Turnaround Challenges in a Manufacturing Unit: A Case Study of Wheel & Axle Plant of Durgapur Steel Plant, SAIL, India

Gautam Kumar Mandal[1*], Amitava Ghosh[2]

[1]Research Scholar, Seacom Skills University, West Bengal
[2] Faculty- School of Management Studies, Secom Skills University, West Bengal
*Corresponding Author Email gkm008@gmail.com

Abstract

Wheel & Axle Plant at Durgapur Steel Plant, a unit of state owned steel giant SAIL, was commissioned in 1961-62 to produce forged and machined railway wheels for locomotives, coaches and wagons of Indian Railways with an annual capacity of 90,000 nos. wheels & 45,000 nos. axles. During Modernization of Durgapur Steel Plant in 1992-93 Rated Capacity of W & A Plant was revised to produce 50,000 OK wheel sets or 1,00,000 nos. wheels per annum, which is equivalent to 42,000 T wheels and 16,000 T axles. But unfortunately, this unit of DSP could never achieve the desired volume of production, neither with respect to its Rated capacity nor in terms of APP fulfilment (i.e. Indian Railway's annual order). Lot of corrective measures were taken by Management including experts, but average rated capacity utilization remained around 60% or even less. Later due to introduction of some new products and changes in process as per requirement of Indian Railways, the Rated Capacity of Wheel & Axle Plant reduced to 70,000 finishing wheels per annum from its existing capacity of 1,00,000 wheels annually. Revised Rated capacity, however, also did not help much due to some constraints at CNC machine stage. Compelled with the situation, DSP started partial outsourcing of machining activities for these wheels in order to fulfil Railways orders. Outsourcing helped WAP increase in some volume but not significantly. To improve the poor performance of W&A Plant with respect to its rated capacity and increase the productivity of the shop, initially various technical & special studies had been carried out to find out the reasons and remedial measures but that also didn't yield desired result. Therefore focus given on motivational aspect of human resource to explore the possibilities of bringing the desired break through changes and turn around in this plant and HR initiated was taken for re-designing the existing incentive scheme and its implementation to improve the motivation level of human resource associated to Wheel & Axle Plant. A new motivational Incentive Scheme has been designed and implemented after due discussion with shop floor management and workers involving trade unions. Finally, this initiative brought the desired turnaround in the W&A Plant and now W&A Plant is the Centre of Excellence in the Company.

Keywords:

Rated Capacity, Productivity, Turnaround, Wheel & Axle, Motivation.

Introduction:

Wheel & Axle Plant is a special feature and pride unit of Durgapur Steel Plant (DSP). It has been declared as the Centre of Excellence of DSP. The main customer of wheels and axles is Indian Railways, although the wheel sets are exported to other countries. It is truly said that, 'India Runs on DSP Wheels'. This plant was commissioned in 1961-62 to produce forged and machined railway wheels for locomotives, coaches and wagons of Indian Railways with an annual capacity of 90,000 nos. wheels & 45,000 nos. axles. The Wheel & Axle Plant has undergone a massive modernisation in early '90s. During Modernization of Durgapur Steel Plant, W&A Plant was provided with few important facilities like new Band Saws, 63/12 MN Forging Press, 20 MN Dishing Press, 15 nos. CNC machines, etc. and based on the same, it was envisaged to produce 50,000 OK wheel-sets or 1,00,000 no. wheels per annum, which is equivalent to 42,000 T Wheels and 16,000 T Axles.

Wheels are produced by pressing and rolling of wheel blocks while axles are produced by forging of axle blooms. Subsequently both are heat treated and machined. For the ease of production, wheel manufacturing section and axle manufacturing sections are located in two different bays. Tested wheel and tested axles finally meet in assembly section. Indian Railways takes both loose and assembled Wheels & Axles as per their requirement. A schematic process flow diagram is shown below for better understanding.

