Title:
Product Innovation based on Technology Recombination

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Introduction:

Product innovation can be conducted by recombination of technical elements of the product to form a complete process of technology development [6]. Research has discussed the quantification of technological innovation as a combination process based on a large number of data analysis [3], such as functional modeling of technology for reusability [5], a framework to explore promise and potential technology convergence relationships in the field [2], and the path for technology convergence between specific industries [1]. Although the existing methods have made progress in technology recombination, there is a lack of path to find key sub-technologies for the recombination. It is required to have a systematic and effective method to guide every step of technology recombination.

Technology recombination is typically manifested through introduction of new technological functionalities into a set of existing technologies [3]. This paper proposes a product innovative process based on technology recombination. The product technology system is analyzed by building an analysis diagram of existing products. Two paths driven by the problem and new requirement are proposed for the technological innovation opportunity discovery. Potential alternative technologies and new technologies are sought for the recombination with existing technologies of the product prototype. Innovative design of an automatic quantitative Chinese medicinal materials (CMMs) dispensing machine verifies the proposed method.

Main Idea:

Identifying and analyzing product technologies

Technology provides a means to achieve the design intent through product functions. Effective identification and analysis of existing technologies of products are the basis of technology-based innovations. Following two processes can be applied.

1) Main functions and key technical characteristics are extracted according to the design task. An existing mainstream product which can meet functional requirements is selected as a prototype product. Then, the relationship of product functions can be built based on the function decomposition and flow analysis of a product as shown in Figure 1(a).

2) A product technology system consists of sub-technologies related to power, transmission, execution and control, which can be sorted according to their importance. Therefore, a product technology system can be expressed as T = (T1, T2, … , Ti, Ti+1…) with the importance of Ti>Ti+1). A set of functions formed by technologies can be decided by analyzing the product function model, in

which functions with the greatest impact on the product system are core functions of the product. The principle and carrier of each core function can be decided as shown in Figure 1(b).

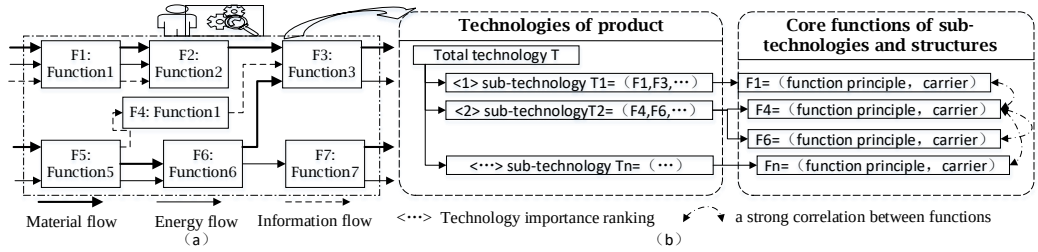


Fig. 1: Product technology analysis: (a) Function structure model, (b) Product technology analysis diagram.

Discovering technology opportunities

Problem driven and new requirement driven are two paths to determine objectives of technological innovation. The former is applicable to equipment problems, or when the improved technical indicators are clear. The fishbone diagram can be used to find the root cause and locate the final cause in the sub-technology system. Core functions of existing sub-technologies are determined as a key of technological innovation to build a simple technology model. The latter finds unsatisfied functions through the analysis of product requirements for the technical realization of new functions.

To implement key functions by potential technologies, software tools can be used to find the relevant effect or effect chain, and abstract the key functions for knowledge base. The effect input/output can be provided by the prototype product with a small amount of improvement, or technical characteristics matched to design requirements. Furthermore, technologies based on the effect chain can be implemented by designer experience, patent retrieval, and market research to finally form new technology solutions.

3.2 Production innovation based on technology recombination

The technology composition of the prototype product T= (T1, T2, …, Ti, …, Tn) and the potential technology are obtained in the above steps for a recombined technology system. Three basic operations rules are as follows.

1) If there are problems in the sub-technology of the prototype product, and the potential technology meets design requirements, the potential technology Tp replaces the corresponding sub-technology Ti to form a new T'= (T1, T2, …, Tp, …, Tn).

