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Triz Methodology in Sand Casting Process

TRIZ is an analytical tool, and it categories problems faced by people into two major groups, those with generally known solutions and those with unknown solutions. Those with known solutions can usually be solved by information found in books, technical journals, or with subject matter experts. These solutions follow the general pattern of problem solving method shown in Figure-1. Here, the particular problem is elevated to a standard problem of a similar or analogous nature. A standard solution is known and from that, standard solution comes a particular solution to the problem.

Table - 4 : Rough Surface Defect	
Defect Physical	Rough and porous surface found throughout the casting. Pores or small blowholes with a smooth surface found on the casting.
Source 1	The surface reaction of water vapour with other elements in the molten gives rise to metal oxides and atomic hydrogen, which diffuses into the molten metal. Similarly, nitrogen-hydrogen compounds dissociate on the hot metal surface and diffuse into the molten metal. **GREEN SAND** ● Nitrogen content in the sand too high ● Moisture content of the sand too high ● Lustrous carbon production in the molding sand too low Gating and pouring practice ● Pouring passages too long ● Too much turbulence and slag formation during pouring
Source 2	It is highly probable that this defect is caused by problems of solidification pressure. Defects indicate that the following measured values deviate according to height of the pouring system.
Remedies	**SOURCE 1 : METALLURGICALLY** ● Use charge components with low nitrogen content, e.g. reduce the quantity of steel scrap. ● Use scrap and return material free of rust, water and oil impurities. Use circulating materials free of impurities adhering to sand and feeder auxiliaries. ● Use charge materials and especially inoculants and circulating materials with low aluminum and titanium contents. ● Deoxidize melts as well as possible. ● Green sand aspect.

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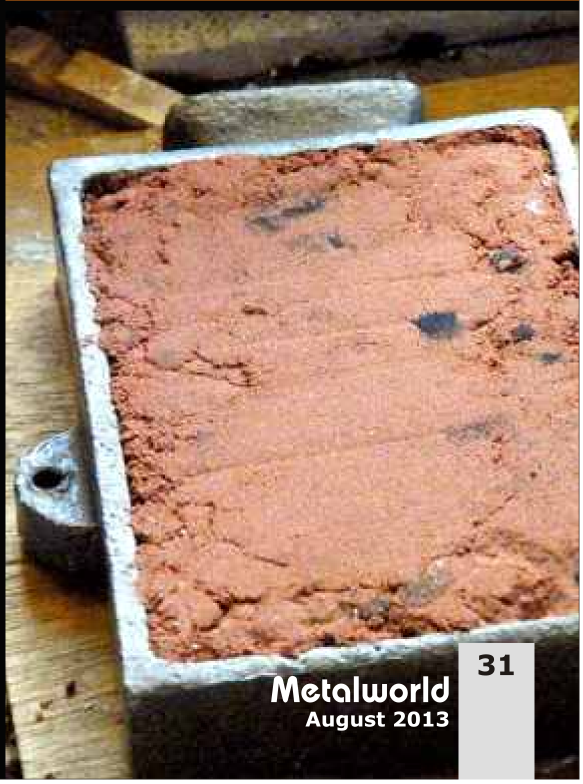

Remedies	• Reduce the quantity of inflowing nitrogen-containing core sand. If necessary, add new sand to the circulating sand. • Lower the bentonite content. Improve development of the molding sand. If necessary, reduce inert dust content. Keep amount of lustrous carbon carrier at the minimum level. • Reduce the moisture content of he sand. • With an oxidizing atmosphere in the mould cavity, if necessary increase the quantity of lustrous carbon producer in the molding sand. Avoid adding too much. **SOURCE 2 : LOWER POURING HEIGHT**

Flash Formation

● The formation of flash can be easily spotted on the casting and it occurs throughout all the area contact with the parting line of the sand mould and presented in Table-5.

● Defects like these require considerable time and man power to remove and it size does not affects the effort of removal.