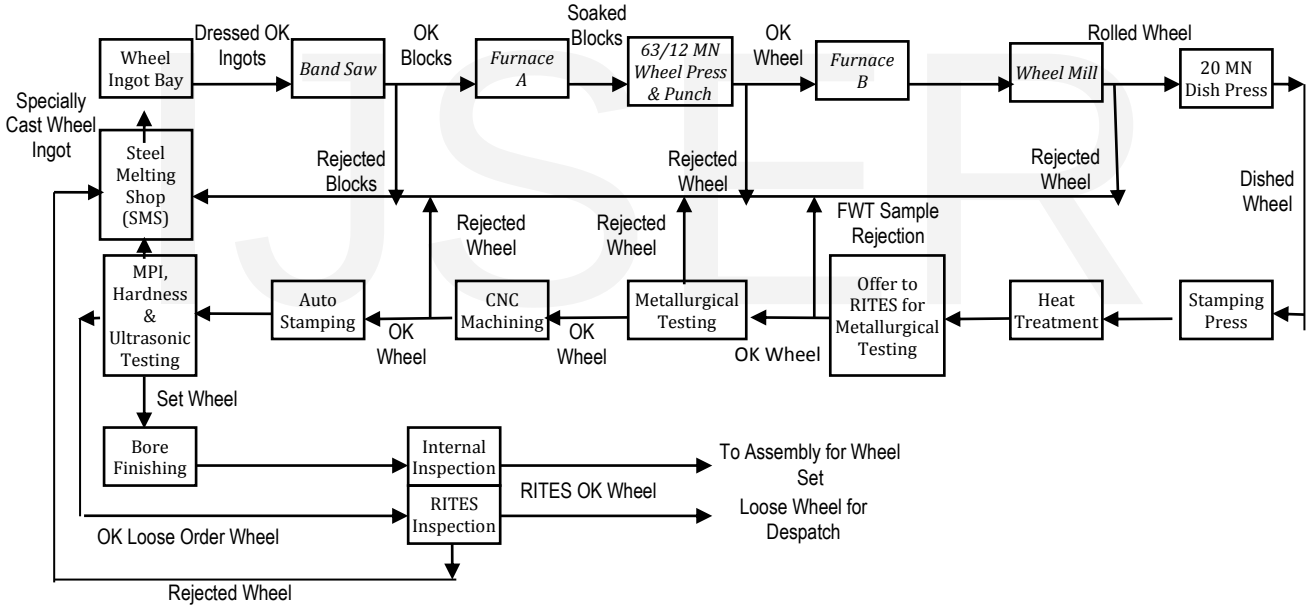

Fig.1 Schematic Process Flowchart for Wheel Plant

Problem Statement:

Wheel & Axle Plant at Durgapur Steel Plant was commissioned in 1961-62 to produce forged and machined railway wheels with an annual capacity of 90,000 nos. wheels & 45,000 nos. axles. During Modernization of Durgapur Steel Plant in 1992-93, the rated capacity of W & A Plant was revised to produce 50,000 OK wheel sets or 1,00,000 nos. wheels per annum, which is equivalent to 42,000 T wheels and 16,000 T axles. But W&A Plant could never achieve the desired volume of production, neither w.r.t it's Rated capacity nor in terms of APP fulfilment (i.e. Indian Railway's annual order). Lot of corrective measures were taken by the management including expert recommendations, but average rated capacity utilization remained around 60%

or even less. Annual Railway's order was also remained un-fulfilled in most of the time. Later due to introduction of some new products and changes in process as per requirement of Indian Railways, the Rated Capacity of Wheel & Axle Plant reduced to 70,000 finishing wheels per annum from its existing capacity of 1,00,000 wheels annually which has also remained unachieved. Since 1980s many studies were carried out earlier by various external & internal agencies like MECON, TPE, RDCIS (SAIL), Industrial Engineering Department (DSP) and RCL (DSP) etc. for improvement in achieving the Rated Capacity of W&A Plant but Rated Capacity never could be attained. Our objective is to find out the exact reasons and explore the solution of this complex problem.

Process of Making of Wheel and Axle in DSP:

a) Wheel Making Process:

In W&A Plant, wheels are produced in following basic steps

- Cutting of steel ingots into pieces (blocks/cheese) using Band Saws
- Rough shaping of wheel by pressing of hot block at 63& 12 MN Press
- Final shaping by rolling and dishing at Rolling Mill & 20 MN Dishing Press
- Heat treatment of black wheels at HT Section
- Machining of heat treated wheels by CNC Machines.

Specially-cast ingots (Fluted or Round) of special grade steel are sent to W&A Plant from SMS. After necessary dressing of ingot (removal of fins etc. by gas cutting) these are cut into small cylindrical pieces (called as block/cheese) by Band Saws at Mill Providing Section of W&A Plant. Then the blocks are heated in rotary hearth furnace (Furnace A) for 6-8 hours to a temperature of around 1300^0C.The heated blocks are de-scaled and fed to 63/12 MN Press for forging & punching. After this, black wheels are treated in batch type reheating furnace (Furnace B) to 1150^0C. The wheel is then rolled in a computerized wheel mill, where wheels achieve proper profiles & dimension in step by step.

After rolling, the wheels are fed to a 20 MN Dishing Press, where the web profile is achieved. The wheel is then fed to a marking press of 3 MN where Sl. No., Year and Cast No. are stamped on the back rim.

b) Axle Forging Process:

In W&A Plant, axles are produced in following basic steps:

- Receiving of Axle blooms from Alloy Steel Plant (ASP)
- Inspection &Testing of received Axle blooms
- Gas cutting of Axle blooms into desired lengths for forging
- Heating & Soaking of gas cut blooms into reheating furnace (Furnace F)
- Shaping of axle through forging of soaked blooms at pneumatic forging hammer
- Stamping of identification no. on forged axle
- Heat treatment of forged axles
- End cutting of axles for ultrasonic testing
- Ultrasonic Testing of heat treated axles
- Sending black axles for Machining by outside agency or supply of black axles to Railway

From process flow of Wheel and Axle production streams the difficulty levels, complicacy and speciality can be assumed. As Axle production is much easier process than wheel making process, our main focus is on Wheel Plant. Details of Wheel making process are elaborated further below:

Step-1: Cutting of Wheel Blocks from Steel Ingots

In the wheel stream of Wheel & Axle plant, Wheel ingots (fluted/round) of 14" & 16" diameter and 2m-2.5m length made of special grade steel produced at Steel Melting Shop (SMS)of DSP are cut into blocks/cheese by 8 no. Band Saws at Mill Providing Section of WAP for further processing i.e. forging and machining. Both 12-sided fluted ingots (around 20%) and round ingots (around 80%) are cut for preparation of blocks for various categories of wheel.

