computer utility using simple GUI configuration options; no programming is required. This processing occurs prior to problem solving projects so that the semantic information fund is ready when needed. In addition to worldwide patents, most users would typically populate the Fund with data from internal corporate knowledge bases as well as various world-wide web sites. In short, this Fund can reflect the "concentrated experience" of virtually unlimited digital data sources, thus making it comprehensively large, while advanced retrieval methods, shown in the next section, make the Fund pragmatically small for efficient use in daily problem solving.

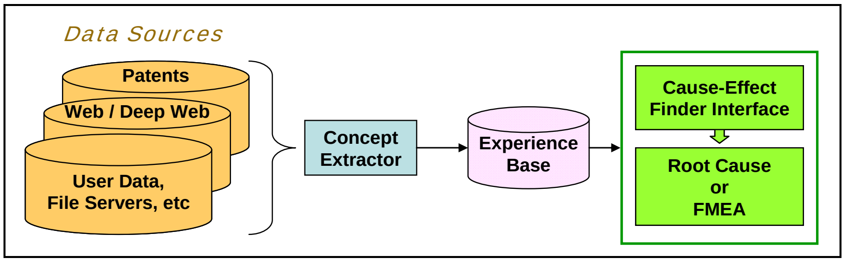


Figure 4. Creating the Fund via Concept Extraction

Root Cause Analysis Driven by the Information Fund

We begin the problem analysis process by placing a simple noun phrase, or noun-verb phase, into the starting box of our causal diagram (Fig.5). In this scenario, we start with the phrase “pores destruction” with the intention of exploring the vulnerability of porous material – helping us to better understand how and why it can break down. Conventional root-cause analysis would now depend on the team members’ memory and the brainstorming insights to draw out subsequent causal boxes. But with the aid of semantic technology, the team can click the “Cause-Finder” icon in the upper right corner (noted by the red circle). This signals the software to query the Information Fund for previously extracted concepts related to the destruction of pores. Thirty-eight categories of relevant causality, some with multiple examples, are returned (Fig.6). A phrase or sentence fragment describes the most relevant instance of each category. The complete sentence from a supporting patent or source document can be reviewed by clicking on the document icon just to the left of each instance (Fig.7). For additional in-depth research, a hyperlink will retrieve the full source document and position the reader at the highlighted sentence describing the cause-effect relationship under review (Fig.8).

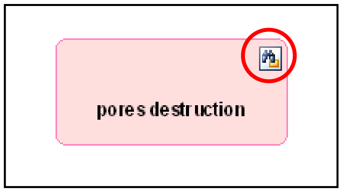
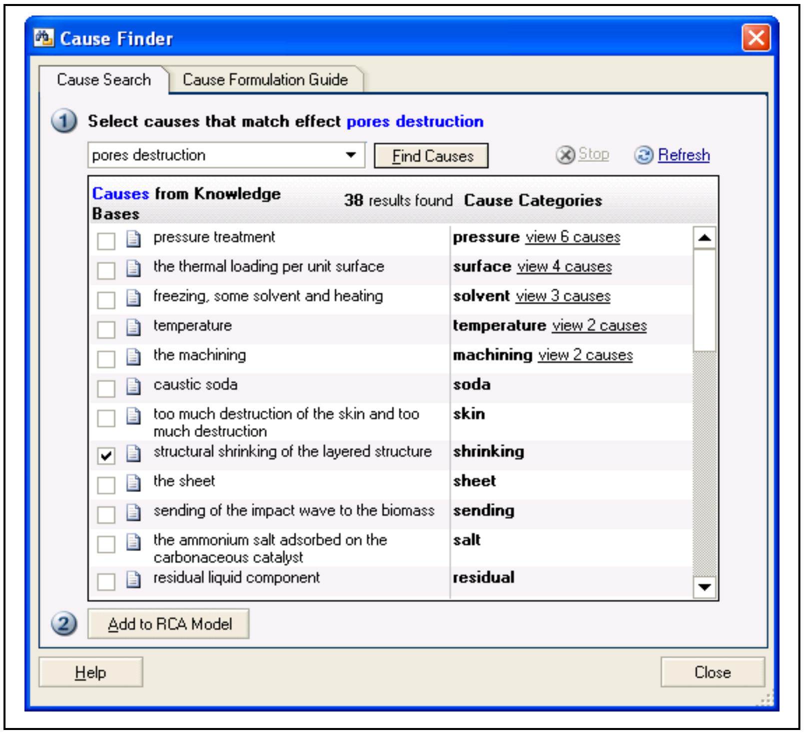


