CHAPTER 3

SYSTEM ANALYSIS AND DESIGN

3.1 Overview

System analysis is the process of needs assessment from the current problem and environment. What need to be done, by whom and when, in order to achieve the objective of the study defined in chapter 1. The output from system analysis will be the input to system design.

3.2 Radial Tire Components

As the manufacturing and design process of radial tire are described in detail in Appendix A and B respectively, in this chapter, all the concerned radial tire components will be depicted and analyzed in order to assess what would be the requirements of the proposed system and how to get it done.

The standard form to present each radial tire components is shown in Figure 3.1.

Name of Component

[Photo]

Purpose:

Process:

Green Characteristics:

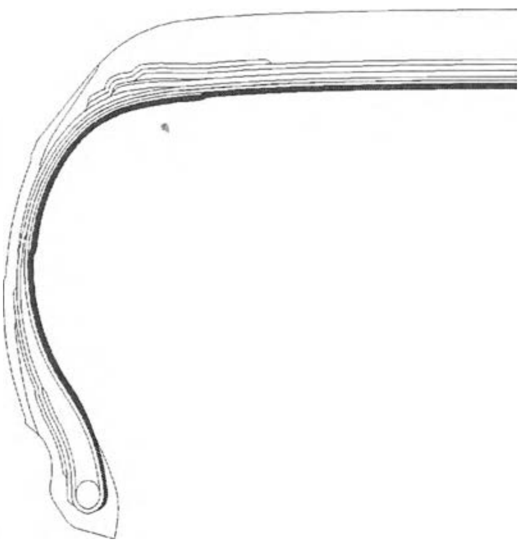
Design Parameters:

Design Criteria:

Figure 3.1 The standard form presenting each radial tire component

3.2.1 GI (Gomme Interior) – LINER

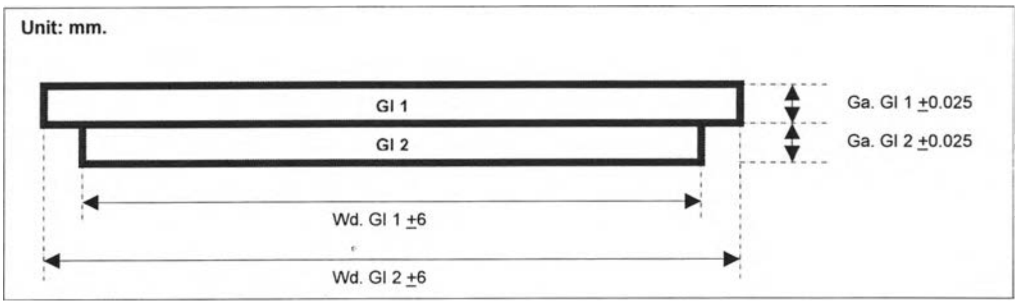
[Photo]



Purpose:
- Air retention
- The GI takes the place of the inner tube for tubeless tires.

Process:
- Gum Calendering
- CX1

Green Characteristics:

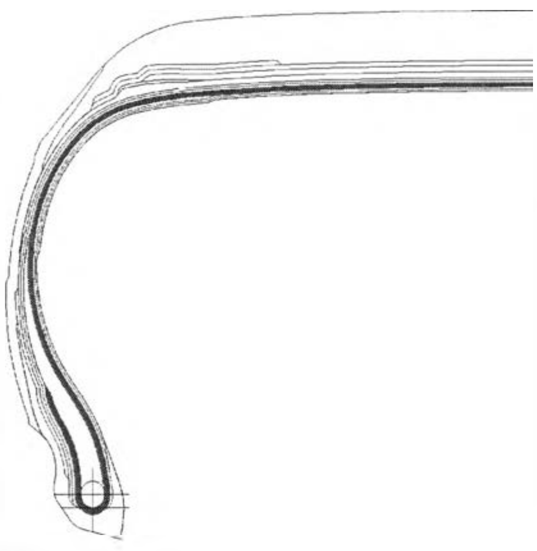


Design Parameters:
1. Compound
2. Gauge
3. Width

Design Criteria:
1. Gauge: 0.85mm, 0.90mm, 1.20mm
2. Width increment: @5mm

3.2.2 NC (Nappe Carcasse) – CARCASSE PLY

[Photo]



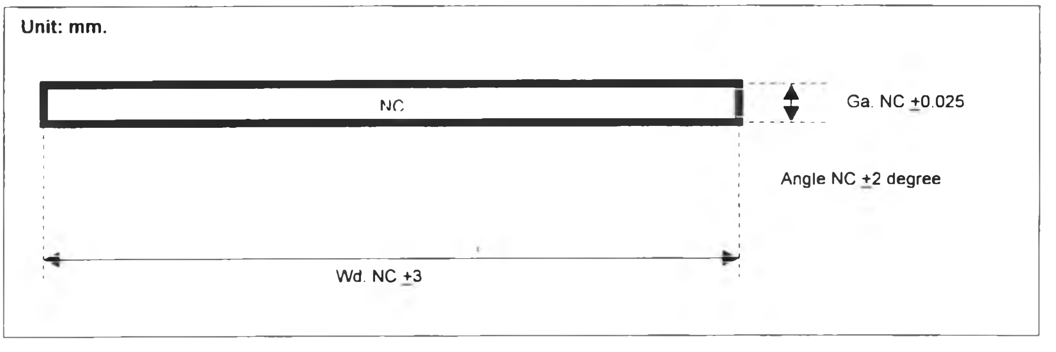
Purpose:

- Carries load and transmits forces from the bead to the summit.
- It is the main structural component of the carcasse.

Process:

- Fabric Calendering
- NC Cutting
- CX2

Green Characteristics:



Design Parameters:

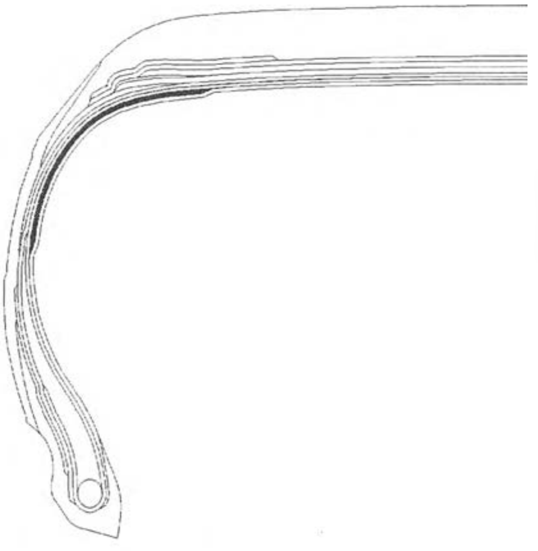
1. NC style
2. Width
3. Angle

Design Criteria:

1. Angle: 85°, 90°
2. Width increment: @5mm

3.2.3 RFI (Reinforcement Flanc Interior) – SHOULDER STRIP

[Photo]



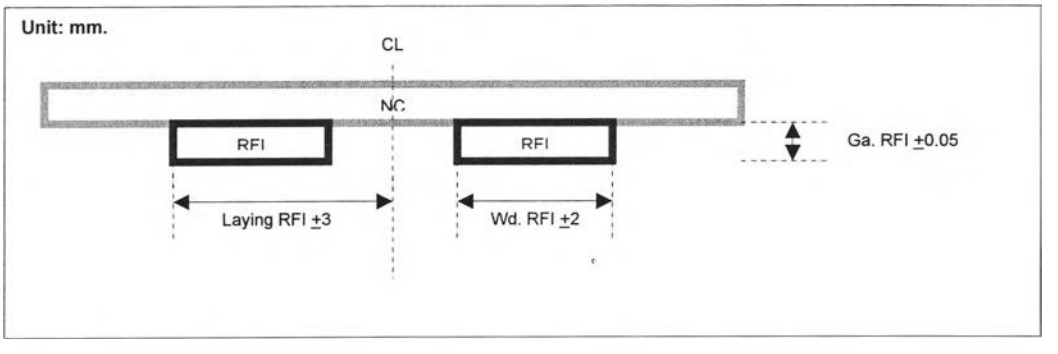
Purpose:

- Reduce "Fluage" (GI penetration between NC cords)
- "Fluage" weakens the NC cord/rubber matrix.