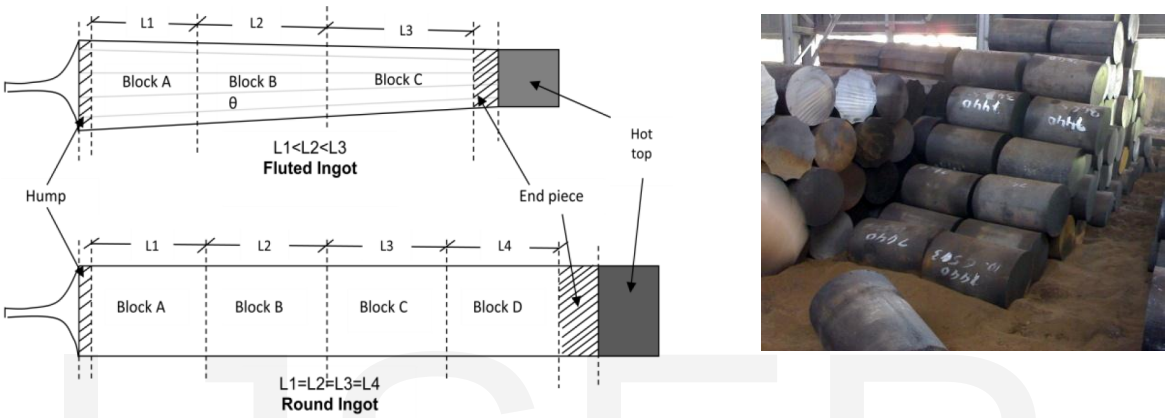

Fig.2 Schematic diagram and actual pic of Blocks (Fluted & Round)

Existing setup for block cutting:

During last modernization of the Wheel stream in 1992, the block cutting area got a new look as 6 nos. of new PLC controlled Amada (Japan)-make band saws (Model: HFA-500) were installed for accurate slicing of ingots (replacing earlier nicking system of block cutting from ingots) with automatic roller conveyor system for shifting of ingots and blocks. Later,2 nos. ITL made (indigenous) band saws were installed in 2005-06 with higher cutting speed and improved (magnetic) chip removal system with respect to Amada-make machines. But, performance of these two new indigenous band saws are nowhere matching with the old Amada band saws. Recently, a Circular saw has been installed in 2015-16 which alone can cater present block requirement.

Step-2: Wheel Forging Process

Wheel Forging Area is the place where actually a wheel takes its primary shape from the steel block and also undergoes the infantry stage of getting desired primary shape for further journey. Therefore, this is an important area in Wheel manufacturing process, where all sorts of precaution & care are required to be taken cautiously for smooth operations of the wheel before it is sent for machining for finishing operations.

Fig.3 Forging of Wheel

But, quite some time, this important area is reported to be under-performing and has of-late developed serious problems like:

- Poor output
- Low utilization of available time
- Huge loss of operation time due to frequent break-downs of vital equipment

In the Mill Providing section of W&A Plant, an upstream unit of Wheel Forge, required size blocks are cut from input ingots received from SMS. These blocks are than send to entry door area of A- Furnace (rotary hearth type) through Roller table. The Rail Charger picks up blocks one by one and places in A-Furnace. From discharge door, mobile charger G2 takes the soaked blocks and places on the descaling platform. After descaling by shaking on platform, G1 picks the block &places on the anvil of 63/12MN Forging Press. In the Forging Press the block is given the shape of wheel with punching hole at centre in three stages. After completion of punching, the block is taken away by mobile charger G2 at Wheel Mill side for placing in B- Furnace. The whole operation has been shown in schematic layout given below:

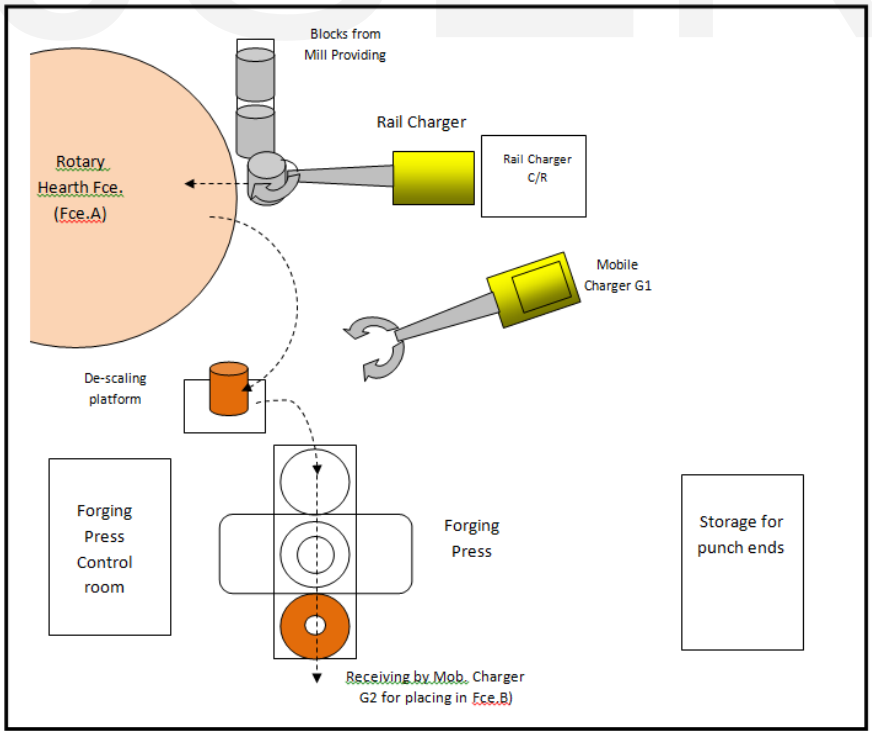

Fig.4 schematic layout of Wheel Forge area

Step-3: Rolling Process at Wheel Mill

Forged wheel is taken from 63/12MN Forging cum Punching Press by Mobile Charger G2 and placed in B-Furnace for re-heating to raise the rolling temperature for rolling in Wheel Mill. From B-Furnace, hot wheel sent to Wheel Mill by same charger G2 for rolling and a final shape (profile) in obtained.

