PRODUCTIVITY IMPROVEMENT IN ROBOT WELDING AT RANE NSK STEERING SYSTEMS

Report submitted to the SASTRA Deemed to be University
as the requirement for the course

BMECME 801 R01 PROJECT WORK

Submitted by

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May 2021

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SCHOOL OF MECHANICAL ENGINEERING

THANJAVUR, TAMILNADU, INDIA-613401

PRODUCTIVITY IMPROVEMENT IN ROBOT WELDING AT RANE NSK STEERING SYSTEMS

Thesis submitted to the SASTRA Deemed to be University
in partial fulfillment of the requirements
for the award of the degree of

B. Tech. Mechanical

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BonafideCertificate

This is to certify that the report titled "**Productivity Improvement in Robot Welding at RANE NSK Steering Systems**" submitted as a requirement for the course, **BMECME 801 R01 PROJECT WORK** for B.Tech, Mechanical Engineering, is a bonafide record of the work done by **Mr. DANNY SNEHAM S (Reg. No. 121009062), Mr. LINGAMGUNTA SAI KIRAN KUMAR (Reg. No. 121009134), Mr. VAMSI KRISHNA M (Reg. No. 121009260)**, during the academic year 2020-21, in the School of Mechanical Engineering, under my supervision.

Signature of Project Supervisor : N. Sathiya Narayanan

Name with Affiliation : Dr. N. Sathiya Narayanan, AP-II

Date : 29/05/2021

Project *Vivavoce* held on ________________

Examiner 1 **Examiner 2**

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Declaration

We declare that the report titled "**Productivity Improvement in Robot Welding at RANE NSK Steering Systems**" submitted by us is an original work done by us under the guidance of **Dr. N. Sathiya Narayanan, School of Mechanical Engineering, SASTRA Deemed to be University** during the 8th semester of the academic year 2020-21, in the **School of Mechanical Engineering**. The work is original and wherever we have used materials from other sources, we have given due credit and cited them in the text of the report. This report has not formed the basis for the award of any degree, diploma, associate-ship, fellowship or other similar title to any candidate of any University.

Signature of the candidates :

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Vamsi Krishna M

Date : 29/05/2021

Acknowledgements

First of all, we express our gratitude to **Dr. S.VAIDHYA SUBRAMANIAM**, Vice Chancellor, SASTRA Deemed to be University, who provided all facilities and the necessary encouragement during the course of study, we extend our sincere thanks to **Dr.R.Chandramouli ,** Registrar, SASTRA Deemed to be University for providing the opportunity to pursue the project. It is our privilege to express our sincere regards to our Dean **Dr. S.Pugazhenthi** (SOME) and **Dr. S.Raghuraman** Associate Dean (SOME), who motivated us during the project.

We owe a debt of deepest gratitude to our guide **Dr. N. Sathiya Narayanan** (AP II/ SOME) for his valuable inputs, able guidance, encouragement, wholehearted cooperation and constructive criticism throughout the duration of our project on the topic "**Productivity Improvement in Robot Welding at RANE NSK Steering Systems"** and we take this opportunity to thank all our lecturers, who have directly or indirectly helped in our project.

We also thank **RANE NSK Steering Systems Pvt. Ltd**. for allowing us to take part in the robot welding project. We are grateful to **Mr. Jai Anbu, Manager, MED** and **Mr. B. Thirumurugan, Asst. Manager, MED** for spending their valuable time in guiding and helping us throughout the course of this project.

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Abbreviations

CAD	Computer Aided Design
LH	Left Hand
RH	Right Hand

Notations

English Symbols

mm	Milimeter
cm	Centimeter

Abstract

The RANE NSK Steering, located in Chennai, specializes in manufacturing manual steering columns for different kinds of automobiles. The manufacturing of steering columns involves many subsequent operations from its initial design to final assembly. Our teams' project focused on improving the productivity of robot welding by applying and utilizing various lean manufacturing techniques. As a result, the manual steering column passes through various workstations before coming out as a finished product was analyzed individually. One such is the robotic welding workstation, where outer tubes of different steering column models are welded to its specific child parts. However, the robotic welding workstation seemed to be consuming wastage in unwanted transportation and was facing downtime for various reasons ranging from improper bin management to motion wastage and material handling. Therefore, a chute system and phosphating trolley were introduced to reduce time wasted on material handling and the KANBAN system to avoid confusions and errors. In addition, a simple collet was also designed and fabricated for a forming machine since the default collet was costly and required a lot of services.

Specific Contribution:

- Contributed in the designing of material handling system to avoid the unwanted transportation
- Worked in group technology concept in the grouping of child parts of sub-assembly.

Specific Learning:

- Understand the importance of implementing lean principles in any industry.
- Practically visualized the difference between the traditional and lean manufacturing industry.

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Abstract

RANE is a renowned manufacturer in the automobile industry. RANE NSK mainly focuses on manufacturing steering columns for various automobiles. In particular, in the plant located in Chennai, manual steering columns are manufactured for 120 models. Each of these models undergoes a different set of processes under different production lines in the plant. Every part has to go through Robo welding, and the probability of errors and delays in this section was high. So, Lean manufacturing methodologies have been applied to detect waste and take necessary countermeasures to overcome bottlenecks. In our work, we specifically concentrated on removing unwanted transportation and motions in the Robo welding process. With the data collection phase and proper analysis of the production line, we have suggested a chute system connected via a universal trolley and a waste management system, using KANBAN visual system that would help operators in loading parts. The system introduced by our team found to be effective and easy to implement in the considered production line and finally well appreciated by the production workers.

