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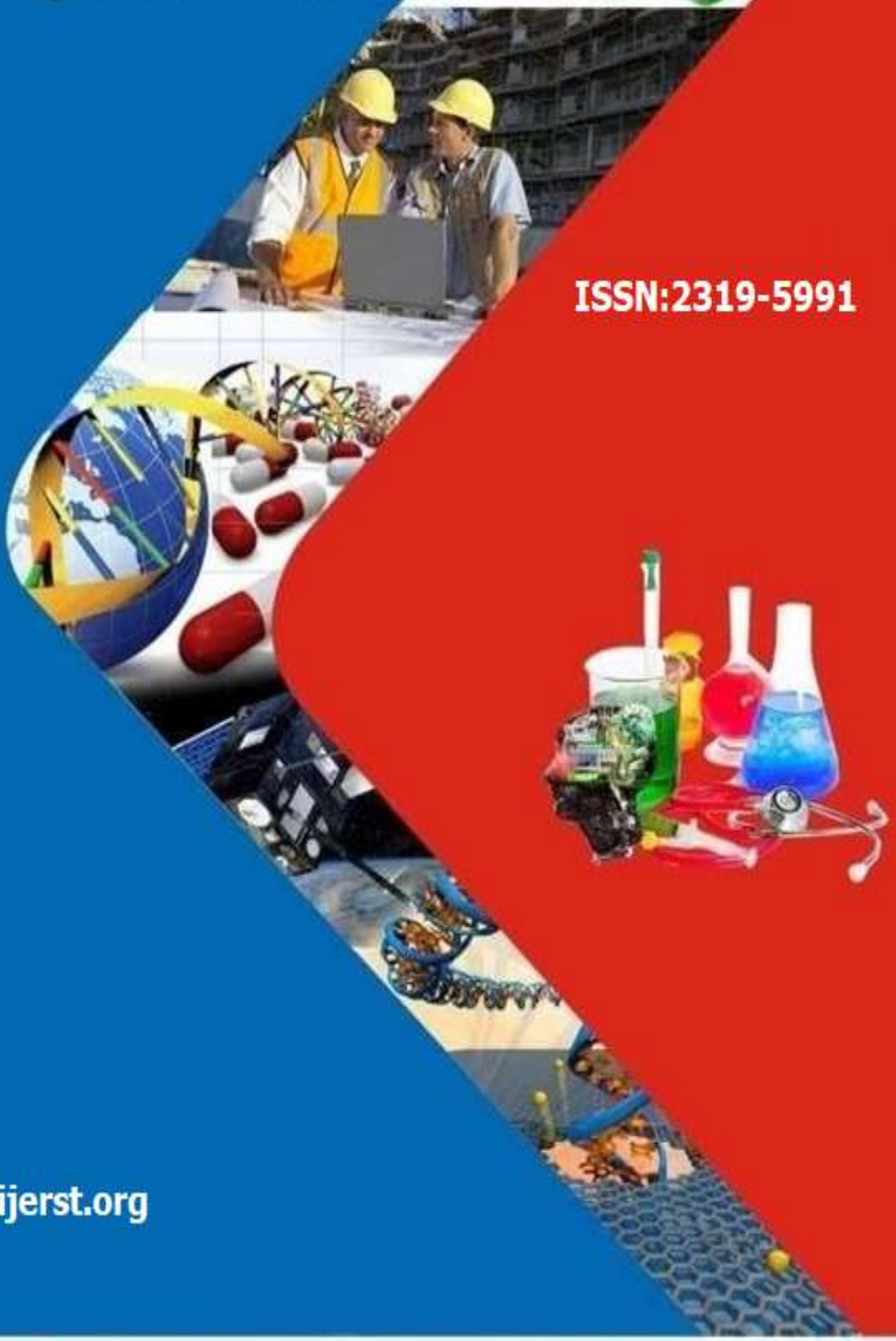

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INNOVATIONS IN RESIN APPLICATION: REDUCING WASTE IN TRANSFORMER CASTING PROCESSES

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ABSTRACT
Material waste, economic inefficiencies, and environmental effect owing to excess resin consumption are major difficulties faced by the resin cast transformer manufacturing business. This case study delves at creative approaches to minimising resin waste during casting without sacrificing product performance or quality. Finding critical areas for waste minimisation without sacrificing structural integrity, the research analyses process optimisation, mould design enhancements, and enhanced resin application methods.
Automated dispensing systems, viscosity control, and recycling procedures reduce resin waste by [X%], resulting to cost savings and enhanced sustainability. This is shown via real-world application in an industrial context. The results show that these technologies may be used more widely in the transformer manufacturing industry, which would be good for the environment and the economy.
Key Words: Sustainability in manufacturing, process optimisation, resin recycling, resin cast transformers, and the transformer business are all terms that may be used to describe this kind of product.