Fig.5 Rolling of wheel in Wheel Mill and final wheel after forging

The rolled wheel is then taken by mobile charger M1 to put on Dishing Press for dishing. Dished wheel is moved to Stamping press by M1 for stamping this is for identification of the wheel and after stamping the finished forged wheel is placed on floor by M1. Mobile charger, M2 moves these hot wheels to hot bed in stack of 2 wheels for air-cooling. These wheels after preliminary cooling is then moved by crane 7 to heat treatment area. The entire operations at Wheel Mill area have been shown in the schematic diagram below:

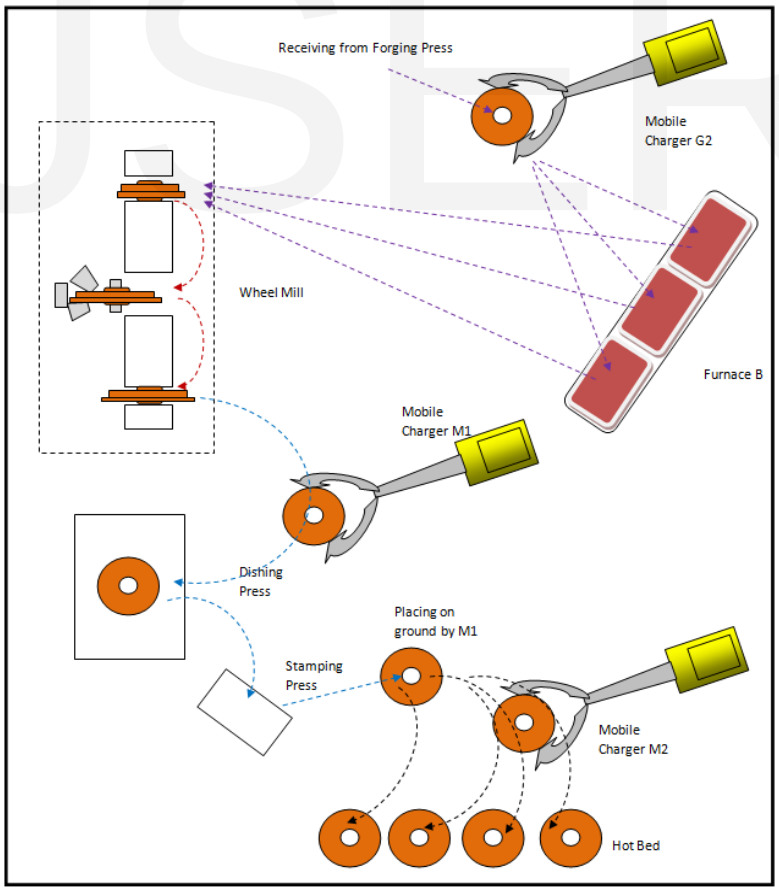

Fig.6 Schematic flow diagram at Wheel Millarea

Step-4: Process of Heat Treatment

After getting final shape of wheel through Forging, Rolling & Dishing processes, it is then subjected to heat treatment which includes quenching and tempering to give hard rim and tough core. This prevents high internal stress during cooling and prevents warping of wheels.

