Design & Construction of an Aluminum Can Recycling System

PRESENTED BY:

ALI AL HASHEL 201302480

MOHAMMED ALKHALIFAH 201200269

Outline

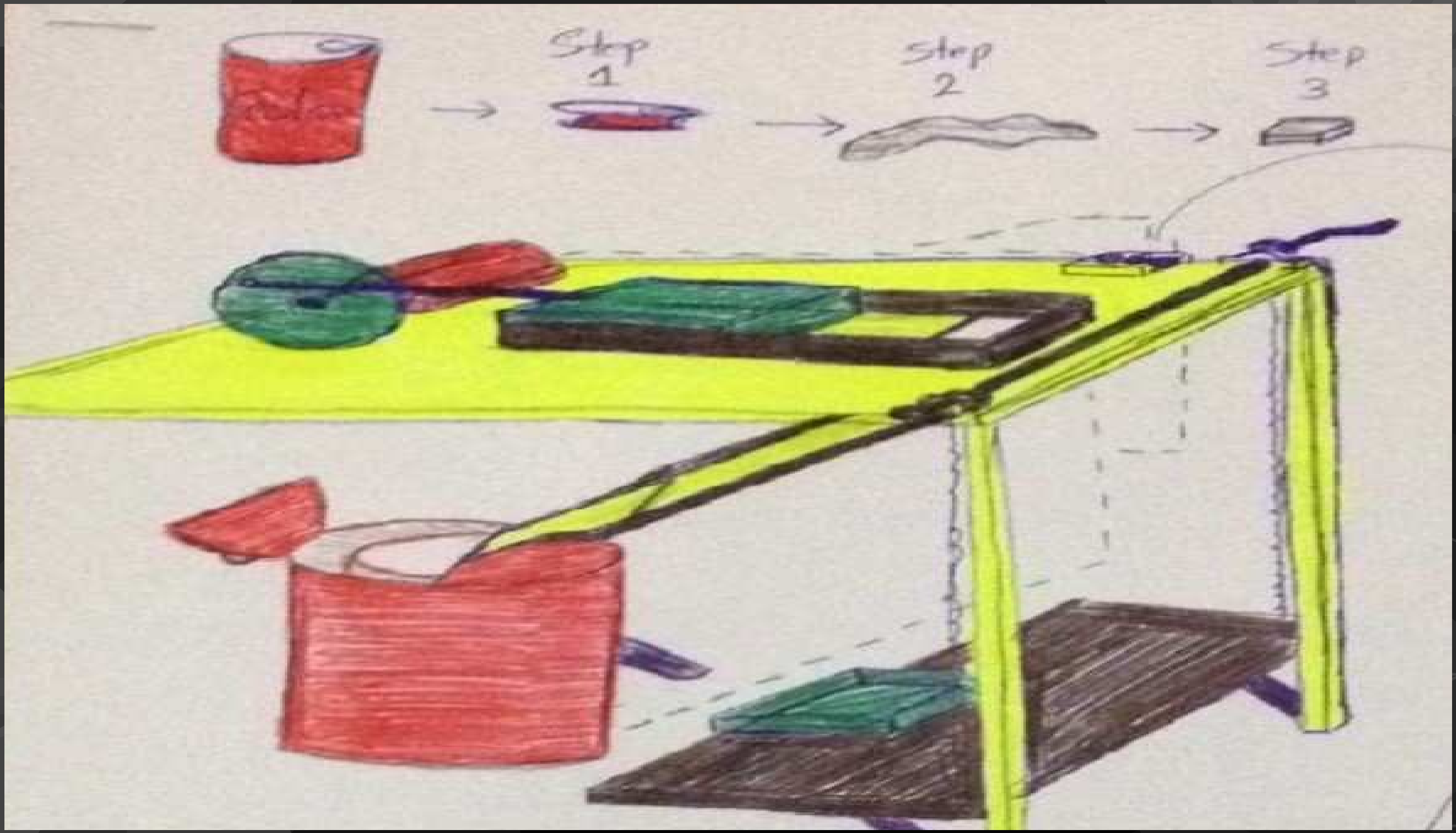
- Background Information
- Objectives
- Literature Review
- Design Methodology
- Work Tasks Performed
- Calculations
- Challenges and Obstacles
- Video

Background Information

- Recycling plays a very important role to save our natural resources, as all we know we have limited natural resources.
- This project is about designing and fabricating a compact recycling aluminum can system.
- This project involves the process of designing three main parts are the automatic can smasher, induction furnace and mold
- The design will help to raise the awareness of waste management in the kingdom.

Background Information

First stage drawing



Background Information

- **Objectives:**
- To construct a simple and compact system which can achieve the following:

1. Constructing a can smasher that will reduce the capacity of aluminum cans to fit the specifications of the induction furnace.

2. The ability to melt an amount of 0.27 kg of aluminum cans.

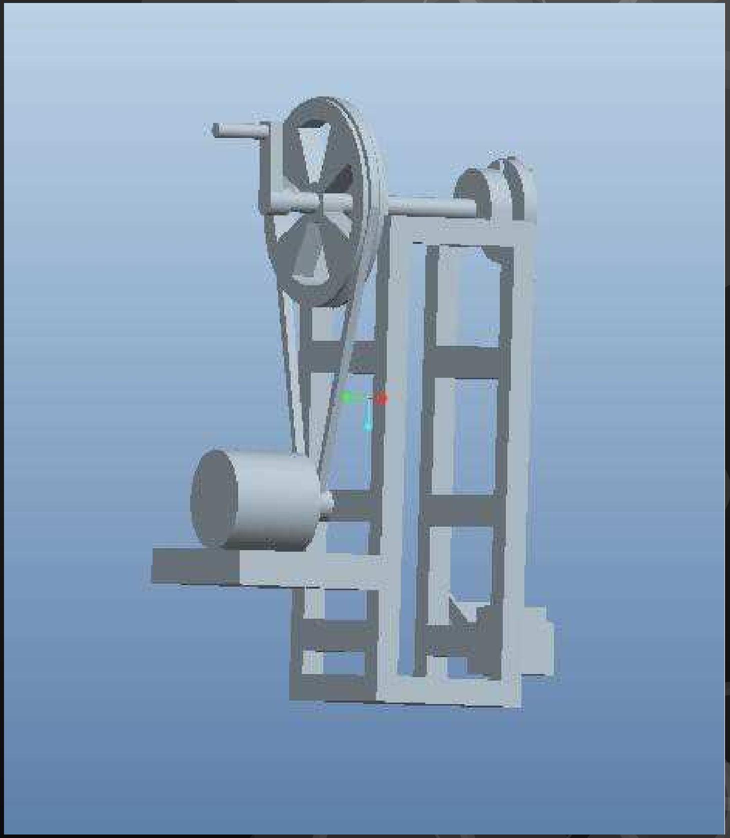
3. To fabricate recycle aluminum machine low cost and time consuming

4. Being able to produce a cylinder of aluminum which can

Literature Review

Research About Can Smasher:

- By Kannan, DESIGN OF MECHANICAL CRUSHING MACHINE



1. The can smasher is designed to operate on a crank and slotted lever mechanism and the power for the electrical operation of the smasher is taken from an electrical motor.

2. Using an optimization technique for the vertical smashing machine

3. An electrical motor of 0.5Hp

Literature review

Research About Can Smasher:

- By Saif, FULLY AUTOMATIC CAN CRUSHER

1. The can smasher machine is a pneumatics can smasher.

2. Using pressurized gas to produce mechanical motion

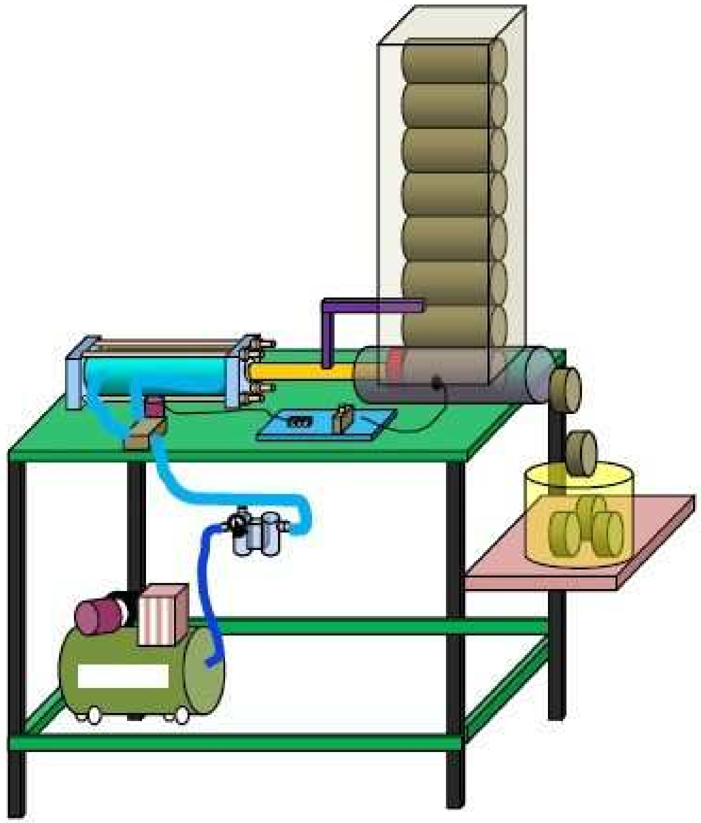


Figure 4 project model

Literature review

Research About Induction Furnace:

- By Bala, Design Analysis of an Electric Induction Furnace for Melting Aluminum Scrap

1. The crucible is formed from a Fireclay refractory material, which the furnace coils is lined with.

2. The inductor coil is a tubular copper coil with a specific number of turns.

3. tilting mechanism: Tilting of the furnace is to effect pouring of the melt as a last operational activity

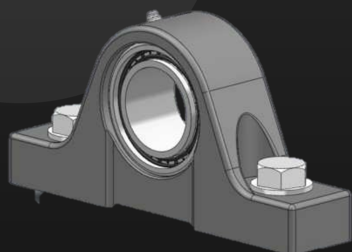
Design Methodology

Can Smasher :

1. Motor : AC motor with 1 hp and 1600 rpm.
2. Reducing Gear Box: to reduce 1600 rpm to an output of 110 rpm.
3. Crank: a diameter of 290 mm And a bearing placed at a distance of 100 mm away from center. This distance will give us the travel distance needed for the smasher to smash the aluminum can.
4. Long\Short Arm: having a diameter of 40 mm/ 10 mm and a length of 260 mm / 180 mm respectively connected by one stand bearing and two ball bearings.
5. Smasher: having dimensions of 200 mm x 75 mm x 140 mm
6. Steel Compartment : absorbing the impact of the smasher on the aluminum cans. Having dimensions of 450 mm x 88 mm x 140 mm

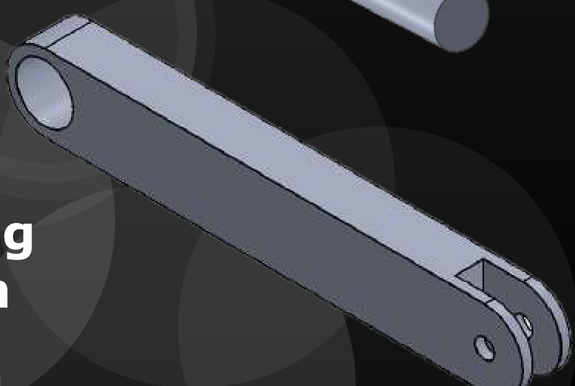
Bearing

Stand bearing

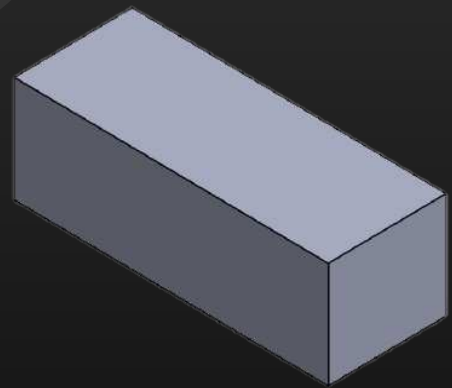


Short arm

Long arm

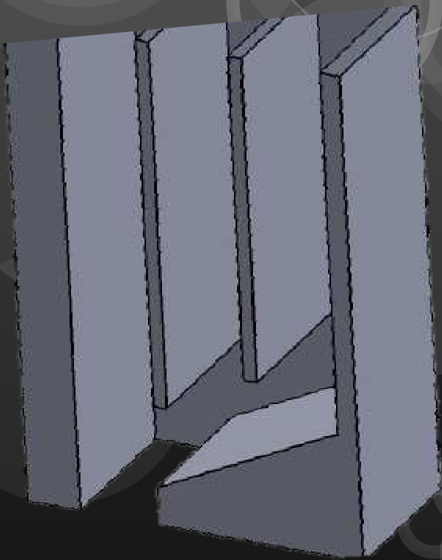


Smasher



Crank

Can holder



AC motor

Design Methodology

Induction Furnace:

1. Heating element coil with 5000 watt and 220 volts generating heat from electricity up to 1000 C.
2. Pottery (Clay) for insulation.
3. Container for Pottery.
4. Furnace built out of fire extinguisher.
5. Single phase wire
6. Plug
7. Wire isolator
8. Small Steel pipe
9. Furnace Stand

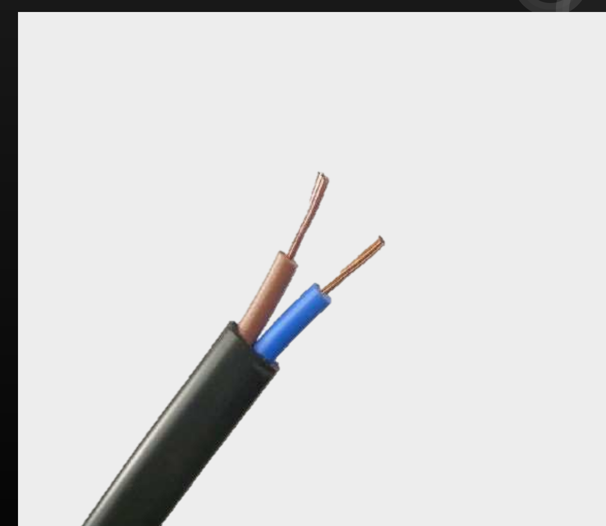
Insulator Ceramics

Electrical Plug

Induction Furnace

Fire extinguisher (inner furnace)

Electric Wire



Design Methodology

Mold

Die

Cylindrical Aluminum

Work Tasks Performed

Fabrication shop :

- Crank, short arm, long arm, compartment and front face of the smasher → all made of Steel.

Carpentry shop:

- Table, can holder, gates, motor base and smasher → all made of Lumber Wood.

Parts that have been purchased :

- Bearings, Motor, Gearbox, Wires, Wire Insulator, Plug, heating element coil, fire extinguisher furnace, Pottery, Pottery container and Thermocouples.

Work Tasks Performed

- ## Description of Can Smasher Assembly :

Based on the calculations regarding the load required to smash the aluminum cans and the specifications of parts :

- The motor was connected to the crank using push fitting.
- The short arm was connected to the crank using ball bearing and the bearing was fitted onto the crank by wielding.
- The long arm was linked with the short arm by another ball bearing in an L-Shaped design.
- The other side of the long arm is connected to a stand bearing which is connected to the smasher.
- The smasher is moving freely in the steel compartment.
- The can holder has been connected on top of the steel

Work Tasks Performed

- **Description of Induction Furnace Assembly :**

- The fire extinguisher furnace is placed inside of a steel container. The clearance (between the furnace and container) has been filled with Pottery in order to create an isolation area.

- Heating coil element placed on the pottery by using steel hocks.

- The wire was connected to the plug.

- The wire isolator has been connected to the heating element coil.

Final Prototype:

Challenges and Obstacles

Senior year project

Calculations

Force of can Smasher:

Due to friction loss we will take 80% of the force in to be out. So

Fout = 615.7 * 0.8

= 492.56 N

Time required for one cycle on can Smasher :

V= d/t

T= R4 / V4

= 0.28 / 1.218

= 0.229 s

Which means the compressing time is 0.1145 s

Calculations

- Heat inside the furnace:

$q1 = (Ts - T\infty in) / (R1 + R2)$
$= (1460 - 800) / (0.367)$
$= 1798.4$ w

-Heating Loss:

$q2 = (Ts - T\infty out) / (R3 + R4+ R5) = (1460 - 25) / (1.194) = 1201.6$ w

- The furnace required 60 min to heat up to 800 C

- The Cans will take an approximate time of 100 s:

Time = $[m * c * (T\infty in - Tout)] / q1$

$= [260 * 0.9 * (1073 - 298)] / 1798.4$

$= 100.8$ s

Video

- https://www.youtube.com/watch?v=o2vO9ANuDVA

Thank You For Your Attention

جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

Fall 2016-2017

Senior Design Project Report

Project Title

DESIGN & CONSTRUCTION OF AN ALUMINUM CAN RECYCLING SYSTEM

Team (8) Members

	Student Name	Student ID
1	Mohammed Alkhalifa	201200269
2	ALI AL HASHEL	201302480
3	TAHER ALARBASH	201100813
4	OMAR BASLEEM	201200606

Project Advisors:

Advisor Name: FARAMARZ DJAVANROODI
Co-Advisor Name: NADER SAWALHI

Abstract

Recycling plays a very important role to save our natural resources; all we know the natural recourses are limited. In recent years, all packaging materials available are made up of recycling materials like paper, Aluminum etc. This project is about designing and fabricating a compact recycling aluminum can system, which produces a cylindrical aluminum cast. Our project involves the process of designing three main parts are the automatic can smasher,

induction furnace and mold. Automatic can smasher is a machine designed to reduce large cans material into a smaller volume, or smaller pieces. The Automatic can smasher is the first process and it consists of motor, gearbox, crank, long arm, short arm, smasher, compartment, can holder and two bearings. All these parts designed to crush the cans and reduce it capacity to fit the specification of the induction furnace. The induction furnace is the second part of the project, which is an oven, designed to melt the smashed cans under a certain temperature of 800 C. finally, the third part, which is the mold, will collect the melting aluminum into a cylindrical shaped die. This project required using welding, drilling, calculations and drawing using SolidWork. The main goal for our project mainly about generating a new concept of a compact recycling aluminum can system that would make it portable and easy to use. The result of this project is a successful design, which is capable of smashing seventeen cans and melting the aluminum in short time of an approximation of 1 hour all these processes led to the product that we aim for and that is 0.27 kg of a cylindrical aluminum cast.

Table of *Contents*

Chapter 1: introduction

1.1 Project Definition

1.2 Project Objectives

1.3 Project Specifications

1.4 Product Architecture and Components

1.4.1 First stage drawing

1.5 Applications

1. Introduction

1.1 Project Definition:

Our design is a Compact Recycling Aluminum Can System, where it consists from three parts which are an automatic can smasher to crush the cans into small pieces, induction furnace used to melt the cans into pure aluminum, and a lift mechanism (mold) where we will save the pure aluminum bars.

1.2 Project Objectives:

This project went through couple of modifications to meet the objectives that we looking for to design and construct aluminum can recycle system and those objectives are:

1. To develop a simple compact recycling aluminum can system, where it can be placed everywhere, in the park, houses.

2. The ability to melt an amount of 0.27 kg of aluminum cans.

3. Being able to produce a cylindrical aluminum cast, which can be used for other applications.

4. To increase the awareness of waste management by recycling aluminum cans.

5. To fabricate recycle aluminum machine low cost and time consuming.

6. To minimize air pollution caused by burring wastes.

1.3 Project Specifications:

We have three main parts in our designing, and in each part there are particular specifications will be used:

- **a.** The Can Smasher consists of (Motor, bearings, small bar, long arm, circular steal, rectangular steal connected to the arm)

- **b.** The Induction Furnace consists of (Wire 220V, resisting heat wire, mid-size container, small-size container, Pottery)

- **c.** The Lifting Mechanism mold has (bearings, shaft, handle)

1.4 Product Architecture and Components:

Figure 1.1 Design of the subsystems

1.4.1 First stage drawing

The drawing in the figure below figure **(1.2)** showed the first attempt drawing in the brainstorming stage. This drawing showed the main parts and the mechanisms of the system, can smasher, induction furnace and the mold. Therefore, the automatic can smasher placed over the table where the can will crushed then it will go to the induction furnace in order to melt and transferred into cylindrical shape aluminum cast. After melting, the pure aluminum will move directly through the semi-circular steel into the lifting mechanism (Mold) to get the aluminum bar.

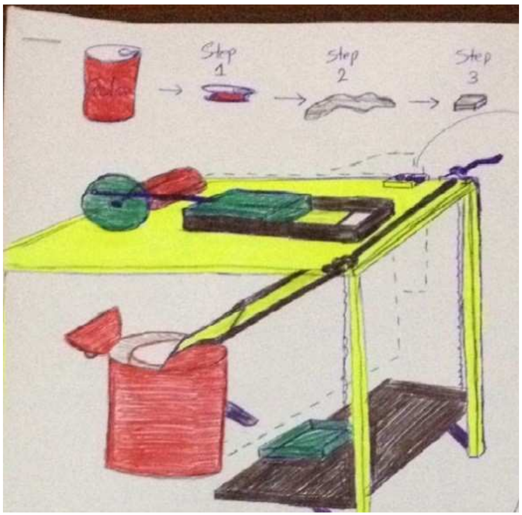


Figure 1.2 First stage drawing of the recycling system

1.5 Applications:

Individual use: This recycling aluminum machine can be placed anywhere in park, restaurant, home, etc.

Industrial use: The recycling machine also can be used in industries to get the pure aluminum and use it to make the other aluminum materials.

Chapter 2: Literature Review

2.1 Project background

2.2 Previous Work

2.2.1 Research: Design of Mechanical Crushing Machine

2.2.2 Research: Fully Automatic Can Crusher

2.2.3 Research: Can Crusher Device

2.2.4 Research: Recovery of Aluminum in the Induction Furnace

2.2.5 Research: Design Analysis of an Electric Induction Furnace for Melting Aluminum Scrap

2.2.6 Research: Design and Construction of the Coreless Induction Furnace

2.2.7 Research: Kanthal supplier of electric heating elements

2.2.8 Research: An Automatic For Can/Plastic Bottle Crusher Machine

2.2.9 Research: Design and Fabrication of Can Crusher, International Journal of Innovative Research in Science

2.2.10 Research: Electroheat Induction Website

2.3 Comparative Study

2. Literature Review

2.1 Project background:

Recycling plays a very important role to save our natural resources, as all we know we have limited natural resources. In fact, aluminum recycling is one of the best and easiest things we can do to save the environment. This project is about designing and fabricating a compact recycling aluminum can system to get a pure aluminum 100% renewable resource. This project involves the process of designing three main parts are the automatic can smasher which is a machine designed to reduce large cans material into a smaller volume, or smaller pieces. The Automatic can smasher is the first process and it consists of a motor and some steel parts to crush the cans. After crushing process the cans will go to the second part which is the induction furnace. The induction furnace is used to melt the cans by high temperature inside the furnace to get the melting aluminum. After the second process of furnace finish, the melting aluminum will go through a semi-circular steel to the third part which is the lifting mechanism (mold) where the melting aluminum will solidify to a pure aluminum bar. Methods and process involve in this project, for instance, joining using bending, welding, drilling, and cutting process. This project mainly about generating a new concept of designing and construction of an aluminum can recycling system that would make easier to bring anywhere and easier to recycling cans.

2.2 Previous Work:

Designing and construction of an aluminum can recycling system requires an amount of good understanding on the knowledge of the science. Executing a research is very important to obtain all the information available and related to the topic. Therefore, we did some researches about the can smasher and its specifications, also we did some researches about the induction furnace.

2.2.1 Research: Design of Mechanical Crushing Machine

Kannan and Prasad have presented their research **[1]** the working principle of the can smasher, where the can smasher is designed to operate on a crank and slotted lever mechanism and the power for the electrical operation of the smasher is taken from an electrical motor. In their research, they use an optimization technique for the vertical smashing machine as shown in figure **(2.1)** Side view of the Can Smasher and in figure (**2.2)** a front assembled view of the can smasher). According to the (research) “The machine has been constructed in such a way that it can be operated by both electrical and mechanical means. The drive unit consists of an electrical motor of 0.5 Hp. The motor is fitted with a smaller pulley of 0.05m diameter. The power from the motor in the form of rotation is converted to reciprocating motion by means of the crank and slotted lever mechanism. Thus the cans are crushed efficiently.

Table **(2.1)** shows design parameters of the can smasher parts which are the diameter of the two pulleys, length of connecting rod and mass of ram. Also it shows the design calculations of the can smasher which are the motor power, speed of the motor and force exerted to smash the cans.

