AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Design and Production Engineering Department
2nd year, Mechanical Engineering

PERMENANT MAGNET SYNCHRONOUS GENERATOR

(PMSG)

NAMES

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GROUP : 8
SECTION : 2
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DATE :
28/12/2019

MDP251: Mechanics of machines 1

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Introduction:
Wind energy:

Wind energy is one of the fastest-growing energy sources in the world as it offers many advantages. Research efforts are aimed at addressing the challenges to greater use of wind energy.

Advantages of Wind Power:

Wind power is cost-effective. Land-based utility-scale wind is one of the lowest-priced energy sources available today, costing between two and six cents per kilowatt-hour, depending on the wind resource and the particular project’s financing

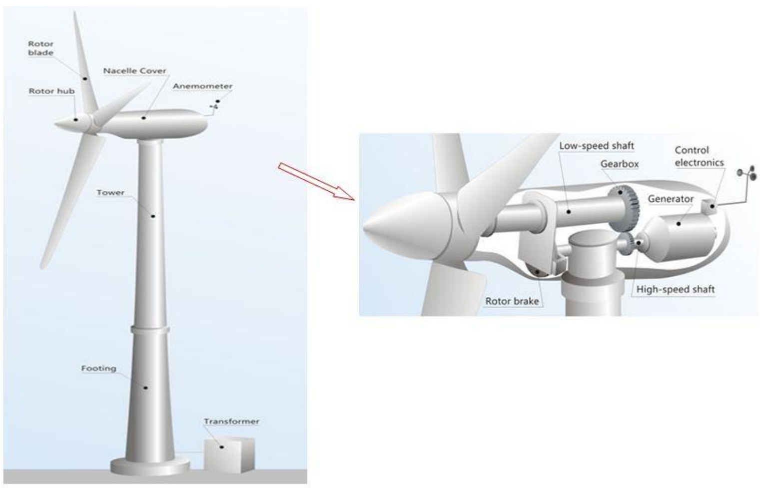
It’s a clean fuel source. Wind energy doesn't pollute the air like power plants that rely on combustion of fossil fuels, such as coal or natural gas, which emit particulate matter, nitrogen oxides, and sulfur dioxide—causing human health problems and economic damages.

Wind is a domestic source of energy. The nation's wind supply is abundant and inexhaustible. Over the past 10 years, cumulative wind power capacity in the United States increased an average of 30% per year.

It’s sustainable. Wind is actually a form of solar energy. Winds are caused by the heating of the atmosphere by the sun, the rotation of the Earth, and the Earth's surface irregularities. For as long as the sun shines and the wind blows.

Wind turbines components:

It includes critical mechanical components such as turbine blades and rotors, drive train and generators. They cost more than 30% of total capital expenditure for offshore wind project. In general, wind turbines are intended for relatively inaccessible sites placing some constraints on the designs in a number of ways. For offshore environments, the site may be realistically accessed for maintenance once per year.



Wind Turbine Generators:

One of limiting factors in wind turbines lies in their generator technology. There is no consensus among academics and industry on the best wind turbine generator technology.

Traditionally, there are three main types of wind turbine generators (WTGs) which can be considered for the various winds turbine systems, these being direct current (DC), alternating current (AC synchronous) and (AC asynchronous) generators. In principle, each can be run at fixed or variable speed. Due to the fluctuating nature of wind power, it is advantageous to operate the WTG at variable speed which reduces the physical stress on the turbine blades and drive train, and which improves system aerodynamic efficiency and torque transient behaviors.

(a) DC Generator Technologies:

In conventional DC machines, the field is on the stator and the armature is on the rotor. The stator comprises a number of poles which are excited either by permanent magnets or by DC field windings. If the machine is electrically excited, it tends to follow the shunt wound DC generator concept.

(b) AC Synchronous Generator Technologies:

AC synchronous WTGs can take constant or DC excitations from either permanent magnets or electromagnets and are thus termed PM synchronous generators (PMSGs) and electrically excited synchronous generators (EESGs), respectively. When the rotor is driven by the wind turbine, a three-phase power is generated in the stator windings which are connected to the grid through transformers and power converters. For fixed speed synchronous generators, the rotor speed must be kept at exactly the synchronous speed. Otherwise synchronism will be lost. Synchronous generators are a proven machine technology since their performance for power generation has been studied and widely accepted for a long time. PM generators have been gradually used in wind turbine applications due to their high-power density and low mass. Often these machines are referred to as the permanent magnet synchronous generators (PMSGs) and are considered as the machine of choice in small wind.

Axial and radial PM generator:

The structure of the generator is relatively straightforward. The rugged PMs are installed on the rotor to produce a constant magnetic field and the generated electricity is taken from the armature (stator) via the use of the commutator, sliprings or brushes. Sometimes the PMs can be integrated into a cylindrical cast aluminum rotor to reduce costs. The principle of operation of PM generators is similar to that of synchronous generators except that PM generators can be operated asynchronously. frequency and magnitude). It is also very attractive to use these permanent magnet machines for direct drive application. Obviously, in this case, they can eliminate troublesome gearboxes which cause the majority of wind turbine failures. The machines should have large pole numbers and are physically large than a similarly rated geared machine.

RPMG	APMG
Lower cost / torque	More costly
Lower toque / volume	High torque
eliminate troublesome	
easy construction	

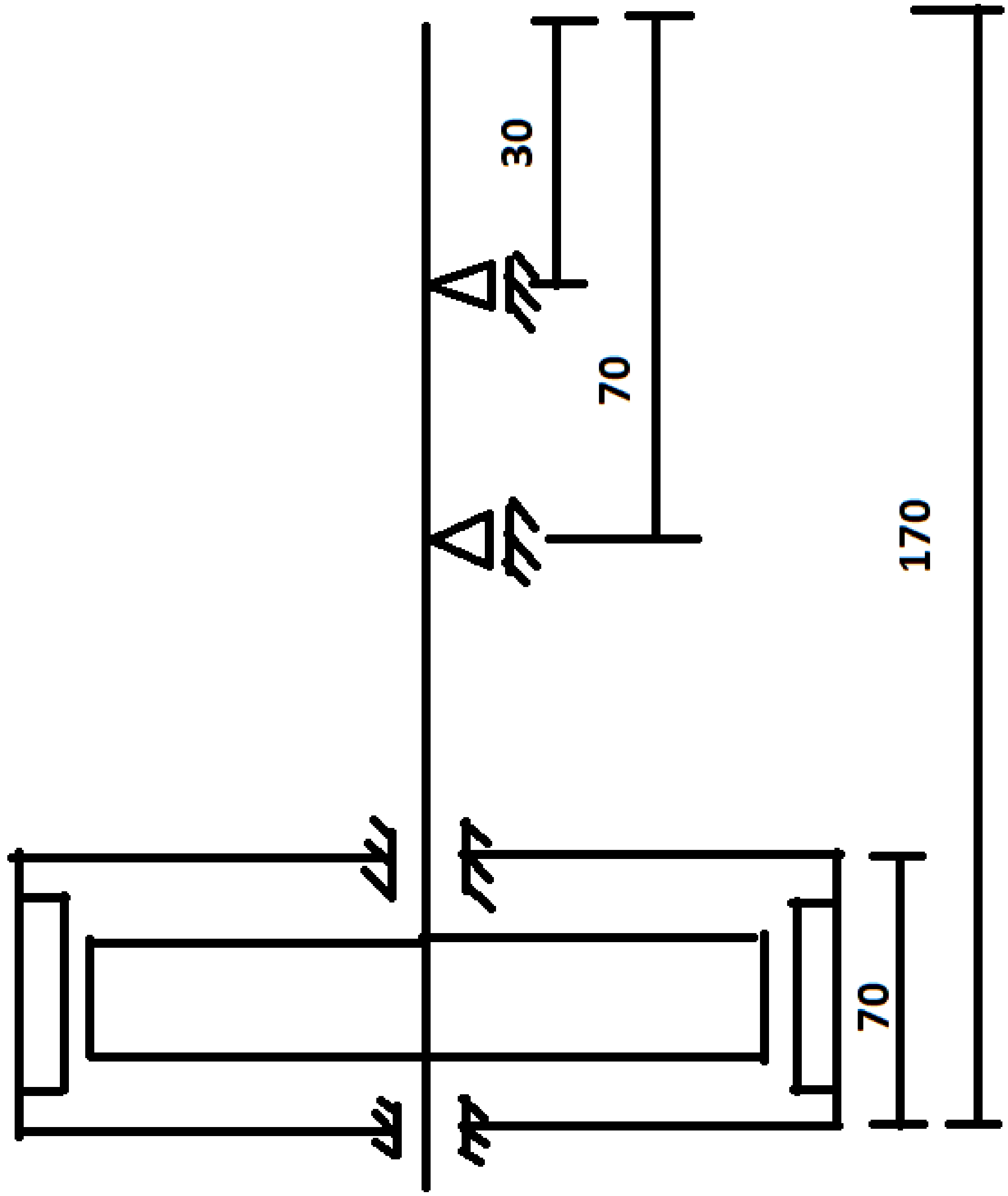
Design Considerations and Challenges:

Generally speaking, wind turbine generators can be selected from commercially available electrical machines with or without minor modifications. If a wind turbine design is required to match a specific site, some key issues should be taken into account.