Process:

- Gum Calender
- Slitting
- CX2

Green Characteristics:



Design Parameters:

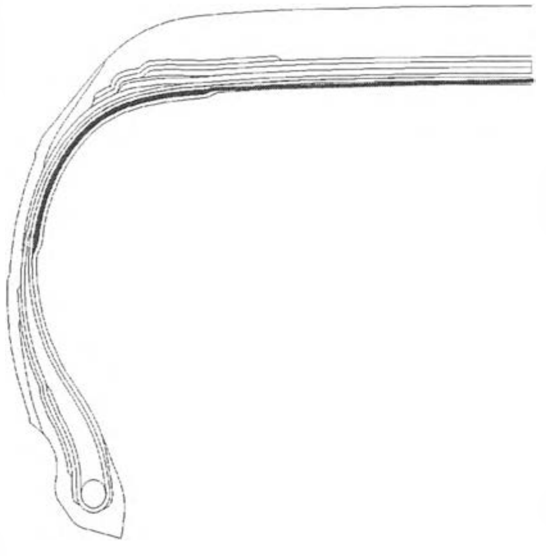
1. Compound
2. Gauge
3. Width

Design Criteria:

1. Gauge: 0.9mm
2. Width: 60mm, 80mm

3.2.4 RIC (Reinforcement Interior Center) – CENTER/SHOULDER STRIP

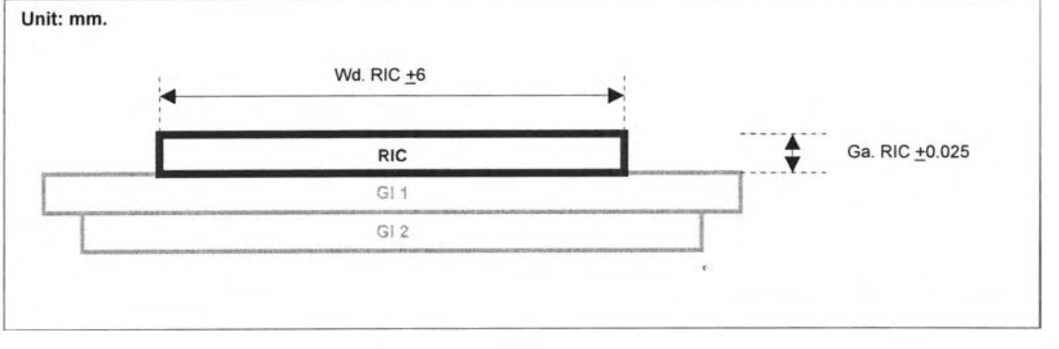
[Photo]



Purpose:
- Reduce "Fluage" (GI penetration between NC cords)
- "Fluage" weakens the NC cord/rubber matrix.

Process:
- Gum Calender
- CX1

Green Characteristics:

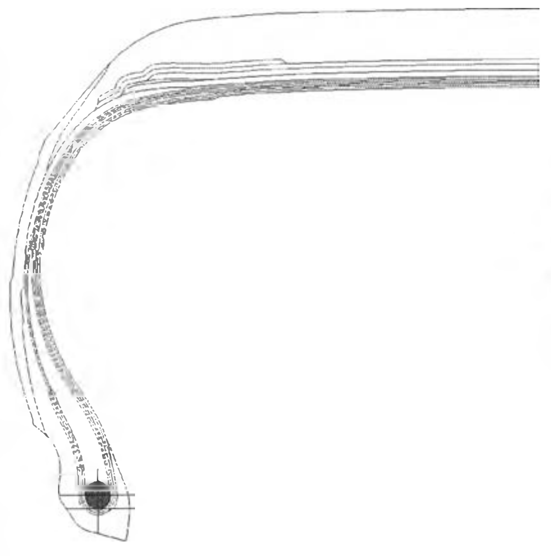


Design Parameters:
1. Compound
2. Gauge
3. Width

Design Criteria:
1. Gauge: 0.5mm
2. Width: 215mm, 230mm

3.2.5 TP (Tresse Ptringle) – BEAD WIRE

[Photo]



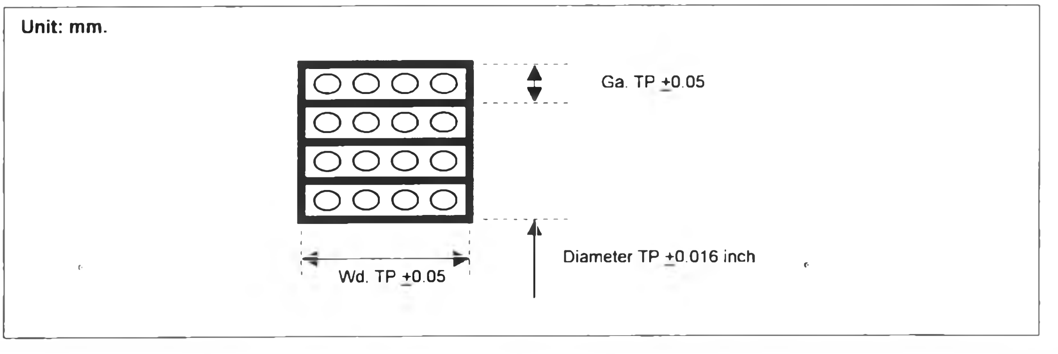
Purpose:

- Holds tire on Rim and transmits forces from bead to carcasse.

Process:

- Bead Winding
- CX3

Green Characteristics:



Design Parameters:

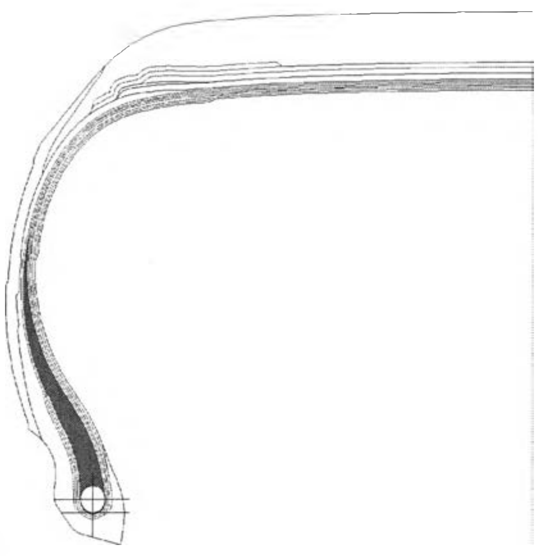
1. Construction
2. Diameter

Design Criteria:

Pick from the 14 existing codes

3.2.6 BT (Bourage Tringle) – APEX, PROFILE FILLER

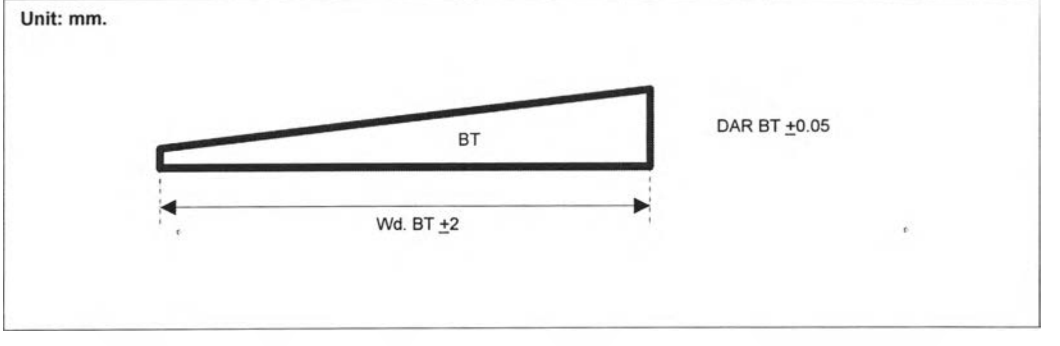
[Photo]



Purpose:
- Lateral Rigidity (handling) and ZB endurance
- Harder rubber, taller BT, and thicker BT all increase handling.

Process:
- Extrusion
- CX3

Green Characteristics:

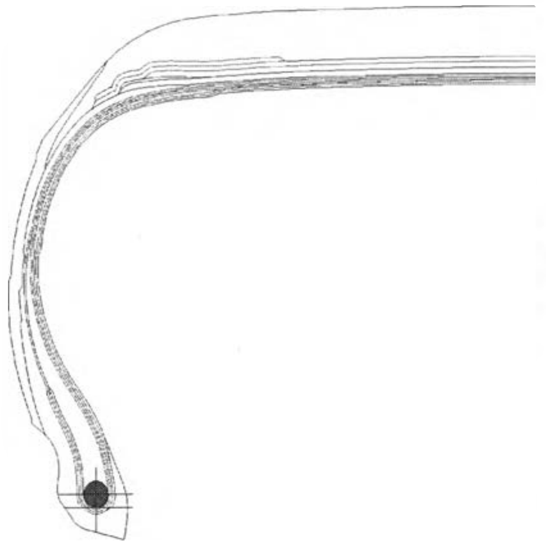


Design Parameters:
1. Profile (Area)
2. Width

Design Criteria:
None

3.2.7 LI (Lourage Iringle) – BEAD COVERING

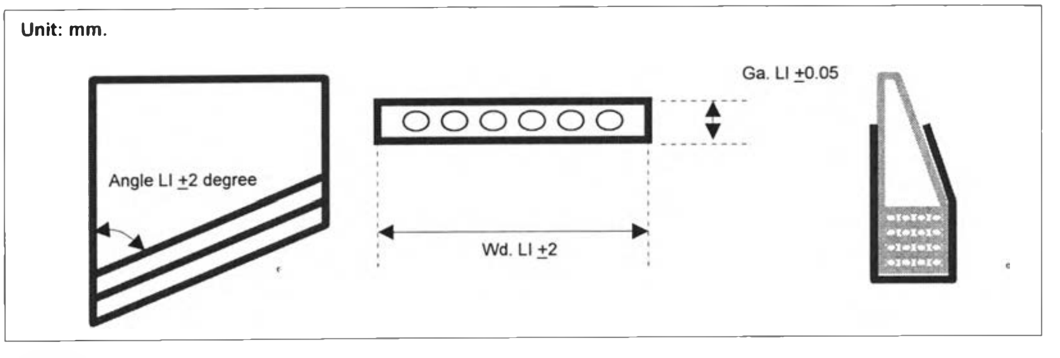
[Photo]



Purpose:
- Lateral Rigidity (handling) and ZB endurance
- Harder rubber, taller BT, and thicker BT all increase handling

Process:
- Fabric Calendering
- NCA Cutting
- CX3

Green Characteristics:

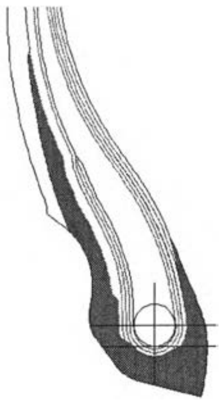


Design Parameters:
1. LI style
2. Width
3. Angle

Design Criteria:
1. Width: 111mm
2. Angle: 45°

3.2.8 PT (ProTecteur) – TOE STRIP, RIM CUSHION

[Photo]



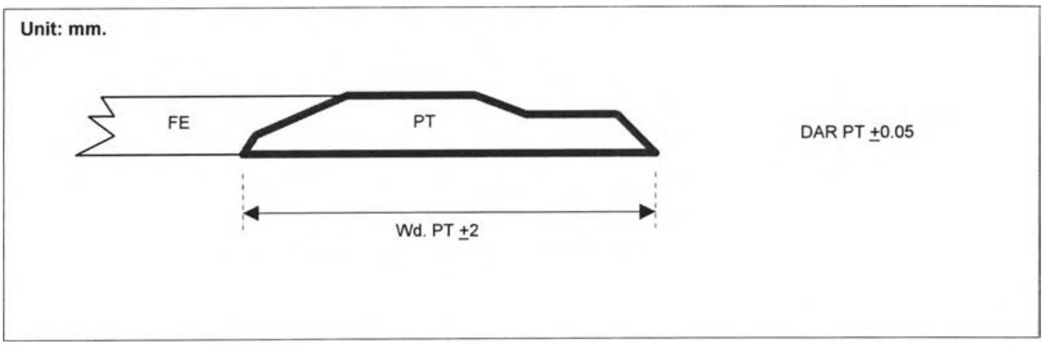
Purpose:

- Protects NC from rim abrasion and helps maintain the air seal with the rim.

Process:

- Extrusion / CX4

Green Characteristics:

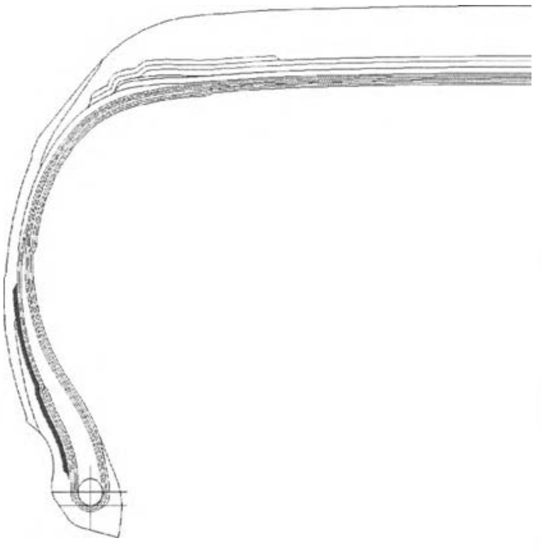


Design Parameters:
1. Compound
2. Profile (Area)
3. Width

Design Criteria:
None

3.2.9 GRL (Gomme Reinforcement Local) – FLAT STRIP

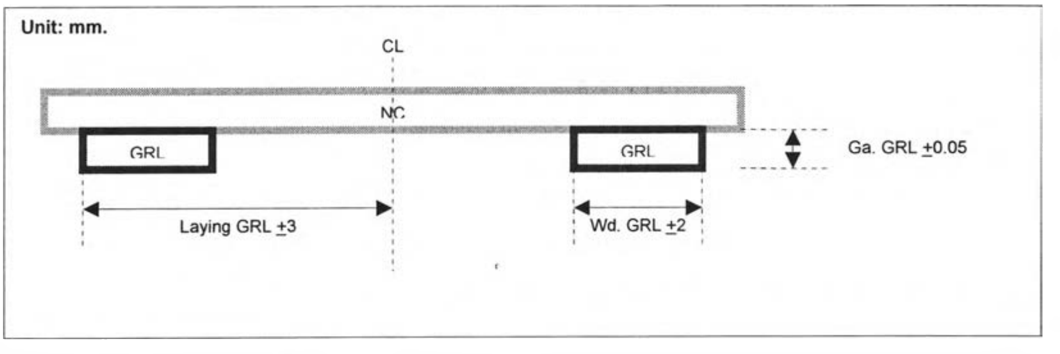
[Photo]



Purpose:
- ZB Endurance
- GRL is a sulfur donor for vulcanization of rubber in curing, and it has a modulus roughly midway between the products it comes in contact with (PTR and NC calanderage).