Heat Treatment (HT) is done in two phases namely,

i) Rim Spraying (quenching) and
ii) Tempering

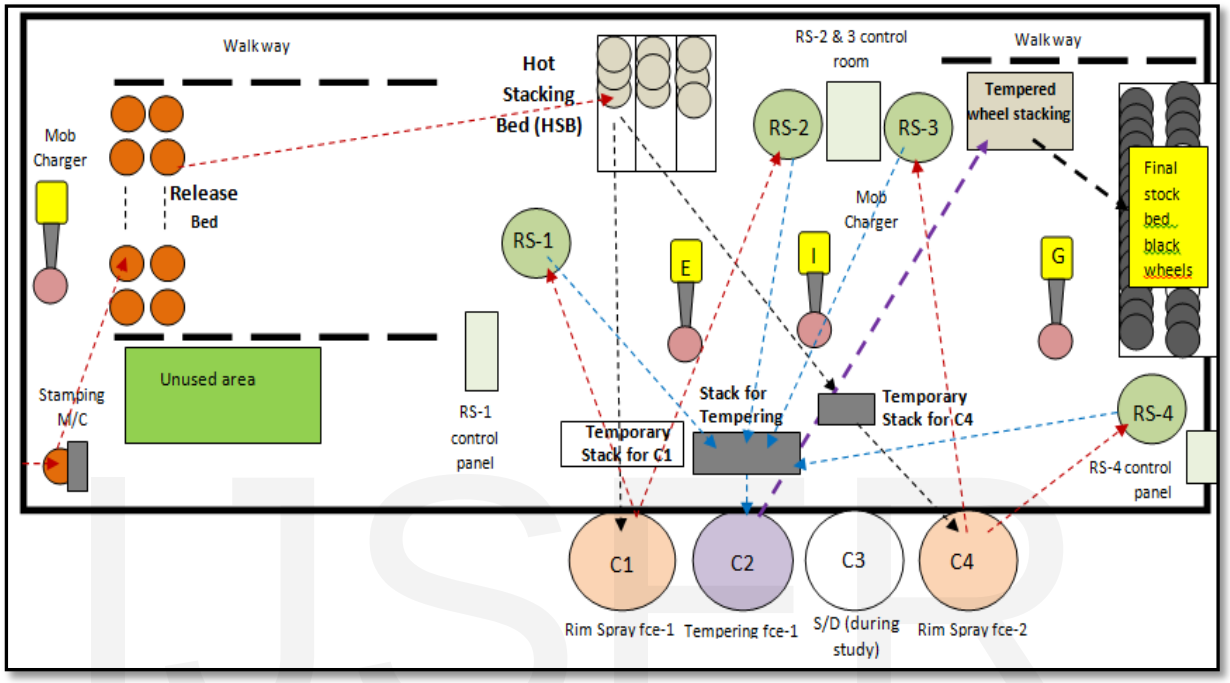

Fig.7 Schematic flow diagram at Heat Treatment area

Flow of material in Heat Treatment section has been shown in above sketch of HT area through arrow marks and various operations involved in it is explained in sequence below:

i) **Temporary stacking at Release Bed (RB):** After dishing, red hot wheels are placed on floor at Release Bed as stacks of two wheels for primary cooling purposes.

ii) **Temporary stacking at Hot Stacking Bed (HSB):** These pairs of semi-hot wheels are then transported to HSB by EOT crane (#7) holding one pair at a time and stacked haphazardly at Stacking Bed near HT Furnace C1.

iii) **Charging to HT furnaces:** There are 4 rotary furnaces (C1, C2, C3 and C4) for Heat Treatment, out of which 3 run at a time and other remains under shutdown. For operational convenience, out of 3 running furnaces, two extreme end furnaces are used for **Rim Spraying** and middle one is used for **Tempering.** On cooling, depending upon vacancy in furnaces, Charging cars put these wheels one at a time in any of two Rotary HT furnaces for heat treating & soaking.

iv) **Rim Spraying:** The heated & soaked wheel is than placed on Rim Spraying Machine and quenched by cold water with specific time. There are 4 nos. Rim Spraying machines usually two for each rotary furnace.

v) **Tempering:** Quenched wheels are then again heated up for Tempering in Tempering Furnace (rotary furnace in the middle).

vi) **Stacking for inspection:** Tempered wheels are then cooled in air, transported to stacking space and stacked as black wheel and offered for testing by RCL & RITES.


Fig.8Heat Treatment of wheeland stacking of Heat Treated black wheels

Step-5: Machining of Heat Treated Black Wheels

After heat treatment, next comes the machining part, where rim face, boss face, rim blending, condemning glove, chucking glove are machined by means of CNC machines. There are 15 no. CNC machines to do machining operation. At present outsourcing is being done for machining of wheels along with in-house machining.

Fig.9 Machined wheel

Step-6: Testing and Despatch of OK Wheels

Finally, the wheels are subjected to various tests such as Ultrasonic Test, Magnetic Particle Test and BHN which are certified by Railways own quality checking agency RITES. RITES certified wheels are despatched to Railway either as loose wheels or making set with RITES certified Axles. Rejected blocks/wheels at different stages are re-melted at SMS for recycling.


Fig.10 Tested OK loose wheel and assembled wheel sets ready for despatch

As safety of human is linked with quality of wheels, stringent quality control is done and each & every wheel undergoes all sorts of quality test as mentioned above. If certain no. of wheels fail quality test the entire batch of produced wheel is rejected by RITES. Rejection of finished wheels due to failure in metallurgical tests, creates lot of frustration among WAP employees as it consumed full efforts of employees.

Meeting an Industrial Challenge through Technical and HR Intervention

The Challenge:

As mentioned earlier, Wheel & Axle Plant at Durgapur Steel Plant, a unit of state owned steel giant SAIL, was commissioned in 1961-62 to produce forged and machined railway wheels for locomotives, coaches and wagons of Indian Railways with an annual capacity of 90,000 nos. wheels & 45,000 nos. axles. During Modernization of Durgapur Steel Plant in 1992-93, the rated capacity of W & A Plant was revised to produce 50,000 OK wheel sets or 1,00,000 nos. wheels per annum, which is equivalent to 42,000 T wheels and 16,000 T axles.

Unfortunately, W&A Plant could never achieve the desired volume of production, neither w.r.t it's Rated capacity nor in terms of APP fulfilment (i.e. Indian Railway's annual order). Lot of corrective measures were taken by the management including expert commendations, but average rated capacity utilization remained around 60% or even less. Annual Railway's order was also remained un-fulfilled in most of the time.

Later due to introduction of some new products and changes in process as per requirement of Indian Railways, the Rated Capacity of Wheel & Axle Plant reduced to 70,000 finishing wheels per annum from its existing capacity of 1,00,000 wheels annually.

The revised rated capacity, however, also did not help much as CNC machine operators at finishing stage were not willing to machine the special Loco other than basic BG wheels for fear of losing incentive. Compelled with the situation, DSP started outsourcing machining of these wheels in order to fulfil Railways orders. Outsourcing helped WAP increase in some volume but not significantly.