2) If the product needs to add new functional requirements, potential technology Tr for a new functional requirement is added into the original technology system to form a new T'= (T1, T2, …, Ti, …, Tn, Tr).

3) According to the requirement analysis, the removal defect technology Ti does not affect other technologies, a new technology system can be formed as T= (T1, T2, …, Ti-1, Ti+1,…, Tn).

If multiple sub-technologies need to be recombined, the one with the higher importance rank is recombined first. If the next sub-technology is affected by the first, technology system will be re-analyzed after the single recombination, otherwise, it can be recombined at the same time. The recombined technology is expressed as the principle solution or conceptual structure of the new product. The result is then evaluated. The TRIZ tool is introduced to solve any conflict between solutions. Otherwise, the next step should be executed.

Scheme output and optimization

Based on the solution sought for, technology system and function structure of the new product is established. Technical details are clarified to optimize the design and build a complete technology system. A new function structure can then be built. It is also important to evaluate the new scheme. A method of value engineering [19] is introduced as follows.

$$Vi=Fi/Ci \quad (1)$$

where V*i* is the coefficient value of scheme *i*, F*i* is the function score of scheme *i*. C*i* is the cost coefficient of scheme *i*. In summary, the proposed design process based on technology recombination as shown in Fig. 2.

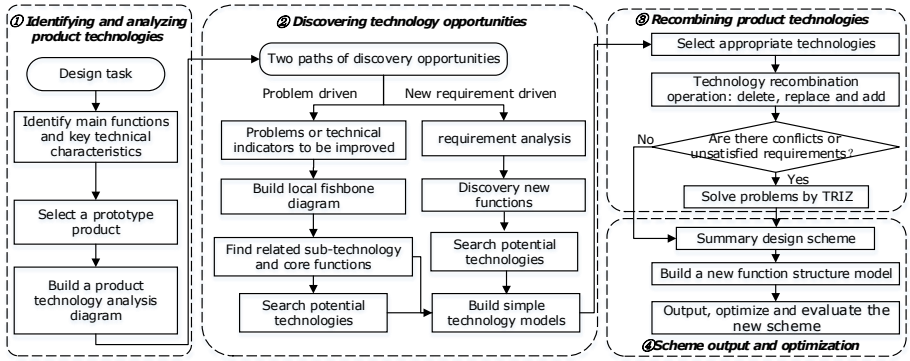


Fig. 2: Technology recombination based on the product innovative design process model.

Case Study:

The proposed method is applied in design of an automatic quantitative Chinese medicinal materials (CMMs) dispensing machine as follows.

1) The main functional requirement is “dispensing CMMs”, the key technical characteristics are “automatic operation”, “configuration speed”, “accurate weight”, and “safe and reliable”. A mainstream automatic quantitative CMMs dispensing machine is selected as the prototype product shown in Fig. 3 after analyzing the related equipment and patents.

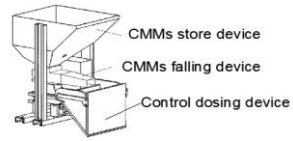


Fig. 3: A mainstream automatic quantitative CMMs dispensing machine.

By analyzing the working principle and functional structure of the prototype product, the function structure model and technology analysis diagram are formed as shown in Figs. 4 and 5, respectively. The total technology of the prototype product is T= (T1, T2, T3, T4).

2) Problems identified for improvement are low weight precision Q1, low dispensing speed Q2 and unable to continuously configure multiple pharmaceutical Q3. As a typical problem driven innovative design, Q1 and Q2 are not satisfied by the existing technology system, Q3 brings a new functional requirement “continuous dispensing”, but it has a strong correlation with T3 and can be used as a technology supplement to T3.