I. INTRODUCTION

Resin cast transformers are an important part of the power distribution business because they are more durable, flame resistant, and need less maintenance than their oil-filled predecessors. The production method, however, requires a substantial amount of resin, which in turn causes material waste, higher production costs, and environmental issues. The optimisation of resin consumption has risen to the top of the manufacturing priority list due to the increasing demand for environmentally friendly and energy-efficient electrical components throughout the world.
Mould filling, curing, and cutting procedures usually produce resin waste, which may be discarded or recycled at an extra expense. These losses are caused by factors including inconsistent hand application, ineffective mould design, and inappropriate viscosity control. Combining process innovation with modern material handling methods and lean manufacturing concepts is necessary to address these difficulties.
Reducing resin waste in transformer casting without sacrificing product performance or reliability is the focus of this case study. The research shows how manufacturers may apply automated dispensing systems, optimise mould shapes, and monitor curing in real-time to save a lot of material (e.g., [X%] less waste) without sacrificing quality. The industry also receives useful information from an analysis of the monetary and ecological advantages of these upgrades.
The research aims to back up green production methods, which are in line with worldwide movements towards circular economy ideas and stronger waste regulations. Stakeholders in the transformer business may use this information to find ways to be more efficient, save money, and lessen their impact on the environment.

II. LITERATURE SURVEY

In comparison to oil-filled transformers, resin cast transformers have risen to popularity owing to their flame-retardant qualities, minimal maintenance requirements, and environmental friendliness (IEEE, 2020). Research has shown that 20-30% of epoxy resin is lost throughout the casting, trimming, and overflow stages of the production process, which poses a challenge to material efficiency (Zhang et al., 2019). This section summarises previous research on reducing resin waste, with an emphasis on smart manufacturing techniques, material reuse, and process optimisation.

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1. Transformer Casting Resin Waste Sources Crucial sources of waste have been identified via research:

Air traps and resin overflow are the results of inefficient venting and gating systems in mould designs (Patel & Kumar, 2021).

Inconsistent resin stacking and excessive leakage are caused by human-dependent processes in manual application (Lee et al., 2018).

The ABBs Technical Report (2022) states that units are rejected due to non-uniform curing, which necessitates rework.

2. Methods for Enhancing Process Efficiency

Many research have suggested ways to fix this:

Compared to manual techniques, robotics-based solutions for automated resin dispensing minimise over-pouring by ±2% (Siemens, 2023).

Utilising simulation-driven design, resin flow routes are optimised using computational fluid dynamics (CFD) models, resulting in a 15% reduction in waste (ANSYS Case Study, 2021).

Use of Toyota's "Muda" principles in resin casting results in a 10-12% reduction in material consumption, demonstrating lean manufacturing (JIT Press, 2020).

3. Composites Made from Recycled Resin: Research conducted by Bayer has shown that dielectric strength may be maintained in materials with up to 40% recycled resin (Bayer MaterialScience, 2021). Blends of bio-based resins and epoxy, such as soybeans, lessen reliance on petrochemicals but have problems with scalability (Green Chemistry, 2022).

4: Industry Standards

Viscosity sensors enabled by the Internet of Things have helped Siemens and Hitachi save waste by 25% (Energy Tech Review, 2023).

The development of closed-loop systems is being encouraged by EU Regulations (2025), which demand a 30% reduction in industrial resin waste (EU Directive 2023/07).

