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Increasing productivity of cylinder head cores by process modification: A case study

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ABSTRACT

Casting manufacturing consists of various processes like Sand making, moulding, core making, melting, pouring and post casing treatments like fettling, cleaning and inspection.The productivity of the casting process as a whole depends upon the productivity of each of the processes. One of the important processes is core making. The selection of type of core making process is very important and influences the productivity, casting cost and quality. The production of sand cores is a complex process filled with technical challenges that can often delay the production, create scrap and rework, and increase the overall cost of a finished casting. As casting geometries become more and more challenging in their designs, the demand for intricate and high quality sand cores will also continue to increase. Even in recent times the concept of productivity of core making was not looked upon seriously until and unless the Original Equipment Manufacturers demanded the numbers, casting surfaces finish even from the inside, optimum cost and with no defects.

Hence it was thought of increasing the core shop productivity along with the study of optimum layout in a systematic way. Main issues were to satisfy the customer by increasing delivery performance and excellent quality. The case study thus focuses on the following

1.To study the process of enhancing the productivity along with keeping the objective of reducing manufacturing cost so that cost of casting manufacturing would be reduced.

2.To study various layouts of core making and Assembly for the specific product "Cylinder Head" using cell concept along with time and motion study.

The method adopted is to develop an efficient layout with alternate core making process which will deliver cores / core assembly for manufacturing the good casting with minimum inventory and at the same time it will enhance the numbers to satisfy the customer and improve the bottom line. The paper is a case study of enhancement of productivity of core making by systematic process and layout study and thereby reducing the cost of casting manufacturing.

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I. INTRODUCTION

METAL CASTING is a unique among metal forming processes for a variety of reasons. Perhaps the most obvious is the array of molding and casting processes available that are capable of producing complex components in any metal, ranging in weight from less than a gram to single parts weighing several hundred tons. Beyond the rapidly emerging technologies that are keeping metal casting in the forefront in the metal forming industry, castings possess many inherent advantages that have long been accepted by the design engineer and metal parts user.

In terms of component design, casting offers the greatest amount of flexibility of any metal forming process. The casting process is ideal because it permits the formation of streamlined, intricate, integral parts of strength and rigidity obtainable by no other method of fabrication. Scope in converting his ideas into an engineered part. The freedom of design offered through the metal casting process allows the designer to accomplish several tasks simultaneously. These include the following

- Design both internal and external contours independently to almost any requirement
- Place metal in exact locations where it is needed for rigidity, wear, corrosion, or maximum endurance under dynamic stress.
- Produce a complex part as a single, dependable unit
- Readily achieve an attractive appearance

Rapid Transition to Finished Product. The casting process involves pouring molten metal into a cavity that is close to the final dimensions of the finished component; therefore, it is the most direct and simplest metal forming method available.

Suiting Shape and Size to Function. Metal castings weighing from less than an ounce to hundreds of tons, in almost any shape or degree of complexity, can be produced. If a pattern can be made for the part, it can be cast. The flexibility of metal casting, particularly sand molding, is so wide that it permits the use of difficult design techniques, such as undercuts and curved, reflex contours, that are not possible with other high-production processes. Tapered sections with thickened areas for bosses and generous fillets are routine.

Placement of Metal for Maximum Effectiveness. With the casting process, the optimum amount of metal can be placed in the best location for maximum strength, wear resistance, or the enhancement of other properties of the finished part. This, together with the ability to core out unstressed sections, can result in appreciable weight savings.

Optimal Appearance. Because shape is not restricted to the assembly of preformed pieces, as in welding processes, or governed by the limitations of forging or stamping, the casting process encourages the development of attractive, more readily marketable designs. The smooth, graduated contours and streamlining that are essential to good design appearance Usually coincide with the conditions for easiest molten metal flow during casting. They also prevent stress concentrations upon solidification and minimized residual stress in the final casting. Because of the variety of casting processes available, any number of surface finishes on a part is possible. The normal cast surface of sand-molded casting often provides a desired rugged appearance, while smoother surfaces, when required, can be obtained through shell molding, investment casting, or other casting methods.

Complex Parts as an Integral Unit. The inherent design freedom of metal casting allows the designer to combine what would otherwise be several parts of a fabrication into a single, intricate casting. This is significant when exact alignment must be held, as in high-speed machinery, machine tool parts, or engine end plates and housings that carry shafts. Combined construction reduces the number of joints and the possibility of oil or water leakage. part that was converted from a multiple-component weldment into a two-part cast component. **Improved Dependability.** The use of good casting design principles, together with periodic determination of mechanical properties of test bars cast from the molten metal, ensures a high degree of reproducibility and dependability in metal castings that is not as practical with other production methods. The functional advantages that metal castings offer and that are required by the designer must be balanced with the economic benefits that the customer demands.