Table **(2.1)** Design Calculation of the Can Smasher

Design Parameters	Design Calculation
Crank diameter = 0.2 m	Motor power = ¾ HP = 0.566025 kW
Length of connecting rod = 0.2 m	Speed of the Motor = 1440 rpm
Mass of ram = 2 Kg	Force exerted (F) = m*g = 19.62 N
Diameter of Pulley 1 = 0.063 m (d)	Speed = 1440 rpm (N1)
Diameter of Pulley 2 = 0.464 m (D)	Speed = ? rpm (N2) D/d = N1/N2 N2 = 225 rpm
Centre distance of pulley = 2 (D + d) C = 0.94 m	P = (2πNT)/60 T = 0.94 Nm

2.2.2 Research: Fully Automatic Can Crusher

Qais and Saif have presented their research **[2]** the working principles of the can smasher. The can smasher machine in this research is a pneumatics can smasher. Pneumatics is a section of technology that deals with the study and application of pressurized gas to produce mechanical motion as shown in figure **(2.3)**. According to the (research), "The engine is attached at compressor site. The compressor is made ON till the pressure in storage tank reaches 5 bar pressure. Here, the minimum operating pressure is 3 bar to crush the can. The flexible hose coupled with the compressor tank and the air storage tank installed on the air engine." This system will drive a piston forward or reverse backward. When the piston is moved forward a plate which acts as a bore of the piston moves along the piston smashes the can.

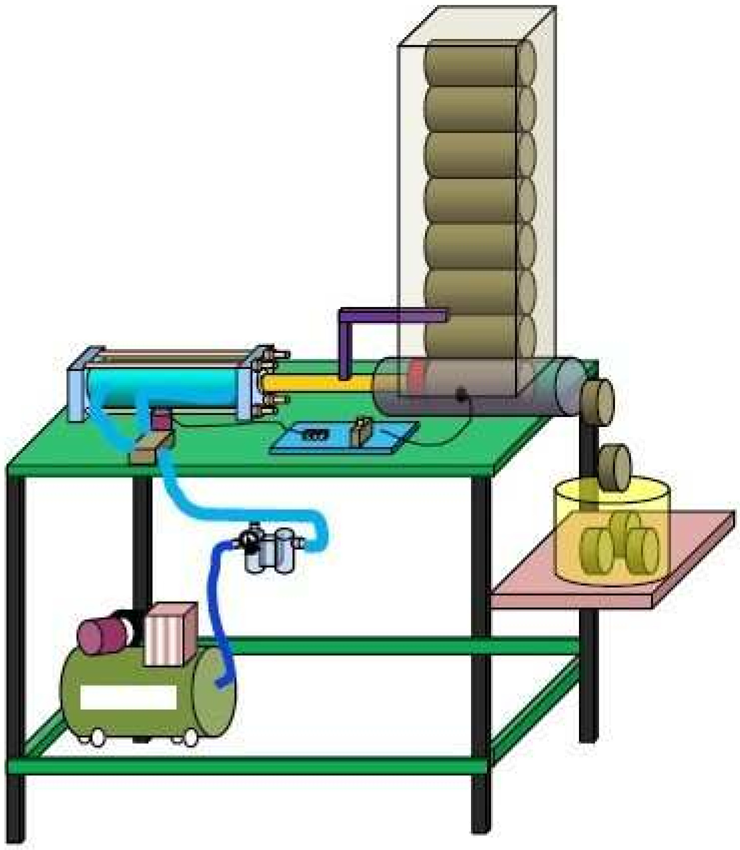


Figure 2.3 Model of the Pneumatic Can Smasher

This material is a separate pneumatic aluminum cylinder is used to push the can in a smashing zone figure **(2.4).** This cylinder is having a specification of 50 diameters, 100mm in length and permissible load (ft.) 180N/mm2. They selected 50mm diameter cylinder in order to get proper force intended on the can and it gets smashed, here is the calculation carried out in table **(2.2)**.

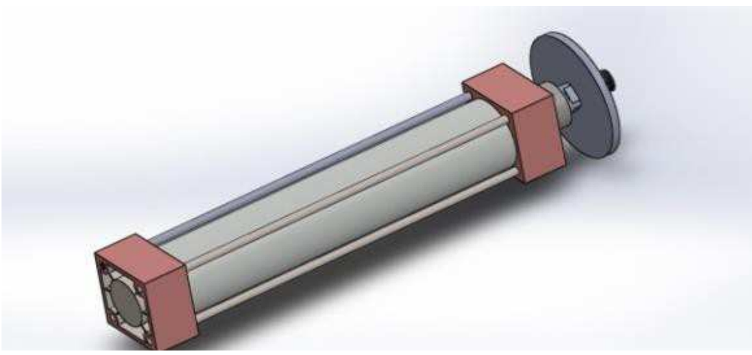


Figure 2.4 Separate Pneumatic Aluminum Cylinder

Table **(2.2)** Calculations for design parameters of the can smasher

The outer diameter of the cylinder,	Therefore, Force generated by cylinder
Outer diameter Do = Di + 2 (t)	F = P x A
= 50 + 2 (3)	A = 3.14 / 4 x D2
= 50 + 6	A = 3.14 / 4 x 502
= 56 mm	A = 1964 mm2
	F = 2.45 x 1964 = 4808 N = 490 kg

2.2.3 Research: Can Crusher Device

Farag and Majed have presented their research **[3]**, the working of a slider-crank in a can smasher system figure **(2.5)**. The can smasher employs a slider-crank as it's a sliding mechanism. This allows the smasher to exert a larger amount of mechanical leverage to the can. The motor drivers the crank-arm which then slides the piston forward via connecting linkages. After the piston has smashed the can, the discharge door expels the smashed can into a receptacle below.

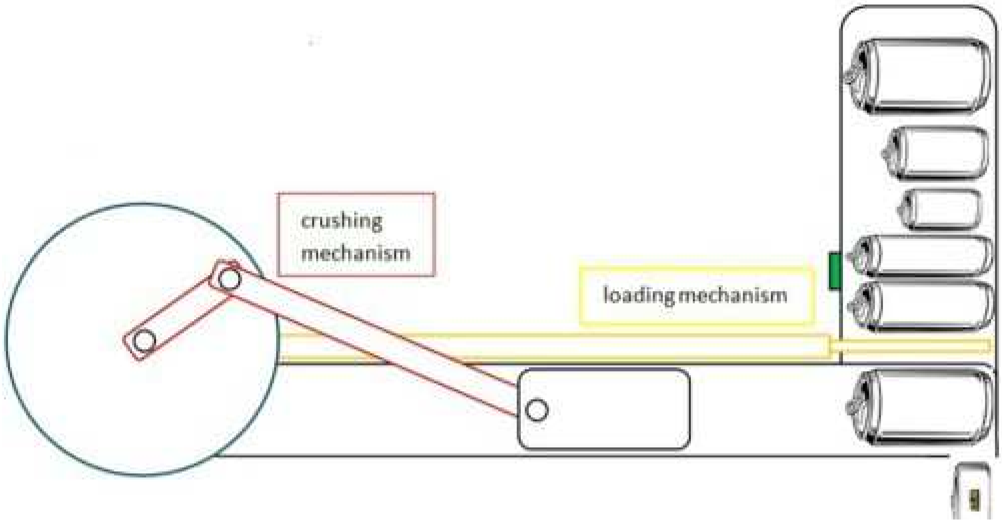


Figure 2.5 Crushing Mechanism & The loading mechanism

The 3D Model shown in figure **(2.6)** shows the parts of the can crusher device for this research.

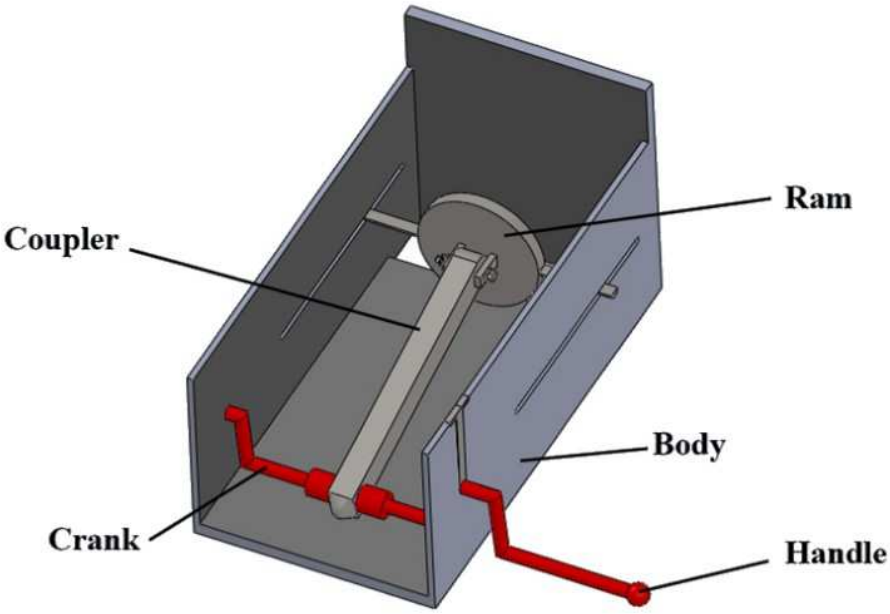


Figure 2.6 Model of the Can Crusher Device

2.2.4 Research: Recovery of Aluminum in The Induction Furnace

A study by Antão Valentim **[4]** was used an electric induction furnace as shown in figure **(2.7)**, with a power of 100 kW, working in a frequency de 3.000Hz and a graphite can with maximum capacity of about 55 kg of melted aluminum. The working temperature ranged from 750°C to 780°C. Kurzan (2006) "studied the use of electric induction furnace, in the casting of aluminum cans, achieving an efficiency equal to 90.8%, efficiency higher than the obtained with another technologies, like the rotary plasma furnace to similar materials." Although that the electric induction furnaces aren't often used in aluminum recycling, the results obtained in this study shows that researches of the use of this kind of furnace in the aluminum recycling must be interesting.

Figure 2.7 Loading the Furnace

This research presented a method to calculate the load in each fusion, to obtain the SAE 305 alloy, was used a spreadsheet elaborate in the software Microsoft Excel. Table **(2.3)** below brings the amount of material used in six rounds of 79 realized, as the efficiency of each one.

Table **(2.3)** Charts of loads in a few rounds

Material	**01**	**02**	**03**	**04**	**05**	**06**
Aluminum foil (kg)	46,08	45,68	45,80	45,36	45,26	45,06
Silicon (kg)	6,40	6,40	6,40	6,40	6,40	6,40
Total Load(kg)	52,48	52,08	52,20	51,76	51,66	51,46
Weight of the part (kg)	45,34	48,64	50,40	49,50	44,64	47,86
Efficiency	**86,39%**	**93,39%**	**96,55%**	**95,63%**	**86,41%**	**93,00%**

2.2.5 Research: Design Analysis of an Electric Induction Furnace for Melting Aluminum Scrap

K. C. Bala has presented a research **[5]** about the design analysis of an electric induction furnace for melting aluminum scrap figure **(2.8)**. The induction furnace consists basically of a crucible, inductor coil, and shell, cooling system and tilting mechanism. The crucible is formed from a refractory material, which the furnace coils is lined with. This crucible holds the charge material and subsequently the melt. The inductor coil is a tubular copper coil with a specific number of turns. An alternating current (A.C) passes through it and magnetic flux is generated within the conductor. The shell is the outer part of the furnace. This houses the crucible and the inductor coils and has a higher thermal capacity. The cooling system is a through - one way - flow system with the tubular copper coils connected to a water source through flexible rubber hoses. The inlet is from the top while the outlet is at the bottom. Tilting of the furnace is to effect pouring of the melt as a last operational activity before casting. Since this furnace is of small capacity, a manually operated tilting mechanism is adopted.

Figure 2.8 Electric Induction Furnace for melting aluminum

Design analysis for the electric induction furnace for melting aluminum. This calculations shows the heat energy and electrical parameters. The required theoretical heat energy, consumed during the first period of melt is given by:

$$Q_{th} = Q_m + Q_{sh} + Q_s + Q_{en} - Q_{ex}$$ ………………………………. Equation **(2.1)**

- Q_m = amount of heat energy to melt 10kg of charge material, J;
- Q_{sh} = amount of heat energy to superheat the melt to temperature of superheat, J;
- Q_s = heat required to melt slag forming materials, J;
- Q_{en} = energy required for endothermic process, J;

- Qex = amount of heat energy liberated to the surroundings as a result of exothermic reactions, J.

$$Q_m = MC(\theta_1 - \theta_0) + L_{pt}$$ ………………………………………. Equation **(2.2)**

- M = mass of charge, kg;
- C = specific heat capacity of charge material, (for aluminum, C = 1100J/kg K);
- Lpt = amount of heat to accomplish phase transformation,
- (for pure aluminum Lpt = 0, no phase transformation);
- θ1 = melting temperature of charge, (for aluminum θ1 = 660°C);
- θ0 = ambient temperature, 25°C;

$$Q_{sh} = MC_m\theta_{sh}$$ ……………………………………………………. Equation **(2.3)**

- Cm = average heat capacity of molten Aluminum, (= 992J/kg K);
- θsh = amount of superheat temperature, taken as 40°C.

$$Q_s = K_sG_s$$ ……………………………………………….……... Equation **(2.4)**

- Ks = quantity of slag formed in (kg),taken as 8% of furnace capacity;
- Gs = heat energy for slag = 18kJ/kg.