Methodology Adopted:

Study at site, Data collection from site, discussion with concerned technicians & officials and statistical analysis of data have been adopted as methodology to find out the solutions of the complex problem.

Previous Initiatives Taken in Wheel & Axle Plant:

Since 1980s many studies were carried out earlier by various external & internal agencies like MECON, TPE, RDCIS (SAIL), Industrial Engineering Department (DSP) and RCL(DSP) etc. for improvement in achieving the Rated Capacity of W&A Plant.

Since 2011-12, as an Industrial Engineer and leader of IED team, the author carried out series of studies at W&A Plant at different sections like Mill Providing, Wheel Forge, Heat Treatment, CNC Machines and Axle Plant to identify the reasons for poor performance and recommended the remedial measures based on study observations & data analysis. Some of the studies are mentioned below:

Table-1 : List of projects / studies carried out during 2011-2018

Year	Sl. No.	Name of Project/Study carried out by IED
2011-12	1.	Study on identification of reasons for declining performance of WAP
	2.	Study on utilization of Wheel Forge, Mill Providing and Wheel Machine Shop
2012-13	1.	Study on performance of band saws at Mill Providing section of W&A Plant to find out the bottlenecks/ performance of Band Saws and suggest measures for maximization of block productions.
	2.	Study on productivity improvement at heat Treatment area of WAP Reviewing of manpower & identifying bottlenecks in achieving higher productivity of Heat Treatment section of WAP.
	3.	Study on utilization of EOT cranes at WAP
2013-14	1.	Study on Wheel Forge and Wheel Mill Operations
2014-15	1.	Time Study to modify existing Multiplying Factor of EMU wheel machined outside of DSP
2015-16	1.	Study on Exploration of Developing Suitable Nomogram for accurate cutting of wheel blocks to get desired weight by the Band saws at Mill Providing Section of WAP
2016-17	1.	Study on Circular Saw to find out Optimum Block Output of Circular Saw
2017-18	1.	Time Study to modify Multiplying Factor of BG wheel machined internally for transition to Alt-12 variation from Alt-8 variation.

Impact of IED Initiatives:

Since 2011-12, for carrying out above mentioned technical & special studies and implementation of various study recommendations improvements in performance at different areas of W&A Plant were observed. Growth in Finished Wheel production (in physical nos.) since IED intervention in 2011 is shown below:

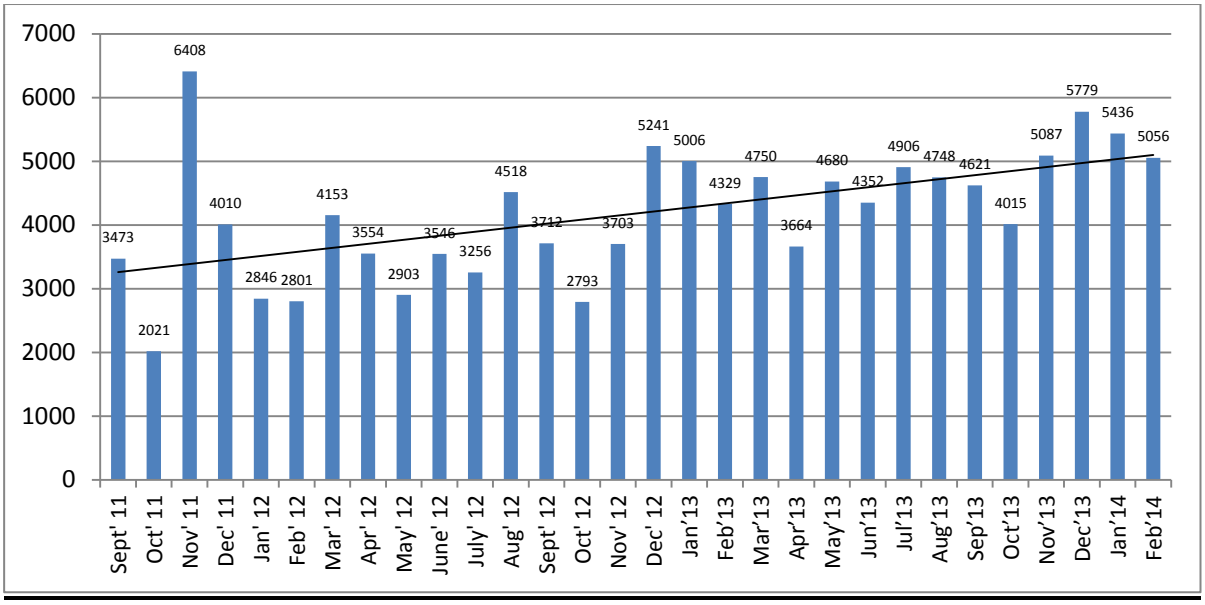

Fig.11 Finished Wheel production since IED intervention in 2011

Prior to 2011, the studies carried out by different agencies were mostly technical studies through which various technical hiccups & disorders have been tried to be sorted out. But still the desired result could not be achieved. Keeping in mind that thing, during the studies carried out since 2011-12, instead of adopting its conventional and familiar shop floor time and method study as was since 1980s, a holistic view of this complex problem was adopted along with the investigation of technical problems and time was spent in interactions with all cross-sections of employees and thus discovered the 'human factor' responsible for the complex problem. It has been identified that, it is the motivation level of employees which is the prominent prime cause of all disorders other than the technical problems. The interesting findings of these studies are as follows:

The findings were classified under four basic `M's involved in any production system – Man, Machine, Material and Method, An **Ishikawa diagram** as given below was prepared based on the information collected from various deliberations and statistics.

