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TRIZ reverse-based new application identification for low-density, high-strength thin cement sheets

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Abstract

The theory of inventive problem solving (TRIZ) reverse is a process in which known solutions are used as a basis for seeking new problems or applications and involves steps such as back-tracing product strengths to inventive principles, selecting catchwords, conducting database searches, analyzing patent lists, and identifying opportunities for patent exploitation. This paper explores the application of TRIZ reverse methodology to the identification of new markets for patented products, with a focus on low-density, high-strength thin cement sheets. Although research in the literature has used these methods, the details are often kept confidential. This study bridges that gap by offering a detailed examination of the TRIZ reverse process and its application to cement sheets, with specific demonstrations of patent search commands and a discussion of potential exploitation avenues. The insights provided here can facilitate a broader understanding and implementation of TRIZ reverse, thus empowering researchers to identify untapped market opportunities for existing technologies. The search results revealed various potential applications of thin cement sheets beyond solar panels. These include construction materials such as outer skins for wall panels, siding, partition walls, roofing, and ceilings; food industry applications such as food containers and boxes; wet-area lining boards; and smoke containment curtains for public buildings, including hotels, restaurants, prisons, hospitals, airports, and aircraft.

Keywords: Catchwords, High-Strength Thin Cement Sheets, Low-Density, New Market Identification, Patent Exploitation Opportunities, TRIZ Reverse.

1. Introduction

The concept of open innovation, proposed by Chesbrough (2003), suggests that in-house technologies or patents can be extended beyond their original domain by licensing them to other companies. However, there is no clear methodology for identifying new markets outside the primary domain of a given technology. Common practices in business research include market segmentation, which involves demographic analysis, geographic segmentation, psychographic segmentation, and behavioral segmentation, which are typically followed by studies of customer needs and pain points through surveys, questionnaires, focus groups, and customer feedback (Kotler et al., 2022). This process often continues until a business model canvas is built (Osterwalder & Pigneur, 2010). However, the identification of new markets largely relies on the subjective judgment of market researchers, and no systematic approach has been developed.

The theory of inventive problem solving (TRIZ) was developed by Altshuller (1984; 1996) to address inventive problems that involve contradictions in properties or functions. Conventionally, such problems have been handled by finding compromises between conflicting properties, neither of which is fully optimized. However, TRIZ takes a different approach by introducing an additional property to resolve the conflict between the original properties. For instance, the properties of strength and the requirement for a lightweight product may conflict in the design of a table (Dewulf, 2005). TRIZ resolves this by adding a property such as porosity or fragmentation, leading to a solution such as a porous or segmented table that is both strong and lightweight.

Whereas TRIZ follows a "problem seeks solution" methodology, TRIZ reverse applies a "solution seeks problem" approach, which involves identifying new potential applications or problem areas based on a known technical solution. Several researchers have contributed to the development of procedures for implementing TRIZ reverse (Glaser & Miecznik, 2009; Bianchi et al., 2010; Günther et al., 2021; Günther & Popova, 2022; Dewulf et al., 2023). For example, Glaser and Miecznik (2009) proposed a six-step process for applying TRIZ reverse to a fully implantable distraction system, a device that gradually increases the distance between two bone segments using a telescopic implement (Wittenstein, 2006). There were numerous steps in their process, including constructing contradiction pairs, selecting patent database search terms, and choosing the most promising applications.

Bianchi et al. (2010) later introduced a five-step procedure for searching alternative technology applications (ATAs), another term for identifying new markets. Their process began with defining the requirements for the technology, followed by TRIZ-based analysis, abstraction, and patent database searches. However, the specifics of the patented technology, patent search commands, and twenty applications were omitted.

Subsequent research by Günther et al. (2021) and Günther and Popova (2022) refined these processes. These authors developed a seven-step method for systematic knowledge and technology transfer and included detailed procedures for creating search commands for the German patent database (DPMA), although these were limited to specific patents, and the researchers did not address the broader issue of industrial applications.

Dewulf et al. (2023) simplified their process to give a five-step procedure, using software tools such as Patent Inspiration (AULIVE, 2024) to automate parts of the analysis. However, challenges in terms of implementation, particularly regarding the identification of suitable industries for technology transfer, remained unaddressed.

Based on previous research on TRIZ reverse, the TRIZ reverse procedure can be depicted as in Fig. 1.

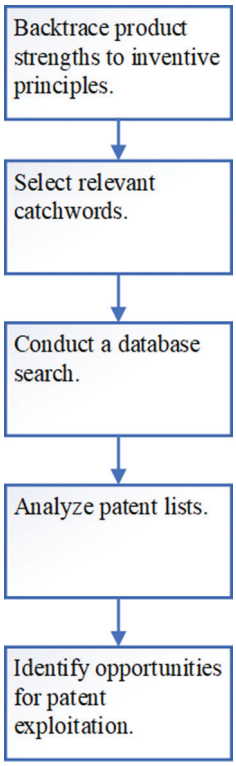

Fig. 1. TRIZ reverse procedure

Given the limitations of previous research, this paper aims to bridge the current gap in the area of TRIZ reverse implementation using low-density high-strength thin cement sheets as an example. There are two objectives in this study: first, we aim to provide a detailed procedure for TRIZ reverse that can be easily applied using the European Patent Database, and secondly, we aim to discuss the potential pitfalls of current methodologies in identifying promising applications and proposing remedies. The remainder of the paper is organized as follows: section 2 presents a review of the literature, section 3 describes the application of our TRIZ reverse method, and Section 4 concludes the study.