Process:
- Gum Calendering
- Slitting
- CX2

Green Characteristics:

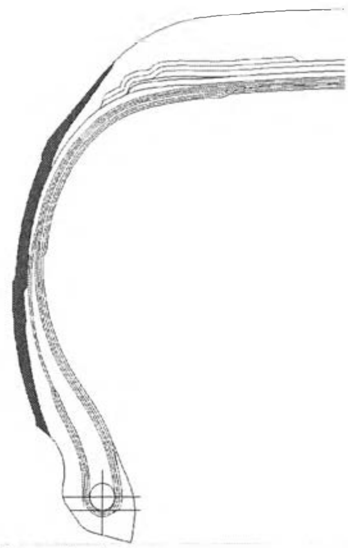


Design Parameters:
1. Compound
2. Gauge
3. Width

Design Criteria:
1. Gauge: 0.8mm
2. Width: 35mm, 45mm, and 50mm

3.2.10 FE (Flanc Exterior) – SIDEWALL

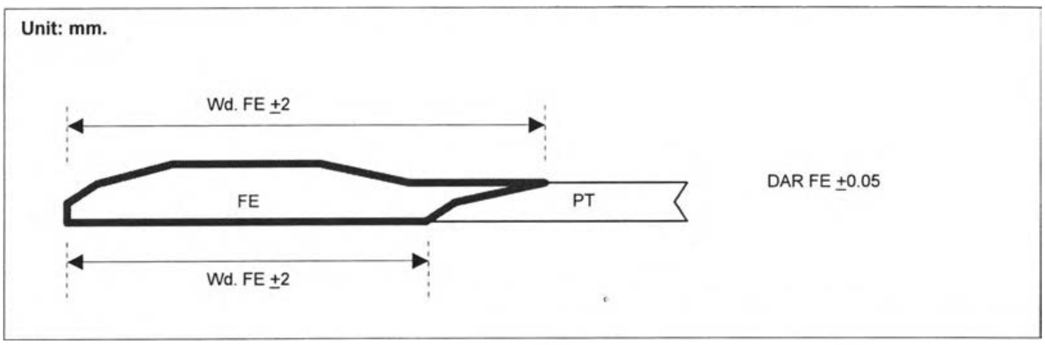
[Photo]



Purpose:
- Protects NC from load hazards and ozone

Process:
- Extrusion / CX4

Green Characteristics:



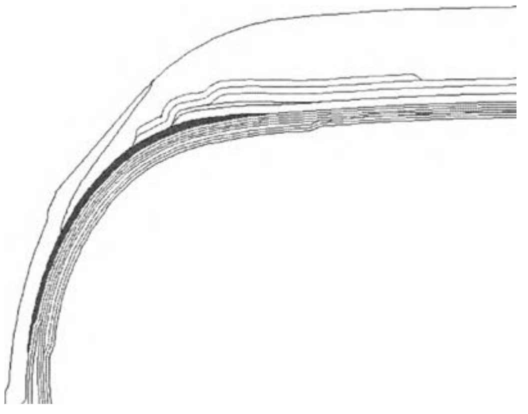
Design Parameters:
1. Compound
2. Profile (Area)
3. Width

Design Criteria:

None

3.2.11 PS (Pied Summit) – BELT EDGE CUSHION

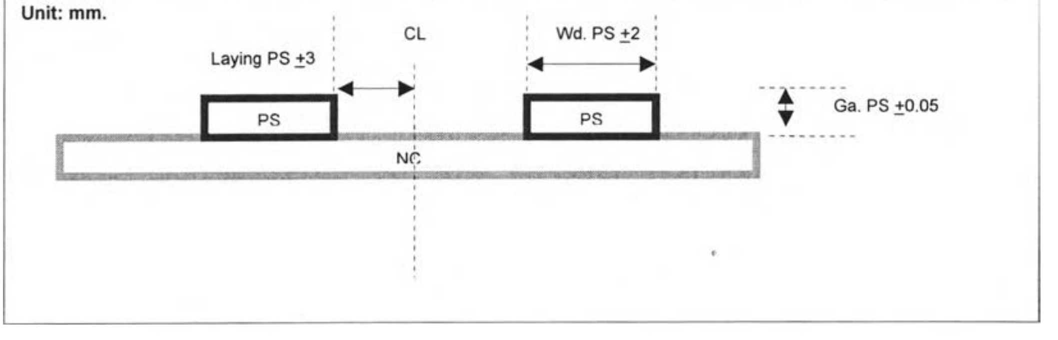
[Photo]



Purpose:
- Summit Endurance
- Reduces the shear between the edge of NST1 and the NC

Process:
- Gum Calendering
- Slitting
- CX2

Green Characteristics:

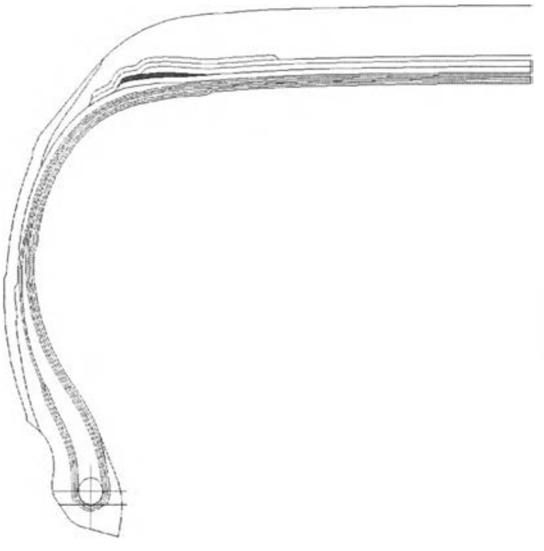


Design Parameters:
1. Compound
2. Gauge
3. Width

Design Criteria:
1. Gauge: 0.8mm, 1.00mm
2. Width: 45mm

3.2.12 GBS (Gomme Basse Summit) – BELT EDGE GUM

[Photo]



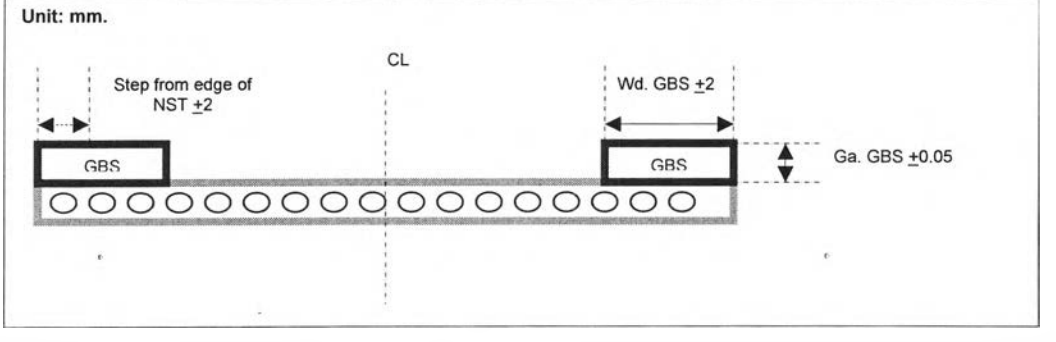
Purpose:

- Summit Endurance
- Reduces the shear between the edge of NST1 and the NST2

Process:

- Sub-Extrusion (in Steelastic)
- CX5

Green Characteristics:



Design Parameters:

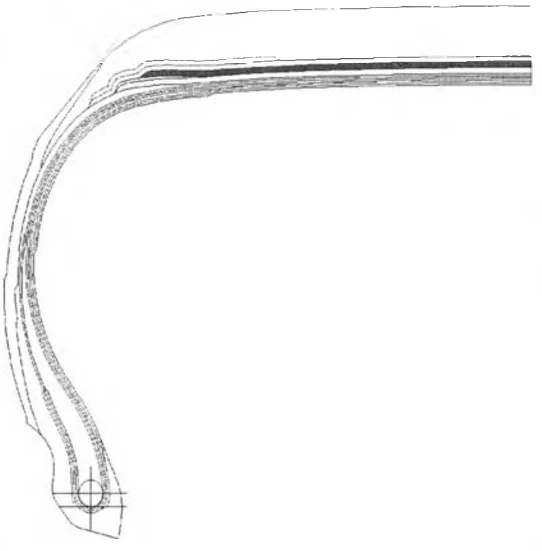
1. Compound
2. Gauge
3. Width

Design Criteria:

1. Gauge: 0.8mm, 1.00mm
2. Width: 20mm, 33mm

3.2.13 NST (Nappe Summit Triangulation) – STEEL BELT

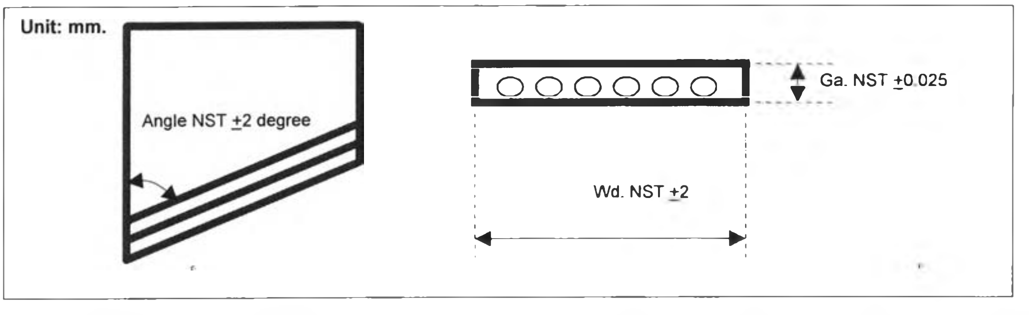
[Photo]



Purpose:
- Provides summit rigidity for cornering
- Protects the tire from road hazards

Process:
- Steelastic
- CX5

Green Characteristics:

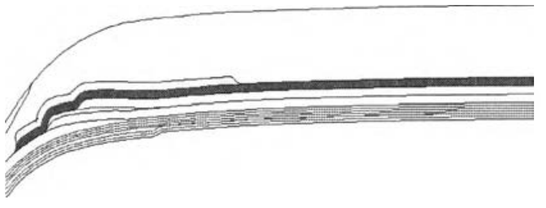


Design Parameters:
1. NST style
2. Width
3. Angle

Design Criteria:
1. Angle: 19°, 23°, 25°, 27°, 29°
2. Width increment: @2mm

3.2.14 NSF (Nappe Summit Frettage) – CAPPLY

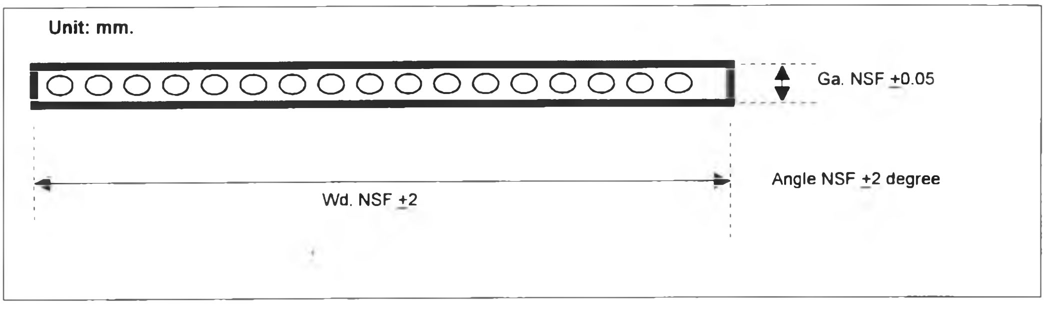
[Photo]



Purpose:
- Provides increased High Speed capability
- This product is usually made of nylon at zero degrees, which limits the growth of the tire in the shoulder region during centrifugation.

Process:
- Fabric Calendering
- Slitting

Green Characteristics:

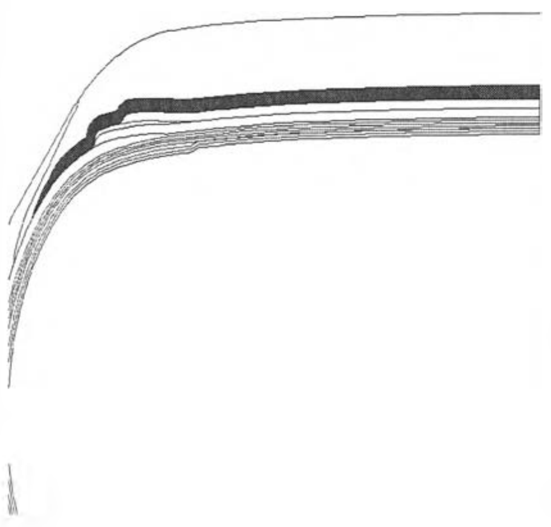


Design Parameters:
1. NSF style
2. Width
3. Angle

Design Criteria:
1. Angle: 0°
2. Width increment: @2mm

3.2.15 GSK (Gomme Sous KM) – UNDERTREAD

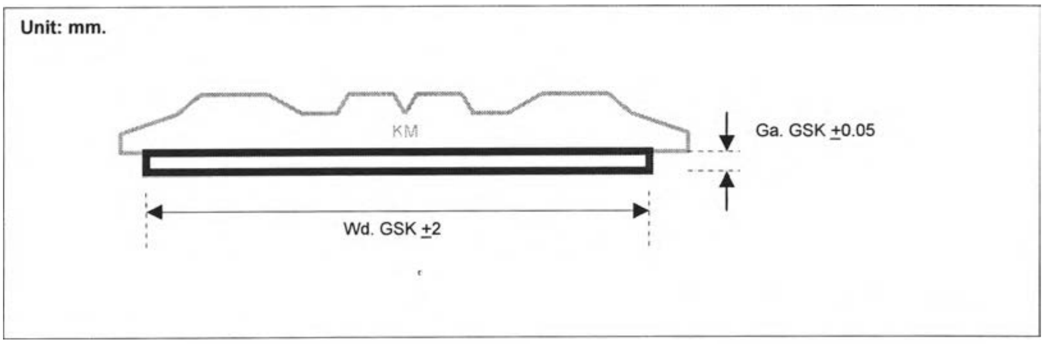
[Photo]