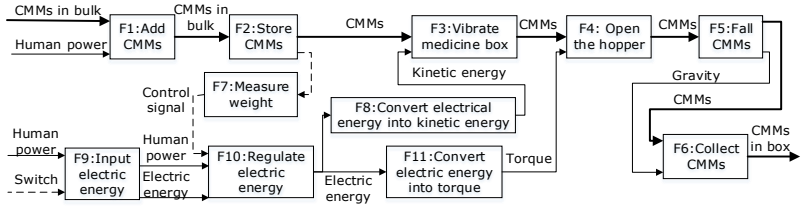


Fig. 4: Function structure model of the prototype product.

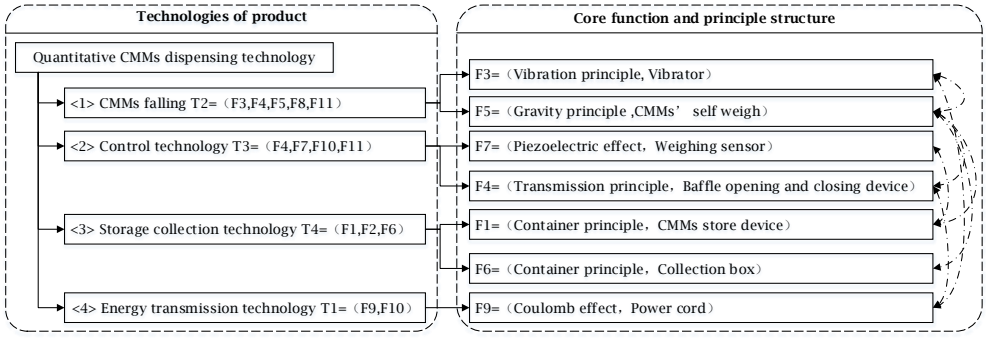


Fig. 5: Technology analysis diagram of the prototype product.

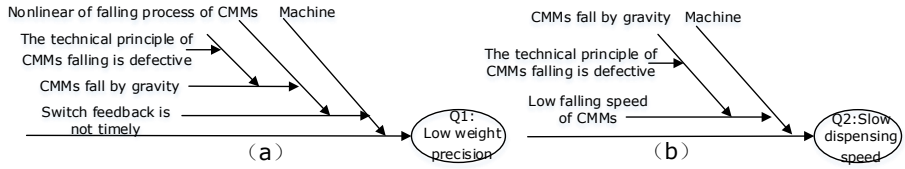


Fig. 6: Question analysis based on local fishbone diagram: (a) low weight precision Q1, (b) low dispensing speed Q2.

By analyzing local fishbone diagrams of Q1 and Q2 in Fig. 6, it is found that the main problem is that "CMMs falling technologies defective", function "F5: Fall CMMs" of sub-technology T1 has a strong correlation with "F3: Vibrate medicine box".

A simple technology model is shown in Fig. 7(a), the corresponding effect chain is "forced vibration →gravity drop". These key functions can be abstracted as function "move solid". The knowledge base called "effect knowledge base for function realization of different forms of matter" is then used to search available effects: brush, vibration, gravity, Pascal's law, and spiral principle. After analysis and synthesis, a new effect chain "spiral feeding →gravity drop" is established. Its technology model is shown in Fig. 7(b). The selected principle structure is a spiral feeding barrel driven by a stepping motor. For Q3, a similar process is used. An appropriate effect chain is then found as "container holding→ belt conveying". The selected principle structure is a conveyor belt with a series of equal capacity cubicle driven by a stepper motor to receive quantitative CMMs.

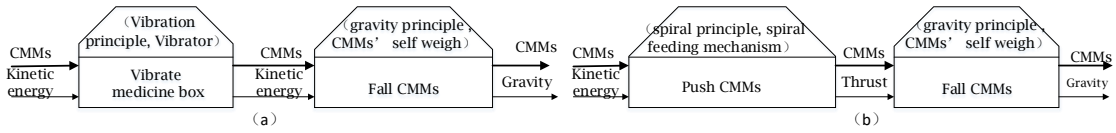


Fig. 7: Simple technology model: (a) sub-technology of the prototype product, (b) a new scheme.