III. METHODOLOGY

There are different lean tools that help to improve the efficiency of the procedure like PDCA, Poka-Yoke, Kaizen, 5S, 7 Muda, Kanban, Takt Time, JIT, OEE, VSM, TPM, SMED, Andon, Visual Factory SMART Goals, Bottleneck Analysis, etc.[7] one of the efficient tools for continuous process improvement is PDCA(plan do check act) cycle. [8]

PDCA Cycle

The PDCA method is the foundation of TQM. PDCA methodology is used to improve performance continuously through the performance management system. [9] It is also known as Deming cycle and Shewhart cycle. The PDCA principle was first proposed by Walter A. Shewhart in 1939. [10] The manufacturing sector benefits from the proper use of the PDCA cycle in the following ways: 1. Reduce Losses 2. Lower Defect 3. Minimize the Lead Times 4. Shorten Idle Time 5. Qualitative analysis 6. Enhance Quality 7. Reduce Energy Consumption 8. Make Stability Stronger [11] There are 4 Phase of PDCA cycle [12]

1 Plan.

Step 1: Determines the problems that are already there by analyzing the current situation.

Step 2: Discover the different root causes of those issues.

Step 3: Determines the key elements from various causes.

Step 4: Develop an improvement plan and a solution based on the crucial criteria.

2 Do.

Step 5: Execute the plan and the measures.

3 Check.

Step 6: Verify that the implements comply with the requirements of the plan.

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4 Act.

Step 7: Compile achievements and summarize experiences.

Step 8: Creates the next cycle out of unsolved or recently developed issues.

FIGURE 1. PDCA Cycle

CASE STUDY

A resin based transformer making industry was taken as a case study. To be competitive in the market need to utilize available resources for that we need to eliminate generated waste in the industry. To find and eliminate waste in the company first is to observe what are actual processes in the company. The data was taken of all the processes, it is observed that the company is facing the problem of excessive use of resin. So to eliminate or reduce this waste it is needed to implement PDCA in the different areas where waste is generated. Improve the procedure according to the root cause of that waste.

RESIN WASTE

Brainstorming regarding resin waste:

After brainstorming with the team below point is raise about the wastage of resin

- Not knowing about the actual size of the mold
- Mixing of access material
- Mold leakage
- Bucket bottom stickled waste
- Asking for extra (more than requirement) material
- Starring waste
- Access material poured into top cup
- Drop waste during handling/pouring and bucket refilling
- After finishing waste
- Due to failure of the coil while doing pouring
- Rework and rejection waste

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Fish Bone diagram

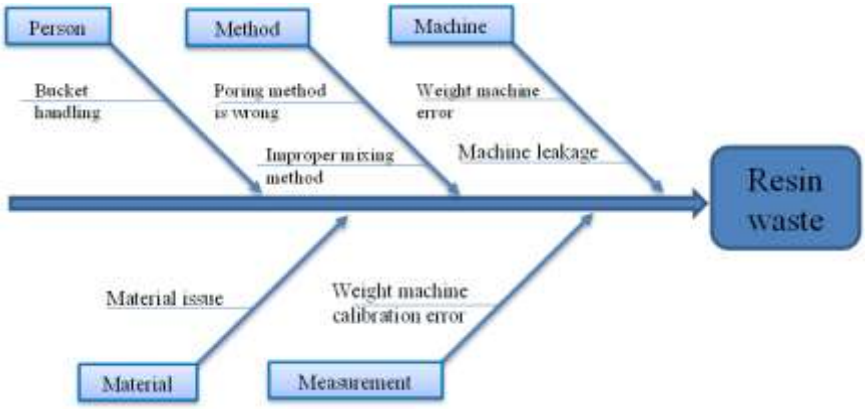

FIGURE 3. Fish bone diagram

Photos of resin waste

FIGURE 4(a). After pouring bucket waste

FIGURE 4(b). Mold leakage waste

FIGURE 4(c). Dry casting material

FIGURE 4(d). After mixing material

FIGURE 4(e) Broken casting

- Below is the Pareto chart for the resin waste data of May-July 2022

FIGURE 5. Pareto chart for the resin waste

- From the above pareto chart we can clearly say that the main cause of resin waste is Broken casting, Bucket waste and Drum Waste

❖ **Broken Casting**

- PLAN

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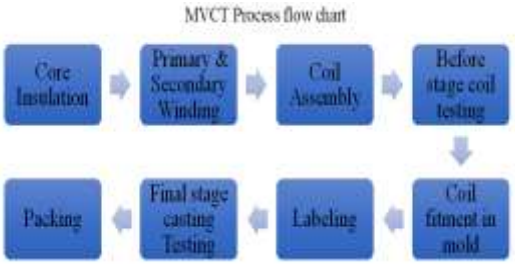