These include:

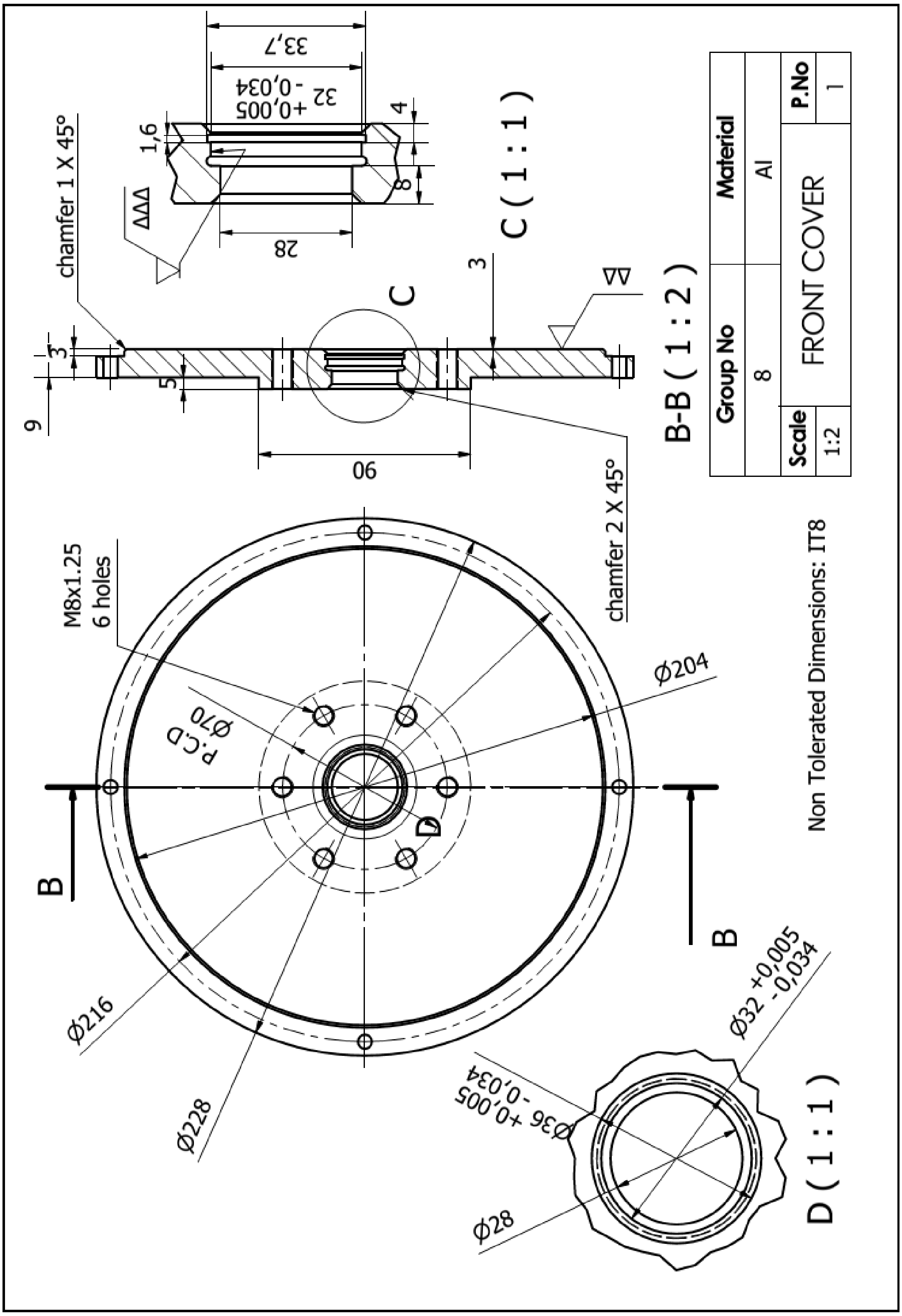
- Choice of machines.
- Power and current.
- Voltage regulation (synchronous generators).
- Methods of starting.
- Starting current (induction generators).
- Synchronizing (synchronous generators).
- Cooling arrangement.
- Power factor and reactive power compensation (induction generators).
- Power converter topology.
- Weight and size.
- Protection (offshore environment).
- Capital cost and maintenance.

Schematic:

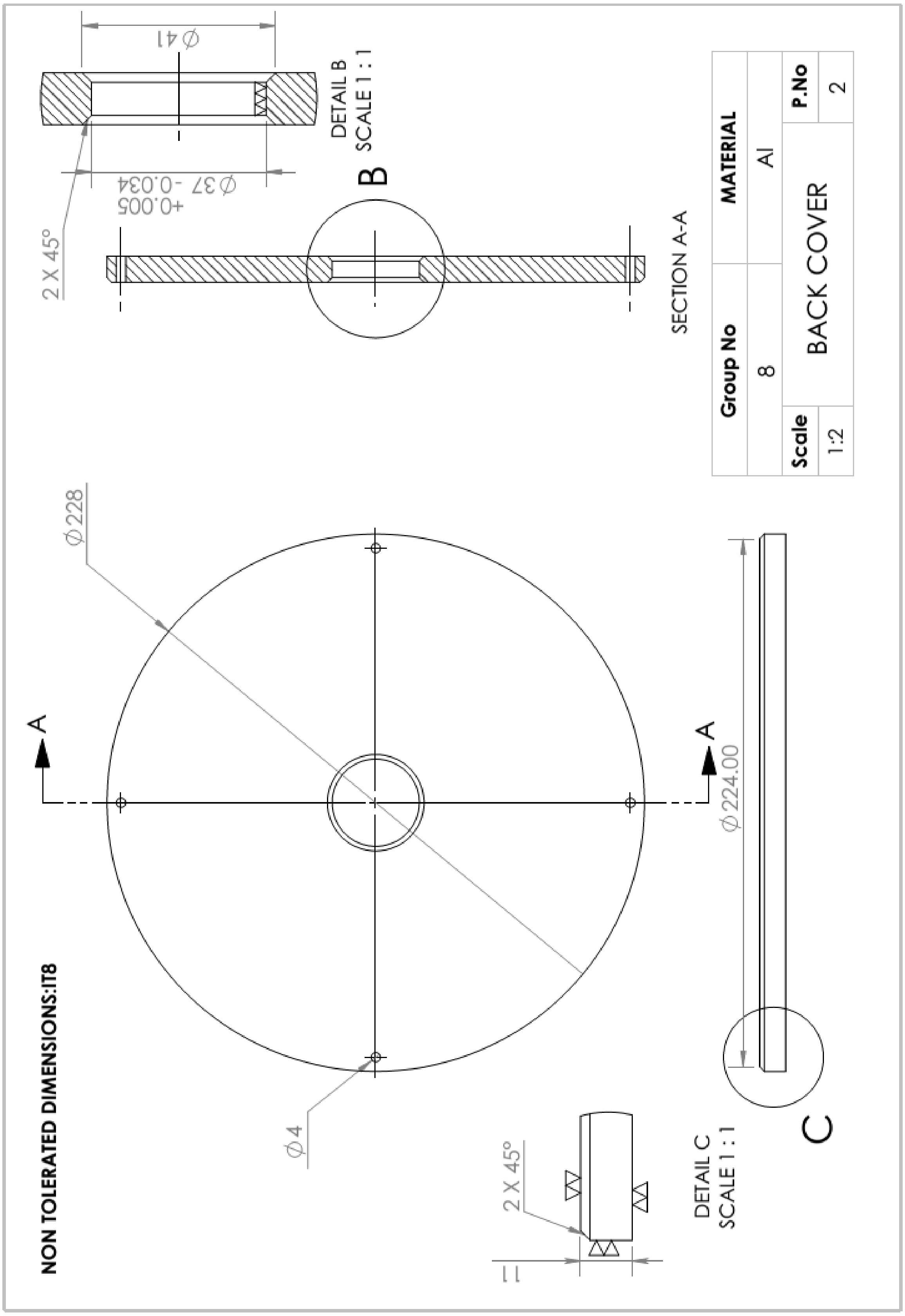


Working Drawings:

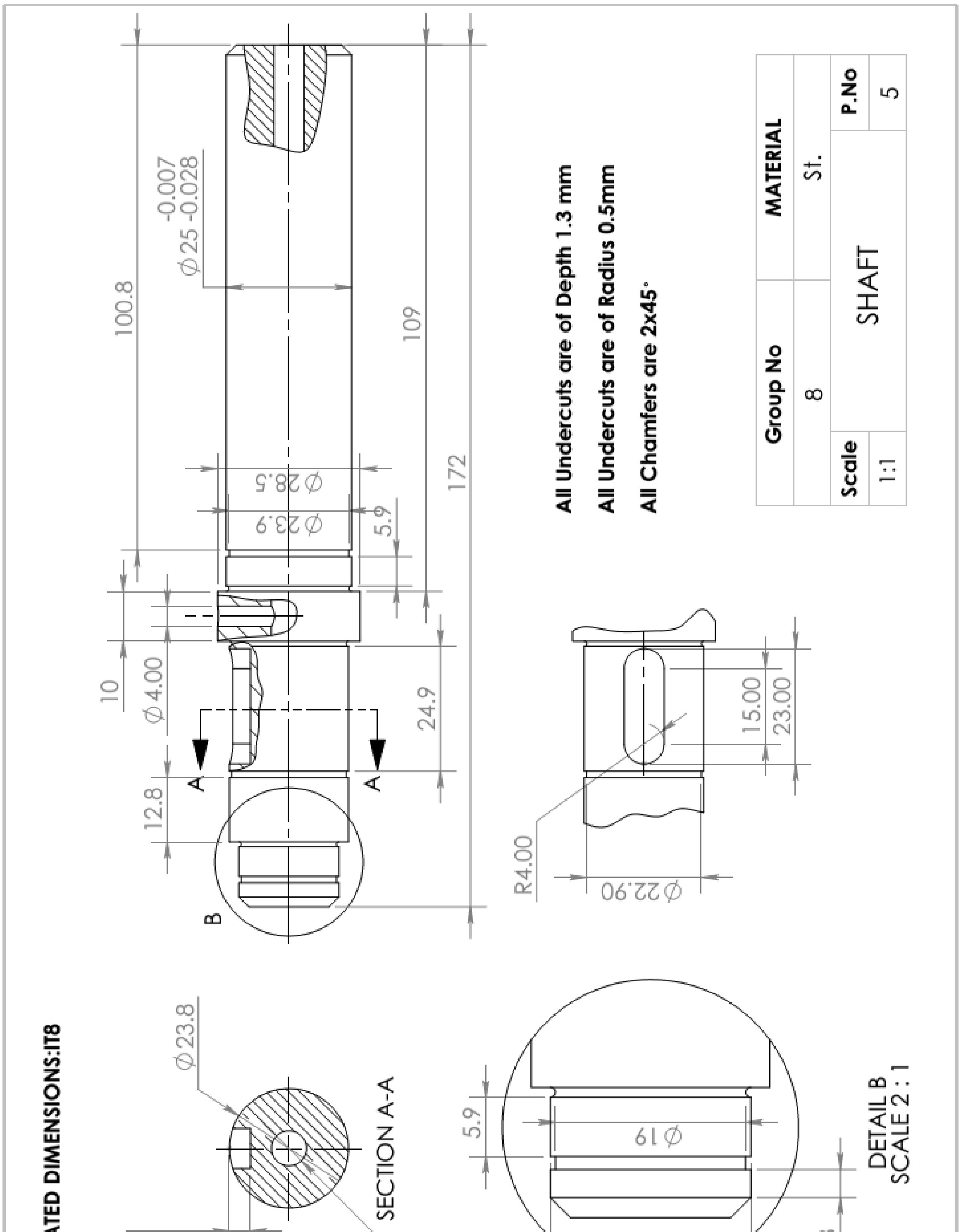
Front Cover:



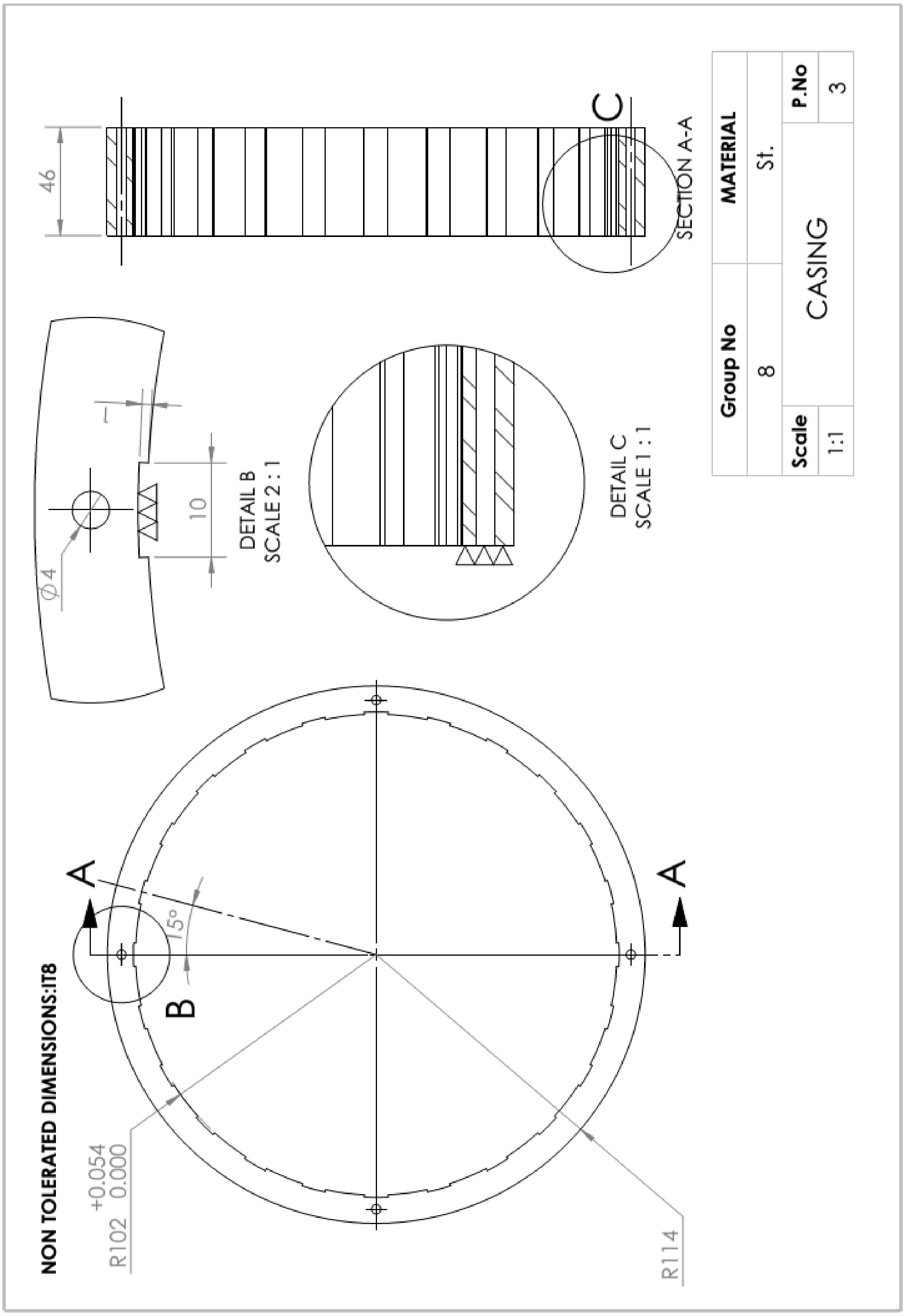
Back Cover:


NON TOLERATED DIMENSIONS:IT8
A
A
Ø228
Ø4
Ø224.00
C
DETAIL C
SCALE 1 : 1
2 X 45°
11
Ø41
Ø37 -0.034
+0.005
2 X 45°
DETAIL B
SCALE 1 : 1
B
SECTION A-A
Group No
8
MATERIAL
Al
BACK COVER
Scale
1:2
P.No
2

Shaft:

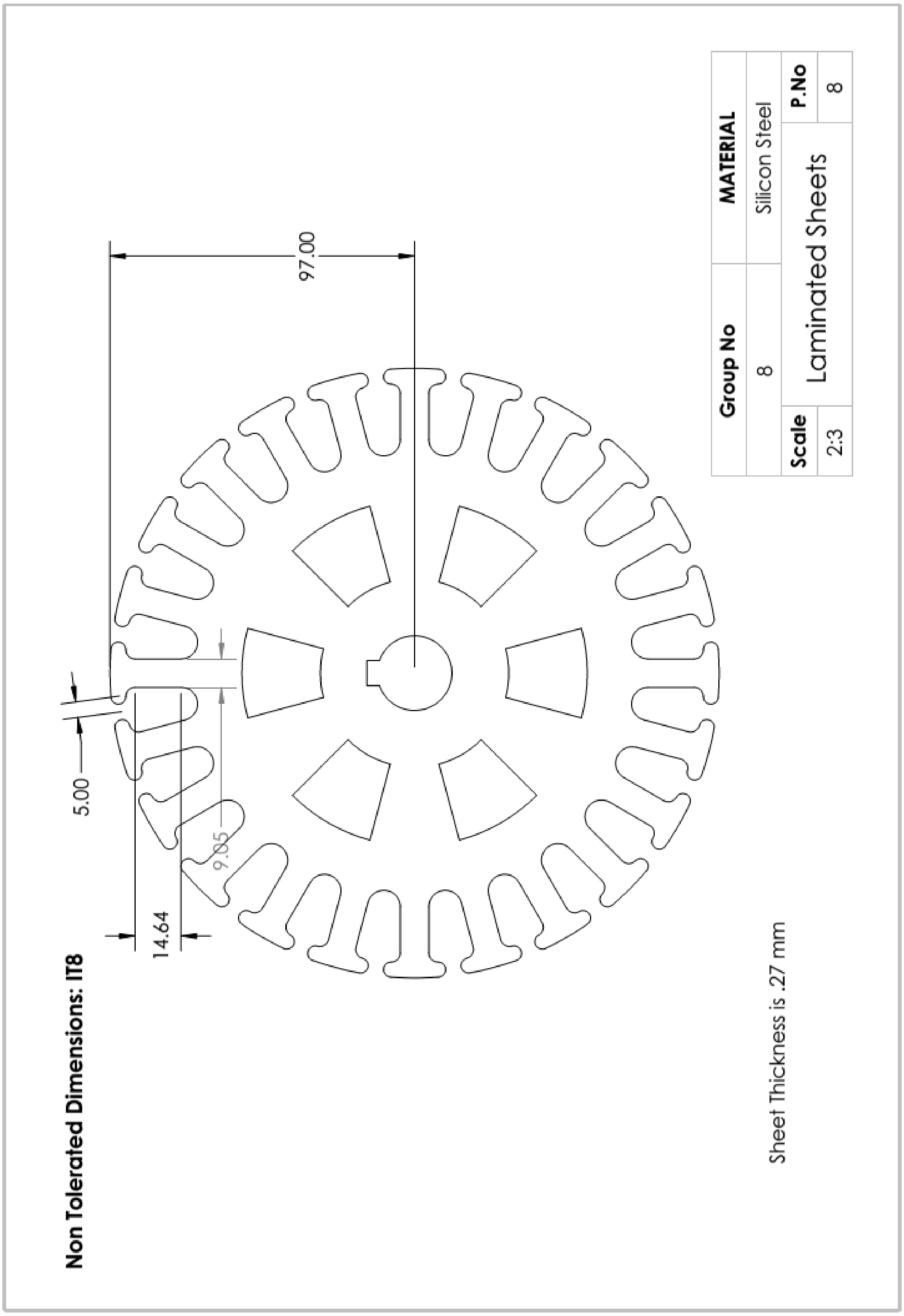

NON TOLERATED DIMENSIONS:IT8
All Undercuts are of Depth 1.3 mm
All Undercuts are of Radius 0.5mm
All Chamfers are 2x45°
SECTION A-A
DETAIL B
SCALE 2 : 1
Group No
8
MATERIAL
St.
SHAFT
Scale
1:1
P.No
5