Purpose:
- Reduces rolling resistance by replacing tread rubber with a material having lower heat generation

Process:
- Sub-Gum Calendering
- CX6

Green Characteristics:

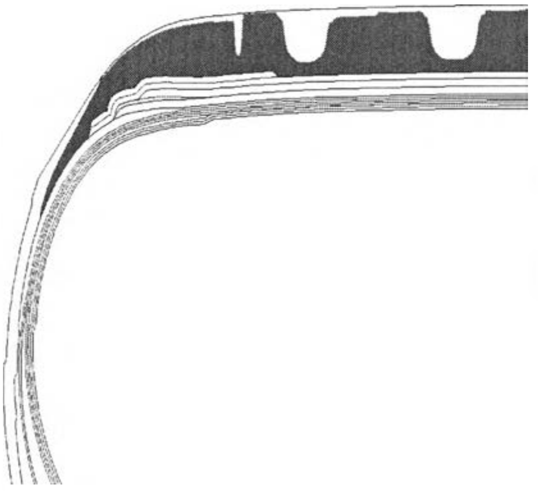


Design Parameters:
1. Compound
2. Gauge
3. Width

Design Criteria:
None

3.2.16 KM (Kelly Michelin) – TREAD, CAP

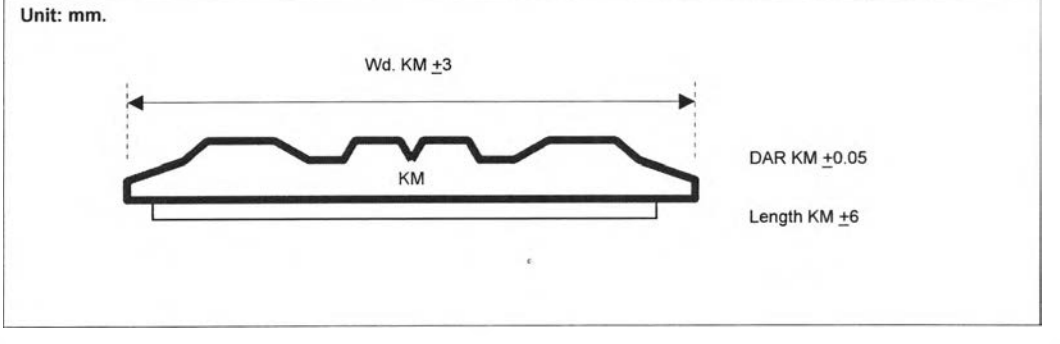
[Photo]



Purpose:
- Provides traction (dry, wet, snow) and wear characteristics

Process:
- Extrusion
- CX6

Green Characteristics:



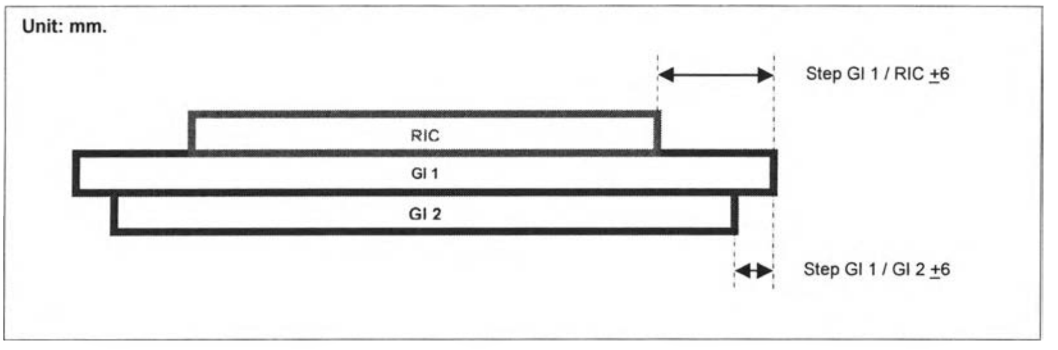
Design Parameters:
1. Compound
2. Profile (Area)
3. Width
4. Length

Design Criteria:
None

3.3 Complexing Parts

3.3.1 CX1 – GI 1 / GI 2 / RIC

Green Characteristics:

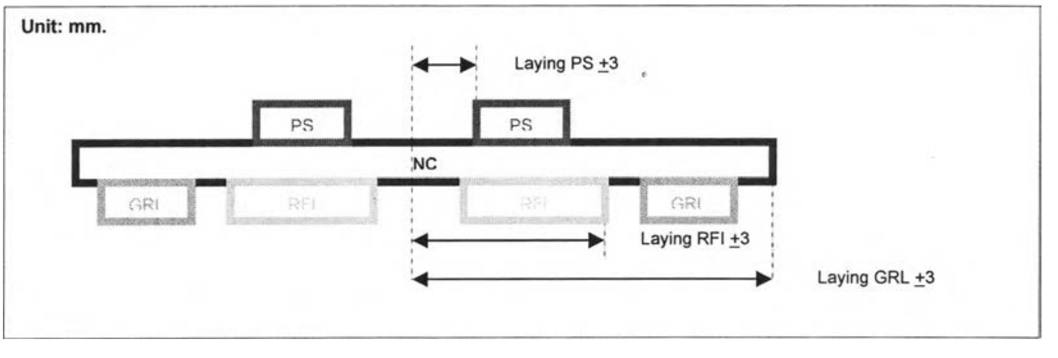


Design Parameters:
1. Step GI 1 vs. GI 2

Design Criteria:
1. GI 1 – GI 2 = 25mm. in average

3.3.2 CX2 – NC / RFI / PS / GRL

Green Characteristics:

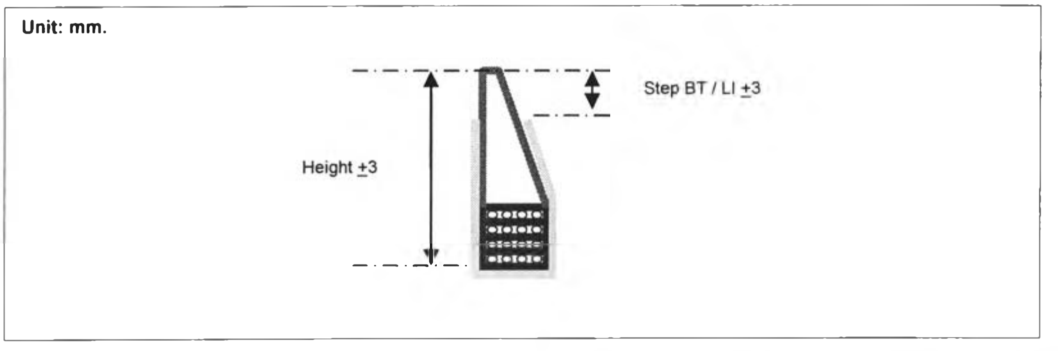


Design Parameters:
1. Position of RFI, PS, GRL

Design Criteria:
1. Position increment @ 5mm.