Heat loss through conduction:

$$Q_L = \frac{\pi H_m(\theta_2 - \theta)}{\frac{1}{2}[\frac{1}{\lambda_{zi}}\ln\frac{d_2}{D_c} + \frac{1}{\lambda_{as}}\ln\frac{D_{in}}{d_2} + \frac{1}{\lambda_{cu}}\ln\frac{d_3}{D_{in}}]}$$ ……..…….. Equation **(2.5)**

- λ = thermal conductivity, with subscripts for zircon, asbestos, and copper respectively;
- λ_{zi} = 2.093w/m K; λ_{as} = 0.117w/ m K; and λ_{cu} = 380w/m K;
- d2 = outer diameter of crucible = Dc +2Br, m;
- d3 = inductor diameter surrounding crucible + 2 thickness of coil, m;
- $\theta_2 = \theta_1 + 40°C$ – superheat temperature, °C;

Discharge rate in m3/sec is obtained from the relation:

$$Q = VA_w$$ ………………………………………………………….. Equation **(2.6)**

- Pc: Coil loss due to resistance
- V = velocity of heat carrying fluid, m/sec;
- Aw = cross sectional area of flow, m2

2.2.6 Research: Design and Construction of the Coreless Induction Furnace

Dr. Al Shaikhli, Dr. Alkhairo have a research **[6]** about design and construction of the coreless induction furnace figure **(2.9)**. A coreless induction furnace is a simple unit consisting of a helically wound coil surrounding a refractory crucible containing the molten charge and connected to an alternating excitation system.

Design Steps of the Coreless Induction Furnace:

1. Design of crucible which includes the determination of height to diameter ratio (Lw/Dw), coil diameter to charge diameter Dc /Dw, and the crucible wall thickness.
2. Frequency selection: The physical specification of the workpiece and its dimension determine the frequency of the power supplies for heat process
3. Determination of the required power: the power supply is selected based on power and frequency required for melting process.

4. Induction coil design: which it consists of number of copper conductor with proper cross-section

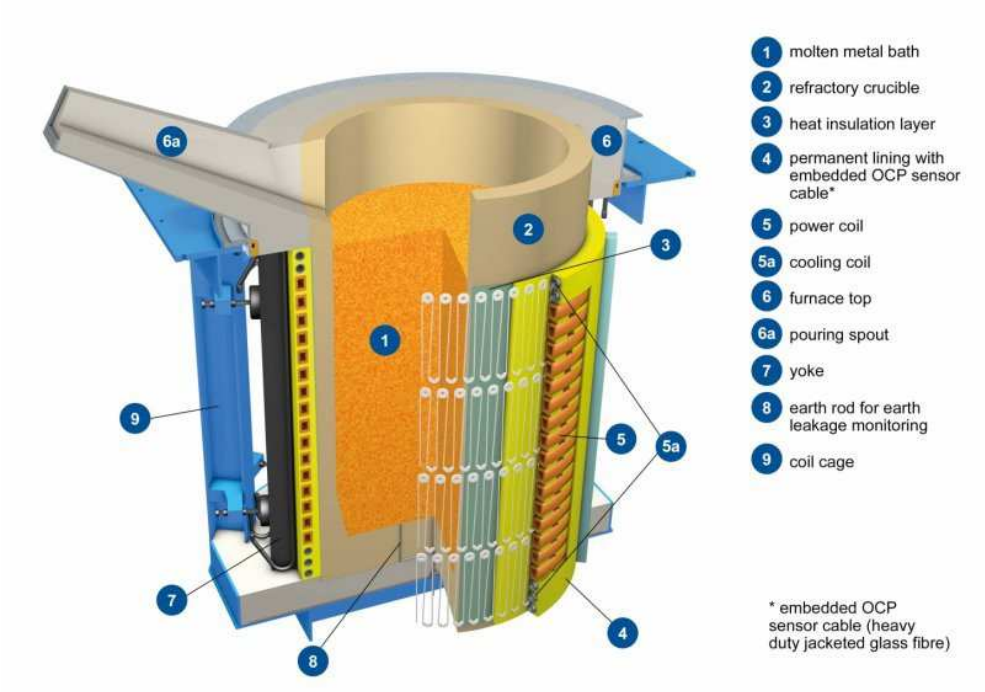


Figure 2.9 Coreless induction furnace

2.2.7 Research: Kanthal supplier of electric heating elements

According to the Kanthal supplier of electric heating elements **[7]**, the induction furnaces use the induction heat generated by an induction coil around a conductive medium which runs on a higher frequency (usually some kilohertz). This document shows a very small model (induction furnace) powered by a 40 Volts welder with 1.5m of 0.7mm Kanthal wire and built it from 2 bricks of alumina bricks glued figure **(2.10)**. The coils is made by winding around a knitting pin in the lathe which allows a very tight wound coil. For controlling the current through the Kanthal wire (to prevent burnout) disco light dimmer is used which is also suitable for inductive loads such as a welding transformer. The device in figure **(2.11)** allows loads up to 6 amperes. So the Kanthal coil in the furnace connected to the secondary of the welder (40 volts). This ‘short circuit’ will not damage or overheat the welder as this is only 7-10 amps which is much below the 110 amps rating. But when the current becomes too high, the Kanthal wire may burn out, when it gets above 1400C. So hence the dimmer for the welder. Starting from a cold furnace can be done with full power but when the furnace is hot, one has to pay attention that the Kanthal does not get too hot: when becoming light-yellow, then it has to be dimmed. A test with melting copper (1083 C) by putting a cold crucible with about 50g of red copper into a cold furnace. The melt took 45 minutes but with a very low energy consumption.

Figure 2.10 The Small Induction Firnace Type

Figure 2.11 Loads Up Controling Device

2.2.8 Research: An Automatic Approach for Can/Plastic Bottle Crusher Machine

Kshirsagar and Choudhary have a research **[8]** about experimentation and analysis of an automatic can/plastic bottle crusher machine. This research explains a fully automatic can smasher figure **(2.12)** by using electronics equipment like sensors, microcontroller, IC's etc. After all process has been done, this crusher may help us to understand the fabrication and designing process as well as electronics equipment that involved in this project. The Electric Motor and a microcontroller make up the backbone for this project. Overall, this project involves processes like design, fabrication and assembling procedures. This project is mainly about generating a new concept of can/bottle crusher that would make easier to bring anywhere and easier to crush the can or bottle.

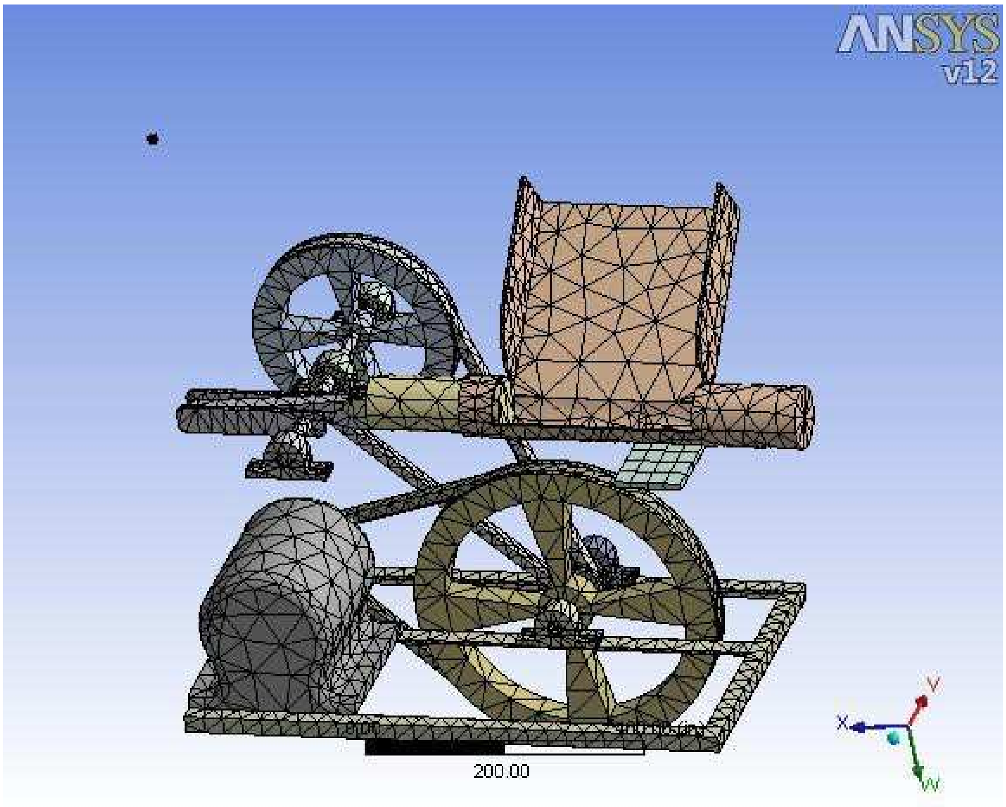


Figure 2.12 Automatic can/plastic Bottle Crusher Machine

This machine works on the principle of Single Slider Crank Mechanism where, it converts rotary motion into a reciprocating machine to crush the Cans. As shown in Figure **(2.13**) link 1 is fixed and link 2 which is a crank is rotating about fixed link 1 and converts this rotary motion into the reciprocating motion of slider (corresponds to the link 4) by means of connecting rod which corresponds to the link 3. This is the inversion of single slider crank which is obtained by fixing link 1.

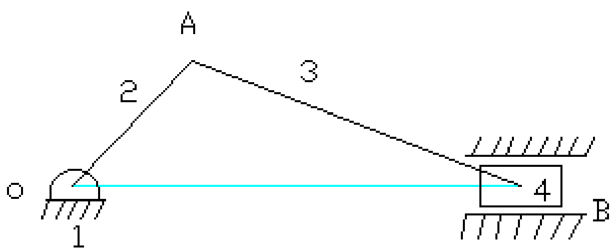


Figure 2.13 Single Slider Crank Mechanism

The working principle of the system:

As the motor rotates the motor is having a smaller pulley connected to its shaft, the smaller pulley through the v-belt is connected to secondary pulley (Larger pulley) on another shaft which rotates it. Another i.e. third pulley (Smaller pulley) is mounted on the same shaft next to the secondary pulley, and is connected to the fourth pulley (Larger pulley) which is on the main shaft by means of v-belt. This arrangement has been done solely for the purpose of reduction of speed. After machine gets started the power of electric motor is transmitted to the slider mechanism through belt and pulley arrangement and rotary motion of crank is converted into the reciprocating motion of slider thus Cans/Plastic bottles will get crushed. There is a separating bin which is placed beneath a crushing tray to collect the crushed cans/ Plastic bottles also there is a sensor of metal detector type to store the plastic bottles and cans separately.

Results and Discussion:

The following Table **(2.4)** shows the comparison between uncrushed and crushed cans as well as plastic bottles.

Dimensions of Plastic bottle-500 ml

Diameter, D = 58 mm

Length, L = 206 m

Table **(2.4)** Reduction in Volume of Cans after Crushing

Sr. No.	Time required	Original Length (mm)	Crushed Length (mm)	Original Volume (mm^3)	Crushed Volume (mm^3)	Reduction in Volume (%)
1.	1.6	206	58	544.26×10^3	153.24×10^3	71.84
2.	1.65	206	62	544.26×10^3	163.80×10^3	70.00
3.	1.6	206	63	544.26×10^3	166.45×10^3	69.5
4.	1.65	206	63	544.26×10^3	166.45×10^3	69.5
5.	1.7	206	60	544.26×10^3	158.52×10^3	70.87
6.	1.6	206	62	544.26×10^3	163.80×10^3	70.00
7.	1.65	206	60	544.26×10^3	158.52×10^3	70.87
8.	1.65	206	63	544.26×10^3	166.45×10^3	69.5

2.2.9 Research: Design and Fabrication of Can Crusher, International Journal of Innovative Research in Science.

Selvadurai and Veeramuthu have a research **[9]** about design and fabrication of can crusher. This research also explain an electric can smasher as shown in figure **(2.14)**, where the system has a crank attached at right angles to a rotating shaft by which reciprocating motion to or received from the shaft. It is used to convert circular motion into reciprocating motion.