Casing:

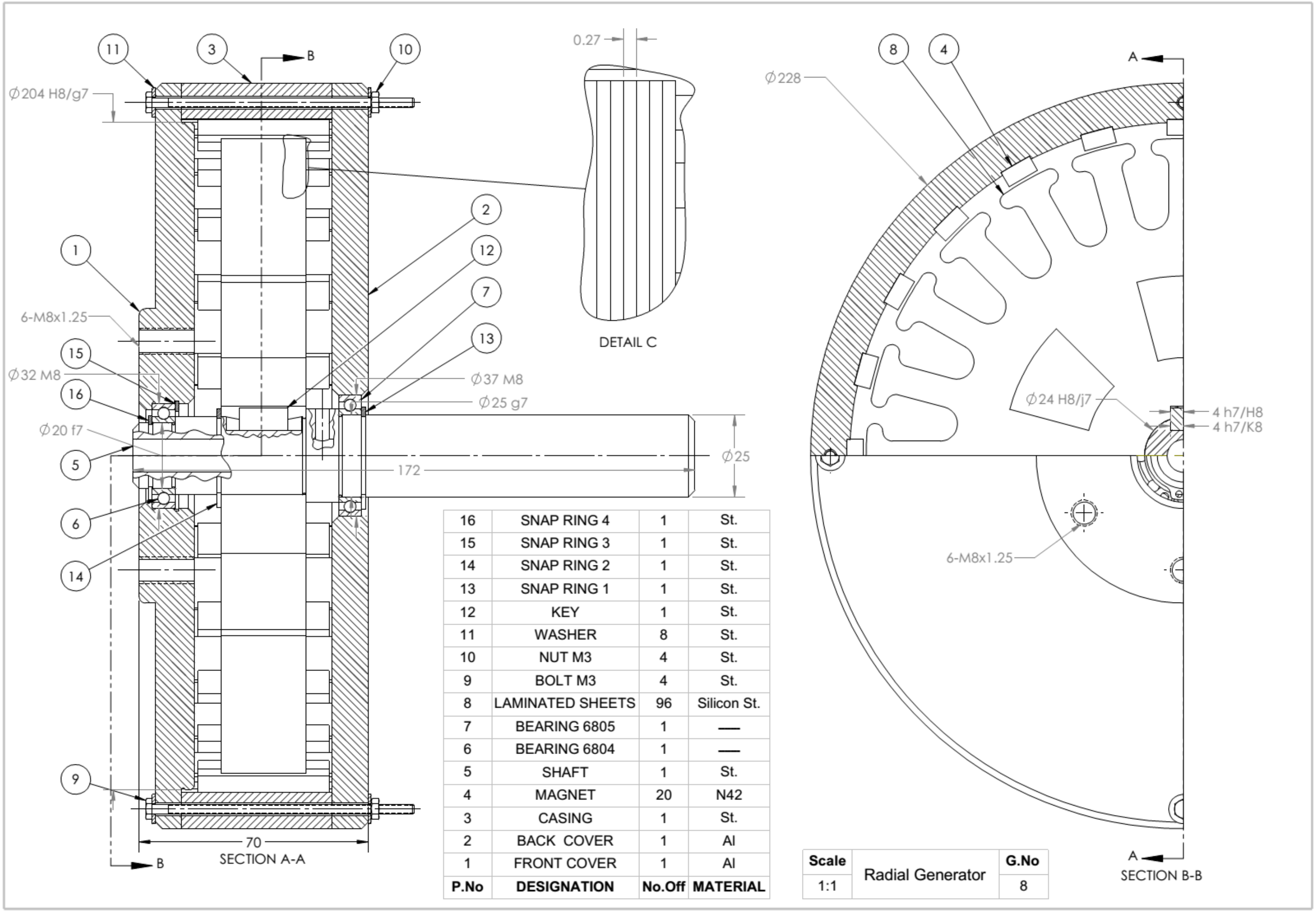


NON TOLERATED DIMENSIONS:IT8
R102 +0.054 0.000
R114
A
A
B
15°
Ø4
10
1
DETAIL B
SCALE 2 : 1
DETAIL C
SCALE 1 : 1
46
SECTION A-A
C
Group No
8
MATERIAL
St.
Scale
1:1
CASING
P.No
3

Laminated Sheets: [1]



Construction Drawing:



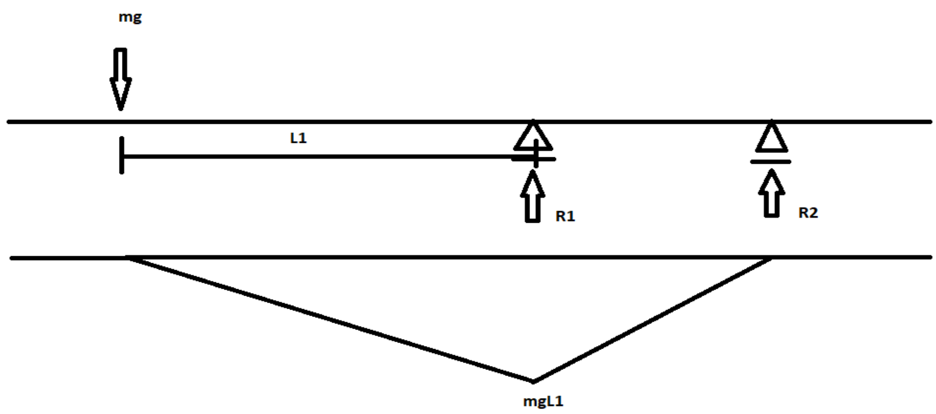
P.No	DESIGNATION	No.Off	MATERIAL
16	SNAP RING 4	1	St.
15	SNAP RING 3	1	St.
14	SNAP RING 2	1	St.
13	SNAP RING 1	1	St.
12	KEY	1	St.
11	WASHER	8	St.
10	NUT M3	4	St.
9	BOLT M3	4	St.
8	LAMINATED SHEETS	96	Silicon St.
7	BEARING 6805	1	—
6	BEARING 6804	1	—
5	SHAFT	1	St.
4	MAGNET	20	N42
3	CASING	1	St.
2	BACK COVER	1	Al
1	FRONT COVER	1	Al

Scale	Radial Generator	G.No
1:1		8

Note: To get more information about Manufacturing Process go to Appendix A.

Mechanical Analysis:

Bending Moment Diagram (BMD):



Stress Equations:

According to Shear Stress theory:

$$\tau_{max} \leq \tau_{a_{ll}}$$

$$\tau_{a_{ll}} = \frac{\tau_y}{n} = \frac{\sigma_y}{2n}$$

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Assumptions:

$$\sigma_y = 0$$

$$\tau_{xy} = 0$$

$$\tau_{max} = \frac{\sigma_x}{2}$$

$$\sigma_x = \frac{M_x}{I_x} y$$

$$M_x = mgL_1$$

$$I_x = \frac{\pi}{64}(D^4 - d^4)$$

$$\sigma_x \leq \frac{\sigma_y}{n}$$

$$\frac{k_b M_x}{I_x} \cdot \frac{D}{2} \leq \frac{\sigma_y}{n}$$

$$\frac{32k_b mgL_1 D}{\pi(D^4 - d^4)} \leq \frac{\sigma_y}{n}$$

Final Equation:

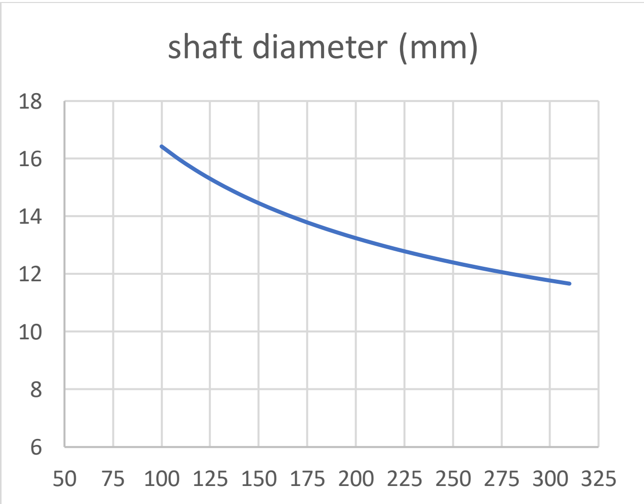
$$\pi\sigma_y D^4 - 32k_b ngL_1 mD - \pi\sigma_y d^4 \geq 0$$

Result Data:

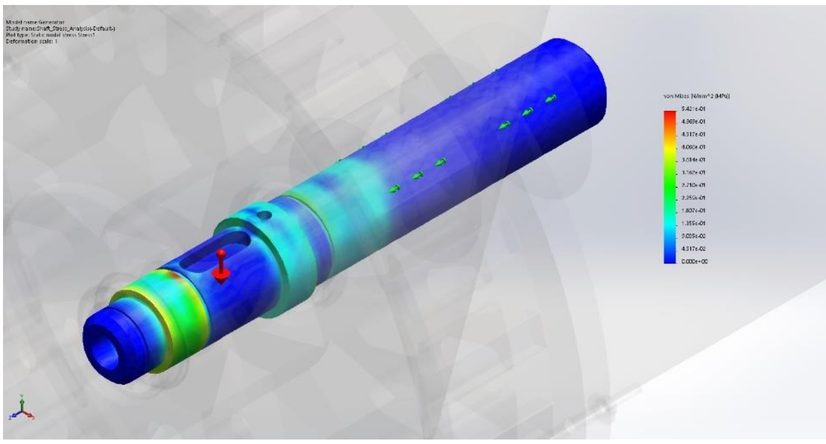
Substitute with parameters from table into the previous equation in GMC [2]:

Shaft data	Units
hole diameter	7mm
rotor mass	11 Kg
safety factor	3
distance from nearest fixation	6.5 Cm
Kb	2

σ (MPa)	shaft diameter (mm)
100	16.4252332
110	15.93498736
120	15.50272717
130	15.11773346
140	14.77190525
150	14.458985
160	14.17404806
170	13.91315568
180	13.67311298
190	13.45129613
200	13.24552641
210	13.05397684
220	12.87510179
230	12.70758318
240	12.55028878
250	12.40223957
260	12.26258387
270	12.13057661
280	12.00556267
290	11.88696326
300	11.77426477
310	11.66700955



Stress Analysis on SolidWorks:



Note: To get more information about Parts' Material go to Appendix B.