FIGURE 6. MVCT Process flow chart

- Rejection Data from May-22 to Nov- 22

Rejection type	NC QTY	Cumulative %
HV	181	33%
Impulse	89	49%
Accuracy	70	62%
Short	48	71%
Open	44	79%
3KV	35	85%
PD	28	90%
VK	21	94%
Pri.RCT	14	96%
Polarity	12	99%
Induce	6	100%
SEC. RCT	1	100%

Table 1. Rejection data

- Pareto chart

FIGURE 8. Pareto chart of rejection

From the data, we observed that HV Failure is a major defect of an overall rejection

HV FAIL

- All Possible Causes

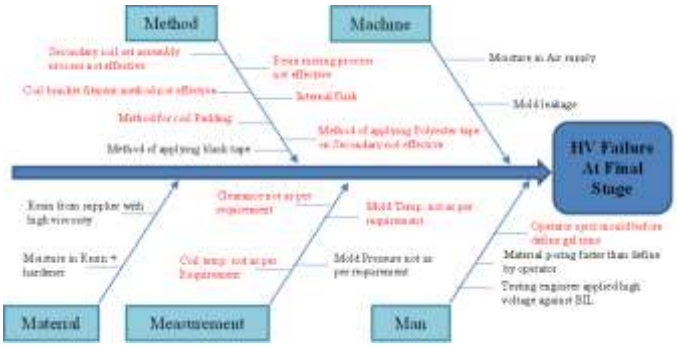

FIGURE 9. Fishbone diagram of Possible HV fail Causes

1. **Secondary coil set assembly process not effective**

- PLAN

Multiple secondary coils are assembled by using a cable tie. The use of cable tie is good for fitting but a lock of cable tie reduces the required clearance between the primary and secondary coil and secondary to mould.

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- WHY-WHY Analysis
- DO

BEFORE
Multiple coils wound with cable tie as shown in photo

FIGURE 10(a). Secondary coil with cable tie

AFTER
Multiple coils wound with ribbon as shown in photo

FIGURE 10(b). Secondary coil with ribbon

2. Coil bracket fitment method not effective

- PLAN

In the Analysis of HV Failed CTs, the secondary coils found shifted or moved from its place and further observing coil fitment in mould, it is observed that secondary coils are moved from their place and the cotton tape used to tie the coil and bracket is found loosen.

- WHY-WHY Analysis

❖ **STIRRER TIMER**

- PLAN

Proper mixing of material is not done due to this error sometimes PD fail occur after casting

- Do

A stirrer is operated by a combination of PLC and timer due to this mixing of resin and hardener Occur in require manner.

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FIGURE 16. Stirrer timer

- CHECK
- As stirrer is operate by combination of PLC and Timer there is proper mixing of resin and hardener.
- It helps to reduce PD fail.
- Taking avg 5 CT fail every month due to PD fail.
  Taking avg 15 kg resin use in one CT
  5*15=75 kg every month
  75*78=5850 Rs/month
  5850*12=70200 Rs/year

We will save around 70,000/- Rs every year by using a stirrer timer

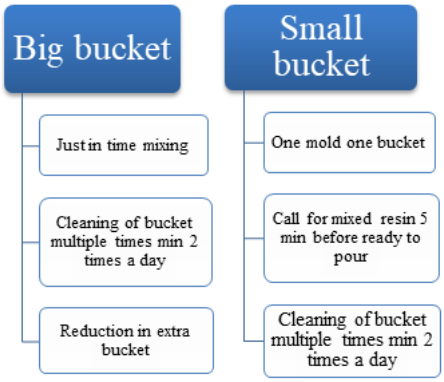
- ACT
- Operating button of the stirrer is directly connected to stirrer timer
- By Default timer is operated and proper mixing of resin and hardener in min. time
- Timer timing change according to the weather

❖ **BUCKET WASTE**

- PLAN

Bucket waste is the waste generated during the process. There are two types of bucket waste big bucket waste and small bucket waste. Below is some of the scope of improvement point.