THE CASTING PROCESS involves the pouring of molten metal into a mold; therefore, the mold material and molding method must be selected with care. Most castings are made in sand molds because metallic molds wear out too quickly to be economical for ferrous metals production. For low and medium production runs, the lower tooling costs of sand molding give it an overwhelming cost advantage over permanent molds or die casting.

Generally, foundry industry suffers from poor quality and productivity due to the largenumber of process parameters, combined with lower penetration of manufacturing automation and shortage of skilled workers compared to other industries. [6]Organizations profit can be increased with the increase of overall casting manufacturing productivity.[7] Facilities layout is a systematic and functional arrangement of different departments, machines, equipments and services in a manufacturing industry. It is essential to have a well developed plant layout for all the available resources in an optimum manner and get the maximum out of the capacity of the facilities.[10]

In today’s environment of foundry industry, reducing manufacturing cost by better or improved Productivity and Quality through Innovative ideas is becoming mandatory for every foundry man.[11]

Effective material handling system to reduce the time required to material movement within plant. Good ergonomics for efficient & effective performance of labour. Objectives towards accomplished this study is to identify problems in the casting industry and improved it in terms of reduction in production time, number of manual process and back flow of materials by proposing an efficient plant layout and design[12]

Jia Zhenyuan et al 2009 mentions the results of the designed facility layout system in cylinder liner production line show that the designed lean facility layout system can effectively enhance the production efficiency and improve the use efficiency of the equipments.[13]

II.PROBLEM DEFINATION

Productivity can be defined as, "The ratio of aggregate output to aggregate input". Productivity implies development of an attitude of mind and constant urge to find better, cheaper, easier, quicker and safer means of doing a job, manufacture a product and providing services.

Some objectives behind problem identification;

1. To study performance of a system
2. To attain a relative comparison of different systems for a given level
3. To compare the actual productivity of a system with its planed productivity.

So following problems in organization are identified.

1. Manual Process: At present situation the processes are performed manually after the core is manufactured from the shell core machine. Hence for operating these activities skilled workers are required. The manual operations are more time consuming and have more limitations in operations.

2. Material Movement Problem: The organization suffers from problem of trolley movement. This problem is due to ineffective plant layout and manual operations. The organization have problem of flow of material improper and time consuming. Sometimes back flow is exists in material movement. So results are lost in productivity. So the data like, existing plant layout, mixed process flow and other some manual operation details is presented in this section.

3. Input Material Storage: On daily basis the shell sand bags are feed to all the machines manually and then as per the requirement the operators are taking and loading the shell sand to his shell sand machine.

4. Shell / Hot Box core making process: This process itself is costly in comparison with other processes like cold box system and or the no bake process. Hence it is absolute necessity to fine the better option which will enhance the productivity, reduce the cost.

Objectives:-

1) Enhance the production Capacity of core making Which a bottleneck for going from 190 nos. to 250 nos.

2) To study all production process of Core making Cell (Manufacturing of individual cores , Assembly of cores for producing the intricate cavities in the cylinder Head Castings, Feeding it to the Molding Line for Pouring)
    - Shell core manufacturing on shell core Shooter.
    - De burring of cores.
    - Core painting in painting tank.
    - Assembly of cores.
    - Oven Baking.

Methodology

- To study the manufacturing process of Core
- Making Cell processes in manufacturing a types of cores, 1. Cold Box core, 2. Shell Core.
- Conduct the time study and Historical Data Analysis.
- Identify the Bottleneck.
- Work on the bottleneck, Time study and Overall equipment efficiency of the shell core making machines.
- Suggestion for improvements and saving in core making.

III.LITERATURE SURVEY

[1] Work done by some of the researchers in the field of productivity improvement is appended here with below. [1] M. Schneider, MAGMA GmbH Germany, R. Stevenson, Schamburg II,C. Kleberg, Magma engineering Asia Pacific Pte. Ltd.Foundry Review Journal - MMR July 2015, Simulation of the entire core making production process The production of sand cores is a complex process filled with technical challenges that can often delay the production, create scrap and rework, and increase the overall cost of a finished casting. As casting geometries become more and more challenging in their designs, the demand for intricate and high quality sand cores will also continue to increase.

[2]Fritz Hansberg spa, **Foundry Trade Journal FTJ 2009 Article – Leading the way in Core Handling and Core Assembly.** No longer can world-class quality and reproducibility be achieved in casting production without total control of the core making activity. The benefits of automatic dressing, coating and assembly of cores are widely accepted by all major foundries throughout the world and the demand for suitable equipment presents a challenge to the leading equipment suppliers.