Electrical Analysis:

Electrical Equations:

$$v_c = N_t \frac{d\phi}{dt}$$

1

$$\emptyset = \emptyset_{max} \sin(wt)$$

2

$$v_c = N_T \emptyset_{max} \mathrm{w}\cos(wt)$$

3

$$f = \frac{n_s p}{120}$$

4

$$v_{c_{rms\ max}} = \frac{\pi n_s p}{60\sqrt{2}} N_T \emptyset_{max}$$

5

$$\phi = BA$$

$$v_g = \frac{N_c}{N_P}$$

Since single phase generator:

$$N_c = p$$

$$v_g = \frac{\pi n_s p^2}{60\sqrt{2} N_P} N_T BA$$

$$N_T = \frac{60\sqrt{2}}{\pi \mathrm{BA} n_s p^2} v_g N_P$$

6

$i = \frac{P}{v_g}$ $\qquad$ $N_P = \frac{i}{i_{wire}}$ $\qquad$ $N_P = \frac{P}{i_{wire} v_g}$

$$P = \frac{i_{wire} \pi \mathrm{BA} n_s p^2 N_T}{60\sqrt{2}}$$

7

$$N_c = N_P N_s$$

Variables:

N_T = 40 turn

N_p = 4

N_s = 6

i_{wire} = 3A

i = 12A

B = 1.32T

Speed of rotation	n_s= 500 rpm	n_s= 700 rpm
Power (P)	1246watt	1744watt

Power losses:

- ### Copper losses:

Copper losses = i^2R

L_{wire}= 150m

Solid Conductor Size (AWG/kcmil)	BARE HARD-DRAWN		BARE MEDIUM-HARD		BARE ANNEALED (SOFT)		TINNED ANNEALED (SOFT)	
	ohms per 1000 ft	ohms per km	ohms per 1000 ft	ohms per km	ohms per 1000 ft	ohms per km	ohms per 1000 ft	ohms per km
4/0	0.0504	0.166	0.0502	0.165	0.0490	0.161	0.0502	0.165
3/0	0.0636	0.209	0.0633	0.206	0.0618	0.203	0.0633	0.208
2/0	0.0802	0.263	0.0798	0.262	0.0779	0.256	0.0798	0.262
1/0	0.1022	0.335	0.1016	0.334	0.0983	0.322	0.1006	0.330
1	0.1289	0.423	0.1282	0.421	0.1239	0.407	0.1275	0.419
2	0.1625	0.533	0.1617	0.531	0.1563	0.513	0.1609	0.528
3	0.2050	0.672	0.2039	0.669	0.1971	0.647	0.2028	0.667
4	0.2584	0.848	0.2571	0.843	0.2485	0.815	0.2557	0.839
5	0.3260	1.070	0.3243	1.060	0.3135	1.030	0.3226	1.060
6	0.4110	1.350	0.4088	1.340	0.3952	1.300	0.4067	1.330
7	0.5180	1.700	0.5153	1.690	0.4981	1.630	0.5126	1.680
8	0.6538	2.140	0.6498	2.130	0.6281	2.060	0.6465	2.120
9	0.8241	2.700	0.8199	2.690	0.7925	2.600	0.8156	2.680
10	1.0390	3.410	1.0330	3.390	0.9988	3.280	1.0390	3.410
11	1.3100	4.300	1.3000	4.280	1.2600	4.140	1.3100	4.300
12	1.6500	5.420	1.6400	5.390	1.5900	5.210	1.6500	5.420
13	2.0800	6.840	2.0700	6.770	2.0000	6.590	2.0800	6.840
14	2.6300	8.940	2.6100	8.580	2.5200	8.270	2.6300	8.640
15	3.3140	10.900	3.2900	10.800	3.1800	10.400	3.3100	10.900
16	4.1800	13.700	4.1600	13.700	4.0200	13.100	4.1800	13.700

R_{Wire} = 3.2 ohm

Copper power loss = 29 watt

- Core losses:

$$P_{Fe} = K_{khysteresis} B_{max}^2 f + K_{eddy} (B_{max} f)^2 + K_{excess} (B_{max} f)^{\frac{3}{2}}$$

Optimal speed (r/min)	Input power (W)	Output power (W)	Loss (W)	Efficiency (%)
612.60	1058.50	183.40	875.10	17.33
806.70	1209.20	399.55	809.65	33.04
1002.90	1287.30	591.30	696.00	45.93
1195.20	1381.10	796.18	584.92	57.65
1402.40	1514.30	1000.16	514.14	66.05
1604.20	1662.70	1241.73	420.97	74.68
2009.90	1895.20	1465.20	430.00	77.31
2009.90	1995.30	1562.32	432.98	78.30

Efficiency $\cong 35$ %

Useful power and voltage:

$$P_{useful} = P\eta - P_{COPPER\ LOSS}$$

	n_s= 500 rpm	n_s= 700 rpm
Power (P)	407watt	581.4watt
Voltage (v)	33volt	48volt

Minimum load capacity:

$$\frac{v_{max}}{i} = \frac{48}{12} = 4\text{ohm}$$

Note: To avoid short circuit, Use load capacity with 100 ohms.

References:

[1] "Chapter4: Lamination Field and Housing Geometry," in *Handbook of Small Electric Motors*, New York, McGraw-Hill, 2001, pp. 497-509.

[2] "GMC:Program created specially to calculate Shaft diameter for RPMSG Project," Group 8, Sec.2, Egypt, 2019.

Effort Sheet:

Name	Percentage
Ahmed Wael Ahmed	17.6 %
Ahmed Mohamed Hesham	17.1 %
Alaa Tarek Mohamed	16.42 %
Omnia Ahmed Mohamed	16.4 %
Ahmed Mohamed Ghazali	16.26 %
Ahmed Mostafa Ahmed	16.22 %

Appendix A:

MANUFACTURING PROCESSES:

1st: CASING:

1- Facing process (turning on center lathe)>>>
as shown in fig 1.

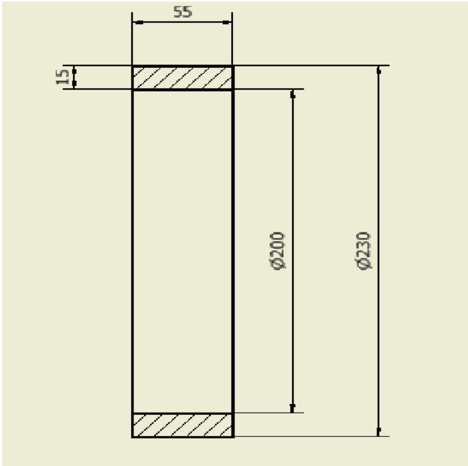


Fig 1

2- Parting off >>>
As shown in fig 2

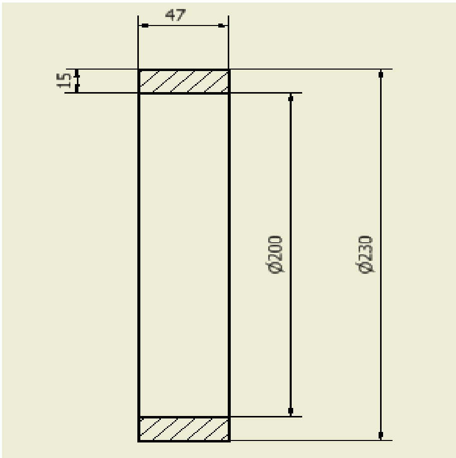


Fig 2

3- Internal turning by 1 mm
and External turning by 2 mm on center lathe >>>
as shown in fig 3

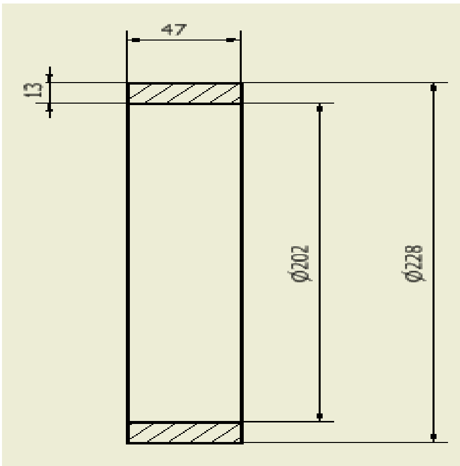


Fig 3

4- Slotting on slotter shaping machine>>>
As shown in fig 4

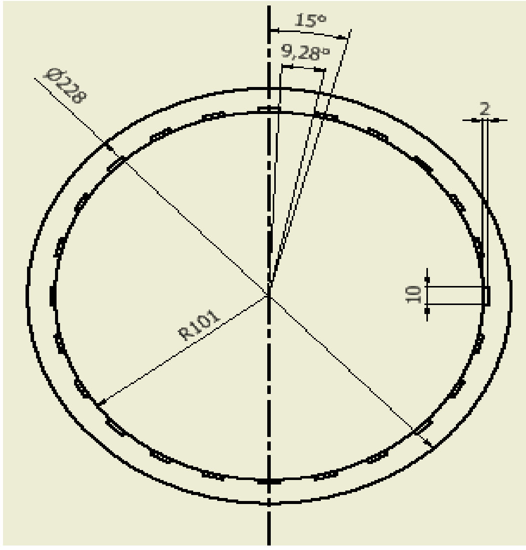
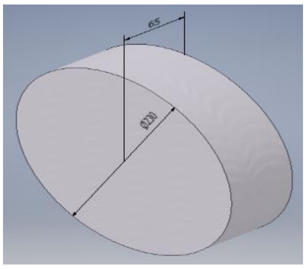