3.3.3 CX3 – TP / BT / LI

Green Characteristics:



Design Parameters:

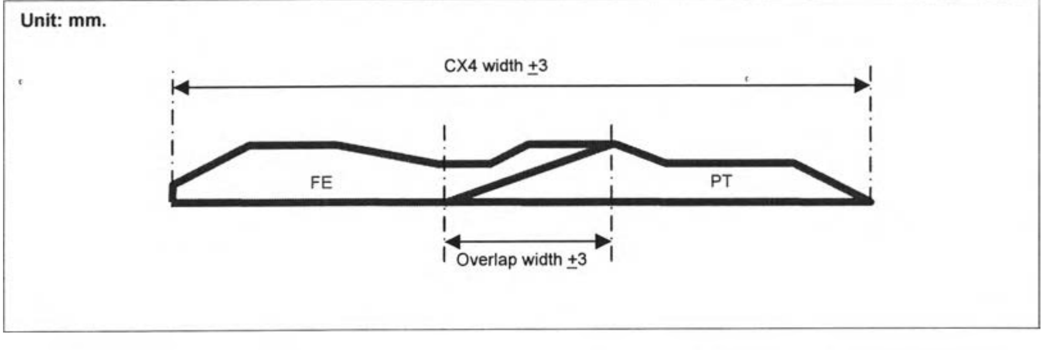
1. None

Design Criteria:

1. None

3.3.4 CX4 – PT / FE

Green Characteristics:



Design Parameters:

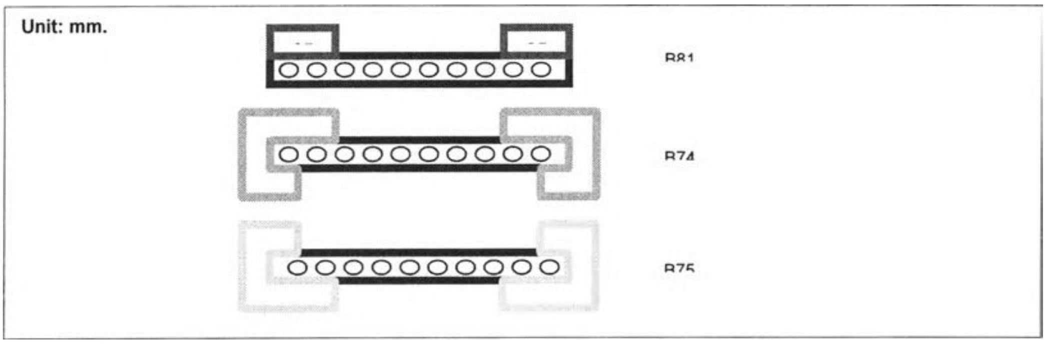
1. None

Design Criteria:

1. None

3.3.5 CX5– NST / GBS

Green Characteristics:



Design Parameters:

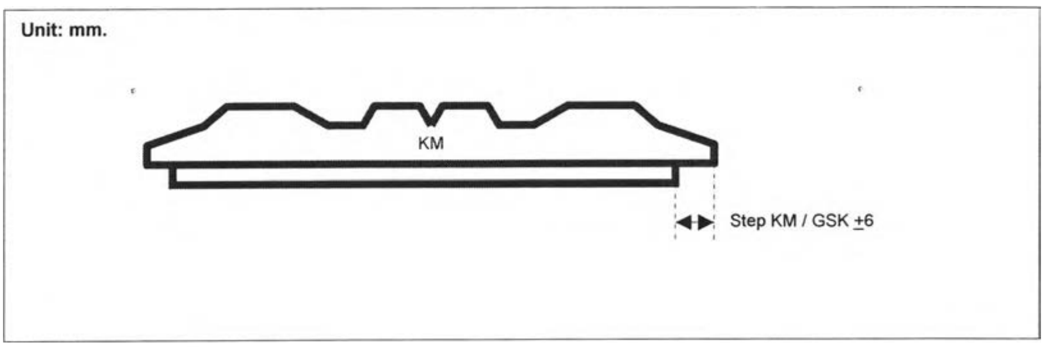
1. None

Design Criteria:

1. None

3.3.6 CX6 – KM / GSK

Green Characteristics:



Design Parameters:

1. None

Design Criteria:

1. None

3.4 Requirement Analysis

As defined clearly in chapter 1, the objective of the study is to create the 3 objects for improvement of tire design process, which are classification and coding, database of radial tire components, and application software for classification and coding for radial tire components.

TABLE 3.1 Requirement Analysis

Requirement	How
1. Classification and Coding structure for radial tire components	For each component: 1. Functionality analysis 2. Characteristic analysis 3. Material analysis 4. Dimensional analysis 5. Others
2. Database of radial tire components	Classification and coding structure
3. Application software for classification and coding for radial tire components	1. Classification and coding structure 2. MS.Excel spreadsheet 3. Visual Basic modules

3.4.1 Functionality analysis

As presented above, each component in a radial tire have specific and unique functionality, even though sometime, the dimension and material are exactly the same. For example, the function of “PS” is to increase summit endurance and reduces the shear between the edge of NST1 and the NC, while the function of “GRL” is to increase ZB endurance.

Consequently, the functionality of a component should “not” be part of the classification structure as we could introduce a new component even all the characteristics and its material are exactly the same.

3.4.2 Characteristic analysis

From the 17 different components segregated by its functionality, we could re-segregate it into only 4 different characteristics based on its manufacturing process as following:

3.4.2.1 Rubber Flat

Concerned processes: Gum calender and Slitter

Concerned components: GI, RIC, GSK, RFI, PS, GRL, and GBS

3.4.2.2 Rubber Profile
Concerned processes: Extruder
Concerned components: BT, PT/FE, and KM

3.4.2.3 Skimmed Fabric
Concerned processes: Fabric calender, NC cutter, and Slitter
Concerned components: NC, LI, LP, and NSF

3.4.2.4 Skimmed Metallic
Concerned processes: TP winding (for TP) and Steelastic (for NST)
Concerned components: TP and NST

To get the benefit of simplified 17 to 4 different components, the characteristic of a component should absolutely be part of the classification structure.

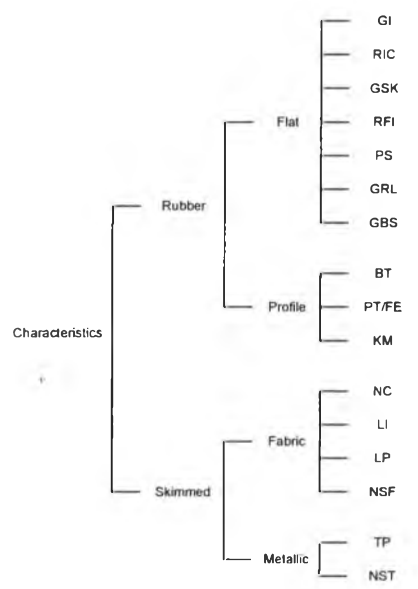


Figure 3.2 Tree diagram of component characteristics

3.4.3 Material analysis

Material of each component is one of the key design parameters because it represents directly the tire performance. As it must be defined by tire designer and local tire designer have to respect strictly, the material of a component must be part of classification structure.

TABLE 3.2 Material of each component

GP	LP	NC1	NC2	PS	RFI	GRL	RIC	TP	LI	BT	FE	PT	NST1
ML06043	N/A	CM10321		ML17000	ML39048	ML39057	ML39048	MP90427	NG10725	ML39055	ML39036	ML39034	NKE20214
ML39048		CM10501		ML39057				MP90428				ML39101	NKE20280
		CM44100						MP90429					CM44240
		CM44390						MP90430					
		CM10344	CM10345					MP90431					
		⇨	CM10663					MP90433					
		⇨	CM10696					MP90434					
		⇨	CM41891					MP90437					
		⇨	CM44288					MP90489					
								MP90490					
								MP90491					
								MP90492					
								MP90493					
								MP90503					
								xxxxxx					

3.4.4 Dimensional analysis

Dimension of component is also one of the key design parameter because it represents directly the tire performance. As tire designer has to specify "green dimension" by respecting tire model, the dimensional of a component must be part of classification structure.

