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Verifying Innovative Solutions of TRIZ Engineering Contradiction Matrix using Substance-Field Analysis in Manufacturing

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Abstract. TRIZ has been well-established and is widely applied in multi-national enterprises to enhance design innovation and problem solving for design and manufacturing problems. Most applications of TRIZ utilise the engineering contradiction tools to solve design and manufacturing problems. This paper initially applied the engineering contradiction matrix to solve a semi-processed material transfer misalignment problem while passing through a furnace via a long mesh metal conveyor belt in the productions of automotive parts. Then, using another TRIZ tool, substance-field analysis to verify the solutions obtained earlier. This verification is to reduce the possible of errors in solving problems using the engineering contradiction matrix.

Introduction

TRIZ has been widely applied to help designers [1] to solve design problems and has been utilised by many multi-national enterprises including Samsung, Proctor & Gamble and many more. Not only TRIZ is widely utilised by large successful companies, the application of TRIZ has been expanding into many areas including software [2,3], social sciences [4,5], manufacturing [6] and others. TRIZ or the theory of inventive problem-solving was derived by Genrich Altshuller [7] from years of study on patent information. One of the main tools of TRIZ is the engineering contradiction matrix which is widely applied in solving many engineering problems. Though widely applied, the solutions obtained by the engineering contradiction matrix are rarely conceptually verified before they are implemented. This research work attempts to investigate whether different TRIZ tools can be utilised to verify the solutions from each other to reduce error.

Engineering Contradiction Matrix

In most application of TRIZ to solve manufacturing problems, the inventive principles recommended to solve the problems are obtained after determining the contradicting features (improving and worsening features) related to the problem that need to be solved from the engineering contradiction matrix (Table 1). These recommended inventive principles are then interpreted to specific solutions to the manufacturing problems. There are 40 inventive principles in the engineering contradiction matrix. Table 2 illustrates the 40 inventive principles.

Table 1 The schematic diagram of engineering contradiction matrix [6].

Worsening feature / **Improving feature**	….	18: Illumination Intensity	….	39. Productivity
⋮	⋮	⋮	⋮	⋮
12: Shape	….	13 15 32	….	17 26 34 10
⋮	⋮	⋮	⋮	⋮
39: Productivity	….	14 10 34 40	….	

Table 2. The 40 inventive principles of engineering contradiction matrix [6].

1. Segmentation	11. Beforehand Cushioning	21. Skipping	31. Porous Materials
2. Taking out/ Extraction	12. Equipotentiality	22. "Blessing in Disguise"	32. Colour Changes
3. Local Quality	13. "The other way round"	23. Feedback	33. Homogeneity
4. Asymmetry	14. Spheroidality - Curvature	24. "Intermediary"	34. Discarding and Recovering
5. Merging	15. Dynamisation	25. Self-Service	35. Parameter Changes
6. Universality	16. Partial or Excessive Action	26. Copying	36. Phase Transitions
7. "Nested Doll"	17. New Dimension	27. Cheap Short-Living Objects	37. Thermal Expansion
8. Anti-Weight	18. Mechanical Vibration	28. Mechanics Substitution	38. Strong Oxidants
9. Preliminary Anti-Action	19. Periodic Action	29. Pneumatics and Hydraulics	39. Inert Atmosphere
10. Preliminary Action	20. Continuity of Useful Action	30. Flexible Shells and Thin Films	40. Composite Materials

Substance-Field Analysis

Another important TRIZ tool developed by Altshuller is the substance-field analysis or Su-Field analysis which are utilised for classifying problems within systems and their solutions. Using simple representation of triangles to zoom into the field of the problematic function and substances that interact with it, this representation allows the engineer to identify the types of interaction and utilise the 76 standard solutions [8] to solve the manufacturing problem. There are 4 types of possible interaction, namely incomplete, ineffective, harmful and measurement/detection. Fig. 1 illustrates a simple triangular representation of the Su-Field model while Fig. 2 shows the guide to solve problems using Su-Field analysis. The schematic representation of the guide to use class of 76 standard solutions to solve manufacturing problems using Su-Field analysis [8] is shown in Fig. 2.

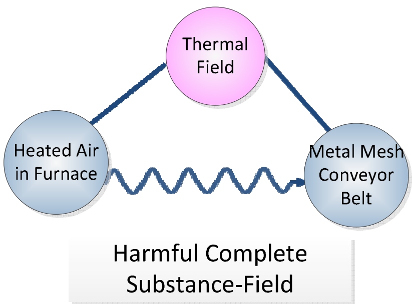

Fig. 1 The triangular representation of a Su-Field model for the material transfer misalignment problem.