Specific Contribution:

- I was part of the team for the design and analysis of the collet operation.
- I have made my specific contribution in framing the KANBAN waste management bin system.

Specific Learning:

- Understood the various types of wastes as listed in lean manufacturing
- Ways to overcome the listed wastages using various tools and techniques of lean manufacturing.
- Identified the ways to find the bottlenecks in any process and the root cause of defective parts.

Name: Lingamgunta Sai Kiran Kumar
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Abstract

Steering columns are a vital component of the steering system of any automobile vehicle. The RANE NSK Steering Systems are involved in manufacturing these steering columns for 120 automobile models. The manufacturing of steering columns involves many subsequent operations from its initial design to final assembly. Our teams' project focused on improving the productivity of robot welding by applying and utilizing various lean manufacturing techniques. Unwanted transportations and motions highly exist in any manufacturing industry as listed in the different forms of wastes. Two sub-assemblies, namely the outer tube and the tilt bracket of the manual steering column, are manufactured and assembled using robot welding processes. The Chute systems and outer tube assembly trolley are designed and manufactured to reduce transportation and motion wastage as specified in lean manufacturing. Our team designed a visual system to aid the operators to load the chutes and a waste management bin for the left-over parts using KANBAN bin system principles. Apart from robot welding, we have also been tasked with designing a more effective, simple and serviceable collet holder used in metal forming processes.

Specific Contribution:

- Design of KANBAN visual aid system.
- Design made for the various parts of the collet holder.

Specific Learning:

- Understand the importance of various tools and techniques of lean manufacturing.
- Design and manufacturing of chutes and trolley.
- Analyzed and implemented the KANBAN visual control in the production line

M. Vamsi Krishna

Name: Vamsi Krishna M
Reg No.: 121009260

CHAPTER 1

INTRODUCTION

1.1 RANE NSK STEERING SYSTEMS PVT. LTD.

Founded in 1929 by Ganapathy Iyer in Madras, RANE started its journey as an automotive parts distributor. Later, the company pivoted towards manufacturing different automobile parts related to steering and suspension systems with several high-profile clients such as TATA Motors, Ashok Leyland, Volvo, Daimler and more. Rane has set up five manufacturing plants in Chennai and Kancheepuram in Tamil Nadu, Mysore in Karnataka, Thirubuvanai in Pondicherry and Pantnagar in Uttarakhand.

RANE's Vision: To achieve profitable growth in steering column business through technology and people development. RANE Steering systems specializes in manufacturing steering columns. Predominantly of two types, manual steering column and electric power steering column.

RANE NSK, Guduvanchery, Chennai focuses on the production of the manual steering column (MSC). The production is carried out through various manufacturing processes like broaching, continuous welding, robot welding, CNC machining and metal forming. We aim to apply lean manufacturing techniques efficiently to boost the productivity of a particular production process, Robot welding.

1.1.1 Robot Welding

In Rane NSK Steering Systems Pt. ltd., robot welding is employed to weld different parts onto the outer tubes/tilt brackets of various steering columns belonging to different vehicle models.

Three robot welding machines are utilized for this purpose. The operators work in 3 shifts spanning 8 hrs. each. Excluding time for leisure, each shift has 7.2 hrs available.

Each of the three machines has one robot and two workspaces to operate within, known as RH (Right hand) and LH (Left hand). The welding is done at RH first and then continued in the LH workspace. Thus, the workflow is from RH to LH always and not the other way around.

1.2 LEAN MANUFACTURING

Lean manufacturing is a manufacturing philosophy or methodology which aims at producing more and more with less and less. 'More and more' symbolizes improvement in production rates, while 'less and less' refers to the utilization of limited resources.

Toyota was the first of the many companies which implemented lean manufacturing on their shop floor. Initially, it was known as the "Toyota Production System" or the "Toyota Way".

1.2.1 Five principles of lean

- To specify the value of each product.
- To identify the value stream of the product.
- Let the value flow.
- Make the customer pull the product.
- Pursue perfection.

1.2.2 Wastages according to lean

- Transportation
- Inventory
- Motion
- Waiting
- Overproduction
- Overprocessing
- Defects
- Over utilization

1.3 LITERATURE SURVEY

Lonnie Wilson, in his book on "How to implement lean manufacturing", writes about the variety of procedures through which lean manufacturing techniques can be implemented in the shopfloor.

Murdock, in his paper on " The Toyota Production System", talks in depth about the same which was the pioneered a way to the current lean manufacturing methodologies.

R.K. Bansal, in his book on Strength of Materials, covers about different types of materials and their properties.

CHAPTER 2

OBJECTIVE

At RANE NSK Steering there are many sections where specific operations are performed to manufacture a manual steering column. Some of the sections are CNC, Robotic Welding, UV joint, assembly, painting, phosphating etc. Our project was focused on maximizing the productivity in the robotic welding section since it was facing a lot of downtime and was failing to meet the projected demand requirements.

Our objective was to reduce the overall downtime and increase the productivity by making use of lean manufacturing tools and principles. Apart from that we also designed a collet holder for a forming machine. The default Collet holder used in the forming section was expensive and had heavy maintenance cost. Our objective was to design a collet that was easily serviceable and easy to manufacture compared to the default one.

