Application of TRIZ theory in steel rolling production

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Abstract. In the face of two problems encountered in the process of steel rolling production, the TRIZ theory was applied to analyse and solve the problems, and unprecedented solutions were put forward, both of which were applied for patents and authorized and published. It is expected that through this paper, innovative thinking will be stimulated and the problems encountered in iron and steel production can be solved quickly.

1. Introduction of the TRIZ theory
The former Soviet scientist Genrich S. Altshuler through the analysis and study of 2.5 million invention patents, established a comprehensive theoretical system composed of a variety of methods and algorithms for solving technological issues and realizing innovation and development, known as the Theory of Inventive Problem Solving (TRIZ) theory.[1] The theory was developed by summarizing the laws and patterns followed by the development and evolution of various technologies in multi-disciplinary fields, and the innovative principles and rules for solving various technical and physical constraints.[2]

The tools included in the TRIZ theory include: 40 principles of invention, conflict matrix, 76 standard solutions, Algorithm for Inventive-Problem Solving (ARIZ), Anticipatory Failure Determination (AFD), substance-field analysis, Innovation Situation Questionnaire (ISQ), Directed Evolution (DE), Ideal Final Result (IFR), trimming, 8 evolution types, effective knowledge base and so on.[3][4] The international research on TRIZ has been pushed from the field of engineering technology to the fields of management, strategy, finance, information and so on. For example, Valeri Souchkov has developed the method of TRIZ application in the field of management, Sergei Ikovenko has successfully applied TRIZ to patent avoidance design and the development of enterprise patent strategy.

2. Application practice of TRIZ theory
The following two examples illustrate the application of TRIZ theory to solve the problem in the iron and steel rolling process.

2.1. Invention of a steel antirust device
We were informed that a black box had been installed behind the rolling production line. When the steel passed through the black box, the surface of the steel was smooth and no rust could be seen. The content of the black box was not revealed and was kept as a technical secret. We initiated a thought-process, yet could not come up with a solution.

After taking part in the technical innovation method and TRIZ theory training, we employed the
principles of the TRIZ theory in the production process of H-section steel using the field analysis and knowledge base. We developed a new device to prevent the corrosion of steel surface by adding a field and a substance, and the patent was declared.[5]

According to the theory, ‘a substance itself could not achieve a certain effect, only after contact with a certain "field" produced the effect on another object or underwent the corresponding reaction’. As far as the field of science is concerned, temperature field, mechanical field, sound field, gravitational field, magnetic field, electric field and so on are the concrete forms of substance field. Substance-field analysis refers to the analysis of the interactions between Substance 1 and Substance 2. Figure 1 represents the existing substance-field model analyzed in the steel rolling process.

![Figure 1](image1)

**Figure 1.** Existing substance-field model.

To address this problem, we considered changing the field model:

**Change 1:** As shown in figure 2, a new field F2 was added in the process.

![Figure 2](image2)

**Figure 2.** Addition of a new field F2 in the substance-field model.

**Change 2:** As shown in figure 3, a new substance S3 was added to minimize S2's harmful effects on S1.
Figure 3. Addition of a new substance S3 in the substance-field model.

The results are presented in figure 4.

Figure 4. Addition of a new field F2 and a new substance S3 in the substance-field model.

2.1.1. Choice of the added new substance S3. The gases H2 and N2, graphite powder, paint and others are considered to be substances. N2 is a colorless and tasteless gas, which is not lively and nonflammable. It is one of the main components of air, accounting for 78.08% (volume fraction) of the total atmosphere, and its density is lesser than that of air. Due to the chemical inertia of N2, it is often used as a protective gas to prevent certain objects from being oxidized when exposed to air. We decided to choose N2.

2.1.2. Choice of the added new field F2. The fundamental cause of steel rust is due to the reaction between Fe and O2 in water and air. Hence, there is a necessity to prevent the formation of the rust (Fe2O3, Fe3O4 and FeO), by increasing the electromagnetic field to move the positively charged Fe ion and the negatively charged O ion in the opposite direction. Due to the difference in the major study in this case, the application effect knowledge base was taken into account.

After screening the various types of electromagnetic radiations such as microwave, infrared ray, ultraviolet ray and so on, considering the difficulties like the effect, reflection and so on, the choice of microwave was finally decided. The developed system is shown in figure 5.

Microwave has the ability to penetrate through the glass, ceramics and other substances, but cannot penetrate through the metal. Therefore, taking advantage of this fact, the microwave emitted on the web of H-section steel was reflected alternately in the upper and lower webs, so that the general H-beam could be treated by microwave.
1. Magnetron, 2. Microwave, 3. Nitrogen, 4. Blowing holes, 5. Box, 6. Upper h-beam web, 7. Lower h-beam web, 8. Opening, 9. Upper h-beam flange, 10. Lower h-beam flange

Figure 5. Steel rust prevention device.