3）Based on the above analysis, two functional units are found as "F1': Push CMMs" and "F2': Convert electrical energy into rotational kinetic energy 1", two new potential sub-technologies are obtained: Tp1= (F1', F2', F5) and Tp2= (F1, F2, F3', F6). According to the operation method of the technology recombination, operation rule 2 is selected, TP1 and TP2 can replace T1 and T3 of the prototype product, respectively. A new product technology system T'= (Tp1, Tp2, T2, T4) is formed to meet the requirements without any obvious technical conflict.

4）In summary, a function structure model of the new product is constructed as shown in Fig. 8. A conceptual design simulation model and a prototype of new CMMs dispensing machine are generated as shown in Figs. 9(a) and (b), respectively. It consists of a screw blanking device, a continuous

weighing and collecting device, a CMMs store device and a control device. The value formula is used to evaluate the scheme. It is found that the value of new scheme is better than the original design.

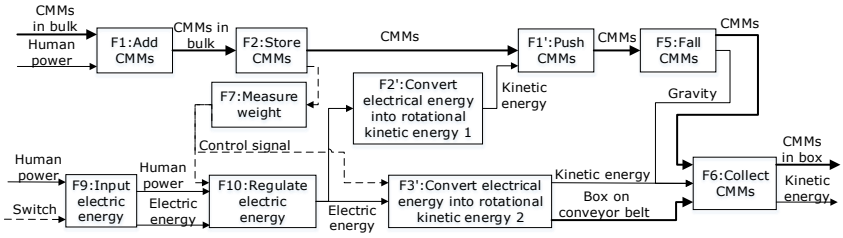
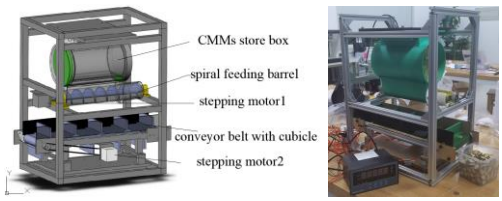


Fig. 8: Function structure model of the new conceptual design.



(a) (b)

Fig. 9: New CMMs dispensing machine: (a) 3D conceptual model, (b) Physical prototype.

Conclusions:

This paper proposes a method of technology recombination for product innovation design based on the product technology and function analysis. Two paths of the technological innovation opportunity discovery are developed as problem driven and new requirement driven methods for searching potential technologies. Operation rules of product technology recombination are proposed for the new scheme and solution optimization. Meanwhile, an evaluation method of design schemes is suggested. Further work will apply the method to different cases for the improvement.

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References:

[1] Fai, F.; Von, T.N.: Industry-specific competencies and converging technological systems: evidence from patents, Structural change and economic dynamics, 12(2), 2001: 141-170. https://doi.org/10.1016/S0954-349X(00)00035-7

[2] Feng, S.; An, H.; Li, H.; Qi, Y.; Wang, Z.; Guan, Q.; Li, Y.; Qi, Y.: The technology convergence of electric vehicles: Exploring promising and potential technology convergence relationships and topics, Journal of Cleaner Production, 2020: 120992. https://doi.org/10.1016/j.jclepro.2020.120992

[3] Parraguez, P.; Škec, S.; Carmo, D.O.; Maier, A.: Quantifying technological change as a combinatorial process, Technological Forecasting and Social Change, 151, 2020, 109803. https://doi.org/10.1016/j.techfore.2019.119803

[4] Robin, C.; Regine, S.: Target Costing and Value Engineering, Productivity Press, New York, NY,1997.

[5] Yoon, J.; Lim, J.; Choi, S.; Kim, K.; & Kim, C.H.: Ontological functional modeling of technology for reusability, Expert Systems with Applications, 38(8), 2011: 10484-10492.https://doi.org/10.1016/j.eswa.2011.02.090

[6] Youn, H.; Strumsky, D.; Bettencourt, L.M.; & Lobo, J.: Invention as a combinatorial process: evidence from US patents, Journal of the Royal Society interface, 12(106), 2015, 20150272. https://doi.org/10.1098/rsif.2015.0272