CHAPTER 3

ROBOT WELDING – MODELS AND WASTAGE

3.1 Models and Demand

Steering columns are manufactured for over 120 models, out of which the following are the significant models. Observation of different child parts of various models that undergo robot welding.

Table 3.1 Models and their demands

Model	Assembly	No. of Child parts	No. of parts RH	No. of parts LH	Output required per shift
VE Regular	Outer tube	8	6	2	111
Daimler	Tilt bracket	5	4	1	111
LPT 1109	Outer tube	8	5	3	135
Q5	Outer tube	5	3	2	151
613T	Outer tube	5	4	1	101
613T	Mounting bracket	6	5	1	101
Daimler	Outer tube	6	3	3	131
FES	Outer tube	5	4	1	100
PHOENIX	Outer tube	5	3	2	100

3.1.1 Models and their respective child parts

Table 3.2 Child parts and their dimensions

Model	**Part**	**Critical dimensions in cm**			
		Length	**Breadth**	**Depth**	**Diameter**
VE regular					
	Outer tube	21			4.5
	Bracket low	15			11
	Lower nascelle bracket	5.2	3	2	
	Spring bracket	3.5	1.5	0.2	
	Bracket	11	5	5	
	Distance bracket	11	7	7	
	Combi switch bracket	12	11	3.5	
	Upper nascelle bracket	3	2	3	
Daimler					
(Outer tube)	Outer tube	29			9
	Upper nascelle bracket	7.5	6	2	
	Lower nascelle bracket	4	3	3	
	Combi switch bracket	12	10.5	0.3	
	Pivot assembly	4.5	4.5	4	
	Bracket	7	4.5	5	
LPT 1109					
	Outer tube	30	9	8.5	3.5
	Lower nascelle bracket	4	2	3	
	Lower sleeve	4.2	2	3	
	Upper sleeve	4.2	2	3.5	
	Upper nascelle bracket	10	1.5	2	
	Distance bracket B	8.5	4.5	4	
	Bracket assembly B	8.5	4.8	3	
	Spring bracket	3	2	0.2	
Q5					
	Outer tube				5
	Distance bracket	9	7.5	4.5	
	Pivot bracket	11	7.5	5	
	Wire harness bracket	11	4	2.5	
	Nascelle bracket assembly	5	1.5	2	

Table 3.2 (contd.)

FES					
	Outer tube	30			4
	Mounting bracket	12	8	4	
	Combi switch bracket	10.5	7.5	1.5	
	Nascelle bracket assembly	12	2	2	
	Sas bracket	9	7.5	0.4	
Phoenix					
	Outer tube	30			4
	Pivot bracket	4.5	4.5	3.5	
	Bracket harness	6	2	2	
	Nascelle bracket	8.5	3	3.5	
	Distance bracket	5	3	3	

Below are two examples of models and their child parts:

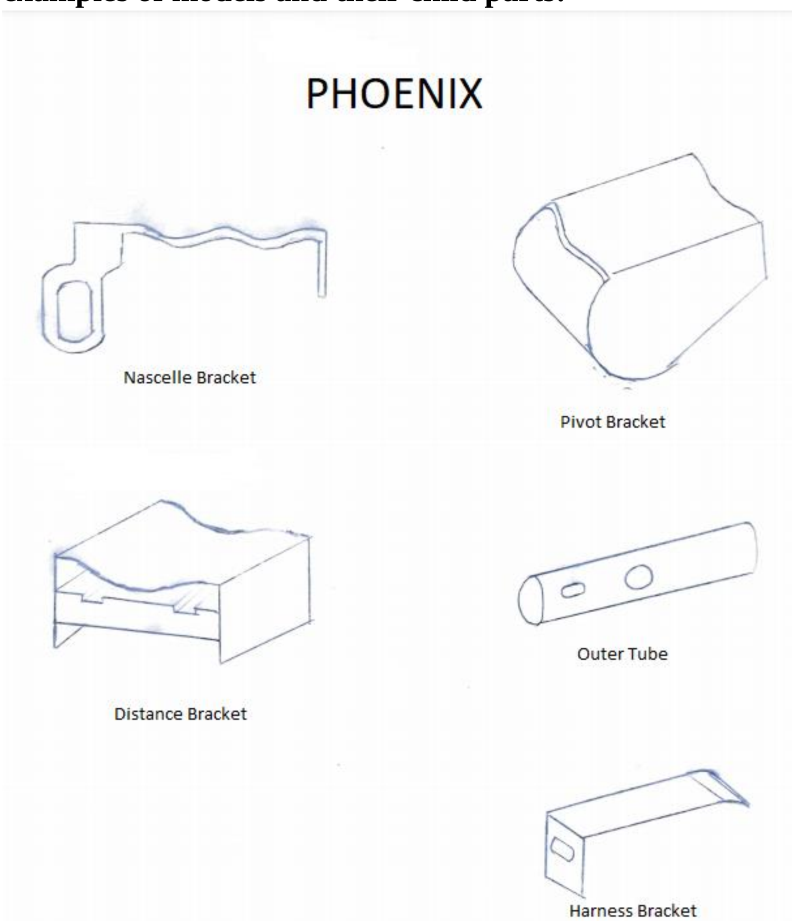

Fig 3.1 Phoenix model – Child parts

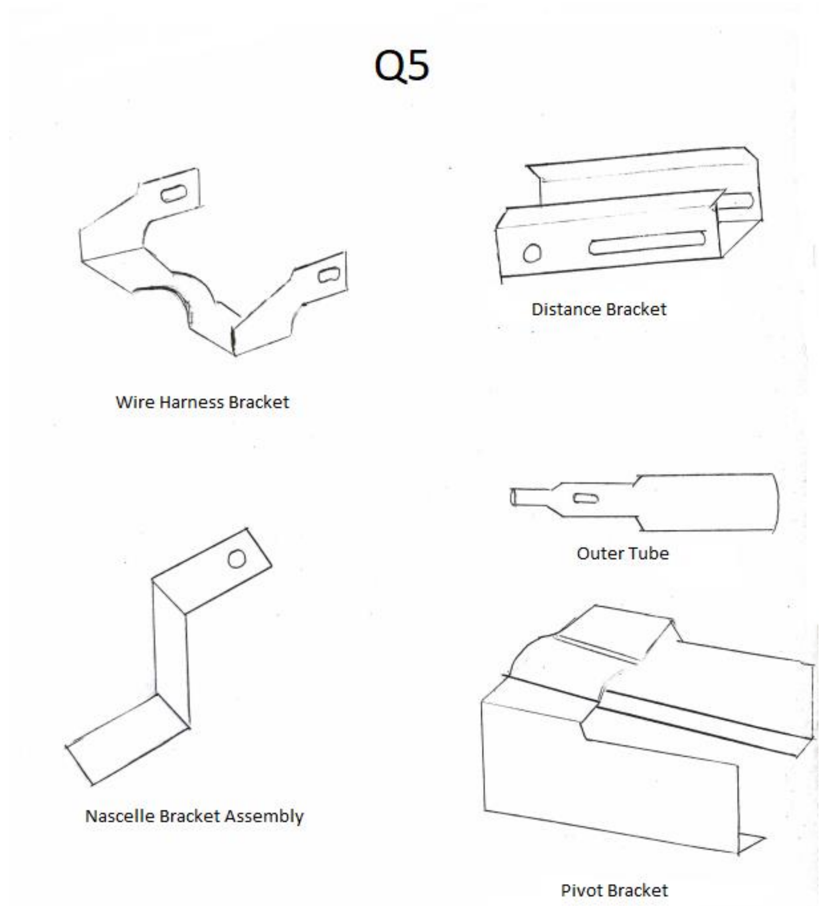

Fig 3.2 Q5 model – Child parts

3.2 OBSERVED WASTAGE

3.2.1 Motion: During loading and unloading of parts into the machine.

- Since the child parts are arranged in an irregular and non-ergonomic manner, the operators cannot load the parts quickly and efficiently.
- When taken to other substations for further processing, the products of robot welding face delay as time is wasted in shifting the outer tube/ tilt bracket assembly from one basket to another.

3.2.2 Transportation: Time wastage during transport of parts from the inventory to the robot welding line.

- The operator must bring the child parts from the inventory to the workspace and do it multiple times to achieve the shift output requirement.
- The outer tube assembly trolley is insufficient to carry the entire shift output. Thus the operators move around the plant a lot to transport the subassembly to the subsequent substations.
- We focus on reducing motion wastage by applying different lean techniques.

CHAPTER 4

METHODOLOGY

4.1 CURRENT TRANSPORTATION METHODOLOGY

Outer Tubes

- The outer tubes are transported via bins of dimensions 60*40*30 cm.
- Each of the bin houses around 60 units.
- Some are transported in different dimension bins based on their size.

Child Parts

- Complex and large parts such as low brackets, distance brackets, etc., are transported via bins separately by stacking.
- Thin and small parts are wrapped up in covers and brought along with the other significant parts.

Outer Tube Subassembly

- Most of the parts, excluding Q5, are taken to phosphating
- Q5 is taken to the bearing assembly centre.

4.2 CHUTES

Gravity chutes were designed for the robot welding operations for the transport of child parts. The child parts would be required to be put into the chutes from one end of the machine, and from the other end, the robot welding operator would collect them and put them into the machine for the welding to take place. They were designed in a manner by which they would be able to hold the entire quantity required for a shift. Thus, replenishments of child parts would not be necessary.

4.2.1 Design considerations

- The chutes are placed beside the robot welding machines in such a way as to minimize the motion of the robot welding operator.
- The chutes were inclined at an angle of 16 degrees to facilitate the free flow of the child parts without any hindrance to their motion.
- The chutes were at the height of 70 cm and 90 cm, respectively, from the ground level, which allows the operator to pick up the child parts with ease and comfort.