Figure 5. Initial Event



① Select causes that match effect **pores destruction**

pores destruction

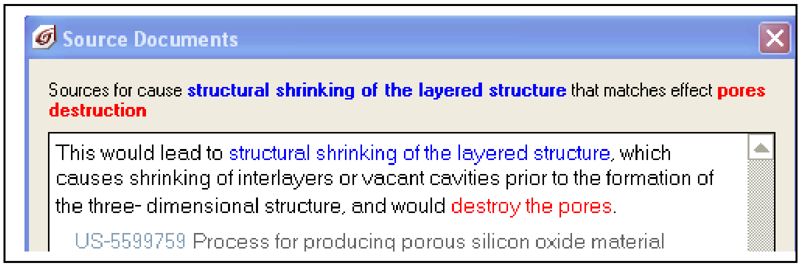
38 results found

	Causes from Knowledge Bases	Cause Categories
☐	pressure treatment	**pressure** view 6 causes
☐	the thermal loading per unit surface	**surface** view 4 causes
☐	freezing, some solvent and heating	**solvent** view 3 causes
☐	temperature	**temperature** view 2 causes
☐	the machining	**machining** view 2 causes
☐	caustic soda	**soda**
☐	too much destruction of the skin and too much destruction	**skin**
☑	structural shrinking of the layered structure	**shrinking**
☐	the sheet	**sheet**
☐	sending of the impact wave to the biomass	**sending**
☐	the ammonium salt adsorbed on the carbonaceous catalyst	**salt**
☐	residual liquid component	**residual**

② Add to RCA Model

Figure 6. Information Fund’s Picklist of Potential Causes

Not only is the process fast and precise, but it reaches well beyond the expertise of the user by retrieving concepts from across disciplines and sources, and across different semantic forms, or expressions, of the language.



Sources for cause **structural shrinking of the layered structure** that matches effect **pores destruction**

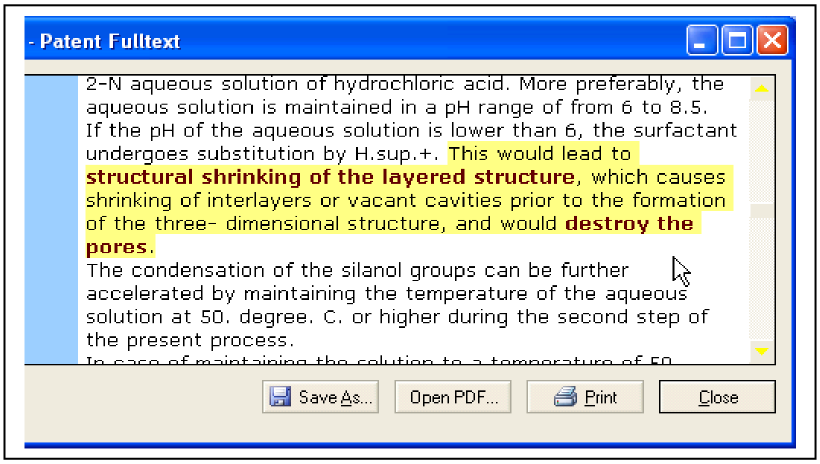
This would lead to structural shrinking of the layered structure, which causes shrinking of interlayers or vacant cavities prior to the formation of the three- dimensional structure, and would destroy the pores.

US-5599759 Process for producing porous silicon oxide material

Figure 7. Full Sentence Description of Selected Cause / Effect

After perusing the picklist of potential causes, and perhaps drilling down into supporting documents, the user selects those causes deemed most relevant to the task at hand. The software transfers the selected causes onto the root-cause palette and draws the appropriate boxes automatically (Fig.9). Multiple causes can be selected and added at once.

The Information Fund continues to support the analysis as the user now explores the leg of the fault-tree for volume expansion. A click on the Cause-Finder button and the Fund reports back with 84 categories of potential causes. Some categories are populated with multiple variant instances, as indicated by the column on the right (Fig.10). By selecting on a category hyperlink, such as "fluid," the user will see each of the specific cause-effect instances in which fluid can contribute to, or cause volume to expand (Fig.11). The user reviews the four instances, checking supporting documents for additional insights,



2-N aqueous solution of hydrochloric acid. More preferably, the aqueous solution is maintained in a pH range of from 6 to 8.5. If the pH of the aqueous solution is lower than 6, the surfactant undergoes substitution by H.sup.+. This would lead to **structural shrinking of the layered structure**, which causes shrinking of interlayers or vacant cavities prior to the formation of the three- dimensional structure, and would **destroy the pores**.
The condensation of the silanol groups can be further accelerated by maintaining the temperature of the aqueous solution at 50. degree. C. or higher during the second step of the present process.