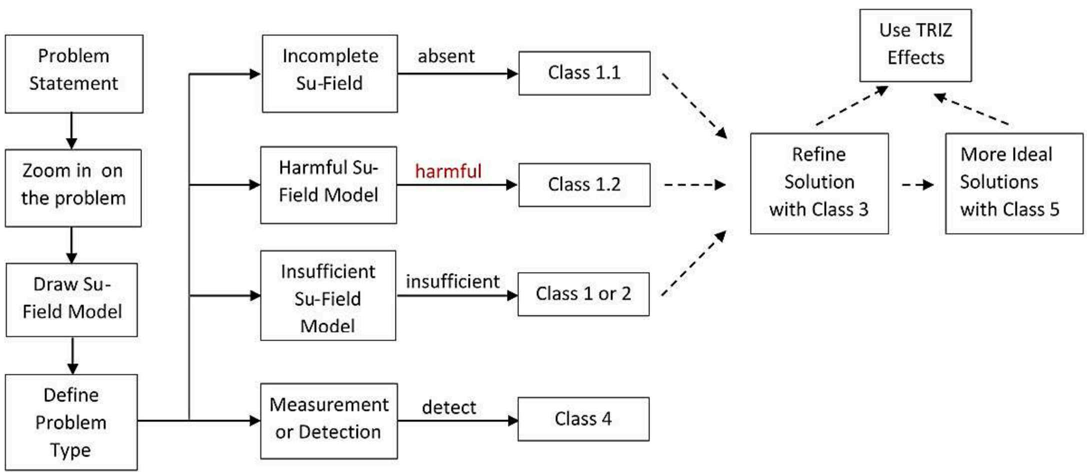

Fig. 2 The flow diagram to solve manufacturing problems using Su-Field analysis [8].

Solving Material Transfer Misalignment Problem using Engineering Contradiction Matrix

In an automative parts manufacturing factory, there is a metal mesh conveyor belt which moves semi-processed material through a 5 meter long furnace. Although material is properly aligned at furnace input, material emerges at the output in a misaligned manner. Since it is difficult to see the inside of the furnace as it is totally encased and extremely hot, nobody knows what happened inside. The solutions are expected to be implemented with minimal productivity impact and cost. Based on this, using the structured problem solving process, the problem was defined as a heat distortion problem. The function analysis model for this problem is shown in Fig. 3. The root cause-and-effect chain analysis was then carried out and Fig. 4 illustrates the model. Table 3 illustrates the application of engineering contradiction matrix to determine the inventive principles to solve the problem.

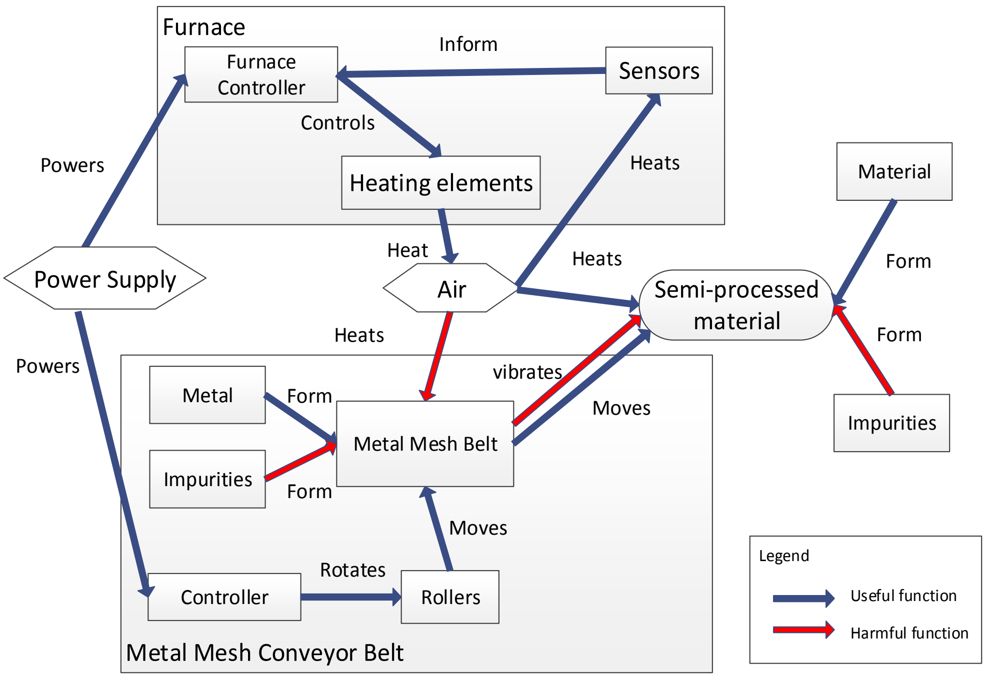

Fig. 3 Function analysis model for the semi-processed material misaligned after moving through the 5m long continuous furnace via a metal mesh conveyor belt.