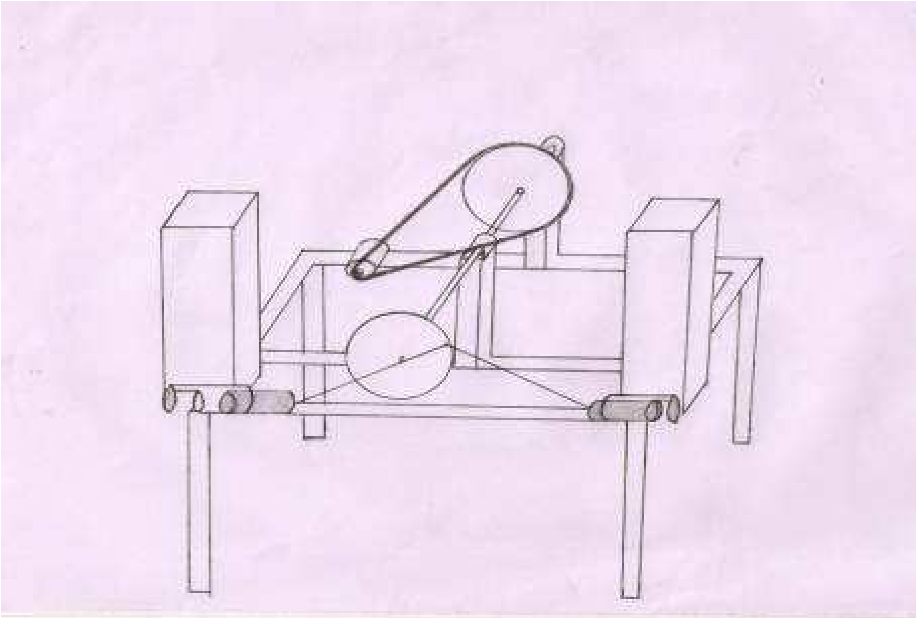


Figure 2.14 Electric Can Smasher

Mechanical Components

- Shaft.
- Pulley (2Nos).
- Belt.
- Single Slider Crank Mechanism.
- Separating Bin..
- Crushing Tray.
- Angles (For Frame)
- Piston (2Nos)
- Hollow Pipe
- Frame

The hollow pipe in figure **(2.15)** is made up of mild steel and it is used when cans are put in a rectangular box after which it holds the cans and main important factor is to grip it and get it crushed one by one. To design this component mild steel is taken on which design is marked then it is cut by hack saw machine according to the marked then this pipe structure is faced from both the ends. Gas cutting is done on the rectangular pipe using gas cutter. Then welding is done on the rectangular face.

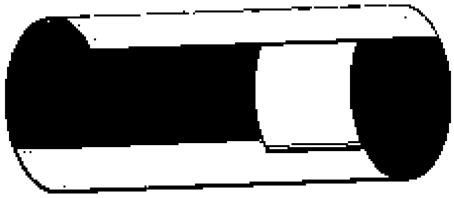


Figure 2.5 HOLLOW PIPE

The frame in figure **(2.16)** is supported due to possibility of vibration. Therefore, for foundation purpose pad plates are provided in between two legs a support of angle is given to avoid splitting of edge.

Figure 2.16 Frame

2.2.10 Research: Electroheat Induction website

According to Electroheat Induction website **[10]**, they provide an article about an induction melting furnace as shown in figure **(2.17)** and its components. The purpose of this article is to provide an understanding of the entire induction melting furnace through pictorial descriptions. The induction melting furnace consists of a main power source panel, control panel and melting furnace. The melting furnace has a steel frame structure and this type of melting furnace comprises of coil cradle and a Base structure. Coil cradle is basically arrangement to hold the working coil along with the liquid metal. On the other hand, the base structure is designed to facilitate the tilting of the coil cradle when the liquid metal is poured.

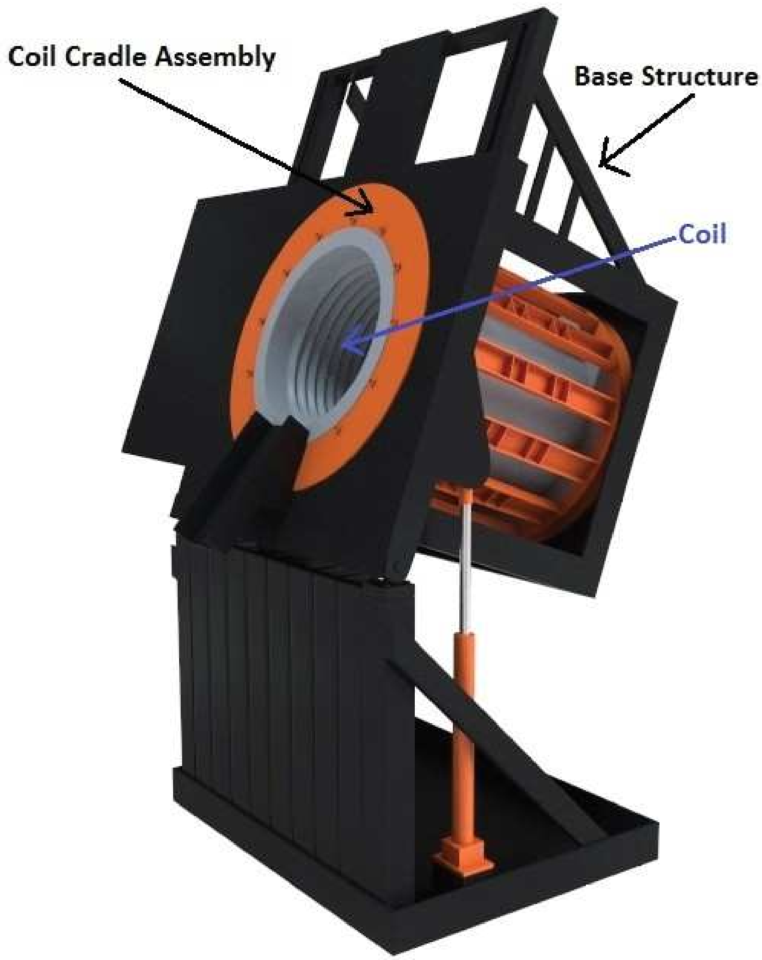


Figure .17 Induction Melting Furnace

2.3 Comparative Study:

According to the first research **[1],** the working principle of the can smasher, where the smasher is designed to operate on a crank and slotted lever mechanism. In this research, they use an optimization technique for the vertical crushing machine. While in the third research **[3]**, the can smasher employs a slider-crank as it's a sliding mechanism (horizontal crushing machine).

According to the second research **[2]**, the can smasher machine in this research is a pneumatics can smasher. Where the pneumatics system works by pressurized gas to produce mechanical motion and to drive the piston forward or reverse backward as shown in figure **(2.7)**. While in third research **[3],** they used a fully automatic electric can smasher as shown in figure **(2.8)**. The electric can smashers work automatically using some sort of electric engine and gear system on most smashers. The thing that make some differences between the electric can smasher and the pneumatic smasher, is that the electric can smasher work fully automatically and you don't have to press any buttons to smash the cans, just turn the machine on, drop some cans in and turn it off.

According to the study by Antão Valentim **[4]** was used an electric induction furnace, with a power of 100 kW with maximum capacity of about 55 kg of melted aluminum. The working temperature ranged from 750°C to 780°C. While, in our design the capacity will be less than 55 kg. The working temperature will be ranged from 850°C to 1200°C.

Chapter 3: System Design

3.1 Design Constraints

3.2 Design Methodology

3.3 Product Subsystems and Components

3.4 Implementation

3 System Design

3.1 Design Constraints:

3.1.1 Functional Constraints:

Overall Geometry: Size Limitation of the project is 150mm height, 100 mm length, 70 mm width

Motion of parts: The velocity of the motor must not exceed 130 rpm

The energy needed: The heating element coil must not exceed 1000 C in temperature inside the furnace.

Materials to be used: Steel and lumber wood

Control system: Electrical

3.1.2 Safety Constraints:

When the induction furnace connecting directly to the electricity, do not touch any bare wires unless the power is disconnected.

A few notes on heating and setting up. Set up and fix the coils before applying power to it for the first time. After the first few heating, the wire gets brittle and tends to break easily.

3.1.3 Economic Constraints:

The limit price for the whole project should not exceed 4500 SAR

3.1.4 Timing Constraints (Gantt chart):

Table **(3.1)** shows the process of the work and due date for submission

Table **(3.1)** Gantt chart

	A	B	C	D
1		TASK NAME	START DATE	END DATE
2		BRAIN STORMING	9/18/2016	9/22/2016
3		STUDY OF MECHANISIMS	9/23/2016	9/26/2016
4		INSTRUCTOR MEETING 1	9/29/2016	9/29/2016
5		LITERATURE REVIEW	9/27/2016	10/27/2016
6		SKETCHING DESIGN	10/4/2016	10/7/2016
7		CALCAULATIONS	10/8/2016	12/3/2016
8		INSTRUCTOR MEETING 2	10/13/2016	10/13/2016
9		LOOKING FOR PARTS	10/15/2016	12/3/2016
10		ASSEMBLY OF 1ST SYSTEM	10/28/2016	11/28/2016
11		MID-TERM PRESENTATION	11/24/2016	11/24/2016
12		ASSEMBLY OF 2ND SYSTEM	11/20/2016	12/1/2016
13		ASSEMBLY OF 3RD SYSTEM	12/1/2016	12/3/2016
14		ASSEMBLY OF WHOLE SYSTEM	12/3/2016	12/10/2016
15		TESTING AND INSPECTION	12/11/2016	12/28/2016
16		2ND PROGRESS REPORT	12/1/2016	12/1/2016
17		FINALIZE THESIS, POSTER	12/22/2016	12/22/2016
18		FINAL REPORT SUBMISSION	12/25/2016	12/25/2016
19		PRESENTATION DAY	12/29/2016	12/29/2016
20		FINAL BOUND THESIS	1/5/2017	1/5/2016

3.2

furnace

ar sign are

as

Figure .1 The whole system as one unit

In the first system, which is the can smasher, we use more than previous research to learn how to make a can smasher and what the changes we need to do to get a perfect system. Also, using SolidWorks program to design the parts of the can smasher and the cans container. Using a motor with a gearbox to reduce the rpm number of the motor.

In the second system which is the induction furnace, also we learn from the previous researches and studies how to make an induction furnace with the required heat in order to reach the melting point of the aluminum. We use a pottery (Clay) for insulation and furnace built out of fire extinguisher. The heating element that will be used in the furnace is a coil with 5000 watts and 220 volts generating heat from electricity up to 1000 C. The coil will be connected with single phase wire and thermocouples will be used to measure the temperature degree of the furnace. Finally, after the cans melt in the furnace it will fall down into a steel cubic mold.

3.3 Product Subsystems and Components:

This is a 3D drawing for the can smasher system exploded parts to clarify each part in the system as shown in figure **(3.2)**.

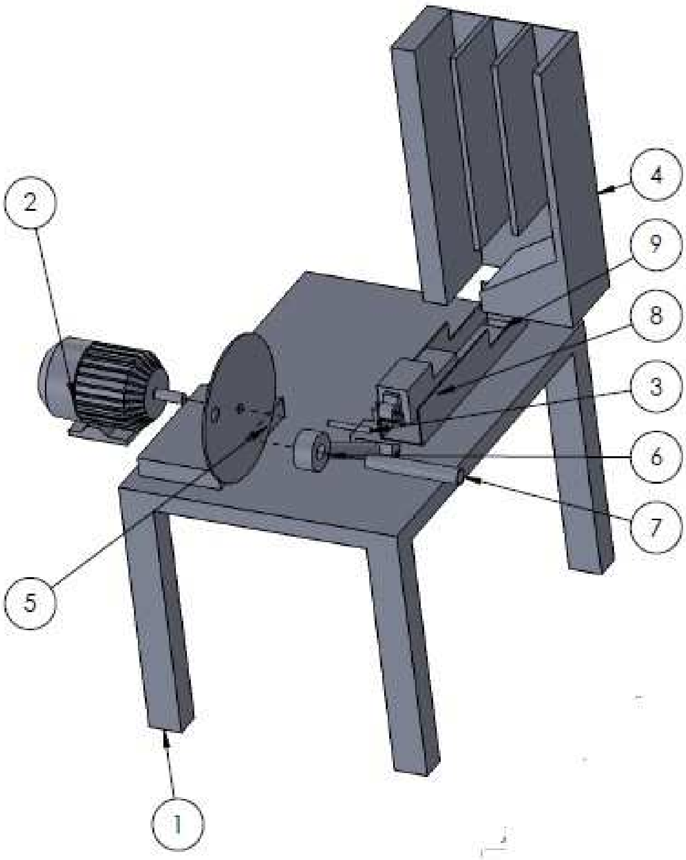


Figure 3.2 Can Smasher System Exploded Parts

Table **(3.2)** shows the number for each part of the can smasher system.