The formation of patent for the utility type model is shown in table 1.

| Patent type | Name                  | Patent number | Application date | Date of announcement of authorization |
|-------------|-----------------------|---------------|------------------|---------------------------------------|
| Utility model | A steel antirust device | 200920280716.6 | 2009-12-9        | 2010-10-27                            |

2.2. Invention of a new universal mill

The technical agreement of forklift gate frame channel steel was made with a forklift truck company. A kind of forklift gate frame steel with high dimensional precision and good surface quality was developed, which was much better than the conventional production in the export forklift, as shown in figure 6.

Figure 6. Surface comparison of channel steel between two forklift gantry frames.

The precision and surface quality directly affect the product grade. Although this fact is clearly known, it was not easy to solve it. Therefore, the TRIZ theory was used and analysis was done. The form of ordinary universal rolling mill is shown in figure 7.

In production, to improve the precision and performance of section steel, the rolling of section steel needs to be done with a controlled rolling, controlled cooling and high strength materials.[6-8] As a result, a higher rolling force is required.[9] However, if the rolling force increases, it may lead to roll
breaking and bring great losses to the production and management.[10]

\[\text{Figure 7. Ordinary universal rolling mill.}\]

Therefore, the physical contradiction existing in the rolling of profile steel is that the rolling force is expected to be both, high and low.[11]

On the basis of a great deal of research, analysis and summary of patents, Altshuler abstracted 40 important principles of invention in TRIZ theory with universal use, which is shown in table 2.

| 1. Fragmentation | 11. Cushion in advance | 21. Rushing through | 31. Porous materials |
|------------------|------------------------|--------------------|---------------------|
| 2. Extraction     | 12. Equipotentiality    | 22. Convert a harm into a benefit | 32. Change the color |
| 3. Local conditions | 13. Inversion          | 23. Feedback        | 33. Homogeneity      |
| 4. Asymmetry      | 14. Spheroidality      | 24. Mediator        | 34. Rejecting regenerating parts |
| 5. Consolidation  | 15. Dynamicity         | 25. Self-service    | 35. Transform the physical/chemical state |
| 6. Universality   | 16. Partial or excessive actions | 26. Copying        | 36. Phase transformation |
| 7. Nesting        | 17. Shift to a new dimension | 27. Disposable objects | 37. Thermal expansion |
| 8. Anti-weight     | 18. Mechanical vibration | 28. Replacement of mechanical system | 38. Strengthen oxidation |
| 9. Prior counteraction | 19. Periodic action    | 29. Pneumatics or hydraulic construction | 39. Inert environment |
| 10. Prior action   | 20. Continuity of useful action | 30. Flexible "shells" or thin films | 40. Composite materials |

The solving physical contradiction guide table in TRIZ theory was used. According to the power which is the general engineering parameter of 15, the corresponding principle of invention is 35,03,13,10,17,19,28. Through comparative screening, 35 this scheme was considered to be more feasible. 35 is the 35th of the 40 principles of invention-transform the physical/chemical state. Applying this principle, we changed each horizontal roll of the universal mill into one horizontal work roll and one horizontal support roll, and changed each vertical roll into one working vertical roll and one supporting vertical roll. In this way, the universal mill improved the rolling precision and offered a higher rolling force. We were able to produce the hot rolled section steel with a thin size and a higher precision to reduce the residual stress in the section steel, which met the user's requirements better, and promoted energy saving and environmental protection. Besides the breakage of the roll was very difficult using the developed strategy.[12] This formed a brand-new universal rolling mill scheme
shown in figure 8 (four more rollers than figure 7).

![Diagram of a new universal rolling mill](image)

**Figure 8.** Developed new universal rolling mill.

The patent formation of the scheme is shown in table 3.

| Patent type       | Name                              | Patent number          | Application date | Date of announcement of authorization |
|-------------------|-----------------------------------|------------------------|------------------|----------------------------------------|
| Utility model     | A universal steel rolling type    | 201020678371.2         | 2010-12-24       | 2011-09-07                             |

### 3. Conclusion

With the application of the TRIZ theory in our study, three major conclusions were pointed out as follows:

3.1. **Stimulate innovative thinking**

The application of TRIZ theory to solve problems made it possible to do things that could not be done before, and made difficult problems easier and clearer.

3.2. **Efficient problem solving**

The problems encountered in the iron and steel production were solved quickly.

3.3. **Universality of participation**

Everyone were able to participate in the great deal of activities of invention and creation.

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