Figure -11 : Formation of Flash on Parting Line Region

Table - 5 : Flash Defect

Defect Physical	Formation of excessive material burrs or flashes on the parting line of the mould used to perform sand casting.
Source 1	Flat projection of irregular thickness, often with lacy edges, perpendicular to one of the faces of the casting. It occurs along the joint or parting line of the mold, at a core print, or wherever two elements of the mold intersect
Source 2	It is highly probable that these two defects are caused by corner scab or pattern adhesion, finding indicates that problem arise from variable of green tensile strength or sand and pattern temperature.
Remedies	**SOURCE 1: SUGGESTED REMEDIES** • Care in pattern making, molding and core making; • Control of their dimensions; • Care in core setting and mold assembly; • Sealing of joints where possible. **SOURCE 2 :** The defect indicates that the following manipulated variables should be changed. • Binder content of mould material • Temperature difference between mould material and pattern plate The following measures should be considered to remove the causes of the defect. • Increase binder content • Preheat pattern plates • More frequently check surfaces of pattern plates

Discussion : Solving Problem for Flash Formation

Basically, three types of defects have been found on the casting experiment conducted. These defects are the metallic projection (sweating), rough and surface cavity and formation of flash. Defects located here are spotted with bare eyes typically located on the casting surface. However, these defects are categorised into two main types and the main reason for doing so is for the ease of future discussion.

Diagnostic Phase

As named above, this phase helps to solve the problem of flash formation by using TRIZ tools. TRIZ solution begins with the usage of MINI-ARIZ problem analytical tool. First phase of MINI-ARIZ starts with the diagnostic statement and this is the stage where diagnostic statement and problem situation is explained. Operative zone and the ideal result is identified and determined.

Diagnostic Statement

During the sand casting process, there is formation of excessive material on the area where the parting line is located. Molten material seems to leak into the parting line area where by two cope boxes are held together. It seems like an area of empty space and is located between the parting lines formed by the greensand. Formation of flash extends throughout the edge of casting and length of the flash is found on the casting varies randomly. Formation of flash results in material waste and considered as scrap in the process. Besides, extra cost and time consumption is due to another consequence of flash formation. More resource is required to remove flash and hence it yields to time wasting in product completion.

Operative Zones

Operative zone is the epicentre of the problem and it lays the key of solution. TRIZ believes that solution can be found within the system and environment surrounding the process. Flash formation in sand casting can be affected by the following factors. It is shown below in Table-6.

Final Ideal Result

Final ideal result in this case study would be forming a casting, which requires no extra process to remove the flash. In another words, casting should not come with formation of flash along its edge. Initiation of reduction phase starts with the proposal of several useful suggestions. All the ideas generated have reduced the flash formation. Generally, these ideas are based on the suggested affecting factors, and ideas are expressed below:

● Increase the compression strength of greensand.

● Change the type of sand.

● Control the temperature of molten metal.

● Remove the parting line in sand mould.

Analysis of these solutions suggests that the first two ideas will yield a dramatic increase in cost. Compression of greensand is done with human hand, and further increase of compression pressure will lead to machinery sand compression (100 psi machine ramming). Machinery compression will dramatically increase the cost of casting process. Besides, excessive compacted greensand might lead to insufficient gas venting for the casting and thus resulting gas blow pinholes. Hence, this idea should not be

Table-6 : Operative Zones Affecting the Formation of Flash

OPERATIVE ZONE	EXPLANATION
Compression of Greensand	Compression of greensand plays an important role in determining the density of the greensand. A loosely compacted sand is prone to form free space between the parting line area, when molten metal is being pour into sand mould, chances of forming flash at the edges of casting is relatively high.
Temperature of the Molten Metal	Temperature of the molten metal also can contribute to the formation of flash; increase of the temperature in molten metal will decrease the viscosity of molten metal, chances of molten metal flood the space between the parting line will increase as well.
Parting Line in Sand Mould	Parting line in sand mould is the main reason for the formation of flash throughout casting edges. As long as there's parting line, casting will always form flash on the edges disregarding its size.

the primary concern where quality is considered more important than its quantity.