Table **(3.2)** Can Smasher Exploded Parts

ITEM NO.	PART NUMBER	DESCRIPTION	A#
1	Table	Wood	A3
2	AC Motor	Steel	A4
3	Bearing Holder Arm	Steel	A5
4	Can Holder	Wood	A6
5	Crank	Steel	A7
6	Long Arm	Steel	A8
7	Short Arm	Steel	A9
8	Smasher	Steel+Wood	A10
9	Steel Compartment	Steel	A11

Table: This is a wood table for the can smasher system as shown in figure **(3.3)**

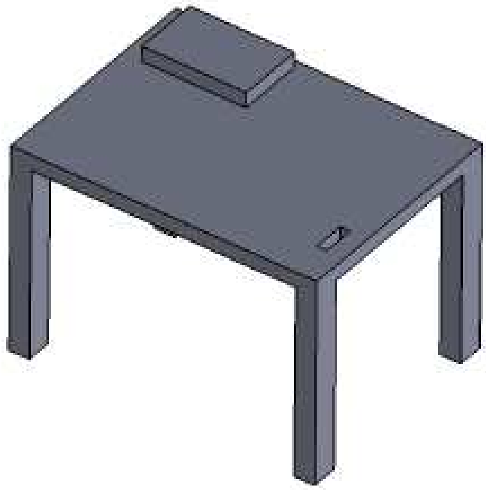


Figure 3.3 Table

AC Motor: AC motor with 1 hp and 1600 rpm with a gear box to reduce 1600 rpm to an output of 110 rpm as shown in figure **(3.3 & 3.4),** the function of the motor is to generate mechanism work to move the box in order to smash the cans.

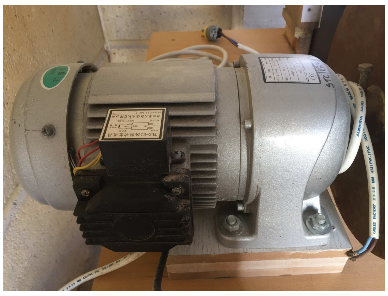


Figure 3.4 AC Motor

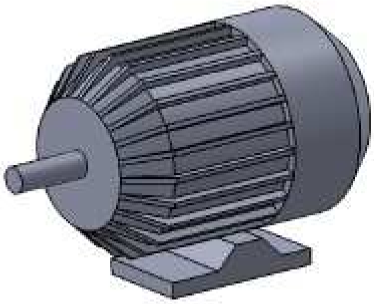


Figure 3.5 SolidWorks Drawing For The AC Motor

Crank and steal arms: These parts used to do the mechanism work to smash the cans. As Shown in figures **(3.6, 3.7 & 3.8)** below.

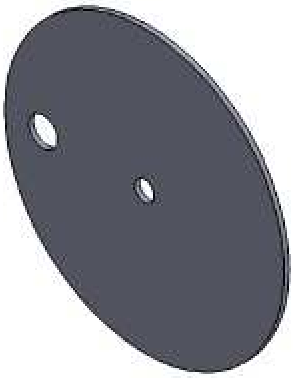


Figure 3.6 Steel Crank

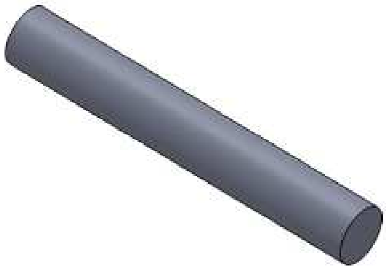


Figure 3.7 Short Arm

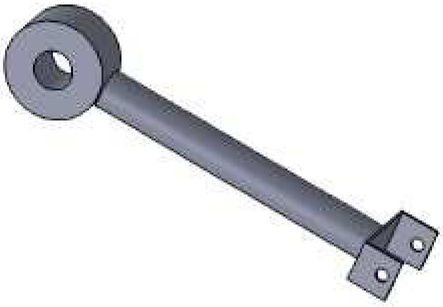


Figure 3.8 Long Arm

Cans Holder: has a capacity of 17 cans divided into three channels as shown in figure **(3.9).**

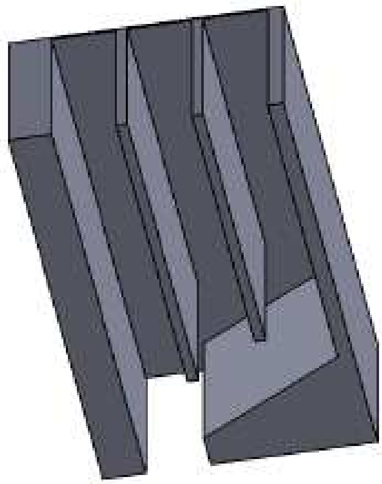


Figure 3.9 Cans Container

Steel Compartment: absorbing the impact of the smasher on the aluminum cans as shown in figure **(3.10).**

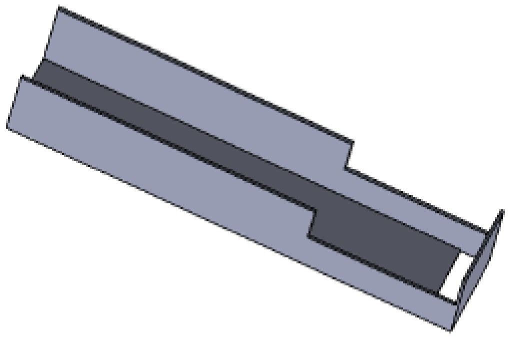


Figure 3.10 Steel Compartment

Smasher: This part used in order to smash the cans. It consist of wood part and a stand steel bearing as shown in figure **(3.11)**

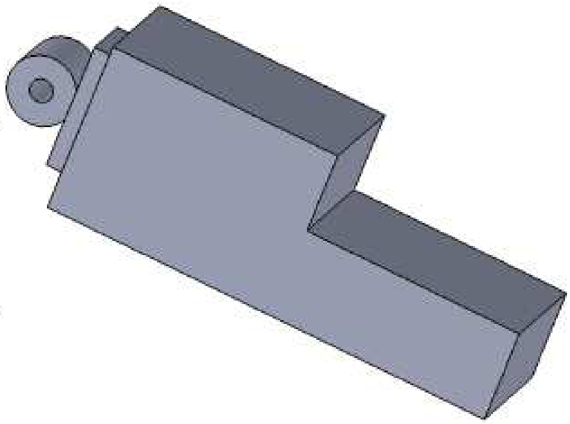


Figure 3.11 Smasher

The Induction Furnace: After the Cans smashed it will fall down inside the furnace figure **(3.12).**

Figure 3.12 Induction Furnace

Coil: Coil is a heating element with 5000 watts and 220 volts generating heat from electricity, it is used to increase the temperature inside the furnace to 630 C in order to melt the cans figure **(3.13).**

Thermocouples: This Device will be used to measure the temperature inside the furnace figure (**3.14).**

Cylindrical Mold: After the cans melt in the furnace it will fall down into a steel cubic mold as shown in figure **(3.15).**

Figure 3.15 Cylindrical Mold

Fire extinguisher Furnace:

As shown in figure **(3.16)**

Figure 3.16 Fire extinguisher Furnace

3.4 Implementation:

3.4.1 Can Smasher system:

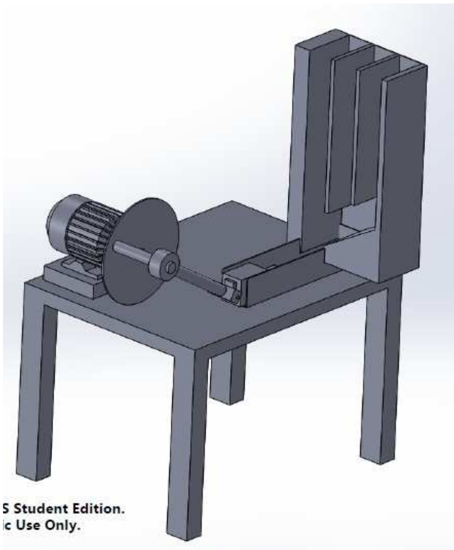


Figure 3.17 3D Drawing of the Can Smasher System

1. Firstly we design the cans container, where the cans will fall down from the container to the steel compartment.

2. Also, we design several metal parts to do the mechanism work in order to smash the cans. The first part is the steel compartment, which is used to absorb the impact of the smasher on the aluminum cans. The second parts are long and short arms respectively connected by one stand bearing and two ball bearings. The third part is the crank which is connected with the motor and the short arm.

3. The Motor: It is an AC motor with 1 hp and 1600 rpm with gear box used to reduce 1600 rpm to an output of 110 rpm. The function of the motor is to generate a mechanism work by rotating the crank. When the crank is rotating the long arm will move in a circular motion, where the long arm connected with the smasher. Therefore, the smasher will travel freely in a horizontal direction.

3.4.2 Calculations for the can smasher:

We want to find the force of the smasher and the time required for one cycle. Firstly, we need to find R_4, Θ_3, W3, V_4.

In Figure **(3.18)** we have the followings:

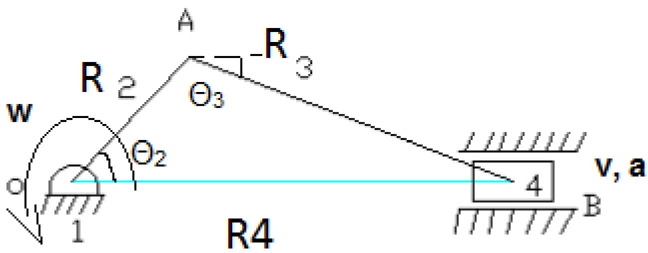


Figure 3.18 Slider Mechanism

R_2 is the distance from the center of the crank to the center of the short arm
R_3 is the distance from the crank to the long arm
R_4 is the distance of the smasher motion
W is angular velocity rad/s
Θ_2 is angle for the Can
Θ_3 angle of the copular
V is the velocity of the Slider

- **R_2= 0.1m**
- **R_3= 0.25m**

- **R_4= ?**
- **W_2= 110 rpm**
- **Θ_2= 60°**
- **Θ_3= ?**

Firstly we need to use Equ (3.1) and Equ (3.2) in order to find R4 and Θ_3:

R_2 Cos Θ_2 + R_3 Cos Θ_3 – R_4 = 0 ……………………….……......... Equ (3.1)

R_2 Sin Θ_2 + R_3 Sin Θ_3 = 0 ….……………………………………. Equ (3.2)

Form Equ (3.2):

1.1 * Sin 60 + 0.25 Sin Θ_3 = 0

Sin Θ_3 = + (√3 / 5)

Θ_3= Sin^{-1} (√3 / 5)

= + 20.2679 °

From Equ (3.1):

R_4= 0.1 Cos (60) + 0.25 Cos (20.2679)

= 0.28 m

First we need to use Equ (3.4.3) and Equ (3.4.4) in order to find W_3 and V_4:

- R_2 W_2 Sin Θ_2 - R_3 W_3 Sin Θ_3 – R_4 = 0 ………………………………… Equ (3.3)

R_2 W_2 Cos Θ_2 + R_3 W_3 Sin Θ_3 = 0 ……………………………..….. Equ (3.4)

From Equ (3.4):

1.1 * 110 * Cos 60 + 0.25 * Sin (20.2679) W_3 = 0

W_3= (+ 5.5 / 0.2345)

= + 23.45 rpm convert W_2 and W_3 to rad/s

W_2= (110*2*pi) / 60 = 11.519 rad/s
W_3= (23.45*2*pi) / 60 = 2.455 rad / s

From Equ (3.3):

- 0.1 * 11.519 * Sin 60 – 0.25 * 2.455 * Sin 20.2679 = V_4

V_4= 1.218 m / s

Force of the can smasher:

F= P/V_4 ………………………………………………….. Equ (3.5)

P is the power in watt.

F= 750 / 1.218 = 615.7 N

Due to friction loss we will take 80% of the force in to be out. So

F_{out} = 615.7 * 0.8

= 492.56 N

Time for one cycle:

V= d/t ………………………………………………………. Equ (3.6)
D is the distance in m
t is the time in second

T= R_4 / V_4 ……………………………………………………. Equ (3.7)

= 0.28 / 1.218

= 0.229 s

3.4.3 Induction Furnace System:

Figure 3.19 The Induction Furnace

The system consists of the Pottery (Clay) for insulation with a container for pottery. The furnace built out of a fire extinguisher inside the container as shown in figure **(3.19)**. Then a heating element coil with 5000 watts and 220 volts generating heat from electricity, it is used to increase the temperature inside the furnace to 630 C in order to melt the cans. The heating element coil will be connected by a single phase wire separated by a wire isolator to prevent heat transfer from heating element to the single phase wire. A small steel pipe will be used inside the furnace will be connected to the fire extinguisher. Where the melting aluminum will fall down from the furnace to the steel cubic mold through the small steel pipe.