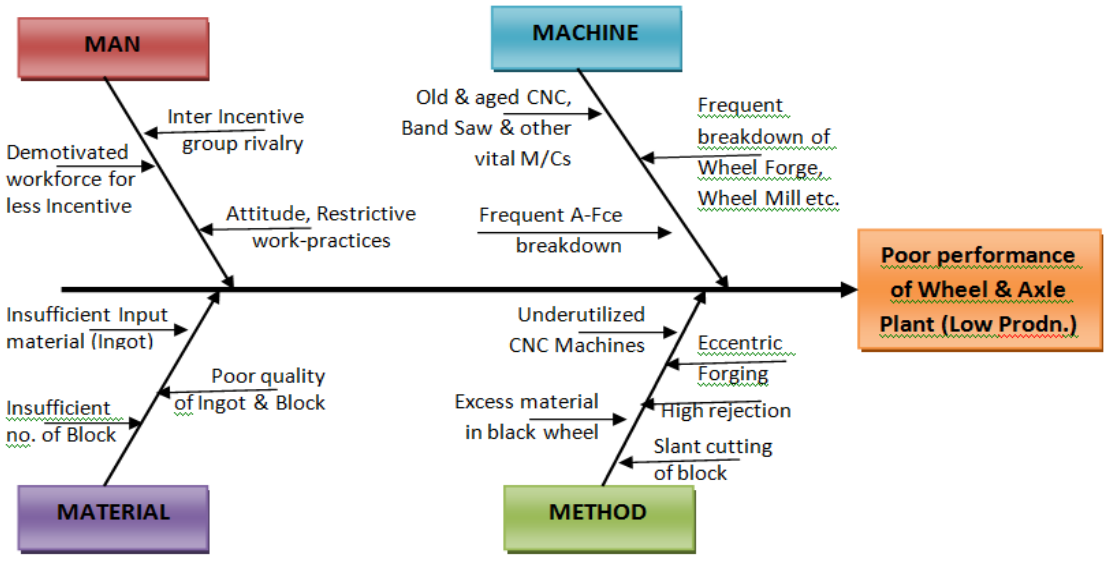

Fig.12 Cause & Effect diagram (Ishikawa diagram) for poor performance

❖ **Man:**

Role of men is most important in any production system. It is comparatively higher in plants like Wheel & Axle Plant, where unlike other process plants, production is highly dependent on individual efforts of MAN behind the machines like the process of block cutting, wheel rolling, wheel machining, wheel transportation and even inspection. All these jobs are highly labour intensive. And maximum problems observed to be from its MANPOWER resources. Situation became so worse that even the Top Managers considered W&A Plant as worthless, spoilt child and beyond repair.

❖ **Machine:**

The line Managers opined `technical problems' being the primary reasons. They blamed poor condition of almost all the vital equipment in the wheel production line namely the ageing Band Saws (fail to yield 300 nos. blocks per day), poor health of 'A' Furnace (frequent break-down), obsolete electronic & hydraulic control system of 63 MN Forging Press, un-suitable Heat Treatment furnaces (not designed to handle special higher diameter wheels like DLW, EMU. S-Profile etc.), the old CNC machines (lost reliability in precision machining) being responsible for low volume and low quality production. Shop cannot improve unless proper up-gradation and replacement are taken up.

❖ **Method (Process):**

WAP management expressed that practice of hot charging in HT furnaces was very useful not only in quality consistency and, reduction in heating cycle time (by approx. 50%) but also helped increasing HT wheels output considerably. But due to shortage of manpower, it had to be stopped, which has affected the output adversely.

Secondly, the practice of stringent inspection of finished wheels by RITES, an external agency, also plays a vital role. The rejection process of RITES of wheels or even a batch of wheels at the final stage, thereby making all efforts and time spent in these wheel-making to zero, perhaps also needed modification in the process of inspection of wheels.

❖ **Material- Bad Quality Ingots:**

Quality of input ingots from SMS is a major concern of WAP, since serious types of defects (like blow-hole, patch etc.) get identified during inspection at various stages of production. It accounts for huge rejection of finished wheels, sometimes even a whole batch (like UT rejection). This nullifies the actual efforts put up by WAP collective due to none of the faults of the WAP.

Approach Adopted

Based on the above findings, the four `M's were prioritized as under and it was also realized that the delicate element, `MAN' among them needs greater care, like handling the fragile glass items.

MAN ====➔ METHOD ====➔ MATERIAL ====➔ MACHINE

It was also clear like `daylight' that to regain the lost morale of WAP collective, the existing motivational incentive scheme needs modification or revision.

To deal with the remaining `M's, various Process/Method Improvement Studies and Time Studies at various production centres of WAP (as shown in Table-1) were carried out by IED since 2011-12. Incidentally, these studies yielded good results. Thus, performance and productivity of plant improved slightly but not at the desired level.

HR Initiative:

In the past, technical and special studies were carried out at WAP to improve its productivity but the results were not as per expectation. It is, therefore, thought of to attack the problem from motivational aspect of employees. A holistic view of this complex problem has been taken up and more time was devoted in interacting with the cross-section of employees in a structured manner rather than moving only around the technical aspects.