Second idea of changing greensand also yield to increase the process cost, but it should not be the primary concern among existing solution. Third solution is to control the temperature of molten metal. Compared to both previous suggestions, this idea appeared to be an economical one and remains practical. However, if the problem lies on the mould and not on the molten metal, formation of the flash will still occur; nonetheless, it should be one of the concerns in future where the problem remains.

Fourth solution is to remove the parting line from the sand mould used in this case study. Suggestion of the solution seems to be absurd, and sand used is the reason to form the cavity. It must be made separately to enable the removal of the shape. Such idea seems absurd, but it should not be removed from the consideration. A contradiction has occurred here, and here MINI-ARIZ is introduced to see if the removal of parting line is possible. The summary is presented below in Table7.

Table - 7 : Summary

Idea/Consideration		Acceptance
Increase Compression of Greensand		X
Change Type of Sand		X
Control Temperature of Molten Temperature		X
Remove the Parting Line in Sand Mould	√	

Functional model has come out with a conclusion of positive factors on the removal of flash and negative factors of increased complexity of making. Analysis from the study is logically making a sense, and removal of parting line in the sand mould will result in the casting to be flash free; and it tends to point out the useful guidance through improved and deteriorated features.

During the process of using TRIZ 40 innovative principles, it is always encouraged to analyze the importance of the question before continuing into further searching of the guidance. As for this case, both the improved and deteriorate factors have been switched for the reason of complexity in constructing the mould is the priority of process. It is shown below in Table-8.

Table - 8 : 40 Innovative Principles for Parting Line Removal.

	Deteriorated Features	
Improved Features	***40 innovative principles***	**05** Precision of manufacture.
	07 Complexity of construction	**9,10,18**

Before continuing to transformation phase, it is important to explain about the relationship between positive factors and improved 39 features. Positive factor contributed by removal of parting line in sand mould will stop the flash formation, and hence it will result improvement in the precision of manufacturing.

As for the negative factors and its deteriorate features, the explanation should be the same as the previous; removal of the parting line will increase the complexity of making the mould, as the deteriorated side will cause the mould to be harder to make. Selections of 39 features are based on explanation from the book; it is shown as below.

Precision of manufacturing is an extent to which the actual characteristic of the system or object match the specified or required characteristics. Sand moulds without parting line used to perform the casting process will directly eliminates the source of parting line formation.

Complexity of construction is a number and diversity of elements and element interrelationships within a system. User may be an element of the system that increases the complexity. The difficulty of mastering the system is a measure of its complexity, which in turns refers to questions on how to make a die without parting line.

Transformation Phase

Moving into transformation phase, analysis is conducted in the reduction phase has filtered several useful guidance. These guidance is filtered from the matrix table of 40 innovative principles, and it is helpful to user throughout the process of generating useful ideas. Before continuing further analysis, selected principles will be stated and it is shown below in Table-9. It should be selected on relativity to the application.

Table-9 : Principle to Remove Parting Line

Selected Principles
Principle 9, Change in color. (Optical property changes.)
Change the color of an object or its external environment. Change the transparency of an object or its external environment.
Not relevant or unusable as guidance.
Principle 10, Copying.
Instead of unavailable, expensive, or fragile objects, use simpler, inexpensive copies.
Use something inexpensive to cover or replace on the parting line area.
Principle 18, Mediator. (Intermediary)
Use an intermediary carrier article or intermediary process. Merge one object temporarily with another (which can be easily removed).
Use something to seal or attach the parting line, it can be remove later.

Upon solving the problem of parting line in the sand mould, the filtered principles mentioned above t will guild towards solution. Each principle tends to guide the thinking pattern towards to eliminate the parting line in the sand mould. Making the parting line to disappear is virtually impossible. However, guidance is provided to use a less expensive material in order to overcome this problem. Principle 18 clearly states the usage of intermediary process to temporarily merge both the objects, and principle 10 emphasize on the usage of an inexpensive or simpler material near the parting line area.