[3] Andrea Ferkinghoff, ProTEC Marketing, and Verena Skelnik, ASK Chemicals, consider the importance of added supplier value in the foundry industry, Foundry Management and Technology Journal April 11, 2005.**Improving Process Efficiencies in Core making.**

It gives foundries a capability that no other metalworking process offers: the ability to form external and internal contours, shapes, cavities, and passageways in one operation.

Davies elaborates. "We feel that in some instances shell core making can provide better quality, dimensionally and cosmetically [2]

[4]Principles of Foundry Technology (fourth edition) P.L. Jain, by TATA McGraw Hill @2003 says that, There are seven requirements for core: Green Strength: In the green condition there must be adequate strength for handling. In the hardened state it must be strong enough to handle the forces of casting; Permeability must be very high to allow for the escape of gases. Friability: As the casting or molding cools the core must be weak enough to break down as the material shrinks. Moreover, they must be easy to remove during shakeout.Good refractoriness is required as the core is usually surrounded by hot metal during casting or molding.A smooth surface finish.Minimum generation of gases during metal pouring.

[5]**D.M. Trinowski Delta-HA, Inc., Detroit, MI G. Ladegourdie, K. Löchte Hüttenes-Albertus Chemische Werke Gmbh, Düsseldorf, Germany**

A new solvent system based on methyl esters of vegetable oils, when used to formulate phenolic urethane resins, shows a reduction in volatile emissions and improved process performance. Pattern release, for both cold box and nobake cores and molds, is significantly improved. Humidity resistance and dip and dry tensile of cold box systems are improved. In cold box core production, increased cure efficiency has resulted in greater productivity in high-production operations. New Cold box Binder System for Improved Productivity.

[6]AFS –American Foundry Society's hand book 2009 edition, One of metal casting's strongest selling points is its ability to encompass several parts, often in the form of a welded assembly, into one component. This is possible because the nature of the metal casting process lends itself to complex geometries. At the heart of many of these complex geometries is a core or core assembly.

[7]**Anirudha Joshi [1], Prof.L.M.Jugulkar [2] 1. Student of M-Tech (Automobile), RIT, Islampur, Maharashtra, India Faculty, Automobile Engineering,** Productivity Improvement of Metal Casting Industry.

This paper represents the data of manual metal casting operations collected from one organization which produces automotive components. The paper represents solutions, effective plant layout, automatic mold making operation and sequential process flow with minimization of back flow of material helps to solve these problems.

[8]AFS – American Foundry Society Handbook. Mold & Core Test Handbook, 3rd EditionUpdates from 2004 and 2006 have been incorporated into this reprint of the Mold and Core Test Handbook, 3rd Edition. The third edition of the Mold and Core Test Handbook, published by the American Foundry Society, contains information on sand testing technology that is especially important for today's metal casters. ChemicallyBonded Cores & Molds is a true "how-to-do-it" documentation of operationally useful data pertaining to all known chemical binder systems that can be successfully used in the processing of cores and molds for casting production.

[9] Klaus Löchte Hüttenes-Albertus Chemische Werke GmbH, July, 1998 Introduction In recent years, the cold box process has become increasingly popular in the Indian foundry industry. Many foundries already use this core making process, or are interested in doing so.

[10] Vivekanand s Gogi1, Rohith et al R V College of Engineering, Bangalore-560085, Karnataka, India International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 4, April 2014 Copyright to IJIRSET

The efficiency of production depends on how well the various machines, services production facilities and employee's amenities are located in a plant. This research paper aims to study and improve the current plant layout and are analyzed & designed by using string diagram. An Attempt is made to simulate the current and proposed factory layout by using ARENA software. Efficiency of the current & proposed plant layout are calculated.

[11] R. Venkatraman, a foundry Consultant and ex. Employee of Mahindra and Mahindra says in his paper " Innovative ideas for improving productivity and quality " , Paper is presented of two to three case studies on design of product, Methoding Practices, Pattern making, molding, core making , melting , pouring , post processing etc..

[12] Prof. DR S.M. sane, promod p. shewale, Manmath S. shete, et al. on "Improvement in plant layout using systematic layout planning (SLP) for increased productivity",This research used changes in; flow of material movement for better utilization of plant area for improves the productivity. Of components used for loading of material used in casting process. This research used systematic plant layout technique, concept of semi automation in casting process, material handling system ergonomics, and rework reduction methods.

[13] Jia Zhenyuan, LU Xiaohong, Wang Wei, Jia ,International Journal of Industrial Engineering, 18(5), 260-269, 2011. ISSN 1943-670X, DESIGN AND IMPLEMENTATION OF LEAN FACILITY LAYOUT SYSTEM OF A PRODUCTION LINE. The application results of the designed facility layout system in cylinder liner production line show that the designed lean facility layout system can effectively enhance the production efficiency and improve the use efficiency of the equipments.