Finally, beyond above technical improvements, HR initiated had been taken for re-designing the existing incentive scheme and its implementation to **improve the motivation level of human resource** associated to Wheel & Axle Plant. Accordingly a **new motivational Incentive Scheme** has been designed and implemented after due discussion with shop floor management and workers involving trade unions. They appreciated the effort and accepted the solution gladly. Motivation level of Wheel & Axle Plant collectives raised in all time high and their involvement in work has been increased at a level which couldn't be seen earlier and their mind-set has changed drastically in positive direction. This initiative brought the desired turnaround in the W&A Plant and now W&A Plant is the Centre of Excellence in the Company. This could happen only after implementation of the new Incentive Scheme in W&A Plant and thereby boosting the morale & motivation of collectives. Due to limited space, details of the Incentive Scheme has not been discussed in this article but presented in a separate paper. Though the production of W&A Plant is completely dependent on railway orders but still the production trend has been found upward after implementation of new Incentive Scheme. Month-wise finished wheel production after implementation of new Incentive Scheme is shown below:

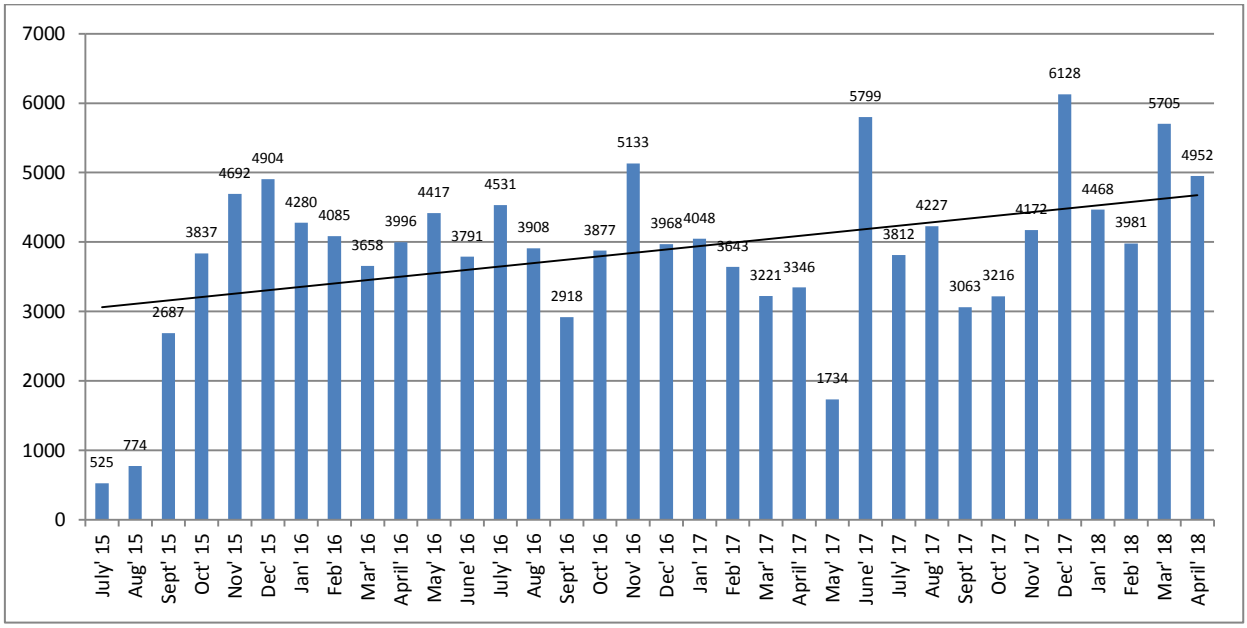

Fig.13 Month-wise finished wheel production after implementation of new Incentive Scheme

CHARTS & GRAPHS

Table-1: List of projects / studies carried out during 2011-2014
Fig.11: Finished Wheel production (in physical nos.) since IED intervention in 2011
Fig.12: Cause & Effect diagram (Ishikawa diagram) for poor performance
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GLOSSARY

APP: Annual Production Plan
ASP: Alloy Steel Plant
BG: Broad Gauge
CNC: Computer Numerical Control
DLW: Diesel Loco Wheel
DSP: Durgapur Steel Plant
EMU: Electric Multiple Unit
EOT:
FWT: Falling Weight Test
Fce. : Furnace
HSB: Hot Stacking Bed
HR : Human Resource
HT: Heat Treatment
IED: Industrial Engineering Department
MECON: Metallurgical & Engineering Consultants
MN: Mega Newton
MPI: Magnetic Particle Inspection
RCL: Research & Control Laboratory
RDCIS: Research & Development Centre for Iron & Steel
RITES: Rail India Technical & Economic Service
SAIL: Steel Authority of India Limited
SMS: Steel Melting Shop
UT: Ultrasonic Testing
WAP/W&A Plant: Wheel and Axle Plant

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8. Operations Research by Hira & Gupta
9. Production & Operations Management by S. Anilkumar & N. Suesh
10. Industrial Engineering & Management by O.P. Khanna
11. Statistical Process Control Concepts & Methodologies by A. Zaidi
12. IED Study Reports.

Resources/inputs received from different agencies/persons:

1. IED Production Database
2. Employees of W&A Plant

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