3.4.4 Results of the induction furnace:

The induction furnace test works perfectly, it takes about 60 minutes to melt the cans inside the furnace and fall down into the mold. In this part we are considering all the calculation on one dimension.

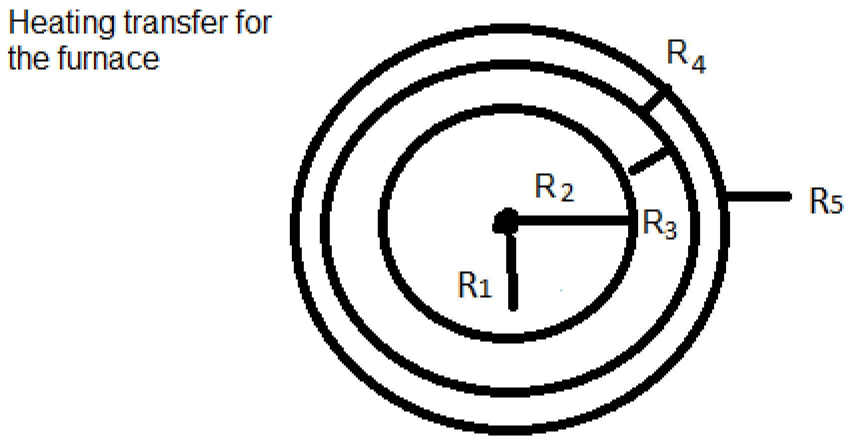


Figure 3.20 Heat Transfer For The furnace

- Thermal conductivity of stainless steel (k) = 29 W / m*K
- Thermal conductivity of Pottery and wood we take it as an average (k) = 0.078 W / m*K
- **Qin=** 5000 w heating element (coil)
- **R** is the resistance

We want to find the conviction heat transfer coefficient:

The property of air in Table (A-15) from heat and mass transfer book

For $\mathbf{h_{out}}$,

We need to find T_f :

Ts= 100 C°

$\mathbf{T_\infty}$= 25 C°

$T_f = (Ts - T_\infty) / 2$ …………………………………………………. Equ (3.8)

= 125 / 25

= 62.5 C°

V= $1.896*10^{-5}$

Pr= 0.7202

$\beta = 1 / T_f = (1 / 335)$

k= 0.02808

$\mathbf{Ra_L}$= [g * β * (Ts - T∞) * Lc³ * Pr] / V² ………………………..………. Equu (3.9)

$= [(9.81) (1/335) (100-25) (0.33)^3 (0.7202)] / (1.896*10^{-5})^2$

$= 1.58*10^8$

Gr= $2.19*10^8$

For vertical cylinder (h_{out})

If D >= 35L / $(7.215*10^7)^{1/4}$

So we trade it as vertical plate

0.3 >= 35(0.33) / $(2.19*10^8)^{1/4}$

0.33 >= 0.094

So

Nu= 0.59 $Ra_L^{1/4}$

$= 0.59 * (1.58*10^8)^{1/4}$

= 66.14

h_{out} = k Nu / L ………………………………………………..………. Equ (3.10)

= (0.02808 * 66.14) / 0.33

= 5.627 W / m^2* k

For h_{in}

From engineering tool box website we found h_{in} is 10.45 W / m^2* k

<u>Now we will find resistance values:</u>

D= 0.26, r_0= 0.145 and r_i= 0.13

$\mathbf{R_1}$= (1 / h_{in} A_0) ………………………………………………… Equ (3.11)

= (1 / 10.45* pi * 0.26 * 0.33)

= 0.355 (conviction)

$hr = \epsilon\, \sigma\, (Ts^2 + T_\infty^2)(Ts + T_\infty)$ …………………………………………….…. Equu (3.12)

$= 0.9*5.678*10^{-8} * (1273^2 + 1073^2)*(1273+1073)$

$= 331.83$

R_2= $1 / h_r A$

= 1 / (331.83 * pi * 0.26* 0.33)

= 0.012 (Radiation)

R_3 For Pottery and wood k= 0.078

R_3= $[\ ln(r_0/r_i) / 2*pi*k*L\ ]$ ………………………………………… Equ (3.13)

= [ln(0.145 / 0.13) / 2*pi*0.078*0.33] = 0.675

D= 0.33, $r_{0=}$ 0.165 and $r_{i=}$ 0.1625

R_4 for stainless steel

R_4= $[\ ln(r_0/r_i) / 2*pi*k*L\ ]$

= [ln(0.165 / 0.1625) / 2*pi*29*0.33]

$= 2.539*10^{-4}$

R_5= $[\ 1/ h_{out}\ (pi*D*L)\ ]$ …………………………………………….……Equ (3.14)

= [1 / (5.624)* pi * 0.33 * 0.33]

= 0.5194

$R_{out\ total}$ $= R_3+R_4+R_5$

=1.194

We will take q_{total}= 3000 due to the loss of the other dimension

$q_{total} = [(Ts - 800) / (R_{in\ total})] + [(Ts - 25) / (R_{out\ total})]$ …………….………. Equ (3.15)

3000 = [(Ts - 800) / (0.0116)] + [(Ts - 25) / (1.194)]

3000 * 0.0116 * 1.194 = 1.194 Ts – 955.2 + 0.0116 Ts – 0.29

Ts= 827 C^o

q_1 = (Ts - $T_{\infty in}$) / ($R_{in\ total}$) ………………………………………….……. Equ (3.16)
= (827 - 800) / (0.0116)
= 2327.59 w

q_2 = (Ts - $T_{\infty out}$) / ($R_{out\ total}$) …………………………………………….………. Equ (3.17)
= (827 - 25) / (1.194)
= 671.96 w

Time= [m * c * ($T_{\infty in}$ – T_{out})] / q_1 ……………………………….……………….. Equ (3.18)
= [260 * 0.9 * (1073 – 298)] / 2327.59
= 77.91 s

3.4.5 Summary of Calculations Results :

3.4.5.1 Summary of Calculations Results for Can Smasher System:

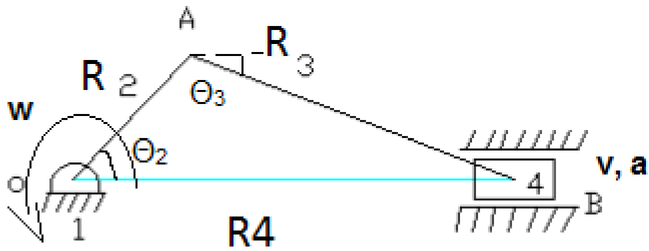


Figure 3.18 Slider Mechanism for Can Smasher

Θ_2	Θ_3	R_2	R_3	R_4	V_4	W_2	W_3	P	F	T
60°	20.2679 °	0.1 m	0.25m	0.28 m	1.218 m / s	11.519 rad/s	2.455 rad / s	750 N	492.56 N	1.229 s

3.4.5.2 Summary of Calculations Results for Induction Furnace:

In the second system which is the induction furnace, the system takes about 1 hour to reach the melting temperature point which is 800 C^o. When the furnace temperature becomes 800 C^o, the cans will fall down inside the furnace and they take 100.8 seconds to melt.

Time= $[\, m * c * (T_{\infty in} - T_{out})] / q_1$ ……………………………….……….. Equ (3.18)

$= [260 * 0.9 * (1073 - 298)] / 2327.59$

$= 77.91$ s

Chapter 4: System Testing and Analysis

4.1 Subsystem 1 (can smasher)

4.2 Subsystem 2 (Induction Furnace)

4.3 Overall Results, Analysis and Discussion

4. System Testing and Analysis

4.1 Subsystem 1 (can smasher)

The objective of this testing is to ensure that the system function in best way possible and that to achieve the followings:

- The ability for the motor to generate enough force to smash the cans and reduce its length to 100 mm
- To ensure there is no conflict in timing between the time for cans to fall and the time required for smasher to arrive to the cans.
  - Smasher horizontal sliding time is 0.28 s
  - The cans timing to fall into the compartment is 0.18 s
- To be able to reduce the vibration throughout the structure.
- To ensure all the wiring connections are correct.
- To ensure all parts assembly and mechanisms are correct.
- To ensure the system is able to smash 17 cans without lagging or failure in parts or in the mechanisms.

The setup for the system took place in two areas, one in the carpentry shop and the other in fabrication shop all of them located in Al-Khodariyah, Dammam, Eastern province, Saudi Arabia.

Instruments used in fabrication shop are:

1. Lathe machine
2. Wielding
3. Drill and hummer.
4. Finishing.
5. Grinder

Instrument used in carpentry shop are

1. Screwdriver
2. Handsaw
3. Tape measure
4. Rasps
5. Chisels
6. Versatile woodworking machine

The result for the can smasher testing went through couple of stages and those are as shown in the table **(4.1)** bellow:

Table **(4.1)** testing of the can smasher

Test number	**Objective**	**Result**	**Status**
1	Assembly and test connections and mechanisms	The bearing broke and short arm bended and vibration level was high	Fail
2	Assembly and test connections and mechanisms after modification on parts (short arm and bearing)	The mechanisms works however, the vibration was high because the table was not stable	Partially successful
3	Force of the motor and timing between smasher and the cans	The motor generate enough power to smash the cans however, there was an issue with the can falling to compartment due to	Successful

		friction with the surface of the can holder but it solved by increasing the space for the cans in the can holder to allow the cans to fall free and smooth.	
4	Test the whole system and test the limitation of its function and how many cans the system actually can smash.	The system faced few small issues like the satiability, vibration and smoothness of the mechanism, with few modifications (shorten the table legs, add a box to keep the smasher in place and prevent vibration) the system works and the test was satisfactory.	Successful

4.2 Subsystem 2 (Induction Furnace)

The objective of the second system is to ensure the induction furnace operated and run within the specification and regulation of the safety purposes. The objectives are as shown below:

The heating element coil generates enough heat to exceed 630 c, which is the melting point of the aluminum.

To ensure the capacity of the furnace is accepted to melt 0.27 kg of aluminum.

The thickness of the insulation material (pottery) is enough to keep the heat inside it and reduce the heat losses of the system.

To ensure all the wiring and the coil are connected right.

To ensure the system has no short circuit.

The setup for the induction furnace system took place in in Al-Khodariyah, Dammam, Eastern province, Saudi Arabia. Instrument used in induction furnace:

1. Drill.
2. Wielding.
3. Screwdriver.
4. Hummer.
5. Electric tapes.
6. Thermocouple.
7. Tape measure.

The result for the can smasher testing went through couple of stages and those are as shown in the table **(4.2)** bellow:

Table **(4.2)** testing of the induction furnace.

Test number	**Objective**	**Result**	**Status**
1	The heating element coil able to generate more than 630 c.	The coil worked and generated 800 c and used 5000 watts	Successful

2	Test the system assembly and ensure no short circuit in the system.	The system was looking good and no short circuit however when turn the system on the pottery fail and led to the whole system to fail dramatically due to short circuit and high pressure the system fail. Therefore, we redesign the furnace by reducing the thickness of the pottery and open release valve to allow the excess pressure to exhaust.	Fail
3	Retest the same objective as above.	The system run within the limitation we design it for.	Successful
4	Test the capacity of the furnace.	It as capable of melting 0.27 kg of aluminum cast within 1 hour	Successful
5	Test the whole system.	Every part did its duty and the function it designed for.	Successful

4.3 Overall Results, Analysis and Discussion:

4.3.1 Result and analysis of can smasher:

In this project, firstly we tested the can smasher separately, in the first test the system is not working well, because there are some problems in the system. For example, the vibration of the table and some steel parts need to change. After we solved the problems that happens in this system by editing some parts, we crushed 10 cans are crushed by a force of 492.56 newton in 0.229 s in one cycle.

Force:

$F = P/V_4 = 750 / 1.218 = 615.7$ N

Due to friction loss we will take 80% of the force in to be out. So

$F_{out} = 615.7 * 0.8$

$= 492.56$ N

Time for one cycle:

$V = d/t$

$T = R_4 / V_4$

$= 0.28 / 1.218$

$= 0.229$ s

4.3.2 Result and analysis of induction furnace:

In the second system which is the induction furnace, the system takes about 1 hour to reach the melting temperature point which is 800 C°. When the furnace temperature becomes 800 C°, the cans will fall down inside the furnace and they take 100.8 seconds to melt.