IV.DISCUSSION

1. It is essential that the core making process is optimized to maintain tighter process control while eliminating sources of wasted time and money.
2. It is absolute necessity to develop the automation for core handling, core dressing, venting and assembly.
3. Robust Processes are required to get consistent quality, reducing the waste and productivity can be increased.
4. Lean Principle Technique and SLP (Systematic Layout Planning) to be applied for effective Layout.
5. New Process like cold box core making process instead of Shell core making process can be tried to work out for enhanced Productivity with minimum cost.
6. Use of string diagram / Spaghetti diagram to reduce the travel time of independent core transfer for assembly.
7. Innovative ideas through "KAIZEN "Principles for improving productivity and quality

V. INTRODUCTION- CORE MAKING

Manufacturing the desired geometry of component. For foundries to stay profitable while meeting these new environmental regulations and increasing customer demands, it is essential that the core making process is optimized to maintain tighter process control while eliminating sources of wasted time and money. It is essential that the core making process is optimized to maintain tighter process control while eliminating sources of wasted time and money [1]

The principle of manufacturing a casting involves **creating a cavity inside** a sand mould and then pouring the molten metal directly into the mould. No longer can world-class quality and reproducibility be achieved in casting production without total control of the core making activity. The benefits of automatic dressing, coating and assembly of cores are widely accepted by all major foundries throughout the worldOut of the several steps involved in the casting process, Core Making, molding, melting and Fettling processes are the most important stages.[2] Core making is central to metal casting. It gives the industry the edge that no other metalworking industry has — the ability to form external and internal contours, shapes, cavities, and passageways in one operation. Thus, the importance of producing high-quality cores efficiently and inexpensively cannot be underestimated.[3]Improper control at these stages results in defective castings, which reduces the productivity of a foundry industry. [5] To produce cavities within the casting—such as for liquid cooling in engine blocks and cylinder heads—negative forms are used to produce *cores*. Usually sand-moulded, cores are inserted into the casting box after removal of the pattern. Whenever possible, designs are made that avoid the use of cores, due to the additional set-up time and thus greater cost.

Different Functions (Purposes) of Cores.

1. For hollow castings, cores provide the means of forming the main internal cavities.
2. Cores may provide external undercut features
3. Cores may be employed to improve the mold surfaces.
4. Cores may be inserted to achieve deep recesses in the castings.
5. Cores may be used to strengthen the molds.
6. Cores may be used to form the gating system of large size mold.

Advantages and disadvantages of cores

Cores are useful for features that cannot tolerate draft or to provide detail that cannot otherwise be integrated into a core-less casting or mold.The main disadvantage is the additional cost to incorporate cores.

Essential Characteristics /Requirements of cores.

There are seven requirements for core:

1. Green Strength: In the green condition there must be adequate strength for handling.
2. In the hardened state it must be strong enough to handle the forces of casting; therefore the compression strength should be 100 to 300 psi (0.69 to 2.07 MPa).
3. Permeability must be very high to allow for the escape of gases.
4. Friability: As the casting or molding cools the

core must be weak enough to break down as the material shrinks. Moreover, they must be easy to remove during shakeout.

5. Good refractoriness is required as the core is usually surrounded by hot metal during casting or molding.
6. A smooth surface finish.
7. Minimum generation of gases during metal pouring.

Types of cores

There are many types of cores available. The selection of the correct type of core depends on production quantity, production rate, required precision, required surface finish, and the type of metal being used. For example, certain metals are sensitive to gases that are given off by certain types of core sands; other metals have too low of a melting point to properly break down the binder for removal during the shakeout.[2]

Core may be classified according to:

A) The state or condition of core

1) Green sand core
2) Dry sand core
3) No bake sand core

B) The Nature of Core Materials employed

1) Oil Bonded core
2) Resin bonded core
3) Shell sand core
4) Sodium silicate cores

C) The type of core hardening process Employed.

1) CO_2 process
2) The hot box process
3) The cold set process
4) Fluid or castable sand process
5) Furan – No Bake Process
6) Oil No Bake Process

D) The Shape and Position of the core.

1) Horizontal Core
2) Vertical core
3) Hanging or cover core.
4) Balance core
5) Drop core or stop off core
6) Ram up Core

Green-sand cores

Green-sand cores makes casting long narrow features difficult or impossible. Even for long features that can be cast it still leave much material to be machined. A typical application is a through hole in a casting.[2]

Dry-sand cores

The simplest way to make dry-sand cores is in a *dump core box*, in which sand is packed into the box and scraped level with the top. A wood or metal plate is then placed over the box, and then the two are flipped over and the core segment falls out of the core box. The core segment is then baked or hardened. Multiple core segments are then hot glued together or attached by some other means. Any rough spots are filed or sanded down. Finally, the core is lightly coated with graphite, silica, or mica to give a smoother surface finish and greater resistance to heat.[2] *Single-piece cores* do not need to be assembled because they are made in a *split core box*. A split core box, like it sounds, is made of two halves and has at least one hole for sand to be introduced. For simple cores that have constant cross-sections they can be created on special core-producing extruders. The extrusions are then just cut to the proper length and hardened. More complex single-piece cores can be made in a manner similar to injection moldings and die castings.