2. Literature Review

Understanding new markets for innovative products is challenging for many large firms, due to the need for cohesive collaboration among various departments (Dougherty, 1990). Established theory suggests that successful market identification relies on the integration of insights from planners, technical teams, field operations, and manufacturing departments. Case studies have demonstrated that when these groups work together organically, a more accurate understanding of new markets can be formed through effective communication. In contrast, product failures often result from siloed relationships, where information is communicated in a linear, rigid manner, as this leads to frequent miscommunications.

Despite this finding, business professionals often rely on their judgment and intuition when exploring new markets, which lacks a systematic approach. Common tools such as questionnaires, interviews, and focus groups are used to gather direct insights from potential customers (Kotler et al., 2022), but this approach tends to target familiar types of customers, driven by preconceived notions, and often overlooks potential customers in other less obvious fields.

To overcome this psychological inertia, the TRIZ reverse methodology can be applied. By abstracting the

product, the TRIZ reverse approach helps to identify potential customers in other industries. As illustrated in the context of ATAs by Bianchi et al. (2010), the TRIZ approach can be reversed: rather than progressing from a specific problem to an abstract problem, then progress from there to an abstract solution, and finally, to a specific solution, TRIZ reverse starts with a specific solution and works backward to a specific problem through abstract solutions and problems. Since all TRIZ tools are derived from patent databases, these databases can be used in accordance with TRIZ tools such as function analysis, evolution potential analysis, the 40 inventive principles, and frequently used terms in patents or research papers, to identify possible applications in other industries.

Günther et al. (2021) attempted to refine this process by providing a specific search command for the DPMA regarding a patented technology (DE10,2017,123,891 B4) of a collagen-based layer material (Harre et al., 2019). Their search command was constructed to identify patents discussing a layered arrangement or process involving collagen materials, with descriptions of properties such as pressure, temperature, and density, and where segmentation or bonding were ensured. Although the search command was effective in retrieving the patent itself, the study did not specify the industry in which the technology would be licensed, thus limiting its broader application.

To facilitate patent retrieval in DPMA, Günther et al. (2021) developed a search command tailored to the patented technology (DE10,2017,123,891), which pertains to a method for obtaining a collagen-based layer material. The command was created as follows: (BI=(Schichtanordnung UND Schichten ODER Sichtmaterial ODER Verfahren UND Kollagenmaterial)) UND (BI=(Eigenschaft? UND Druck? ODER Temperatur? UND Dichte?)) UND (BI= (segmentieren ODER zerlegen ODER teilen)) UND (BI= (Verbund? ODER Verbindung?)).

In this context, "BI" refers to "bibliographic information," indicating that the search command is applied to all fields in the patent document. The command "Schichtanordnung UND Schichten ODER Sichtmaterial ODER Verfahren UND Kollagenmaterial" translates to "Schichtanordnung" (layer arrangement) AND "Schichten" (layers) OR "Sichtmaterial" (visible material) OR "Verfahren" (process) AND "Kollagenmaterial" (collagen material). The command "Eigenschaft? UND Druck? ODER Temperatur? UND Dichte?" translates to "Eigenschaft?" (property?) AND "Druck?" (pressure?) OR "Temperatur?" (temperature?) AND "Dichte?" (density?). The question mark "?" is used as a wildcard that allows for variations of the word (e.g., "Eigenschaften" could be matched). The command "segmentieren ODER zerlegen ODER teilen" searches for documents containing any of these terms related to division or segmentation: "segmentieren" (segment), "zerlegen" (disassemble), or "teilen" (divide). The command "(Verbund? ODER Verbindung?)" searches for words related to composite or connection, such as "Verbund?" (composite?) or "Verbindung?" (connection?). In summary, this search command was designed to find patents that include a discussion of a layered arrangement or process involving collagen materials while also describing certain properties such as pressure, temperature, and density. The search also includes terms related to segmenting or dividing materials and ensuring that those segments form a composite or connection. The use of "?" as a wildcard enabled the search to capture variations of the base words, allowing for broader results.

Note that the five German words in the first BI are derived from the five most frequently used terms in the patent text, which can be retrieved using Voyant Tools (2024). The terms in the other BIs are based on the catchwords for the top three inventive principles: (35) property changes, (1) segmentation, and (40) composite materials (Mann, 2006).

We entered the command in expert mode on DPMA (Fig. 2), resulting in 622 hits, as shown in Fig. 3. Note that in Fig. 2, the top three inventive principles are listed beside the command lines, indicating that command lines 2–4 correspond to these three principles. Note that DE10,2017,123,891 appears as item 376 in the search list (Fig. 4), demonstrating that the command successfully retrieves its patent. However, this paper does not specify the industry in which the patented technology will be licensed. Only rough IPC codes, including section, class, and subclass, are provided.

Günther and Popova (2022) used a similar approach for technology transfer with a patented self-synchronizable network (US 10,241,539 B2) (Wetzel et al., 2019), and crafted a search command to find patents that mentioned specific technical terms. Despite some success, their approach faced challenges in terms of identifying broader industry applications.