Proposed Solution

As suggested by the proposed guidance, it is always good to support the suggested actions based on the reasonable practice. Therefore, practicality of the answer is very important. For the first problem of burr formation, casting defect was commonly occurred on the parting line and solution generated was based on the suggested guidance. Primary objective in this research is to remove the parting line of the mould, as suggested by Guidance 1, **principle 10**. Explanation statement of 40 principles tends to suggest the removal of parting line to be done by replacing with a copying material.

It should be bear in mind that before reaching the solution, it is very normal for psychological inertia to obstruct new idea generation. Many might think of eliminating parting line is virtually impossible. Gert Poppe and Bart Gras support solutions suggested by guidance, for the use of intermediary and copying material to attach parting line together. Industrial common practice includes the use of green sand to adhere it on "spaced" parting line. It is purposed to fill up the empty space near the parting line with green sand. Technique mentioned correspondently supported by principle of applying copying material to paste on the spaced area, however, this technique relies on individual skills of green sand adhering. Further, solutions by another principle suggest the use of intermediary/mediator to merge both copes together. Instead of using green sand, merging of copes should be temporary and easily removed after the process. The guidance enlightens the use of adhering mediator to merge both copes together and eliminates the parting line in sand mould. Now, it is not so impossible to remove the parting line from the mould and a suitable adhesive medium has been applied. It will not cause excessive contamination to green sand and extraction of the layer can be done easily. The silicon characteristics are shown below in Table-10.

Table-10 : Table of Solution (Silicone Characteristic)

Solution	Tools	Characteristic
Applies silicon gasket evenly around the parting line to seal it.	Use hi-temperature RTV silicone gasket maker.	• Hi-temperature silicone gasket. • Resist up to 343°C

Figure-12 : Sequential Steps of Silicone Solution Application and Removal of Pattern

Conclusions

Using TRIZ methodology to solve the problem in sand casting process is an interesting one. Practitioner in this work will be learning on how to develop a solution via TRIZ tools like Mini-ARIZ and 40 innovative principles. TRIZ tools are particularly useful on the initial stage and it prevents the waste of time by obstructing generation of an unpractical ideal. These tools are specially designed to solve problems by systematic analysis. It is done through a series of diagnostic, reduction and transformation phases on the problem. Further, on, it points out which 40 principles should be used as guidance towards the idea generation process. Casting process is one of the major manufacturing methods used to produce parts. Defects are likely to occur and result in time and cost waste. Hence, the main purpose of this work project is to find out an effective solution to prevent casting defects. Generally, defects subjected to TRIZ implementation have all shown positive results. All the problems have been successfully resolved or at least minimized. Effectiveness of solution towards the problem of flash formation has been proved useful. During the experiment, TRIZ implemented solution has successfully minimized flash formation on the casting. Parting line area does not have the problem of flash formation; hence, it yields to time and manufacturing cost reduction. Whereas, secondary defects include all the other surface defects, and this includes metallic projection, rough surface and porosity on the casting surface. TRIZ implemented solution has dramatically reduced casting surface roughness with an astounding value of 77.13% and minimized the formation of porosity. Solutions suggested by TRIZ principles yields to the application of plaster/gypsum green sand mixture on cavity surfaces, and this technique has helped to deploy the mixture layer. It is based on the guidance of 40 principles. Whereas, metallic projection has been completely removed from the casting surface; there is no formation of metallic projection detected through bare eye inspection throughout the casting surface. For verification of the improvement, various tests have been carried out to investigate on the outcome (casting), which includes running surface testing with a profilometer and by optical microscopy observation. Besides, a simple experiment was carried out to determine the quantity of gypsum to be added in green sand. As a general conclusion, TRIZ has been successfully applied in sand casting process. Primary objectives were able to achieve by solving all the defects formed on casting. TRIZ methodology is implemented during the process of seeking solution, and its application has been proved effective, helpful and practical in real time practice.

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