Binders

A Function of Core Binder,

1. Holds sand grains together.
2. Gives strength to core.
3. Makes cores to resist erosion and breaking,
4. Imparts adequate collapsibility to cores.

Core Binders are following types

A) Organic Binder

1. Core Oil – Vegetable oil
2. Whale or Marine oil
3. Mineral Oil

B) Inorganic Binders

1. Fire Clay
2. Bentonite
3. Silica floor
4. Iron Oxide

These binders develop green strength, baked strength, and hot strength and impart smooth finish.

C) Other Binders are Portland cement, sodium silicate etc.

Core making Process

A. Hot box process - It uses heated core boxes for the production of cores.

- The core box is made up of cast iron, steel or aluminium and possesses vents and ejectors for removing
- Core gases and stripping cores from the core box respectively. Core box is heated from 350 to 500 F.
- Heated core box is employed for making shell cores from dry resin bonded mixtures.
- Hot core boxes can also be used with core sand mixture employing liquid resin binders and a catalyst.

B. Shell cores

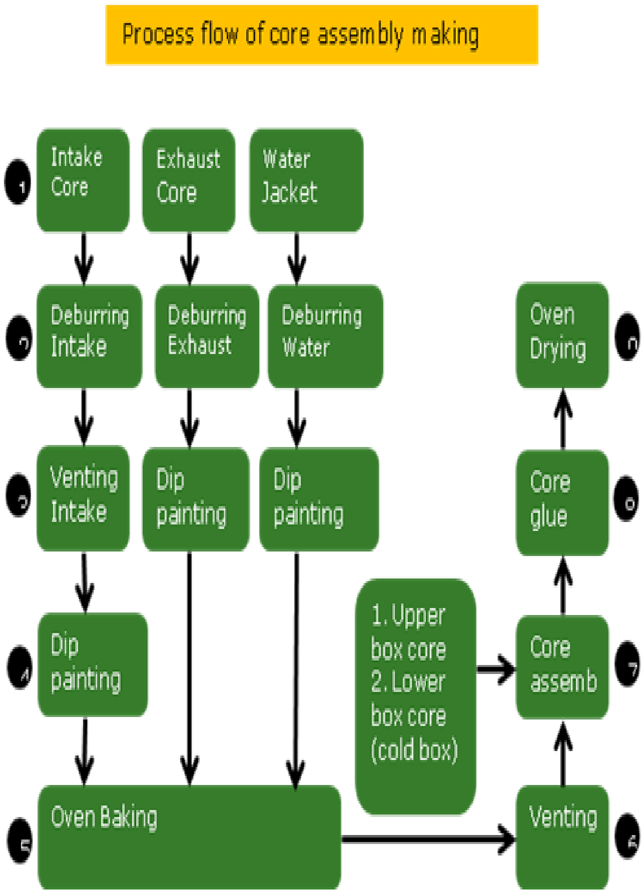
Shell cores can be made manually or on machines.The procedure of making shell cores is as follows:

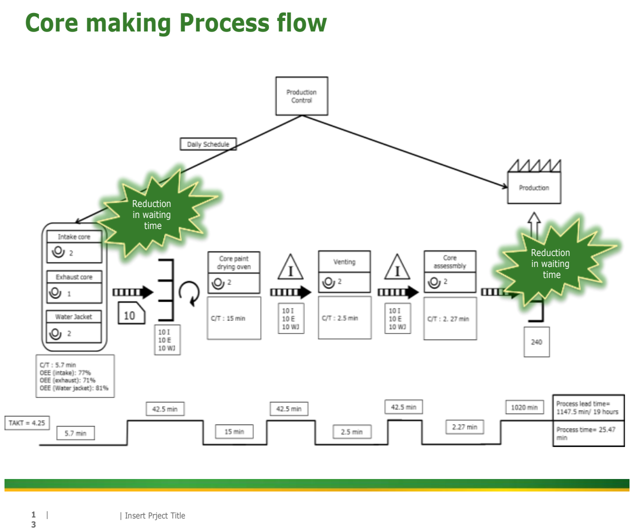
- The core box is heated to temperature of the order of 400 to 600 F.
- Sand mixed with about 2 to 5 % thermosetting resin of phenolic type is either dumped or blown into the preheated metal core box.
- Where sand blowing is employed, it is preferred to use resin precoated sand to avoid resin segregation.
- The resin is allowed to melt to the specified thickness.
- The resin gets cured.
- The excess sand is dumped and removed.
- The hardened core is extracted from the core box.
- Cores thus produced needs no further baking.
- Shell core posses very smooth surface (3125 micro mm root mean square) and close tolerance. (+_ 0.003 mm/mm). ix. Shell core making process can be mechanized and several core making machines are commercially available.
- High permeability is achieved in shell core making.
- Shell cores can easily store for future use.
- Shell cores are costly as compared to cores Produced by other methods.