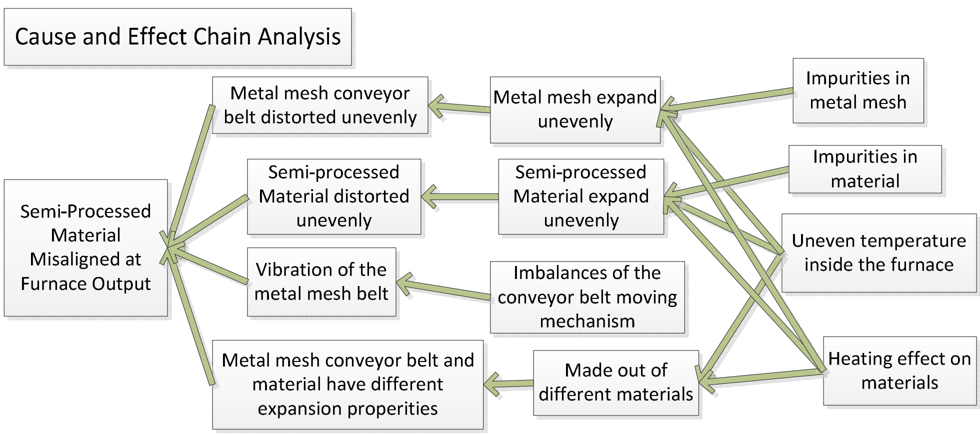

Fig. 4 Function Cause and Effect Chain Analysis for the semi-processed material misaligned at furnace output.

Since we presume that the material of the metal mesh conveyor belt and semi-processed material cannot be changed to avoid major disruption of the production and incur high cost, we have discard the root causes that due to distortion of semi-processed material and solutions that require the change of material (due to impurities, etc.), change of furnace type, etc.. The final decision is to select the inventive principle No.22 (Blessing in disguise) and No.24 (Intermediary/ Mediator) to solve this misalignment problem (shaded cell). Based on these two inventive principles, the misalignment problem can be resolved by introducing fixtures to secure and hold the semi-processed material from the vibration effects and to insulate the metal mesh conveyor belt with the insulating material, such as ceramic fibre to prevent the harmful heating effect.

Solving Material Misalignment Problem using Su-Field Analysis

The Su-Field analysis model for this problem is shown in Fig. 1 and the type of substance-field is a harmful substance field. The solution obtained from 76 standard solutions is in Class 1.2: Introduce a new substance. The solution is to introduce a new substance as shown in Fig. 5 and this new substance can insulate or shield (break) the harmful effects. An example of the new substance that can provide such insulation is ceramic fibre. This solution is consistent with the recommended inventive principle No. 22 obtained from the Engineering Contradiction (indicated by * in Table 3).

Table 3 The utilisation of engineering contradiction matrix to determine the inventive principles to solve the semi-processed material misalignment problem.

Problem Statement	**Possible Cause level 1**	**Possible Cause level 2**	**Possible Cause level 3**	**Contradiction**	**Improving Feature (improving parameter)**	**Worsening Feature**	**Inventive Principles**
Semi-Processed Material Misaligned at Furnace Output	Metal mesh conveyor belt distorted unevenly	Metal mesh expand unevenly	Impurities in metal mesh	If we remove the impurities problem, then there will be less misalignment but this incurs higher cost and disrupts production.	30: Object-affected harmful factors (Remove impurities in metal mesh)	39: Productivity (Disrupt production)	22 Blessing in disguise 35 Parameter Changes 13 The other way round 24 Intermediary/ Mediator
			Uneven temperature inside the furnace	If we control the heat distribution in the furnace then metal mesh expands evenly but some monitoring system need to be used which slow down productivity	17 Temperature (controlled heat distribution)	39: Productivity (Slow down productivity)	15 Dynamics 28 Mechanical substitution 35 Parameter Changes
			Heating effect on material of metal mesh	If we reduce heating effect, then this may avoid expansion caused by heating but may cause material to be heated insufficiently	30: Object-affected harmful factors (Reduce heating effect)	39: Productivity (Material heated insufficiently)	*22 Blessing in disguise 35 Parameter Changes 13 The other way round **24 Intermediary/ Mediator
	Material distorted unevenly	Material expand unevenly	Impurities in material	If we remove the impurities problem, then there will be less misalignment but this incurs higher cost and disrupts production.	30: Object-affected harmful factors (Remove impurities in material)	39: Productivity (Disrupt production)	22 Blessing in disguise 35 Parameter Changes 13 The other way round 24 Intermediary/ Mediator
			Uneven temperature inside the furnace	If we control the heat distribution in the furnace then material expands evenly but some monitoring system need to be used which slow down productivity	17: Temperature (Controlled heat distribution)	39: Productivity (Slow down productivity)	15 Dynamics 28 Mechanical substitution 35 Parameter Changes
			Heating effect on semi-processed materials	If we reduce heating effect, then this may avoid expansion caused by heating but may cause material to be heated insufficiently	30: Object-affected harmful factors (Reduce heating effect)	39: Productivity (Material heated insufficiently)	22 Blessing in disguise 35 Parameter Changes 13 The other way round 24 Intermediary/ Mediator
	Vibration of the metal mesh belt	Imbalances of the conveyor belt moving mechanism		If we remove the imbalances of the moving conveyor mechanism then it will be more stable but the conveyor will be more complicated (high cost).	14: Stability of the object (Remove imbalances)	36: Device Complexity (the conveyor will be more complicated)	2 Taking Out 35 Parameter changes 22 Blessing in Disguise
	Metal mesh conveyor belt and material have different expansion properties	Made out of different materials	Heating affects metal mesh and semi-processed material differently	If we reduce the differences of heating effects to metal mesh and semi-processed material, then misalignment will be reduced but this incurs higher cost and disrupts production.	30: Object-affected harmful factors (Reduce the differences of heating effect)	39: Productivity (Disrupt production)	22 Blessing in disguise 35 Parameter Changes 13 The other way round 24 Intermediary/ Mediator