Fig 4

2nd: COVERS:



A- External turning from 230 to 228 >>>
As shown in fig 5

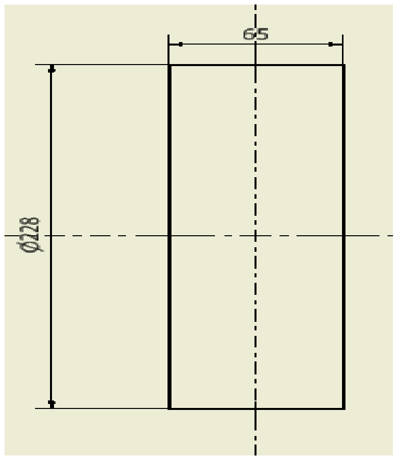


Fig 5

B- Parting off at height 40 mm>>>
As shown in fig 6

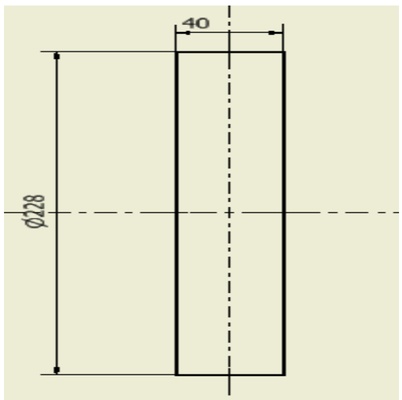


Fig 6

C- Drilling a Ø28 hole>>>
As shown in fig 7

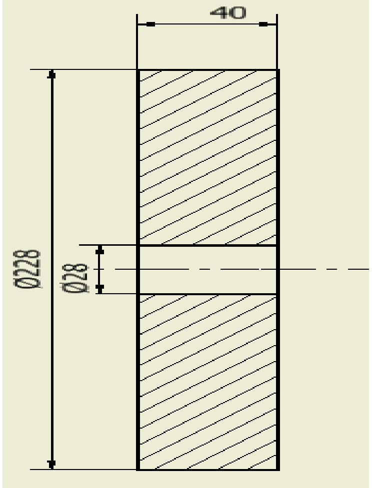
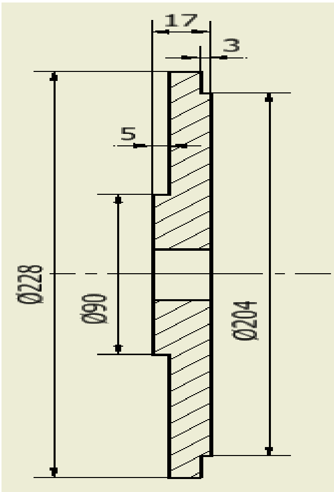
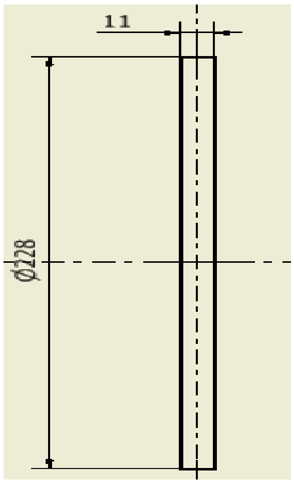
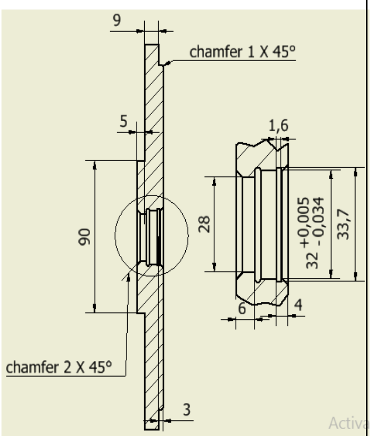
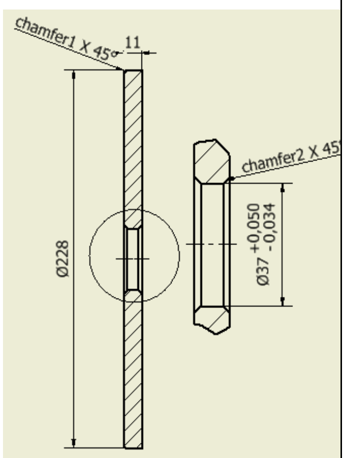
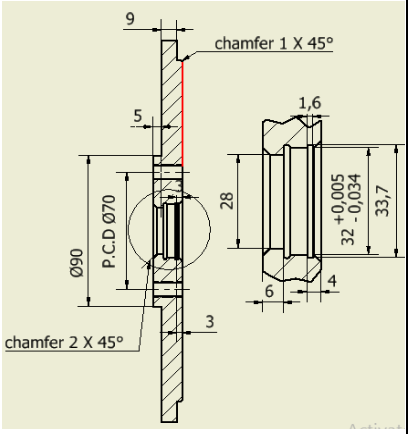
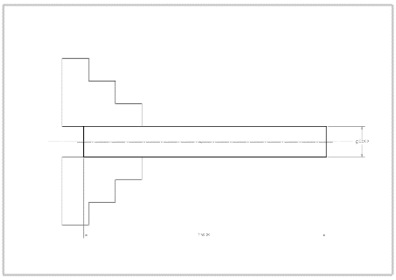


Fig 7

1st Front Cover	**2nd Back Cover**
1) External turning >>> 	1- External turning from 20 to 11 mm>>> As shown 
2) Internal turning>>> 	2- drilling turning on center lathe>>> as shown. 

3) Drilling 6 holes M8*1.25 at PCD Ø70>>> 	

3rd: SHAFT:



1) The shaft will be grabbed by 3-jaw chuck in normal position from one of its ends.
2) Facing the other end of the shaft
3) Longitudinal turning till the shaft reach Ø28.5 from Ø32
4) Longitudinal turning from the other end to 109mm till it reach Ø25
5) Grooving of a=1.3mm and f=0.55mm from 100.8mm of the other end
6) From 108mm of the other end, grooving of R=0.5mm and f=0.5mm
7) Chamfering the other end with 2*45°
8) Longitudinal turning from 119mm of the other end to the end of the shaft till it reach Ø23.8
9) Grooving of R=0.5mm and f=0.5mm from 119 of the other ends
10) Grooving of a=1.3mm and f=0.45mm from 144.9mm of the other end
11) Longitudinal turning from159 mm of the other end to the end of the shaft till it reach Ø20
12) Grooving of R=0.5mm and f=0.5mm from 159mm of the other end
13) Grooving of a=1.3mm and f=0.5mm from 165.9mm of the other end
14) Chamfering 2*45° from 170mm of the other end
15) Parting off from 172mm

a: Depth of cut
f: Feed
R: Radius
Ø: Diameter

COST:

Part	Row Material	Dimensions (in mm)	Cost	Material	Weight
Casing		Ø230 , t=15 h=60	70 L.E	Steel	5kg
Shaft		Ø230 * Ø 7 , L=250	40 L.E	Steel 37	1.5 kg
Cover		Ø230 , h=65	240 L.E	AL	7 kg

Bearing		20*32 25*37	20 L.E 20 L.E		1 piece 1 piece
Magnet		40*10*5	865 L.E	N42	30 pieces

Appendix B Material:

1-Shaft material (st.37)

Source: Roberto Leon, Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, VA

The importance of materials to human development is clearly captured by the early classifications of world history into periods such as the Stone Age, Iron Age, and the Bronze Age. The introduction of the Siemens and Bessemer processes to produce steels in the mid-1800s is arguably the single most important development in launching the Industrial Revolution that transformed much of Europe and the USA in the second half of the 19th century from agrarian societies into the urban and mechanized societies of today. Steel, in its almost infinite variations, is all around us, from our kitchen appliances to cars, to lifelines such as electrical transmission networks and water distribution systems. In this experiment we will look at the stress-strain behavior of two types of steel that bound the range usually seen in civil engineering applications - from a very mild, hot rolled steel to a hard, cold rolled one.

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Jove Science Education Database. Structural Engineering. Stress-Strain Characteristics of Steels Jove, Cambridge, MA, (2019).

PRINCIPLES

The term steel is commonly used to denote a material that is principally iron (Fe), often in the 95% to 98% range. Pure iron is allotropic, with a body-centered cubic (BCC) structure at room temperature that changes into a face-centered cubic (FCC) structure above 912°C. The empty spaces in the FCC structure and imperfections in the crystal structure allow for other atoms, such as carbon (C) atoms, to be added or removed through diffusion from the interstitial (or empty) spaces. These additions, and the subsequent development of different crystal structures, are the result of heating and cooling at different rates and temperature ranges, a process known as heat treatment. This technology has been known for over 2000 years but kept secret for many years in applications such as Damascus steel, which utilized Wootz steel from India (≈300AD).