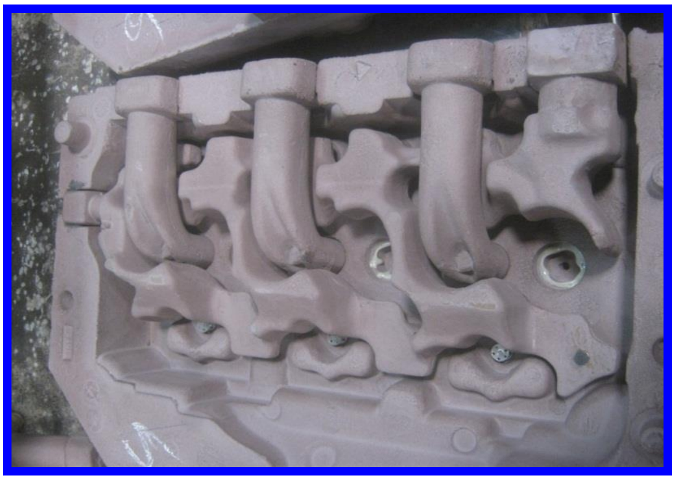
B. The cold set process - While mixing the core sand, an accelerator to the binders.

- The sand mixture is very flowable and is easily rammed.
- Curing begins immediately with the addition of accelerators and continues until the core is strong to be
- Removed from the core box. A little heating of the cores hardens it completely.
- Cold set process is preferred for jobbing production.

Core making and assembly process







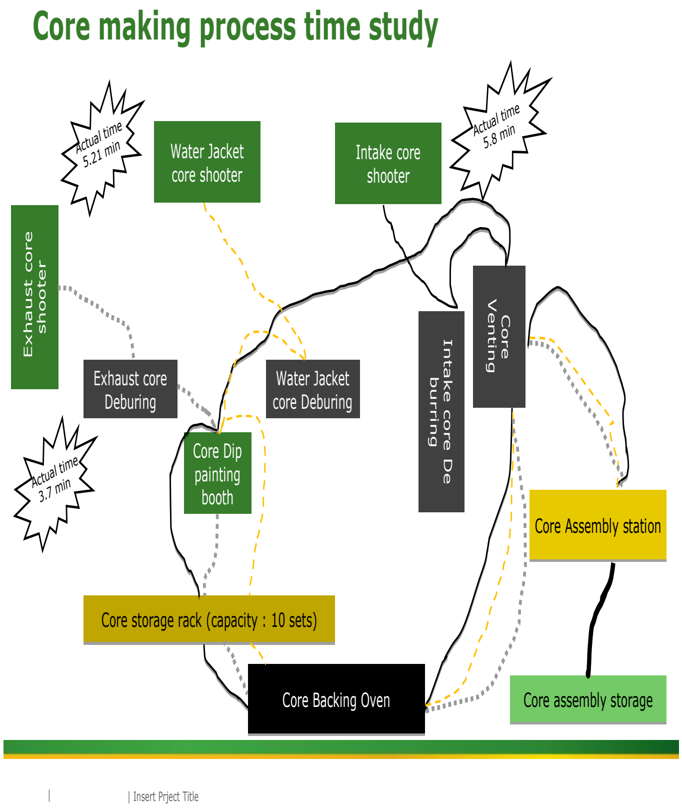
VI.SPAGHETTI DIAGRAM

Spaghetti is a visual representation using a continuous flow line tracing the path of an item or activity through.The continuous flow line enables process teams to identify redundancies in the work flow and opportunities to expedite process flow.Creating a spaghetti diagram is the creation actual flow. The keyword ACTUAL, is what it should be or perceived to be. It is a snapshot in time so it may not include all what – if and special scenarios, but these do warrant decision as team progresses. This is one the best tool for mapping the Process.