The command they used is repeated here for reference: (BI=(Phase ODER Netzwerk ODER Signal ODER Verzögerung ODER Knoten)) UND (BI=(Vibrieren UND Welle ODER Hz UND Gigahertz)) UND (BI=(Elektrisch ODER Atom ODER Drahtlos UND Feld)) UND (BI=(Muster UND UV ODER Synch ODER Frequenz)).

The command "(BI=(Phase ODER Netzwerk ODER Signal ODER Verzögerung ODER Knoten))" searches for patents where the following terms are present: "Phase," "Netzwerk" (network), "Signal," "Verzögerung" (delay), or "Knoten" (node). The command "(BI=(Vibrieren UND Welle ODER Hz UND Gigahertz))" looks for patents containing the

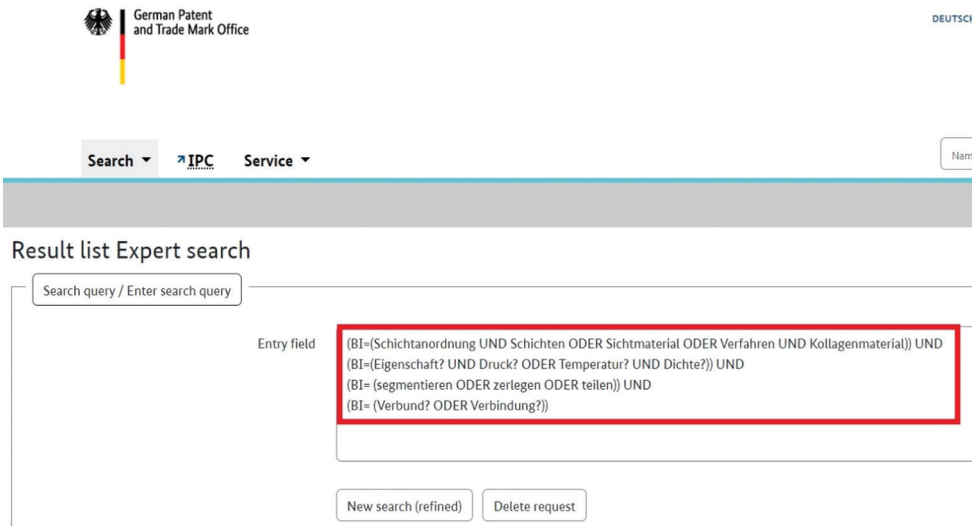

Fig. 2. Search of the German patent database in expert mode for patent DE10, 2017, 123, 891

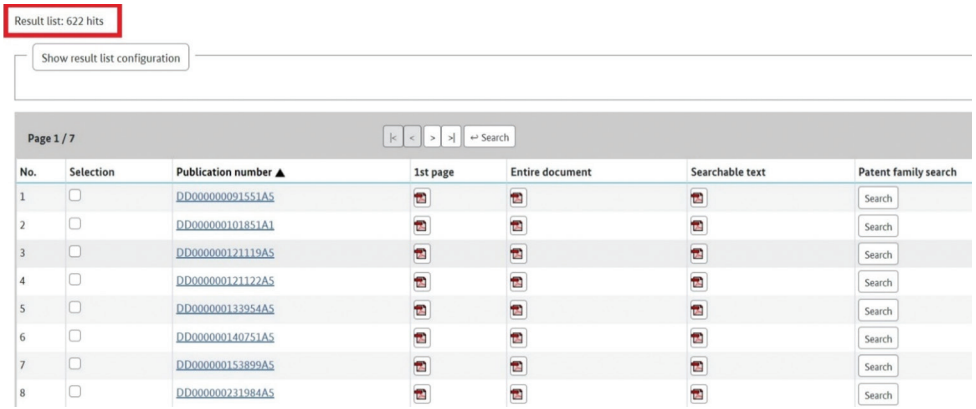

Fig. 3. Results of the search shown in Fig. 2

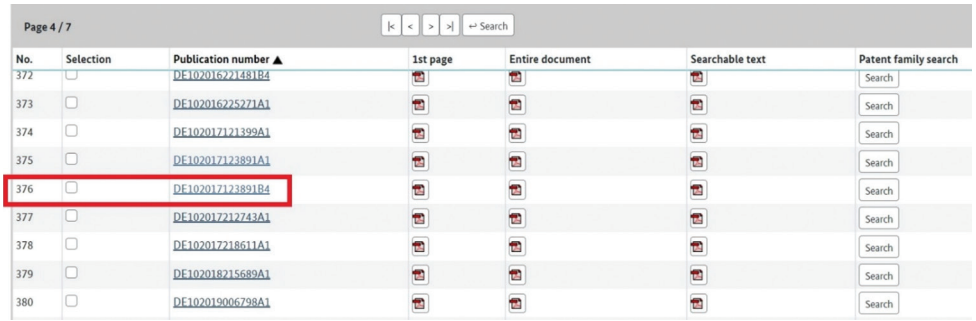

Fig. 4. DE10, 2017, 123, 891 appears in the list of results

words "Vibrieren" (vibrate) and "Welle" (wave) or the terms "Hz" (hertz) and "gigahertz." The command "(BI=(Elektrisch ODER Atom ODER drahtlos UND Feld))" searches for documents containing either "Elektrisch" (electric), "Atom" (atom), or "Drahtlos" (wireless) and "Feld" (field). The command "(BI=(Muster UND UV ODER Synch ODER Frequenz))" specifies that the patents must include the terms "Muster" (pattern) and "UV" (ultraviolet) or the terms "Synch" (sync) or "Frequenz" (frequency). In summary, these commands are used to find patents that mention specific combinations of technical terms. The search will return documents that (i) contain any of the terms related to phases, networks, signals, delays, or nodes; (ii) include either combinations of vibrations with waves or hertz with gigahertz; (iii) mention electric, atomic, or wireless concepts in conjunction with fields; and (iv) discuss patterns with ultraviolet aspects, or include terms related to synchronization or frequency.