LH Chute System comprised of 3 chutes (Fig 4.1):

- Width 30 cm, 10 cm, 20 cm
- Length 150 cm(all)

RH Chute System comprised of 4 chutes (Fig 4.2):

- Width 30 cm, 25 cm, 15 cm, 10 cm
- Length 250 cm(all)

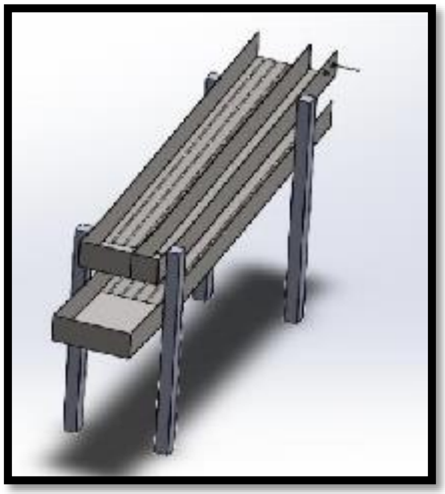

Fig 4.1 LH Chute (CAD)

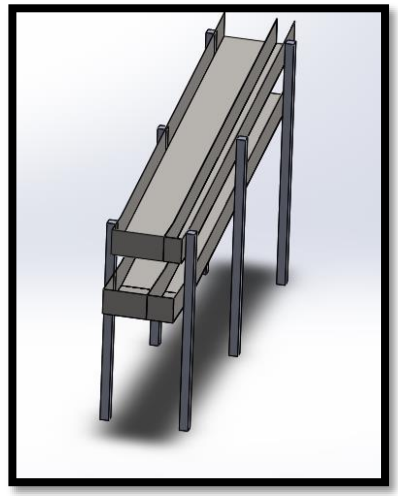

Fig 4.2 RH Chute (CAD)

4.2.2 Chute fabrication

The chutes were fabricated as designed and the material chosen was MS (mild steel) since they are cheap and readily available.

- The thickness of the chute material was fixed as 4 mm.
- The square pipes required for the stand was fixed as 4 cm.
- The material was procured from Guindy, Chennai for the required dimensions mentioned above.
- With the help of fabricators present in the plant, the fabrication was carried out.

Fig 4.3 LH Chute Fig 4.4 RH Chute

4.3 OUTER TUBE ASSEMBLY TROLLEY

4.3.1 Current Methodology

After robot welding is completed, the outer tube assembly is put in a cooling tray. When the assembly is cooled down, the outer tubes are kept in a separate trolley designed for the whole purpose of carrying the tubes. After robot welding, the outer tube assembly is taken for phosphating (all except Q5) and bearing fitting (only Q5). The capacity of these trolleys is not adequate.

During phosphating, the parts should be manhandled and transferred from the trolley into the phosphating baskets.

4.3.2 Proposed Methodology

There is no need for the order of parts to be maintained in the phosphating processes. Instead, the parts are piled upon each other to keep up the efficiency as much as possible.

Thus, we thought of eliminating the current trolley and design a trolley (Fig 4.5) on top of which the basket similar to the one used in phosphating can be placed. Furthermore, a tray is kept beneath the basket seating area to collect the slag from the welding while cooling after welding occurs.

Design considerations:

- The basket is 640 x 640 mm; thus, the same is designed for the trolley with clearances of 5mm on each Side, facilitating ease of movement of the basket.
- The basket would be situated on top, at the height of 680 mm from the ground level, to reach the operators.

The robot welding operator would be required to place the outer tube assembly directly into these baskets. From here, it is taken directly to phosphating, where the baskets are directly taken for phosphating.

This way, the trolley capacity increases tremendously, reducing the requirement of the robot welding operator to travel several times from the robot welding area to the phosphating area. This tremendously decreases transportation wastage.

The motion wastage in the phosphating area is almost eliminated in this method.

.

Fig 4.5 Outer-tube assembly trolley

4.4 KANBAN SYSTEM

Kanban is a visual-based system that helps in the process of loading chutes. It is a box that contains cards with pictures of all child parts of all models. Cards with magnetic pins at the ends that get attached to a Mild steel tab.

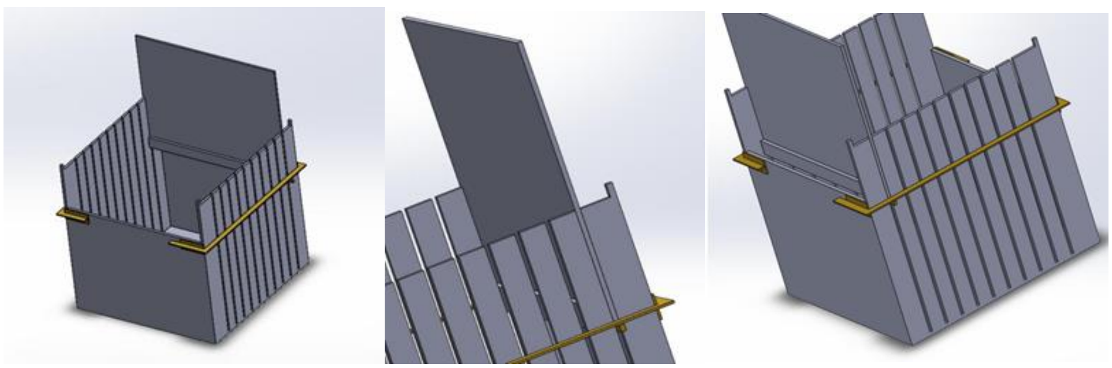

Fig 4.6 Different views of the visual Kanban system (box)

This visual system acts as an aid to facilitate the Kanban operator that would help him load the right child parts in the correct chute. First, a box having various placards (Fig 4.6) displays the part that is being run and the position of the child parts that are to be loaded. The cards are made of foam material as they are of less weight.

The robot welding operator is given the authority to choose which model's child parts must be loaded into the chutes according to the instructions given to him. He transfers this information to the incoming Kanban operator via this Kanban system.