These diagrams are used to track

1. product Flow
2. Paper Flow
3. People flow

SPAGHETTI DIAGRAM



Core making: Activity Time study

Intake core

Process	In Mins.	In Sec
Cleaning of core box	0	18
Core making	4	8
1st venting	0	27
2nd Venting	0	49
Dipping	0	8
Total	**4**	**110**
TOTAL TIME (Sec)		**350**
TOTAL TIME (MIN)		**5.83333**

Exhaust Core

Process	In Mins.	In Sec
Cleaning of core box	0	20
Core making	2	58

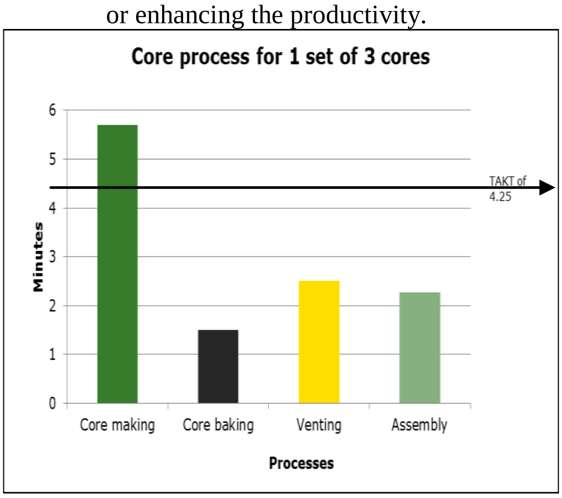
Dipping	0	10
Total	**2**	**88**
TOTAL TIME (Sec)		**208**
TOTAL TIME (MIN)		**3.46667**

Water Jacket Core

Process	In Mins.	In Sec
Cleaning of core box	0	50
Core making	3	40
DE burring/coat application	0	36
Dipping	0	7
Total	3	133
TOTAL TIME (Sec)		313
TOTAL TIME (MIN)		**5.21667**

Core making sub processes analysis:

It can be identified that the activity of core baking, venting and assembly can be well completed within the takt time of less than 3 minutes, however Core making would be bottle neck and taking for achieving 250 good numbers or enhancing the productivity.



Process	**Batch of 10**	**Min/set of cores**
Core making	57	5.7
Core baking	15	1.5
Venting	3	0.3

Assembly	22.7	2.27

TAKT TIME FOR CORE ASSEMBLY FEEDING TO THE LINE

$$\text{TAKT} = \frac{\text{Productive time available}}{\text{Number of required units}} = \frac{22\text{hrs} * 60}{250} = 5.28$$

250 good castings * 1.23 rejection = 307.5 units

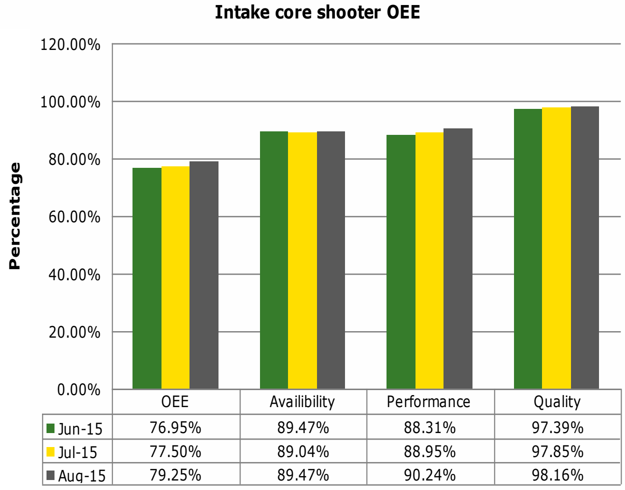
$$\text{Effective TAKT} = \frac{22 \text{ Hrs} * 60}{310} = 4.25$$

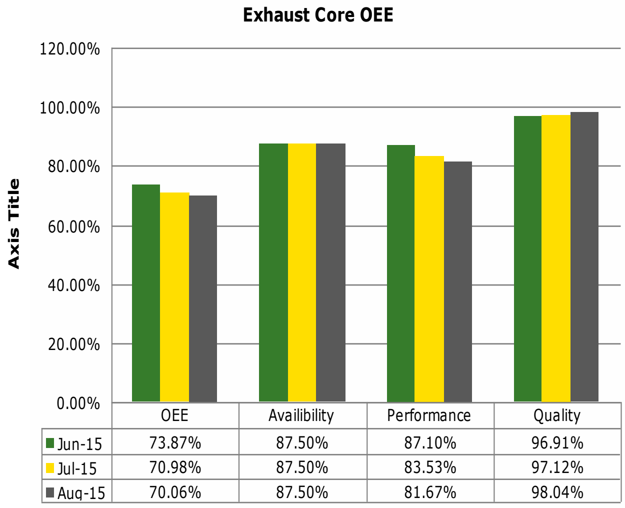
Shell core to cold box core proposal

Core	Current			
	Type	Actual process time (min)	Additional time (sec)	Total time
Intake core	**Shell core**	4.45	84	5.83
Exhaust	**Shell core**	3.3	10	3.46
Water jacket (mchn1+mchn 2)	Shell core	4.5	96	5.21
Total Core production in a day Nos.				253