If we expand the open circles in the FCC structure until the spheres begin to touch, and then cut a basic cube for this atomic structure, the result is the unit cell. Spheres with 41.4% of the iron atom diameter can be added before these new spheres begin to touch the iron ones. Carbon atoms are 56% of the diameter of iron ones, so the new structure becomes distorted as carbon atoms are introduced. The properties of steel can be manipulated by changing the size, frequency, and distribution of these distortions.

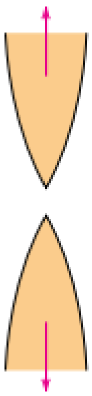
Wrought iron, one of the most useful predecessors of steel, has a carbon content of more than 2%. It turns out that the optimum carbon content for steels from civil applications is the range of 0.2% to 0.5%. Many of the early metallurgical treatment process were aimed at bringing carbon contents to these levels in volumes that were economical to produce. The Bessemer process in the USA and the Siemens process in the UK are two of the more successful examples of those early techniques. The processes most commonly used today are the electric arc furnace and the basic oxygen furnace. In addition to carbon, most modern steels contain manganese (Mn), chromium (Cr), molybdenum (Mo), copper (Cu), nickel (Ni), and other metals in small amounts to improve strength, deformability, and toughness. A simple example of the effect of these alloys on engineering properties is the so-called carbon equivalent (CE):

Equation 1

The CE is a useful index in determining the weldability of a particular steel; typically, a CE < 0.4% is representative of a steel that is weldable. As many connections in metal structures are made by welding, this is a useful index to remember when specifying materials for construction.

As noted in the JoVE video regarding "Material Constants”, for modeling purposes we need to establish some relationship between stress and strains. The best simple description of the behavior of many materials is given by a stress strain curve (Fig.1). As a result of problems with buckling when loading in compression and difficulties in loading a material uniformly in more than one direction, a uniaxial tensile test is usually run to determine a stress-strain curve. This test provides basic information on the main engineering characteristics primarily of homogeneous metallic materials.

The typical tension test is described by ASTM E8. ASTM E8 defines the type and size of test specimen to be used, typical equipment to be used, and data to be reported for a metal tension test



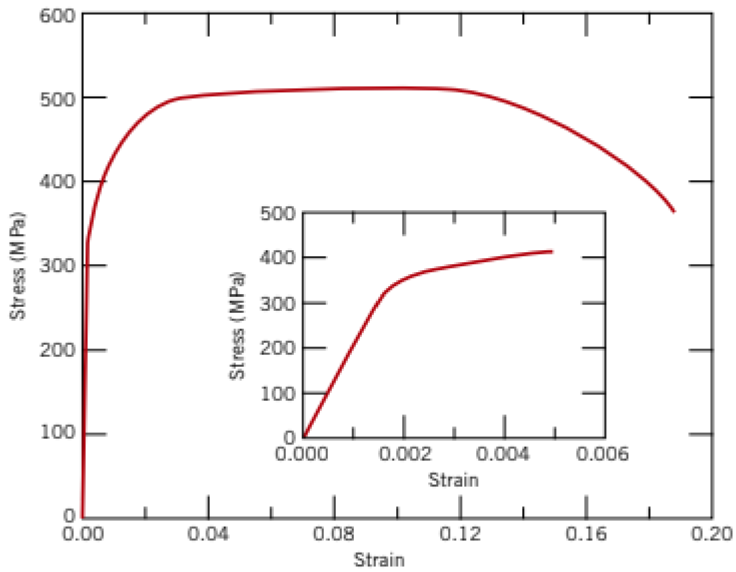


Figure 1. tensile stress-strain behavior for a steel

Material	*Modulus of Elasticity (GPa)*	*Yield Strength (MPa)*	*Poisson's Ratio*
Aluminum alloy	70	200	0.33
Brass alloy	101	300	0.34
Steel alloy	207	400	0.30
Titanium alloy	107	650	0.34

Table1.

2-casing (st.37)

Magnetism, the phenomenon by which materials assert an attractive or repulsive

force or influence on other materials, has been known for thousands of years. However, the underlying principles and mechanisms that explain the magnetic phenomenon are complex and subtle, and their understanding has eluded scientists until

relatively recent times. Many of our modern technological devices rely on magnetism and magnetic materials; these include electrical power generators and transformers, electric motors, radio, television, telephones, computers, and components

of sound and video reproduction systems.

Iron, some steels, and the naturally occurring mineral lodestone are well-known examples of materials that exhibit magnetic properties. Not so familiar, however, is the fact that all substances are influenced to one degree or another by the presence of a magnetic field.This chapter provides a brief description of the origin of magnetic fields and discusses the various magnetic field vectors and magnetic parameters; the phenomena of diamagnetism, paramagnetism, ferromagnetism, and ferrimagnetism; some of the different magnetic materials; and the phenomenon of superconductivity.

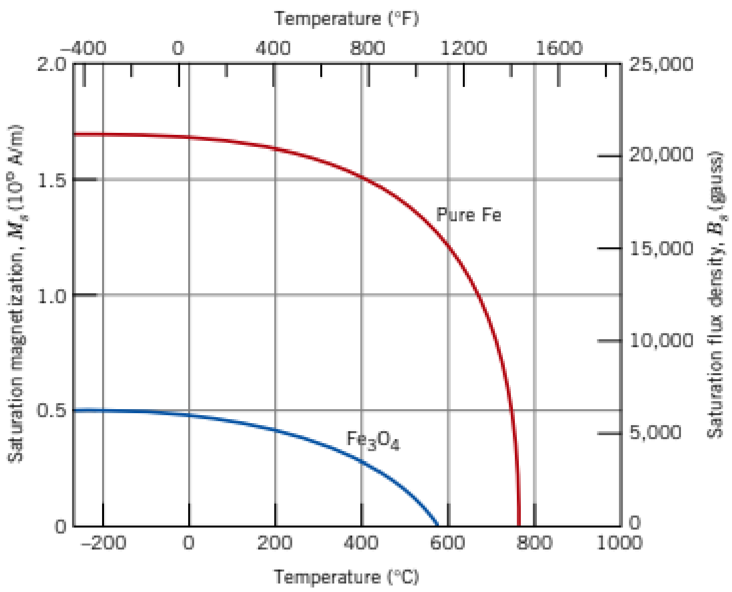


Figure 2.

grow at the expense of those that are unfavorably oriented (insets V through X). This process continues with increasing field strength until the macroscopic specimen becomes a single domain, which is nearly aligned with the field (inset Y). Saturation is achieved when this domain, by means of rotation, becomes oriented with the H

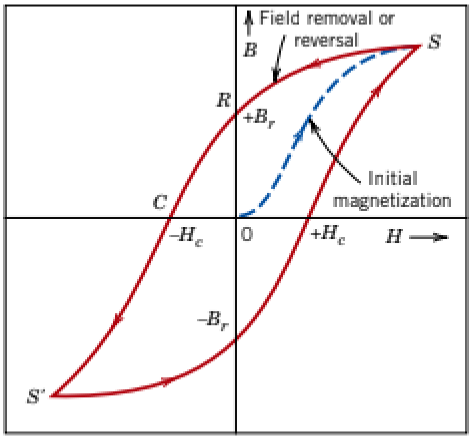


figure 3.

field (inset Z).

From saturation, point S in Figure 20.14, as the H field is reduced by reversal of field direction, the curve does not retrace its original path. A hysteresis effect is produced in which the B field lags behind the applied H field, or decreases at a lower rate. At zero H field (point R on the curve), there exists a residual B field

that is called the remanence, or remanent flux density, Br, the material remains magnetized in the absence of an external H field.

Hysteresis behavior and permanent magnetization may be explained by the motion of domain walls. Upon reversal of the field direction from saturation (point S

in Figure 20.14), the process by which the domain structure changes is reversed.

First, there is a rotation of the single domain with the reversed field. Next, domains having magnetic moments aligned with the new field form and grow at the

expense of the former domains. Critical to this explanation is the resistance to

movement of domain walls that occurs in response to the increase of the magnetic field in the opposite direction; this accounts for the lag of B with H, or the hysteresis. When the applied field reaches zero, there is still some net volume fraction of domains oriented in the former direction, which explains the existence of

the remanence Br.

To reduce the B field within the specimen to zero (point C on Figure 20.14), an H field of magnitude Hc must be applied in a direction opposite to that of the

original field; Hc is called the coercivity, or sometimes the coercive force. Upon continuation of the applied field in this reverse direction, as indicated in the figure, saturation is ultimately achieved in the opposite sense, corresponding to point S. A

second reversal of the field to the point of the initial saturation (point S) completes the symmetrical hysteresis loop and also yields both a negative remanence (Br) and a positive coercivity (Hc).

The B-versus-H curve in Figure 20.14 represents a hysteresis loop taken to saturation. Of course, it is not necessary to increase the H field to saturation before

reversing the field direction; in Figure 20.15, loop NP is a hysteresis curve corresponding to less than saturation. Furthermore, it is possible to reverse the direction

3-magnet

Data sheet article Q-40-10-05-N Technical data and application safety

Webcraft GmbH Industriepark 206 78244 Gottmadingen, Germany

Phone: +49 7731 939 839 2 www.supermagnete.de support@supermagnete.de

1. Technical information Article ID Q-40-10-05-N EAN 7640155436441 Material NdFeB Shape Block Size 40 x 10 x 5 mm Side 1 40 mm Side 2 10 mm Side 3 5 mm Pole faces 40 x 10 mm Tolerance +/- 0,1 mm Direction of magnetisation Axis 5 mm Coating Nickel-plated (Ni-Cu-Ni) Manufacturing method sintered Magnetisation N42 Strength approx. 9,5 kg (approx. 93,2 N) Max. working temperature 80°C (possibly lower) * Weight 15,2000 g Curie temperature 310 °C Residual magnetism Br 12900-13200 G, 1.29-1.32 T Coercive field strength bHc 10.8-12.0 kOe, 860-955 kA/m Coercive field strength iHc ≥12 kOe, ≥955 kA/m Energy product (BxH)max 40-42 MGOe, 318-334 kJ/m³

40 mm5 mm 10 mm

* Based on the dimensions it is possible that this magnet has a reduced temperature resistance. Please review our FAQ: https://www.supermagnete.de/eng/faq/What-temperatures-can-magnets-withstand#pu424

Pollutant-free according to RoHS Directive 2011/65/EU.