Note that the five German words in the first BI are derived from the five most frequently used terms in the patent text, which can be retrieved using Voyant Tools (2024). The terms in the other BIs originate from the catchwords for the top three inventive principles: (18) mechanical vibration, (28) mechanics substitution, and (32) color change (Mann, 2006). In Fig. 5, the top three inventive principles are listed beside the command lines, indicating that command lines 2–4 correspond to these three principles. The search yielded 471 hits, but due to space constraints, the results are not displayed here.

The patent family associated with US10241539B2 includes CN106462177 (A), CN106462177 (B), EP2957982 (A1), EP2957982 (B1), KR102029320 (B1), KR20170021303 (A), TW201601566 (A), TWI721948 (B), US2017139438 (A1), and WO2015193512 (A1), as retrieved from the European Patent Office (EPO) (Fig. 6). This patent has been applied in China, Taiwan, Korea, and the USA and has also been applied by the EPO – which provides a centralized procedure for granting patents in Europe – and the World Intellectual Property Organization, which is responsible for the Patent Cooperation Treaty. DPMA also includes EP patents, but the search results do not include EP2957982 (A1) and EP2957982 (B1), as shown in Fig. 7. In summary, this search command cannot locate its patent in the DPMA, indicating that the recall ability of this command is weak. In the domain of classical information retrieval, and particularly in patent searches, recall is defined as the ratio of the number of relevant patents retrieved to the total number of relevant patents available in the database, as shown in Eq. (1) (Bonino et al., 2010). It measures the completeness of the retrieval process, i.e., how well the system finds all the relevant patents.

$$\text{Recall} = \frac{\text{Number of relevant patents retrieved}}{\text{Total number of relevant patents available}} \quad (1)$$

In this case, the number of relevant patents retrieved was low because the correct patents, EP2957982 (A1) and EP2957982 (B1), could not be retrieved using this search command. Consequently, the recall rate for this search command is low.

Our proposed new methodology is described below. Low-density, high-strength thin cement sheets are designed to satisfy the loading requirements for solar panels (Deng et al., 2023). The purpose of these large, thin cement sheets is to replace the