Figure 8. Full Source Document for of Selected Cause / Effect

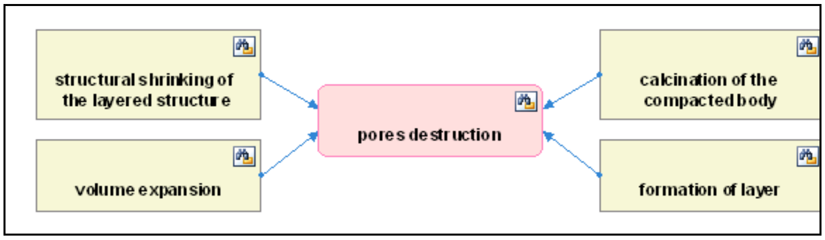
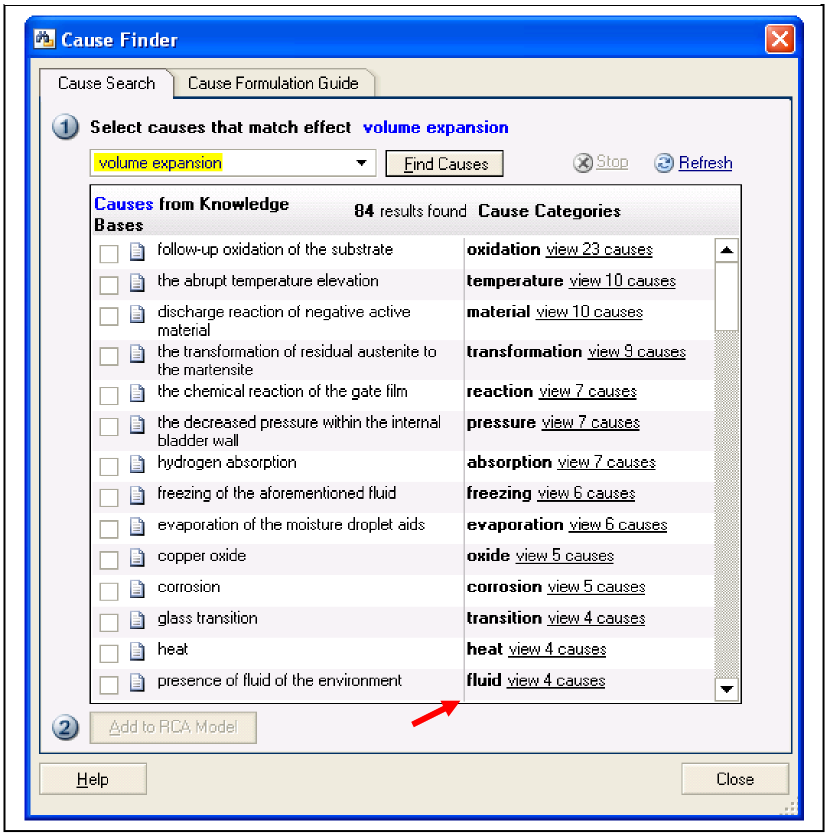


Figure 9. Dynamically Constructed Root Cause Diagram



① Select causes that match effect **volume expansion**

volume expansion

Causes from Knowledge Bases 84 results found **Cause Categories**

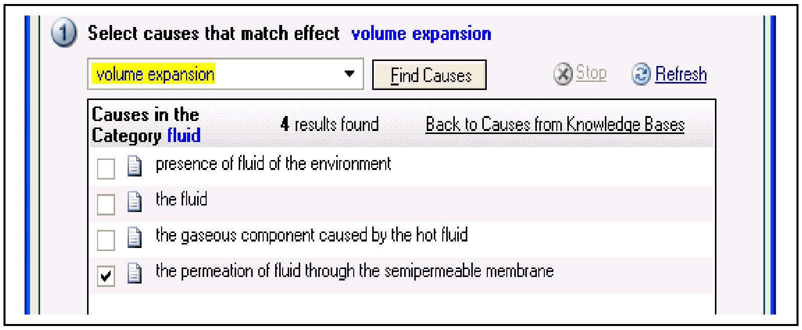
Causes from Knowledge Bases	Cause Categories
☐ follow-up oxidation of the substrate	**oxidation** view 23 causes
☐ the abrupt temperature elevation	**temperature** view 10 causes
☐ discharge reaction of negative active material	**material** view 10 causes
☐ the transformation of residual austenite to the martensite	**transformation** view 9 causes
☐ the chemical reaction of the gate film	**reaction** view 7 causes
☐ the decreased pressure within the internal bladder wall	**pressure** view 7 causes
☐ hydrogen absorption	**absorption** view 7 causes
☐ freezing of the aforementioned fluid	**freezing** view 6 causes
☐ evaporation of the moisture droplet aids	**evaporation** view 6 causes
☐ copper oxide	**oxide** view 5 causes
☐ corrosion	**corrosion** view 5 causes
☐ glass transition	**transition** view 4 causes
☐ heat	**heat** view 4 causes
☐ presence of fluid of the environment	**fluid** view 4 causes

②

Figure 10. Cause-Effect Picklist with Category Drill-down Indicated

and decides that one is worth further research – “permeation of fluid through the semipermeable membrane.” It’s added to the diagram with a simple click (Fig. 12).