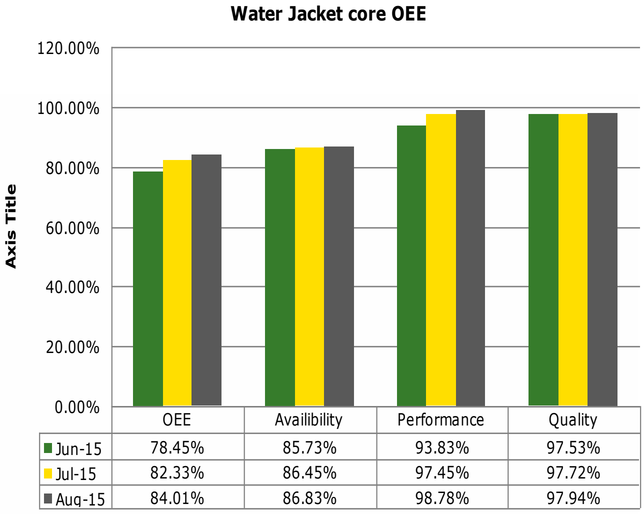
- Quality rejection: 23% (considering all 3 stages) Stagewise added.

OVERALL EQUIPMENT EFFICIENCY OF CORE SHOOTER MACHINES





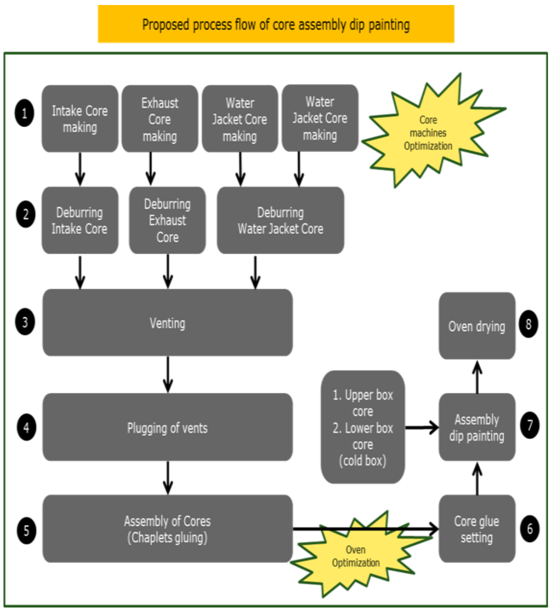
Core	Proposed			
	Type	Actual process time (min)	Additi-onal time	Total Time
Intake core	**Cold box**	.75	84	.15
Exhaust	**Cold box**	.35	10	2.51667
Water jacket (mchn1+mchn 2)	hell core	.25	0	3.25
Total Core production in a day Nos.	318			



Actual Operations showing the core making process: Core Assembly before dipping in paint.

Proposed Process Layout:

In the Proposed flow the individual Intake, Exhaust and water jacket cores are produced. After the de burring / removing the flashes and venting the cores are then assembled in the cold box bottom tray. It is then kept for glue setting and dip painting is done. Hence individual core painting and passing through the core oven is completely eliminated.



Cost Saving in Power, Manpower and Material.

COST SAVING IN POWER ,MANPOWER AND INPUT MATERIAL					
Sr. No.	**Description**	**Per day**	**per month**	**Cost saving / day**	**Cost saving /month Rs.**
A	Man power saving	3	75	1140	28500
B	Power cost	Unit/ day	Rate	Cost Saving / day	Cost Saving / month
1	Intake	144	6.8	979	25459
2	Exhaust	144	6.8	979	25459
				1958	50918
C	Material cost	Monthly qty	Cost saving/ head	Cost saving / day	Cost saving / month
1	Intake & Exhaust core	4500	13	2249	58474
	Total cost saving			5347	137892
		Monthly qty	Cost saving/ head	Cost saving / month	Cost saving / annum Rs.
	Total cost saving/ head	4500	30.91	139094	1669131

VII.CONCLUSION

With this study, it is proved that it is always beneficial to change the shell core making process wherever possible whatever may be the size of the core, to cold set core making process. The shell core making consumes the huge energy to heat and compaction of the core. Along with the saving of Rs. 1.40 lacs per month following benefits are achieved.

- Improved surface finish.
- Clean internal cavities.
- No grinding marks on internal areas
- Improvement in Delivery performance.
- Core assembly flow in a cell after core assembly.
- Reduction in extra effort at fettling (head internal cavity cleaning)
- Reduction in core assembly handling
- Reduction In core rejection , as Individual core handling is reduced
- Operator Fatigue is reduced

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