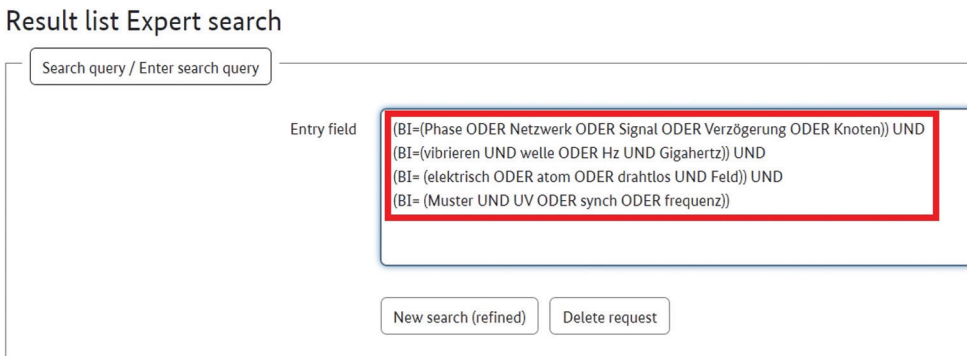

Fig. 5. Search of the German patent database in expert mode for US10241539

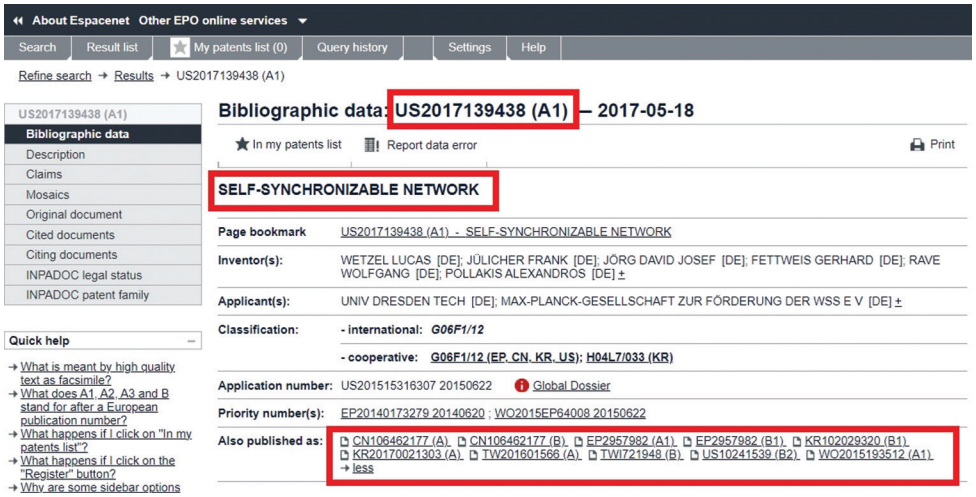

Fig. 6. Patent family for US10241539B2

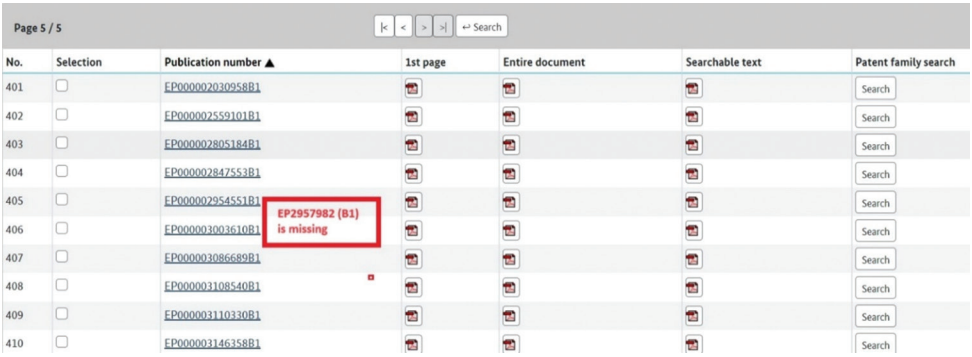

Fig. 7. EP2957982 (B1) is missing from the search list

glass in conventional solar panels, thereby creating a lightweight solar panel weighing less than 10 kg. This weight reduction would enable a one-person installation of solar panels rather than a two-person task, thereby significantly increasing the efficiency of the solar panel installation process. These sheets are used as backsheets in glassless solar panels, as illustrated in Fig. 8 (from a Taiwanese patent by Hsiao et al., 2022).

As a pilot run, Deng et al. (2023) created an A4-sized thin sheet with a thickness of 7 mm that could withstand a load of 1.5 kg. Seaweed powder was mixed with Portland cement, a foaming agent, calcium sulfoaluminate, and water. The resulting sheet was sandwiched between layers of ethylene vinyl acetate and a backsheet, resulting in a composite cement sheet. There are two advantages of a sandwiched cement sheet of this type: first, it can support loads of up to 13 kg in a static mechanical loading test without bending, for over 8 h, and second, it can be quickly recovered at the end of its life cycle.

In contrast to conventional low-density, thin cement sheets that support less than 300 grams, the seaweed-powder-based thin cement sheet can withstand a load of 1.5 kg, demonstrating a load-bearing performance five times greater than that of traditional sheets. Moreover, its composite structure significantly enhances its strength, enabling it to support loads of up to 13 kg. This invention effectively resolves the contradictions between thinness and strength, as well as between weight and strength. Although this invention has not been patented, it serves as a perfect example of a technology to which TRIZ reverse can be applied. An exploration of how this technology can be applied to industries beyond solar panels is presented here to help clarify the process of TRIZ reverse.

In summary, given the limitations of existing approaches, this paper aims to bridge the current gap in the implementation of TRIZ reverse using low-density high-strength thin cement sheets as a case study. The two objectives in this study are (i) to provide a detailed procedure for TRIZ Reverse that can be easily applied using the European Patent Database and (ii) to discuss the potential pitfalls of current methodologies in terms of identifying new applications and to propose remedies.

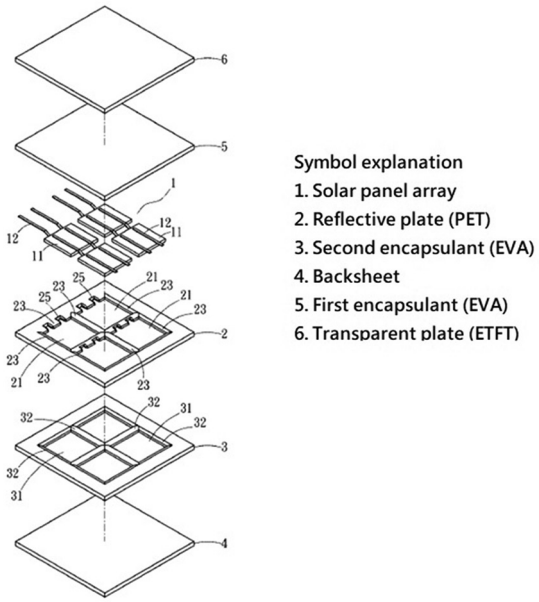

Fig. 8. Detailed view of a glassless panel (Hsiao et al., 2022)
Abbreviations: ETFT: Ethylene tetrafluoroethylene; EVA: Ethylene vinyl acetate; PET: Polyethylene terephthalate
Note: For the meaning of other numbered labels, please refer to the original patent (https://tiponet.tipo.gov.tw/twpat1/twpatusr/00020/GA-I769951.pdf?324551295).

3. Application of TRIZ Reverse

To address the contradiction between the attributes of thinness and strength of the cement sheets, we first identify the relevant engineering characteristics from the 39 engineering parameters recognized in TRIZ: length of a stationary object (Parameter 4) and strength (Parameter 14). Although the goal is to improve strength, the length of the stationary object

poses a challenge. By consulting the contradiction matrix, we can identify the following inventive principles: dynamics (Principle 15), spheroidality–curvature (Principle 14), mechanics substitution (Principle 28), and copying (Principle 26). These principles can guide the development of solutions that can effectively resolve the identified contradiction.