In this manner, the Fund supports the continuous analysis and build-out of even the most complex fault-tree diagram – at each step ensuring that the engineer has visibility to relevant concepts from past knowledge thorough advanced semantic filters.



Select causes that match effect volume expansion

volume expansion

Causes in the Category fluid — 4 results found — Back to Causes from Knowledge Bases

- ☐ presence of fluid of the environment
- ☐ the fluid
- ☐ the gaseous component caused by the hot fluid
- ☑ the permeation of fluid through the semipermeable membrane

Figure 11. Cause-Effect Category Drill Down

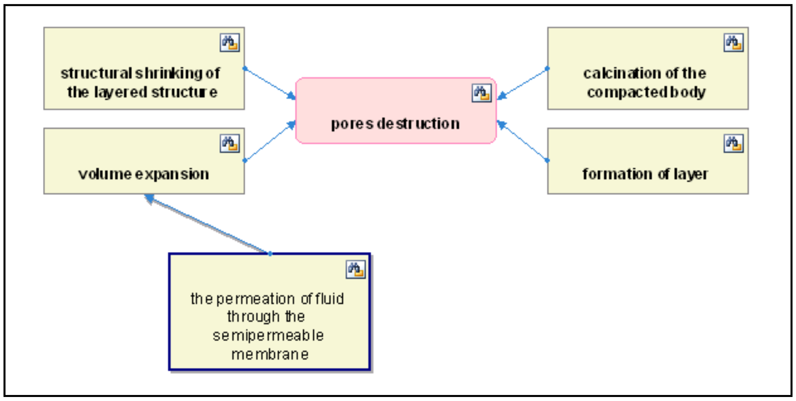


Figure 12. Further Build-out of the Root Cause Diagram

Conclusion

Search is Dead; Concepts-on-Demand is King

Why do engineers rush to solutions without a sufficient understanding of the problem? More often than not, it’s because they lack the ability to research problem causes in a timely manner. As Albert Einstein said, "It's impossible to solve significant problems using the same level of knowledge that created them." So when you need to find causes that lie beyond the "the level of knowledge that created them," or beyond your personal expertise, then you need to tap corporate and worldwide information funds. This need has been recognized for decades, and made all the more urgent by the retirement of our graying workforce and the geometric explosion of digital resources, but it simply was not practical until recent advances in computational linguistics opened the door to precise concept retrieval. When these new technologies are built into a user interface specialized for root-cause or FMEA analyses and their unique requirement for etiologic inquiry, then a passive information fund is transformed into actionable knowledge – acting like a virtual subject matter expert. By delivering contextually relevant answers at the moment and place of need, the process expedites comprehensive problem understanding, makes greater reuse of corporate intellectual assets, and reduces dependence on senior staff resources. Businesses benefit with higher quality product deliverables and enhanced engineering reliability and quality initiatives. And the TRIZ community is advanced by finally getting the long-sought Information Fund that is large enough [during construction] to hold everything needed, and small enough [during use] to actually be usable.

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Isak has spent 7 years at IMC and currently serves as their Chief Methodology Specialist. He is a TRIZ Master, Value Methodology and 6Sigma certified specialist with over 20-years experience on innovation projects targeting product/process development and manufacturing optimization at major global companies. He has delivered numerous seminars (some together with Genrich Altshuller), and educated and trained more than 600 Managers, Engineers, and Researchers in TRIZ, Value Methodology and Process & Product Development.

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Steve is responsible for product marketing activities including the positioning and future evolution of the company's products. He is a frequent symposium speaker on automated techniques for knowledge extraction and innovative problem solving. Prior to Invention Machine, he spent 10 years at Vality Technology, a leading supplier of data quality software for the ERP, CRM, and BI markets where he served as Vice President of Product Strategy until its acquisition by Ascential Software. At Ascential, he served as Executive Director of Product Management and Marketing for Ascential's suite of data-integration products. Previously Steve had served 20 years in technology management and development capacities at Legent Corporation, Cullinet Software and Honeywell. He is a graduate of Harvard College.

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