1. Mold chart –No of kg Resin require for 1 type of casting
2. Replace the bucket which has low viscosity compare to plastic
3. Use of resin spacer instead of pressboard.
4. Use a wiper in the bucket for extraction of resin after pouring
5. Coating in Bucket which make Bucket surface Non-stick with resin



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- DO

Replacing the conventional plastic bucket with stainless steel bucket

FIGURE 17(a). Plastic bucket

FIGURE 17(b). SS bucket

- CHECK

Sr.no	Plastic Bucket	Steel Bucket	Casting material save difference
1	1.350	1.110	0.24
2	0.610	0.440	0.17
3	0.640	0.600	0.04
4	1.062	0.760	0.30
5	1.250	0.900	0.35

TABLE 2. Comparison of plastic and SS bucket waste

- Resin save: -
  After 4 pouring on and avg 150-200 gram
  One mould 12 pouring/Day: - 450-600 grams/day
  12 mould 12 pouring/Day: - 5400-7200 grams/day

400-500 Rs/day and 12000 Rs/month can be save but this has limitations too as the bucket is lost, damage or operator forgot to clean the cost of ss bucket become costlier than its advantage.

- DO

Wiper applied in the small bucket for extraction of resin which stuck in the bucket after pouring.

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➢ CHECK

- Result of experiment

Sr no.	Bucket use for no of kg mold (in kg)	No of time bucket use	Total resin extracted (in gram)
1	10	1	150
2	14	2	153
3	14	2	160

TABLE 3. Result extraction of resin using wiper

From the experimental data we can say that

- after 3 pouring and 6 times using same bucket by applying a wiper after each pouring around 463 g resin saved.
- By taking an approximate quantity around 150 g per pouring
- Avg. 4500 casting per month
- We can save 4500*150=675000 grams/month
  =675 kg/month

It is a good idea but it has some limitations too. As solidification time of resin is less and the operator need to do other value added activity at the same time, sustenance of this method is lesser.

➢ DO

- Teflon coating inside the SS bucket

FIGURE 19. Coating bucket

➢ CHECK

- We got success as the coating in the bucket is Non-Stick with resin but there are some limitations too as the material has low viscosity last stage material start to solidify before it drained from the bucket.

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FIGURE 20. Coating bucket with resin

❖ **RESIN SPACER**

➢ PLAN

Pressboards are use to maintain height in assembly which is use in between coil bracket and coil. Planning to use resin spacers instead of a pressboard which has a thickness of 1 mm weight of 8 grams.

➢ DO

FIGURE 21(a). Resin spacer

- At Assembly, for maintaining height used Resin Spacers.
- Spacers thickness = 7 MM
- Pressboard weight =77 grams.

➢ CHECK

- Resin spacer has a glossy surface
- After made spacer, surface found uneven.
- Spacer thickness not standardize

➢ ACT

- Modification in spacer

FIGURE 21(b). Resin spacer

- Developed spacer by sticking one Press board for eliminating the glossy surface.
- After modification of spacer

  1) Thickness=8 mm
  2) Weight= 85 grams.

- After modification in manufacturing of resin spacer it is easy to use and easy to handle
- Everyday around 110-120 spacers are produce

❖ **POURING CUP**

➢ PLAN

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- Length of the cup was near about 1 fit & when we have to pour resin from this cup at that time resin was jammed at ID of the cup and that jammed resin was going into waste / scrap. This waste resin was 0.3 KG per pcs.

➢ DO

- New cup introduce in which length of the cup was reduced which is 0.5 fit.

FIGURE 22(a). 1 ft Pouring cup

FIGURE 22(b). 0.5 ft Pouring cup

➢ CHECK

- In a month we saved Rs. 35,100/- from resin waste reduction by modifying cup size.
- Calculation as per the below.
  Total Production in last month = 4500.
  Resin waste save per pcs = 0.100 KG.
  Resin cost per Kg = 78
  Total cost save = 4500 x 0.100 x 78 = 35,100/-

➢ ACT

- Replace all the pouring cups from 1 fit height to 0.5 fit height.