The next zone of conflict is the vibration caused by the metal mesh conveyor belt during the transportation of the semi-processed material. The movement of the metal mesh conveyor belt produces some level of vibration which can cause misalignment. The substance-Field modelling for this zone of conflict is shown in Fig. 6. Based on the substance-Field modelling in Fig. 6, the type of substance-field is a harmful substance field. The solution obtained from 76 standard solutions is also in Class 1.2. However, in this scenario, we choose to introduce a second field to counteract the first field as a solution which will counteract the first field as shown in Fig. 7. Therefore, the solution selected to solve substance-field model (Fig. 6) for this Semi-Processed Material Misaligned at Furnace Output Problem is to introduce fixtures to position the material and to prevent misalignment. The fixtures will be designed to fix the semi-processed material from misalignment by preventing the metal mesh conveyor belt from expanding unevenly as well as insulate or counteract the heated air from affecting the metal mesh conveyor belt. The fixture material should not be affected by heat. This solution is consistent with the recommended inventive principle no. 24 obtained from the Engineering Contradiction (highlighted with ** in Table 3).

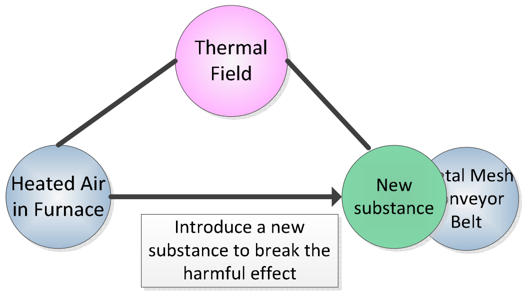

Fig. 5 Substance-Field modelling for the heated air effects on the metal mesh conveyor belt during movement.

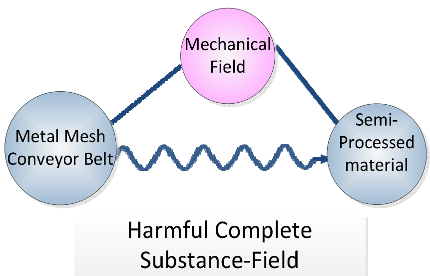

Fig. 6 Substance-Field modelling for the vibration of the metal mesh conveyor belt during movement.

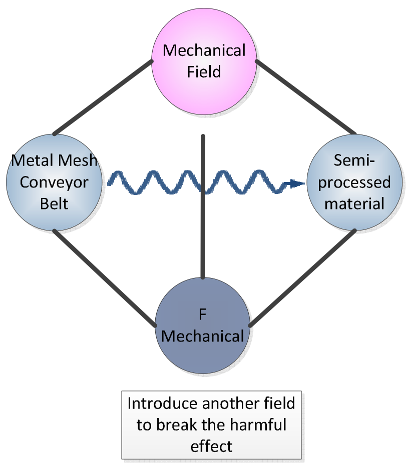

Fig. 7 Introduce a second field to counteract the first field to solve the vibration problem of the metal mesh conveyor belt during movement.

Conclusion

The solutions obtained from both TRIZ tools show that different TRIZ tools can be applied to verify each other's solutions conceptually. This will help engineers to countercheck their solutions obtained from possible mistakes and errors before implementing the solutions and hence, reducing the cost of error and re-work effort.

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