The card is of dimensions: 310 x 300 x 4 mm

The box is of dimensions: 315 x 300 x 250 mm

Advantages of the Kanban system:

- Saves a lot of time.
- Any possible error of loading the wrong parts in the chute is prevented.
- Prevents delays.

4.5 WASTE MANAGEMENT BIN

Not every child part gets the opportunity to be welded to the outer tubes or the tilt brackets. Owing to reasons such as a change in production plan or faults in the child parts itself. These parts require a place to be stored to accommodate the parts of the next shift.

It is not ideal to carry back all the ideal parts back to the inventory as it requires manpower, sorting assistance. Wastages are observed in terms of transportation, movement. A bin is manufactured considering the size of the parts and the number of parts discarded. This gives temporary housing to the parts which can be further used during the production of that particular part.

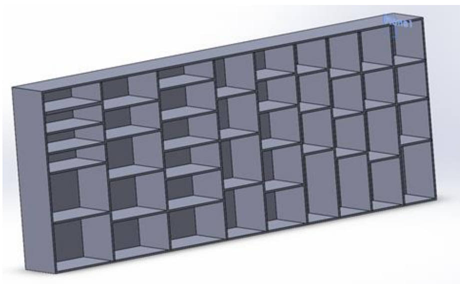

Fig 4.7 Vertical compartment

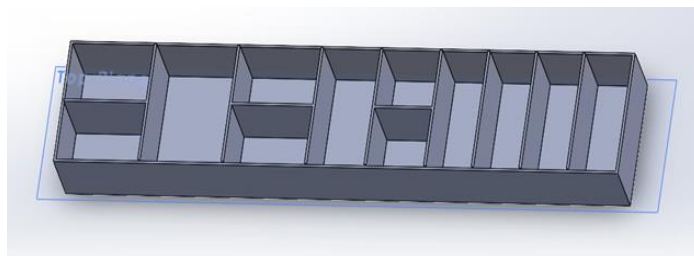

Fig 4.8 Horizontal compartment

Therefore, two compartments were designed, as shown above. Vertical compartment (Fig 4.7) for the child parts, smaller in size and horizontal compartment (Fig 4.8) for the large parts such as outer tubes and tilt brackets. The two compartments are placed perpendicular to each other, and the model's name is specified on a board above their respective columns on top of the vertical compartment.

4.6 COLLET HOLDER

This aspect of the project does not come under Robot welding. Instead, it comes under metal forming. So we were given this opportunity by the company to work on robot welding and the metal forming process.

A colleague is a subtype of chuck that forms a collar around an object to be held and exerts a strong clamping force on the object when tightened. Here, it is used to hold a tube in a forming machine (Fig 4.9). Then, the collet is tightened with the help of the collet holder, as shown below (Fig 4.10).

4.6.1 Current Collet Holder

Initially, RANE NSK Steering Systems used a collet holder, which was cast and expensive. So, to make the component an assembly so that it will be easier to work with and reduce the cost of the component, we were tasked with the design and fabricating one.

The collet holder's dowel pins (6) get inserted into the collet (Fig 4.11), and when torque is given to the handle (black), the dowel pins contract ensuring that the collet also grips and holds the workpiece in place for forming to happen.

Fig 4.9 Forming machine

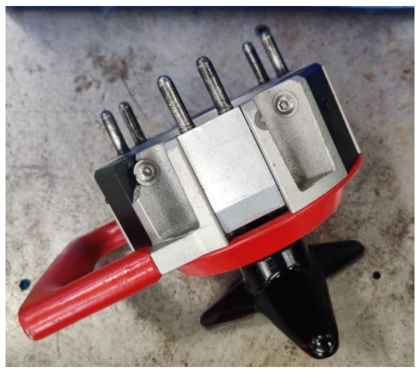

Fig 4.10 Current collet holder

Fig 4.11 Collet

4.6.2 Proposed Collet Holder

The entire collet holder is divided into six different parts, designed according to the required mechanism and machined. A handle is to be attached to the threaded rod for ease of operation. When the threaded rod is given a rotation, the tapered block moves upwards. This motion pushes away the wedge. The dowel pins that are hinged to the wedge and the wedge holder move towards the centre, tightening the collet.

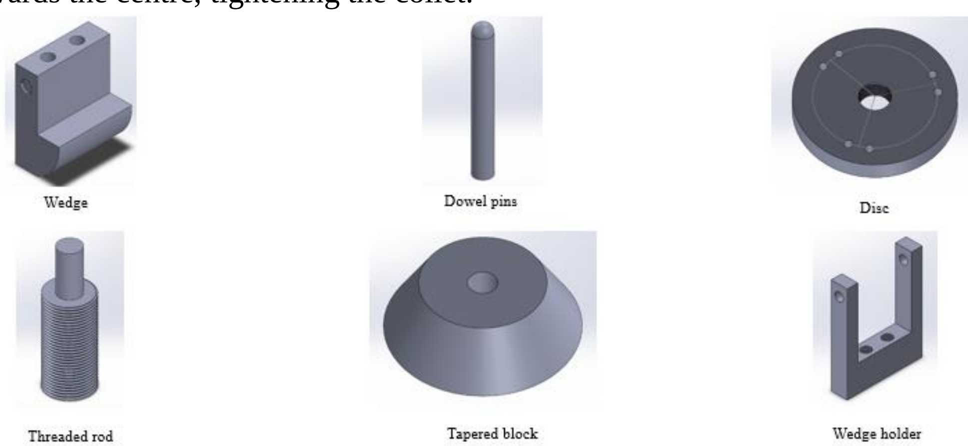

Fig 4.12 Parts of the collet holder assembly (CAD)