Time= $[\, m * c * (T_{\infty in} - T_{out})] / q_1$ ……………………………….……….. Equ (3.18)

$= [260 * 0.9 * (1073 - 298)] / 2327.59$

$= 77.91$ s

Chapter 5: Project Management

5.1 Project Plan

5.1.1 First part the can smasher

5.1.2 Second part the induction furnace

5.1.3 Third part the mold

5.2 Contribution of Team Members

5.3 Project Execution Monitoring

5.4 Challenges and Decision Making

5.4.1 Problems with team members

5.4.2 Members not contributing

5.4.3 Ineffective communication

5.4.4 Conflict between team members

5.4.4.1 Problems of delays in procuring required parts, components and tools.

5.4.4.2 Problems regard to equipment or components.

5.5 Project Bill of Materials and Budget

5. Project Management

5.1 Project Plan

Project management is a key role to any project to success. Therefore, we divided the plan for our senior year into three parts:

5.1.1 First part the can smasher:

- Brainstorming
- Choose best design
- Designing and drawing
- Simulation on CAD
- Buying required tools
- Buying required material
- Finding a good fabrication shop
- Finding a good carpentry shop
- Calculation for can smasher

Manufacturing the mechanism parts for the can smasher

Calculate the dimension for the table which will be the stand for our senior year project

Manufacture the table

Assembly for can smasher

Install the system on top of the table

Test the first part (can smasher)

5.1.2 Second part the induction furnace:

Brainstorming

Choose best design

Designing and dimension specification

Buying required tools

Buying required material

Finding a good fabrication shop

Calculation for the heating element coil

Calculation for heat loss

Calculation for heat requirement for the induction to heat up to 800 c

Calculation for time required to heat up

Insulation material selection

Manufacturing the parts

Assembly for the induction furnace

Install the induction furnace below the table

Test the induction furnace

5.1.3 Third part the mold:

Brainstorming

Choose best design

Buying required tools

Finding a good fabrication shop

Designing and dimension specification for the mold

Manufacture the mold

Install it under the induction furnace

Test the mold by pouring aluminum into the mold.

5.2 Contribution of Team Members

In senior year project contribution of team members add a value to the project and make it easy when all group members contribute in it. Contribution of team members to be part of the project show the connection between members and the team work wish will result in achieve the goal due to time required for the project to be submitted. The following table (5.2) will show the contribution of team members.

Table **(5.1)** Team member contribution:

task	**Team member contribution**	**% Percentage**
Brainstorming	ALL MEMBERS	100%
Drawing CAD and designing	OMAR MOHAMMED ALI	33.33% 33.33% 33.33%
Calculations for can smasher	OMAR ALI MOHAMMED	33.33% 33.33% 33.33%

Finding parts	ALL MEMBERS	100%
Finding tools	ALL MEMBERS	100%
Finding fabrication shop and carpentry	ALL MEMBERS	100%
Assembly for can smasher	ALL MEMBERS	100%
Testing can smasher	ALL MEMBERS	100%
Calculation for induction furnace	ALI OMAR MOHAMMED TAHER	25% 40% 20% 15%
Assembly for induction furnace	ALL MEMBERS	100%
Test induction furnace	ALL MEMBERS	100%

Designing a table	ALI MOHAMMED OMAR TAHER	40% 35% 20% 5%
Test the system	ALL MEMBERS	100%

5.3 Project Execution Monitoring

The things that supported and monitored the execution of our senior year project are as follow:

- Meeting with advisor two times a week.
- Meeting with the co. Advisor Dr. Nader Swalhi once every two weeks.
- Meeting with the group members three times a week + weekends.
- Gathering helps from Dr. Mohammed Assad in regard to calculations and specifications.
- Testing our project two times using different methods
  - One: simulator by using CAD.
  - Second: testing the mechanism and the functions of the project in workshops.

5.4 Challenges and Decision Making:

Through the senior year project we faced couple of challenges such as:

- Problems with team members.
- Problems of delays in procuring required parts/components/tools.
- Problems regard to equipment or components.

5.4.1 Problems with team members:

Due to the nature of working in teams, our group members can sometimes find that they are not working effectively, which negatively impacts on our progress, and our ability to be successful. Here is some the issues that we faced and how we dealt with them in regard to team members not cooperating:

1. Members not contributing
2. Ineffective communication
3. Conflict between team members

5.4.2 Members not contributing

To ensure that all members contribute to the group task we did as follow:

Establish why a member is quiet or not participating.

Communicate that all opinions will be valued.

Ensure that each member gets their turn to contribute, this may mean 'going around the circle.

5.4.3 Ineffective communication

To ensure effective communication between members we did as follow:

Identify specific issues which seem to affect communication.

Consider how to address such issues. For example, if team members seem to be misunderstanding each other, it may be helpful to clarify what is being said.

5.4.4 Conflict between team members

To ensure that disagreements between members are dealt with effectively we did as follow:

Respect the ideas of other group members.

Heard other member's ideas and when disagreeing do so politely and respectfully.

Understand that working in a team requires some negotiation and compromise.

Take a break to diffuse the situation and recollect thoughts at a later meeting.

5.4.4.1 Problems of delays in procuring required parts, components and tools.

At the stage of brainstorming and designing we did not notice that we need a controller to control the temperature due to lake of knowledge therefore, by the time we realized the mistake we ordered a controller however the issue was that the controller will arrive at 10th of January which is after the deadline for the project so we decided to buy a thermocouple instead of a controller and control the furnace manually and we got the approval from the adviser to processed with this action.

5.4.4.2 Problems regard to equipment or components.

At the time of testing the induction furnace for the first time we face a catastrophe event which led to an explosion of the induction furnace due to high pressure and unsolidified pottery. Therefore, we designed another furnace and we sent it to pottery makers to put it in very high temperature furnace to solidify and we drilled a whole in our induction furnace to lower the pressure.

In addition to the problems, when the parts of the smasher's mechanisms manufactured we assumed the fabrication workers were professional and they manufacture the parts based on the specification we provide them and this issue was occurred due to our lack of experience so what happened is when we assembled the parts, they were not mating together. Therefore, we sent the parts back to the fabrication shop to remanufacture some of the parts and modified the others to fit.

5.5 Project Bill of Materials and Budget

This section will provide the bill of materials and the budget for the project that we designed to satisfy its function and that by choosing best materials and minimize cost as possible. The following table **(5.2)** will show the material selection and the budget for each part.

Table **(5.2)** Bill of Materials and Budget.

parts	**Bill of Materials**	**Budget (Saudi riyal)**
Motor and gearbox	Casted iron	1440

Can smasher mechanisms **Crank** **Long arm** **Short arm** **Bearings** **Smasher** **Compartment** **Can holder** **Can collector**	 Steel Steel Steel Stainless steel Lumber wood Steel Lumber wood steel	 200 200 200 100 80 100 300 100
Induction furnace **Pottery** **Thermocouple** **Heating element coil** **Hocks** **Heat insulator for wiring** **Container** **Wire** **Blog** **Fire extinguisher**	 Pottery Plastic cover Nickel chrome Steel ceramic Stainless steel Zinc - steel	 104 360 380 20 20 200 15 20 130
Table	Lumber wood	250
Blocks	ceramic	10
Mold	steel	52
Total		4281

Chapter 6: Project Analysis

6.1 Life-long Learning

6.2 Impact of Engineering Solutions

6.3 Contemporary Issues Addressed

6. Project Analysis

6.1 Life-long Learning:

While working on this project we acquired many useful knowledge, skills and experiences. By working in a group with different students we developed several skills such as, time management, conflict management and self-commitment skills. We developed time management skills by making a schedule for work and everyone on the group has a task to do. Also, while working on this project we learned a lot of information about the devices and elements. For example, we learned about the types of motor, where there are electric motors works by electricity and there are pneumatic motors which is a section of technology that deals with the study and application of pressurized gas to produce mechanical motion. Also, for electric motor there are different types 3 phase and 1 phase, were 3 phase not working in the normal electricity that used in homes and universities. Most of the electric motors which has gearbox are 3 phase. In addition, while working on the induction furnace we learned about several types of the heating elements and what is the best type we need in order to melt the cans as efficiently as possible. We acquired an experience about the workshops and stores that sells the devices and elements such as, motors and heating elements.

6.2 Impact of Engineering Solutions

Recycling plays a very important role to save our natural resources, as all we know we have limited natural resources. In fact, aluminum recycling is one of the best and easiest things we can do to save the environment. In order to reduce the waste, we planned to create a compact recycling aluminum can system to get from the empty cans, a pure aluminum bar. The objective of this machine is to save the environment and for recycling the aluminum cans. It can be placed anywhere in park, restaurant, home, etc. Thus this machine will help to recycle and maintain eco-friendly environment also.

6.3 Contemporary Issues Addressed

Before starting to talk in general I would like to start mentioning couple of issues in regard to the cooperation between students and the university. There were no labs, tools or financial support where the student can develop the skills required in business, and at the same time students have been asked to deliver a project with high standards to compete with other universities in the Kingdom but how?. Moreover, in regards to safety, we were working in areas with very poor safety regulations and that due to lack of resources. The project has been accomplished in brutal places which were not designed for learners or students. Also, when it comes to specifications and material selections based on standards, the workers themselves in the workshops and in the market have no clue on standards and I think this is an issue not only in the kingdom but in GCC as well.

Chapter 7: Conclusions and Future Recommendations

7.1 Conclusions

7.2 Future Recommendations

7. Conclusions and Future Recommendations

7.1 Conclusions

In conclusion, this project is about designing and fabricating a compact recycling aluminum can system to get from the empty cans, a pure aluminum bar. In this project we designed three main parts are the automatic can smasher which is a machine designed to reduce large cans material into a smaller volume, or smaller pieces. The Automatic can smasher is the first process and it consists of motor and some steel parts to crush the cans. After crushing the cans will go to the second part which is the induction furnace. The induction furnace is used to melt the cans by high temperature inside the furnace to get the melting aluminum. After the second process of furnace finish, the melting aluminum will go through a semi-circular steel to the third part which is the lifting mechanism (mold) where the melting aluminum will solidify to pure aluminum bar. Methods and process involve in this project for instance joining using bending, welding, drilling, and cutting process. This project mainly about generating a new concept of a compact recycling aluminum can system that would make easier to bring anywhere and easier to recycling cans. When we tested the first system which the can smasher, we smashed 10 cans and the system work effectively. Then after we finish from the can smasher we test the induction furnace, where the crushed cans melt and fall down into the mold as pure aluminum.

We learned a lot of things in the project such as, time management, knowledge, conflict management and how to deal with challenges. In this project, we face a lot of challenges in the prototype and sometimes about the time, but we solve them as efficiently as possible and we complete the project in the best way. Also, we learned useful information about the electric can smasher system and the electric motor. In addition, we learned about heating elements types and how to make an induction furnace by a coil to reaching the melting point for aluminum 630 C^{o}.

7.2 Future Recommendations

There are some recommendations for the team and about the system in order to make it works better and to avoid problems that happen sometimes in the can smasher.

1- It is better to decrease the speed of the motor in order to avoid any problem when crushing the cans
2- Try to make the table more supported to avoid the possibility of vibration.
3- Make sure to organize time schedule with the group and an obvious weekly plan for the project.

8. References

1] S. Kannan. Design of Mechanical Crushing Machine. International Research Journal of Engineering and Technology.

2] Qais, S., & Saif, S. Fully Automatic Can Crusher. International Journal of Mechanical and Industrial Technology.

3] http://www.slideshare.net/Esraabook/can-crusher-device

4] Valentim, A. Recovery of Aluminum in the Induction Furnace. International Conference on industrial Engineering And Operations Management

5] K. C. Bala, Design Analysis of an Electric Induction Furnace for Melting Aluminum Scrap, Mechanical Engineering Department, Federal University of Technology Minna, Niger State, Nigeria.

6] Alshaikhli, Al-khairo, Design and Construction of the Coreless Induction Furnace, International Journal of Scientific & Engineering Research.

7] http://www.metallab.net/kanthal.php

8] Kshirsagar, Choudhary, An Automatic Approach For Can/Plastic Bottle Crusher Machine, International Journal Of Research In Aeronautical And Mechanical Engineering

9] Selvadurai, Veeramuthu, Design and Fabrication of Can Crusher, International Journal of Innovative Research in Science, Engineering and Technology.

10] http://www.industrialheating.com/ext/resources/images/White-Paper/Understanding-Medium-Frequency-Induction-Melting-Furnace-and-its-Components.pdf

Appendix A: SolidWorks

A1: Assembly Of Can Smasher System

A2: Can Smasher System Exploded

A3: Table

A4: AC Motor

A5: Bearing Holder Arm

A6: Can Holder

A7: Crank

A8: Long Arm

A9: Short Arm

A10: Smasher

A11: Steel Compartment