2. Safety tips Warning Pacemaker Magnets could affect the functioning of pacemakers and implanted heart defibrillators. •A pacemaker could switch into test mode and cause illness. •A heart defibrillator may stop working. •If you wear these devices keep sufficient distance to magnets: www.supermagnete.de/eng/faq/distance •Warn others who wear these devices from getting too close to magnets.

Data sheet article Q-40-10-05-N Page 1 of 3 www.supermagnete.de

Warning Heavy objects Too heavy loads, symptoms of fatigue as well as material defect could cause a magnet or magnetic hook to loosen from the surface that is was attached to. Falling objects could lead to serious injuries. •The indicated adhesive force applies only to ideal conditions. Allow for a high safety cushion. •Don't use magnets in places where people could sustain injuries in case of material failure.

Warning Metal splinters Neodymium magnets are brittle. Colliding magnets could crack. Sharp splinters could be catapulted away for several meters and injure your eyes. •Avoid the collision of magnets. •Wear safety glasses when handling larger magnets. •Make sure that nearby people are also protected or keep their distance.

3. Handling and storing Caution Magnetic field Magnets produce a far-reaching, strong magnetic field. They could damage TVs and laptops, computer hard drives, credit and ATM cards, data storage media, mechanical watches, hearing aids and speakers. •Keep magnets away from devices and objects that could be damaged by strong magnetic fields. •Please refer to our table of recommended distances: www.supermagnete.de/eng/faq/distance

Caution Combustibility When machining magnets, the drilling dust could easily ignite. Stay away from machining magnets or use appropriate tools and sufficient cooling water.

Caution Nickel allergy Many of our magnets contain nickel, also those without nickel coating. •Some people have an allergic reaction when they come into contact with nickel. •Nickel allergies could develop from perpetual contact with nickel-plated objects. •Avoid perpetual skin contact with magnets. •Avoid contact with magnets if you already have a nickel allergy.

Notice Influence on people According to the current level of knowledge, magnetic fields of permanent magnets do not have a measurable positive or negative influence on people. It is unlikely that permanent magnets constitute a health risk, but it cannot be ruled out entirely. •For your own safety, avoid constant contact with magnets. •Store large magnets at least one metre away from your body.

Notice Splintering of coating Most of our neodymium magnets have a thin nickel-copper-nickel coating to protect them from erosion. This coating could splinter or crack due to collision or large pressure. This makes them vulnerable to environmental influences like moisture and they could oxidise. •Separate big magnets, especially spheres, with a piece of cardboard. •Avoid collisions of magnets as well as repeated mechanical exposure (e.g. blows, bashes).

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Notice Oxidation, corrosion, rust Untreated neodymium magnets oxidise quickly and disintegrate. Most of our magnets have a nickel-copper-nickel coating to protect them from corrosion. This coating provides some protection against corrosion, but it is not robust enough for continuous outdoor use. •Use magnets only in the dry indoors or protect them against environmental influences. •Avoid damages to the coating.

Notice Temperature resistance Neodymium magnets have a maximum working temperature of 80 to 200°C. Most neodymium magnets lose part of their adhesive force permanently at a temperature of 80°C. •Don't use magnets in places where they are exposed to extreme heat. •If you use an adhesive, don't harden it with hot air.

Notice Mechanical treatment Neodymium magnets are brittle, heat-sensitive and oxidise easily. •When drilling or sawing a magnet with improper tools, the magnet may break. •The emerging heat may demagnetise the magnet. •The magnet will oxidise and disintegrate due to the damaged coating. Stay away from mechanical treatment of magnets if you do not possess the necessary equipment and experience.

4. Transportation tips Caution Airfreight Magnetic fields of improperly packaged magnets could influence airplane navigation devices. In the worst case it could lead to an accident. •Airfreight magnets only in packaging with sufficient magnetic shielding. •Please refer to the respective regulations: www.supermagnete.de/eng/faq/airfreight

Caution Postage Magnetic fields of improperly packaged magnets could cause disturbances in sorting machines and damage fragile goods in other packages. •Please refer to our shipping tips: www.supermagnete.de/eng/faq/shipping •Use a large box and place the magnet in the middle surrounded by lots of padding material. •Arrange magnets in a package in a way that the magnetic fields neutralise each other. •If necessary, use sheet iron to shield the magnetic field. •There are stricter rules for airfreight: Refer to the warning notice "Airfreight".

5. Disposal tips Small amounts of used neodymium magnets can be thrown out with the regular trash. Larger amounts of magnets need to be recycled as scrap metal. 6. Statutory

provisions Neodymium magnets are not intended for sale/export to the United States of America, Canada or Japan. You are strictly prohibited from directly or indirectly exporting the neodymium magnets that you received from us or the end products that you produced from those magnets to the countries mentioned above.

TARIC-Code: 8505 1100 65 0 Origin: China

For more information about magnets please review www.supermagnete.de/faq.php.

4-laminated sheet (silicon steel)

1. Introduction

Cold rolled grain oriented electrical silicon steel coils, delivered after a final annealing treatment then it about to be applied a special insulative coating CARLITE in coils for the manufacturing of magnetic circuits of transformers.

2. Technical specification 2.1. Quality Specification Prim quality grade first choice and according to IEC 404, NFC 28920, ASTM A725 and JIS – 2553 (1986) DIN 46400.

2.2. Chemical Composition

The basic constituent of Silicon Steel Sheets is Iron, and the primary alloying which the main element is silicon in the range of 3.1% to 4.5%. Other elements are present in these materials.

2.3. Physical Properties ➢ Thickness [mm] : 0.27 ➢ Density [gm/cm3] : 7.65 ➢ Electrical Resistivity [μΩ.cm] : 50 ➢ Longitudinal Tensile Strength [MPa] : 350 ➢ Transverse Tensile Strength [MPa] : 420 ➢ Elongation [%] : 11 ➢ Straightness (Ductility)* : 0.8 maximum for measured length 1.5 m ➢ Hardness [HRB] : 175 test certificate for measuring hardness must be attached (Load 50) ➢ Waviness** : 5mm for 2000mm long sample height of one wave not exceed 1/80 of the length of wave or 1mm, witch ever is the greater ➢ Stacking Factor [%]*** : 96.5 ➢ Magnetization Force [A/m] : 800

** This values are according to ASTM A-721-91 *** This values are according to IEC 60404-8-7 and IEC 60404-13 **** This value is according to IEC 60404-8-7

2.4. Core Loss Core loss grading is conducted using as sheared single sheet. ✓ Core Loss @ 1.5 Tesla and 50Hz [Watt/Kg] : 0.62 to 0.75 ✓ Core Loss @ 1.7 Tesla and 50Hz [Watt/Kg] : 0.85 to 0.95 3. Coil Dimensions and Conditions ✓ Inner Coil Diameter [mm] : 508 ✓ Coil Width [mm] : 900 to 1000 ✓ Weight of Coil [Ton] : 2.5 to 3 The coil will be wound with very limited welding along the length of the strip (not more than two) as it must not cause any over thickness to avoid the peeling or the fracture of the cutting disks. 3.1. Tolerance ✓ Width [mm] : ±2 ✓ Length [mm] : ±0.03 ✓ Barbs after cutting : 0.03 [Maximum] 4. Insulation Insulation will be on both sides by an inorganic extremely thin (CARLITE) which is tightly adherent, oil resistant, and rust – proof insulating coats. 5. Testing Test at manufacturers' works will be made according to up-dated IEC standards to verify the quality and specifications of the supplied material. Complete test* certificate (analysis of chemical composition, physical properties and core losses @ 1.5 and 1.7 Tesla) should be supplied for payments. ELMACO has the right to appoint an inspector to inspect the material and attend the tests, this shall be mutually notified in due time. ELMACO has the right to reject the material if the loss values measured during test exceed the offered values. 6. Quality Assurance The quality assurance program must conform to an internationally well-known standard ISO 9001. 7. Quality Manual The quality manual must be delivered from subcontractor.

*   This values is compiling with IEC 60404-11

8. Evaluation of Losses Offers with losses exceeding the specified values will not be considered. Offers with reduced losses than that specified shall be: Pt = P + K fe … (5.1)

Where;

Pt = total material price for comparison per ton in Egyptian liver (L.E.) P = offered price per ton (C & F) in L.E. K = constant and equal to 1500 fe= specific losses watt / kg at 1.7 tesla and 50 HZ . 9. Packing The coils must be vertically arranged on proper wrapped wooden pallets and will be properly wrapped to avoid any damage during transportation or handling The coils must be protected against oxidation by water proof paper or oily paper. All coils will have a label on both sides indicating mass and ELMACO order number

Cases	Core Loss @ 1.7 Tesla[Watt/Kg]	Weight of req. [Ton]
Mother Coils 900to 1000[mm]	0.85 to 0.95 MAX	2000
Slittied from Width 150 to 610[mm]	0.85 to 0.95 MAX	500

Table 2.

5-front and back cover (Egyptian Al)

We used the Egyptian (Al) because we did need to minimize the weight and cost.

6-copper wires

We used copper wires because has electrical conductivity better than (Al).

Note: reference used in casing is material science and engineering (eighth edition) chapter 20