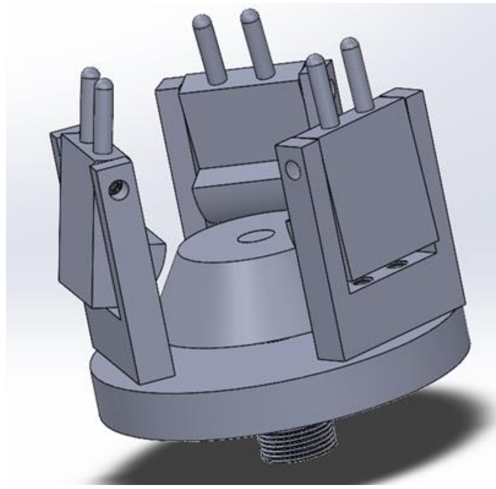

Fig 4.13 Collet Holder Assembly (CAD)

After modelling the parts, the parts were machined. The material chosen was Al alloy for its low-density property. Once the machining was complete, the parts were assembled.

Fig 4.14 Collet holder

CHAPTER 5

TESTS AND RESULTS

5.1 CHUTES TEST

After the fabrication of the LH and RH chutes, its testing was done inside the plant. The test was done to satisfy various conditions, which includes perfect sliding, no sharp edges etc. The testing was done during regular working hours with minimal disturbance from an operator.

Objective: All parts should slide without interruption and settle at the bottom.

Procedure: Child parts are loaded onto the chute like how the Kanban operator would load it.

Test-cases: Single Loading, Cluster Loading, Check for Sharp edges, Ease of Operation

5.1.1 Chutes test – 1

Robot Welding Machine Details:

The R3 robot welding machine was chosen for testing purposes.
The model used was Daimler Outer tube. Model No. RC1447210020.

LH Chute:

Table 5.1 LH Chute Trial 1

Test case	Pass / Fail
Single Loading	Pass
Cluster Loading	Pass
Check for Sharp Edges	Fail
Ease of Operation	Pass

Problems vs Solutions:

Table 5.2 LH Chute Problems v Solution

Problems faced	Solution
Sharp edges on the lower chute	Deburring using file
Component stopping at the bend	Proper grinding of weld beads

RH Chute:

Table 5.3 RH Chute Trial 1

Test case	Pass/fail
Single Loading	Fail
Cluster Loading	Pass
Check for Sharp Edges	Fail
Ease of Operation	Pass

Problems vs Solutions:

Table 5.4 RH Chute Problems v Solution

Problems faced	Solution
Sharp edges	Deburring using file
Parts not sliding properly	More inclination

Changes made after chutes test-1

LH Chute:

1. Deburring was done to remove sharp edges.
2. Weld beads were properly ground for smooth movement of child parts.

RH Chute:

1. Chute inclination was changed from initial 8 degrees to 16 degrees.
2. Deburring was done to remove sharp edges.

5.1.2 Chutes test – 2

LH Chute:

Table 5.5 LH Chute Trial 2

Test case	Pass/fail
Single Loading	Pass
Cluster Loading	Pass
Check for Sharp Edges	Pass
Ease of Operation	Pass

RH Chute:

Table 5.6 RH Chute Trial 2

Test case	Pass/fail
Single Loading	Pass
Cluster Loading	Pass
Check for Sharp Edges	Pass
Ease of Operation	Pass

Chutes Test-2 Review

Since all conditions were met during the second testing phase, the chutes were declared to completed both in design and work-wise.

5.2 OUTER TUBE ASSEMBLY TROLLEY TEST

The outer tube assembly trolly was fabricated inside the plant and was subjected to testing with minimal disturbance to the onsite workers. The primary condition was that the trolly should be easy to use and that it fits inside the phosphating bin carrying frame inside the phosphating area.

Objective: Trolley has to work correctly at both the welding area and phosphating area.

Procedure: An onsite working simulation was done to assess the working efficiency.

Test cases: Ease of Handling, fit with phosphating bin carrying frame.

5.2.1 Outer tube assembly trolley test-1:

Test:

Table 5.7 Outer tube assembly Trial 1

Test case	Pass/fail
Ease of handling	Pass
Fit with phosphating frame	Pass

Problems vs Solutions:

Table 5.8 Outer tube Assembly Problems v Solution

Problems faced	Solution
Noise while moving because of the wastage tray	A strip of Velcro is bolted on the frame upon which the wastage tray is rested.
The handle was welded on the opposite Side	The handle was cut out and welded on the correct side

5.3 COLLET HOLDER TEST

The Collet holder was manufactured, taking into account the suggestions regarding practical manufacturing difficulties from the fabricator. As a result, the collet received after machining was operational, and it was capable of executing the desired mechanism.

Fig 5.1 Collet holder with collet

After testing the collet holder, the feedback that we received was that the travel of dowel pins was relatively high with every rotation of the threaded rod.

Thus, the following changes were made:

- The length of the tapered block was increased.
- The taper angle was decreased.

These changes resulted in

- Reduction of travel of dowel pins for every rotation of the threaded rod.
- More controlled tightening
- Smooth operation compared to the previous prototype while providing the same effort.