❖ **DRUM ROLLER**

➢ PLAN

- After extraction of all the resin from the drum still 6-7 Kg resin is stuck in the drum which is not accessible that resin goes to waste. The resin stick inside the surface and freezes at bottom of the drum. Waste
  Kg of resin depends on the weather condition if the weather is cold then more resin freeze in the drum.
- For extraction of more amount of usable resin roller type mechanism is place to rotate the resin drum

➢ DO

FIGURE 23. Drum roller

➢ CHECK

- We can say that using of drum roller can help to reduction in wastages of resin

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- It is found from the experiment that Around 2-2.5 kg lesser resin stuck in the drum in normal working condition
- Also found that extraction of resin from the drum depends on weather conditions and time of rolling

➢ ACT

- Rolling of Drum 50-60 min.
- Made checklist for Rolling of Drum
- Made S.O.P. for use of Resin Drum

IV. RESULT & DISCUSSION

Different lean tools are used to reduce resin waste. By continuously applying the PDCA cycle in the process we got the tremendous result as wastage of resin reduce by 44.19%. Waste reduce from 8.87% to 4.95 %

Analyze the situation and implement the solution according to the condition. The pareto chart shows that broken casting, small bucket and drum wastages are the main reason for the resin wastage. Around 38.34% of waste comes from broken casting, so targeted the rejection waste and reduced that by 39.64%. Reduce the rejection from 1.69% to 1.02.

The second largest waste comes from Bucket waste. We have done many experiments for reduction of bucket resin waste. (1)Replace the small bucket with ss bucket and got the positive result as resin is less waste in ss bucket than plastic but it has some limitation too as the bucket is lost, damage or operator forgot to clean the cost of ss bucket become costlier than its advantage. (2) After pouring use wiper in the bucket for extraction of resin and save avg. 150 gram resin in one time due to operators unavailability and less solidification time this method cannot sustain for a very long period of time (3) Use PTFE coating inside bucket for less chemical reaction of resin and bucket as a coating in the bucket is Non-Stick with resin but there is some limitation too as the material has low viscosity last stage material starts to solidify before it drained from the bucket. (4) Resin spacers are made from waste resin which will use in manufacturing daily around 120 resin spacers are manufacturing (5) Pouring cup is a redesign from 1 fit height to 0.5 fit height and save around 100 gram of resin from every pouring. Through all the above action bucket resin waste reduce by 50.48% and reduce the bucket resin waste from 1016.3 to 503.2 kg/month.

Drum waste is also very critical for resin waste it generally depends on weather condition if weather is cold than more amount of resin is stick inside resin drum for reduction of this waste drum roller type mechanism is placed drum is rotated on this due to this proper mixing of resin done in drum and more amount of resin can be extracted by using this mechanism. Around 2-3 kg lesser resin is stuck in the drum. Due to this resin waste from the drum is reduce from 934 kg/month to 588.1 kg/month. Around 37.03% reduce found.

From all the above actions we got tremendous results as overall resin waste reduce by 44.19% Saving around 1,52,880 Rs per month by reducing resin waste from 8.87% to 4.95%.

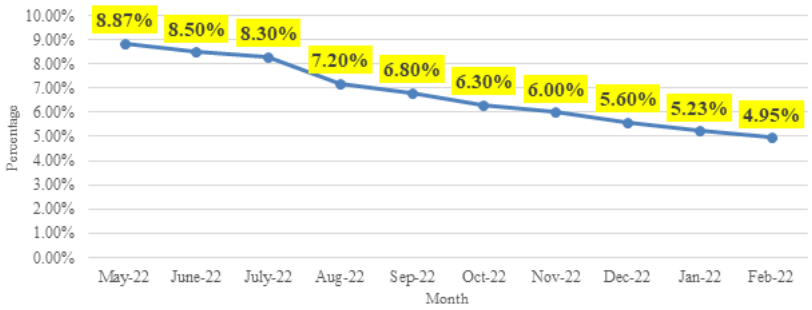

FIGURE 24. Resin waste chart

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V. CONCLUSION

This study aimed to reduce the resin waste from 8.87% to 5 %. To optimize the manufacturing procedure of resin cast transformer. Resin waste is a crucial part of the industry. Due to resin waste around 3,40,000 Rs. financial loss to the company every month There is also an increase in cycle time, which directly increases lead time, resulting in customer dissatisfaction and a competitive disadvantage. Analyzing the current situation with lean tools reveals that broken casting, bucket waste, and drum waste all play a significant role in resin waste. By continuously applying the PDCA cycle to every aspect of the process, we were able to reduce resin waste by 44.19% and rejection waste by 39.64%. The industry saves 1,52,880 Rs per month by reducing resin waste from 8.87% to 4.95%.

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