Similarly, to tackle the contradiction between weight and strength, the corresponding engineering characteristics were identified as the weight of a stationary object (Parameter 2) and strength (Parameter 14). The contradiction matrix suggests the following inventive principles: composite materials (Principle 40), copying (Principle 26), cheap short-lived objects (Principle 27), and segmentation (Principle 1).

Table 1. Catchwords for inventive principles.

IPs	Frequency	Catchwords
26: Copying	2	Optical, virtual, reflect (ion), UV, IR
1: Segmentation	1	Split, segment, multi-, divide, micro
14: Spheroidality–curvature	1	Curve, spiral, rotary, circular, sphere
15: Dynamics	1	Dynamic, variable, flexible, free, adapt
27: Cheap, short-lived objects	1	Disposable, cheap, replace, inexpensive, simplification
28: Mechanics substitution	1	Electrical, magnetic, optical, acoustic, wave
40: Composite materials	1	Composite, fiber, (inter-) layer, grid, filler

Abbreviations: IPs: Inventive Principles; IR: Infrared; UV: Ultraviolet.

Table 1 below lists the inventive principles along with their corresponding catchwords, which were used to guide the search for new applications. The column marked "Frequency" represents the number of times the inventive principles appear in these two contradictions.

Using Voyant Tools (2024), we also extracted the five most frequent words from the work by Deng et al. (2023) as cement (172), sheet (151), solar (71), thin (59), loading (56), and density (56), meaning that "cement" occurs 172 times, "sheet" 151 times, and so on. To search, we entered the command: ("cement sheet" AND load* AND thin AND density AND solar) into the Espacenet database, which returned the patent AU2009279384 (A1). The patent search results are shown in Figs. 9 and 10. We note that in Fig. 9, only the English patent database is selected rather than the entire Espacenet patent database; this is because full-text search is available only in the English patent database, whereas we can only search for keywords in the title or abstract in the Espacenet database. Patent AU2009279384 (A1) describes the use of cement sheets as outer skins for wall panels. From the website for these wall panels, it was found that these cement sheets can also be used for cement sidings, partition walls, roofing, and ceilings (see https://lonwow.en.made-in-china.com/product/fKyxcNHJABVe/China-Fiber-Cement-Exterior-Wall-Panel-with-Australia-Standard-4-5-18mm-Thickness.html). When the command was adjusted to exclude the word "solar" ("cement sheet" AND load* AND thin AND density), it returned 86 patents, which broadened the scope to various construction-related applications. The cooperative patent classification (CPC) codes in the section, class, and subclass for those 86 patents are illustrated in Fig. 11. The meanings of the specified CPC codes are as follows:

1. C04B: Lime; magnesia; slag; cements; compositions thereof; ceramics; refractories;

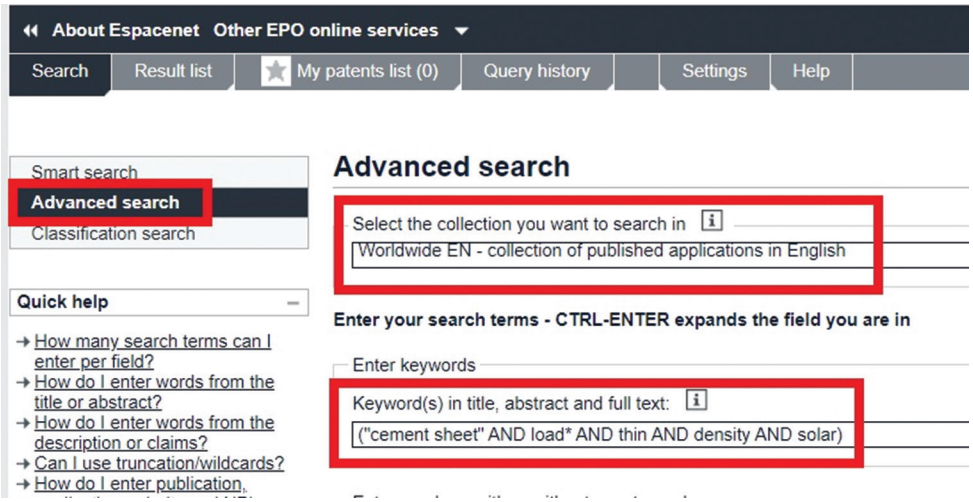

Fig. 9. Advanced search for all requirements using Voyant Tools

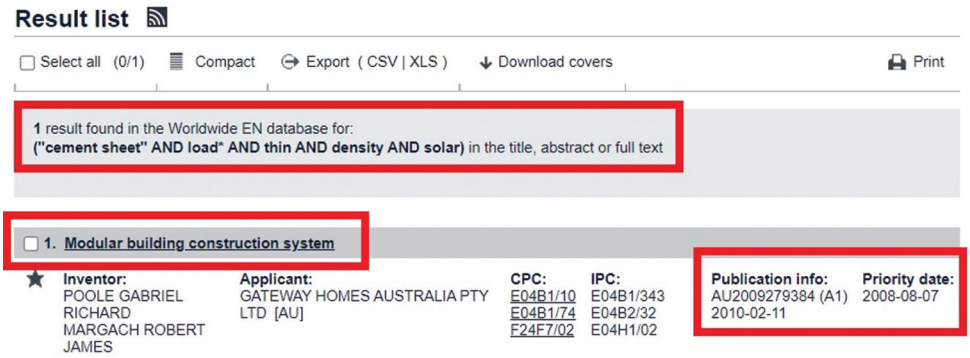

Fig. 10. Results of the search shown in Fig. 9

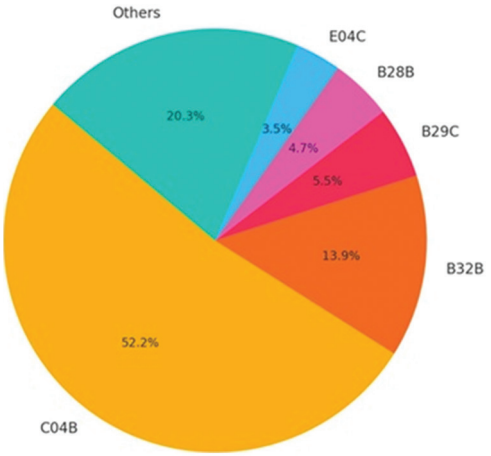

Fig. 11. The distribution of CPC codes among the 86 patents
Abbreviation: CPC: Cooperative patent classification

treatment of natural stone. This code relates to the production and processing of cement, ceramics, and other similar materials.

2. B32B: Layered products, i.e., products built up of strata of flat or non-flat, e.g., cellular or honeycomb, form. This involves the creation and processing of layered or laminated products, including materials such as composites.
3. B29C: Shaping or joining of plastics; shaping of substances in a plastic state, in general. This pertains to the techniques and methods used in molding, shaping, and joining plastics or other materials in a plastic state.
4. B28B: Shaping clay or other ceramic compositions; shaping materials in a plastic state, not otherwise provided for. This code covers the processes involved in shaping ceramic materials and other substances in a plastic state.
5. E04C: Structure elements; building elements; built-up structures. This involves the construction of structural elements such as building frameworks, modular constructions, and other components used in construction.

Each patent has several CPC codes. For example, one of the 86 patents is US2022363602 (A1), which has the following CPC codes: B28B1/16 (EP, US), B28B1/522 (EP, US), B28B1/525 (EP, US), B28B23/0087 (EP), C04B14/06 (US); C04B14/185 (US), C04B18/24 (US), C04B28/02 (US), C04B28/04 (EP), C04B40/0064 (US), E04C5/073 (US), C04B2111/00612 (EP, US), E04C5/073 (EP), and Y02W30/91 (EP). Each CPC code is reduced to its section, class, and subclass, so that B28B1/16 is reduced to B28B. Following this scheme, the patent US2022363602 (A1) has the following classifications: B28B (4), C04B (7), E04C (2), and Y02W (1), meaning that B28B occurs four times, C04B seven times, etc. This process was repeated for all 86 patents, resulting in the data presented in Fig. 11.

Specifically, Fig. 11 presents a pie chart showing the percentage distribution, with CPC codes representing less than 3% grouped under "Other." The specific CPC codes displayed include C04B (764), B32B (204), B29C (80), B28B (69), and E04C (51). The analysis was done using ChatGPT (OpenAI, 2024). The CPC codes indicate that most of the patents are related to construction materials, except for one instance of C04B, which is related to the process of making cement.

When the details of the 86 patents were examined, one particular example – WO199515849 – stood out, highlighting a new direction for the use of cement sheets (Andersen and Hodson, 1995). This patent suggested that cement sheets could be used in food containers and boxes.

We further refined our search by inputting the command ("cement sheet" AND load*) AND (curve OR sphere), which retrieved 35 patents. Of these, WO2020/234622 (Priyadarshana et al., 2020) proposed a new application for wet-area lining boards (where "wet area" refers to spaces such as shower rooms and restrooms). In addition, patent US20150086773 (Grundy et al., 2015) indicated that lightweight cement sheets could be utilized for:

Table 2. Applications of cement sheets

Command in search	Patents retrieved	Patent number	Applications
("cement sheet" AND load* AND thin AND density AND solar)	1	AU2009279384 (A1)	Outer skins for wall panels, sidings, partitions, roofing, and ceilings of buildings
("cement sheet" AND load* AND thin AND density)	86	WO199515849	Food containers and boxes
("cement sheet" AND load*) AND (curve OR sphere)	35	WO2020/234622	Wet-area lining boards
		US20150086773	High-rise buildings or structures built on less stable ground, areas prone to extreme weather conditions
("cement sheet" OR "cement plate" OR "cement board") AND (segment OR divide) AND (dynamic OR flexible)	137	CA2808343A1	Green roofs and living walls
		US5607758	Smoke containment curtains for public buildings such as hotels, restaurants, prisons, hospitals, airports, and aircraft

1. Lightweight building solutions: Due to their reduced density and weight, these materials are suitable for construction projects where minimizing structural load is crucial, such as in high-rise buildings or structures built on less stable ground.
2. Building exteriors: These aerated panels are particularly well-suited for use on building exteriors, especially in areas prone to extreme weather conditions.

Lastly, we input the command ("cement sheet" OR "cement plate" OR "cement board") AND (Segment OR divide) AND (Dynamic OR flexible), which returned 137 patents. Of these, patents CA2808343A1 (Hellwig, 2011) and US5607758A (Schwartz, 1997) revealed new applications. Patent CA2808343A1 indicated that cement sheets, plates, or boards could be used in the following applications:

1. Green roofs: The system is particularly suitable for creating environmentally friendly, energy-efficient roofs that contribute to urban sustainability. It is applicable in both new constructions and retrofits to existing roofs, due to its lightweight nature.
2. Living walls: This technology can be applied to the construction of living walls on buildings, providing esthetic, environmental, and insulation benefits. This would be especially useful for vertical gardening in urban spaces.