After the changes, the collet holder was a success, and it functioned as desired.

5.4 KANBAN SYSTEM AND WASTE MANAGEMENT BIN MANUFACTURING

The Kanban system and Waste management bin weren't machined or manufactured as the company did not have the time to pursue these two aspects of our project. However, the design was accepted by the company, and they promised to pursue them at a later time.

CHAPTER-6

CONCLUSION AND FUTURE SCOPE

The productivity of the robot welding process was improved at RANE NSK Steering Systems by applying and incorporating various principles of lean manufacturing. A chute system was designed and modelled to reduce the motion wastage at the robot welding workspace. A trolley was also fabricated to reduce transportation wastage at the robot welding workspace and motion wastage at the phosphating workspace. A visual Kanban system and a waste management bin were designed but, unfortunately, were not manufactured. We were also involved in the metal forming process and helped the company design and machine a more simple, compact, serviceable, cheap collet holder used in the metal forming machines.

The visual Kanban system and the waste management bin are to be manufactured when the company sees it fit. The chute system and the trolley were machined only for the R3 robot welding machines. The productivity/output pattern is to be studied for this one machine and then replicated for the other two machines in the future if the output pattern yields good results.

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Peer Evaluation Form for Group Work

Name: Vamsi Krishna M

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	Group member: Danny Sneham S	Group member: Sai Kiran Kumar L
Attends group meetings regularly and arrives on time.	3	4
Contributes meaningfully to group discussions.	4	4
Completes group assignments on time.	4	4
Prepares work in a quality manner.	4	4
Demonstrates a cooperative and supportive attitude.	4	3
Contributes significantly to the success of the project.	4	4
TOTALS	23	23

Feedback on team dynamics:

1. How effectively did your group work?

   Each member chose their domain, which they were very much interested in and worked accordingly. This gave us satisfying results.

2. Were the behaviours of any of your team members particularly valuable or detrimental to the team? Explain.

   All of us valuably contributed to the team in whatever way possible, which yielded good results.

3. What did you learn about working in a group from this project that you will carry into your next group experience?

   The importance of teamwork, will and determination and how crucial a role it plays in productivity.

Self-Evaluation Form for Group Work

Name: Vamsi Krishna M

	Seldom	Sometimes	Often
Contributed good ideas			✓
Listened to and respected the ideas of others		✓	
Compromised and cooperated			✓
Took initiative where needed			✓
Came to meetings prepared		✓	
Communicated effectively with teammates			✓
Did my share of the work			✓

My greatest strengths as a team member are:

- Being there for the team whenever required.
- Initiate work when needed.
- Communicate with others effectively

The group work skills I plan to work to improve are:

- Preparation for meetings beforehand.
- Prioritize the ideas of other team members.

Peer Evaluation Form for Group Work

Name: Danny Sneham S

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	Group member: Vamsi Krishna M	Group member: Lingamgunta Sai Kiran Kumar
Attends group meetings regularly and arrives on time.	3	4
Contributes meaningfully to group discussions.	4	4
Completes group assignments on time.	4	4
Prepares work in a quality manner.	4	3
Demonstrates a cooperative and supportive attitude.	4	4
Contributes significantly to the success of the project.	4	4
TOTALS	23	23

Feedback on team dynamics:

1. How effectively did your group work?
   Quite effective

2. Were the behaviors of any of your team members particularly valuable or detrimental to the team? Explain.
   Everyone brought in some innovative ideas.

3. What did you learn about working in a group from this project that you will carry into your next group experience?

   Work planning.

Self-Evaluation Form for Group Work

Name: Danny Sneham S

	Seldom	Sometimes	Often
Contributed good ideas			✓
Listened to and respected the ideas of others		✓	
Compromised and cooperated		✓	
Took initiative where needed			✓
Came to meetings prepared			✓
Communicated effectively with teammates			✓
Did my share of the work			✓

My greatest strengths as a team member are:

- Innovative and work planning

The group work skills I plan to work to improve are:

- Time management.

Peer Evaluation Form for Group Work

Name: Lingamguta Sai Kiran Kumar

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	Group Member: Vamsi Krishna M	Group Member: Danny Sneham S
Attends group meetings regularly and arrives on time.	4	4
Contributes meaningfully to group discussions.	4	4
Completes group assignments on time.	3	4
Prepares work in a quality manner.	4	3
Demonstrates a cooperative and supportive attitude.	4	4
Contributes significantly to the success of the project.	4	4
TOTALS	23	23

Feedback on team dynamics:

1. How effectively did your group work?

   Each member played to their strengths, due to which we could bring some really good ideas.

2. Were the behaviors of any of your team members particularly valuable or detrimental to the team? Explain.

   All the team members played a key role in contributing as much as possible.

3. What did you learn about working in a group from this project that you will carry into your next group experience?

   Tasks can be completed in effective manner by planning the work.

Self-Evaluation Form for Group Work

Name: Lingamgunta Sai Kiran Kumar

	Seldom	Sometimes	Often
Contributed good ideas			✓
Listened to and respected the ideas of others			✓
Compromised and cooperated			✓
Took initiative where needed		✓	
Came to meetings prepared			✓
Communicated effectively with teammates		✓	
Did my share of the work			✓

My greatest strengths as a team member are:

- Time management.
- Decision making.
- Innovative.

The group work skills I plan to work to improve are:

- More communication.
- Leadership