The patent described in the document US5607758 pertains to a "smoke containment curtain." This is designed to contain smoke within a confined area, such as a ceiling segment or corridor, and is particularly useful in environments where fire safety is critical. Cement sheets, plates, or boards can be incorporated into this design. The specific applications of this patent include:

1. Public buildings: The smoke containment curtain can be used in public buildings such as hotels, restaurants, prisons, and hospitals, where fire safety regulations require systems to prevent the spread of smoke and toxic fumes during a fire.
2. Airports and aircraft: The curtain can be applied in airports and aircraft to contain smoke, especially in confined spaces, where toxic fumes can be deadly.

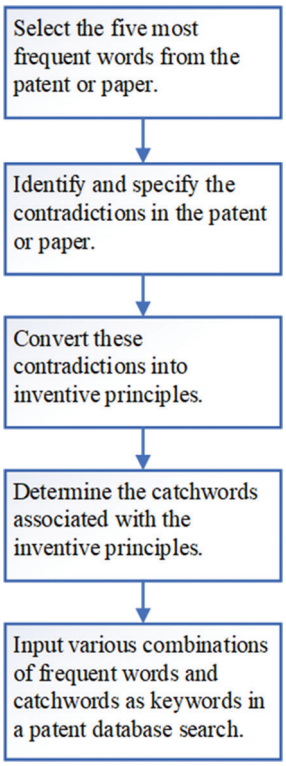

Fig. 12. Patent search procedure

We created a summary of the applications based on the patents retrieved using these commands in searches of the English Espacenet patent database, as shown in Table 2. All patent summaries were generated using ChatGPT (OpenAI, 2024).

The search results revealed that low-density,

high-strength thin cement sheets have potential applications beyond solar panels, extending into various domains including construction, food packaging, and safety solutions. We note that full-text searches of the English patent database were limited to only 10 terms, whereas the German patent database allowed for more than 10 terms in full-text searches, making the English patent database less powerful for comprehensive full-text patent searches.

To address the previous issue of low recall in retrieving the correct patent in Fig. 7, it is suggested that various keyword combinations from Table 2 can help mitigate this problem. Finally, to ensure the completeness of the patent search in TRIZ reverse, a flowchart is presented in Fig. 12.

4. Conclusion

Identifying new markets for innovative products or technologies is essential for firms and typically involves collaboration among planners, technical teams, field operations, and manufacturing departments (Dougherty, 1990). Conventionally, this process is driven by marketing surveys and focus groups, meaning that researchers often have preconceived notions about potential markets. Such psychological inertia can limit the scope of market exploration.

The TRIZ reverse methodology overcomes this inertia by abstracting the contradictions inherent in new products or technologies and retrieving the corresponding inventive principles. Using catchwords derived from these principles (Mann, 2006), specific search commands can be formulated to uncover relevant patents, thereby revealing potential new applications. Although previous studies have laid the groundwork for using TRIZ reverse, they have primarily focused on the German patent database (Günther et al., 2021; Günther & Popova, 2022) or specialized software such as Patent Inspiration (Dewulf et al., 2023), and have often fallen short of identifying specific applications for new products, with only vague patent classification codes.

This paper addresses these gaps in two significant ways: first, we have demonstrated the use of the publicly accessible Espacenet patent database, thus enabling broader access to TRIZ reverse technology for English-speaking users, and second, we have delved into the details of the patents retrieved, thereby identifying specific applications for the product under investigation.

The product considered in this work consisted of low-density, high-strength thin cement sheets, which were designed to meet the loading requirements for solar panels (Deng et al., 2023). These large, thin cement sheets were developed to replace conventional solar panel glass and consist of lightweight panels weighing less than 10 kg, hence allowing for a one-person installation process. This invention resolves the contradictions between thinness and strength as well as between weight and strength. Although not yet patented, this product serves as an ideal example to illustrate the use of TRIZ reverse technology.

Four different search commands were used to explore potential applications:

1. (“cement sheet” AND load* AND thin AND density AND solar), which directly addressed the invention but retrieved only one patent: AU2009279384 (A1) (Poole and Margach, 2010).
2. (“cement sheet” AND load* AND thin AND density), which broadened the search by excluding the solar constraint, resulting in 86 patents.
3. (“cement sheet” AND load*) AND (curve OR sphere), which focused on loading capacity and inventive principle 14: Spheroidality – curvature, retrieving 35 patents.
4. (“cement sheet” OR “cement plate” OR “cement board”) AND (Segment OR divide) AND (Dynamic OR flexible), which expanded the scope to include thicker cement boards or plates, considering inventive principles 1: Segmentation and 15: Dynamics, and retrieved 137 patents.

The search results revealed several potential applications beyond solar panels, including:

1. Construction industry: outer skins for wall panels, siding, partition walls, roofing, and ceilings.
2. Food industry: food containers and boxes.
3. Wet-area lining boards.
4. High-rise buildings or structures on less stable ground and in areas prone to extreme weather conditions.
5. Green roofs and living walls.
6. Smoke containment curtains for public buildings such as hotels, restaurants, prisons, hospitals, airports, and aircraft.

There were certain limitations on this research, particularly in the patent search process, as only the abstracts were reviewed due to time constraints. This approach may have missed some potential applications.

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