TABLE 3.3 Minimum vs. Maximum dimension of each component

	Gauge		Width		Angle		Area		Diameter	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
GI	0.85	1.2	275	455						
RIC	0.5		215	230						
GSK										
RFI	0.5	0.9	60	80						
PS	0.8	1	45							
GRL	0.8	1	35	50						
GBS			20	33						
BT			20	50			48.15	148.92		
PT			36	92			68.3	207.65		
FE			64	155			147.6	741.35		
KM			132	226			910.55	2140.5		
NC	0.89	1.3	355	675	85	90				
LI	0.81		111		45					
LP										
RD										
NSF	0.66	0.72	105	195	0					
TP	1.45		5.4	8.24					12.063	15.164
NST	1.39	1.76	85	185	19	29				

3.4.5 Others (Form features / Tolerances / Size of envelops)

Those parameters are somewhat the secondary design parameters that could be considered as the 2nd priority during the design process because they are not affected directly to tire model and performance.

- Form feature: Ex. Groove under PT to reduce sensitivity of blister after curing
- Tolerances: We can perform capability study to see if the existing process is capable of producing within the C_p/C_{pk} target.

- Size of envelops: Most likely for productivity aspect

To make the classification as simply as possible, those design parameters should "not" be part of the classification structure.

3.5 System Design

According to the 10 selection criteria described in the chapter 2, with the requirement analysis above, the best classification structure named "GT code of radial tire components" that fit all the concerned radial tire components have the following attributions:

- Hybrid structure, most similar to MDSI
- Universal structure for the whole components

Meaning	Characteristic	Material		–	Gauge	Width		–	Angle/Area/Diameter		
Part	1	2		–	3	4		–	5		
Digit	A	N	N	–	N	N	N	–	N	N	N

Figure 3.3 GT code of radial tire components

According to the Figure 3.2, the classification of Radial tire components consist of 5 parts.

3.5.1 Part 1: Characteristic of a component

Part 1 consists of the 1st digit, which defines the main characteristics and processes of manufacturing a component.

TABLE 3.4 Code of the part 1, the1st digit: Characteristics

Code	Characteristic 1	Characteristic 2
A	Rubber	Flat
B	Rubber	Profile
C	Skimmed	Fabric
D	Skimmed	Metallic
E	[New]	[New]

For the 1st digit, the alphabetical code is selected because of the following reasons:

- Only 4 existing classes
- Easier to memorize / recognize than numeric
- Avoid un-recognition of digit "0"

3.5.2 Part 2: Material of a component

Part 2 consists of the 2nd and 3rd digit, which defines the material of a component.

TABLE 3.5 Code of the part 2, the 2nd and 3rd digit: Material

Code	If the 1st digit is "A" or "B"	If the 1st digit is "C" or "D"	If the 1st digit is "E"
00	6043	CM10321	
01	17000	CM10501	
02	39057	CM44100	
03	39048	CM10344	
04	39055	CM10345	
05	39034	CM10663	
06	39101	CM10696	
07	39036	CM41891	
08	39046	CM44288	
09	39038	NG10725	
10	39035	NG10208	
11	39007	NG10729	
12	39006	NG10477	
13	39054	NG10520	
14		NKE20214	
15		NKE20280	
16		[TP-RT]	
17		[TP-HT]	
99			Not specified

According to the TABLE 3.5, the 2nd digit and 3rd digit, in part 2 are depending on the 1st digit.

Case 1: If the 1st digit is "A" or "B", the 2 numeric digits will represent mixed rubber code.

Case 2: If the 1st digit is "C" or "D", the 2 numeric digits will represent either skimmed fabric code, or skimmed metallic code.

3.5.3 Part 3: Gauge of a component

Part 3 consists of the 4th digit, which defines the gauge (or thickness) of a component.

TABLE 3.6 Code of the part 3, the 4th digit: Gauge

Code	X ≥	X <
0	N/A	
1	0	0.4
2	0.4	0.6
3	0.6	0.8
4	0.8	1
5	1	1.2
6	1.2	1.4
7	1.4	1.6
8	1.6	100000
9	Profile	

The part 3, gauge of a component, is the universal range. According to the dimensional analysis done previously, it can cover the whole concerned components.

3.5.4 Part 4: Width of a component

Part 4 consists of the 5th and 6th digit, which defines the width of a component.

TABLE 3.7 Code of the part 4, the 5th and 6th digit: Width

Code	X ≥	X <
00	N/A	
01	0	20
02	20	25
03	25	30
...	@ 5mm. increment	Until
58	300	310
59	310	320
60	330	340
...	@ 10mm. increment	Until
98	700	100000
99		

The part 4, width of a component, is still defined as the universal range in order to keep the structure simple even the range of width is so wide. According to the dimensional analysis shown in TABLE 3.3, we can specify

- 5mm. increment for the range 0 – 300mm.
- 10mm. increment for the range 300 - α

3.5.5 Part 5: Angle / Area / Diameter of a component

Part 5 consists of the 7th digit, which defines Angle, Area, or Diameter of a component. The 8th and 9th digit defines value of the 7th digit.

TABLE 3.8 Code of the part 5, the 7th digit: Angle / Area / Diameter

Code	Angle / Area / Diameter
0	N/A
1	Angle-R
2	Angle-L
3	Area
4	Diameter

The part 5: 7th digit, Angle / Area / Diameter of a component, is usually applicable for NC – NST, all the Rubber Profile components, and TP respectively. Therefore, this digit will be defined as "0" when classify component not concerned those 3 dimensional. The 8th and 9th digit is depending on the 7th digit.

- If the 7^{th} digit is "0", the 8^{th} and 9^{th} digit will be defined as "0" either.
- If the 7^{th} digit is not "0", the 8^{th} and 9^{th} digit will be followed the code.

TABLE 3.9 Code of the part 5, the 8^{th} and 9^{th} digit – If the 7^{th} digit is Angle

Code	**X ≥**	**X <**
00	N/A	
01	0	1
02	1	3
03	3	5
04	5	7
05	7	9
06	9	11
07	11	13
08	13	15
...	@ 2^{o} increment	Until
46	89	91

TABLE 3.10 Code of the part 5, the 8^{th} and 9^{th} digit – If the 7^{th} digit is Area

Code	**X ≥**	**X <**
00	N/A	
01	0	40
02	40	50
03	50	60
...	@ $10mm^2$. increment	Until
18	200	225
19	225	250
20	250	275
...	@ $25mm^2$. increment	Until
46	900	950
47	950	1000
48	1000	1050
...	@ $50mm^2$. increment	Until
98	3500	100000

To keep the structure simple, the part 5, in case the 7th digit is "Area", can be specified:

- $10mm^2$. increment for the range 0 – $200mm^2$
- $25mm^2$. increment for the range 200 – $900mm^2$
- $50mm^2$. increment for the range 900 – α

TABLE 3.11 Code of the part 5, the 8^{th} and 9^{th} digit – If the 7^{th} digit is Diameter

Code	**X ≥**	**X <**
00	N/A	
01	0	10
02	10	11
03	11	12

...	@ 1 increment	Until
11	19	100000

3.5.6 Pros vs. Cons Analysis: GT code of Radial Tire Components

Pros
- High simplification
- Less development period
- Low development cost
- Avoid "MISS" from different component name

Cons
- Some area has inappropriate range that could effect "HIT" rate (too many)

3.6 Data Base for Radial Tire Components

3.6.1 Data Base Design

As the current application software for issuing tire specification is MS.Excel, and regarding to the defined classification structure, the data base of radial tire components can be easily created now in MS.Excel spreadsheet with the support of Visual Basic modules.

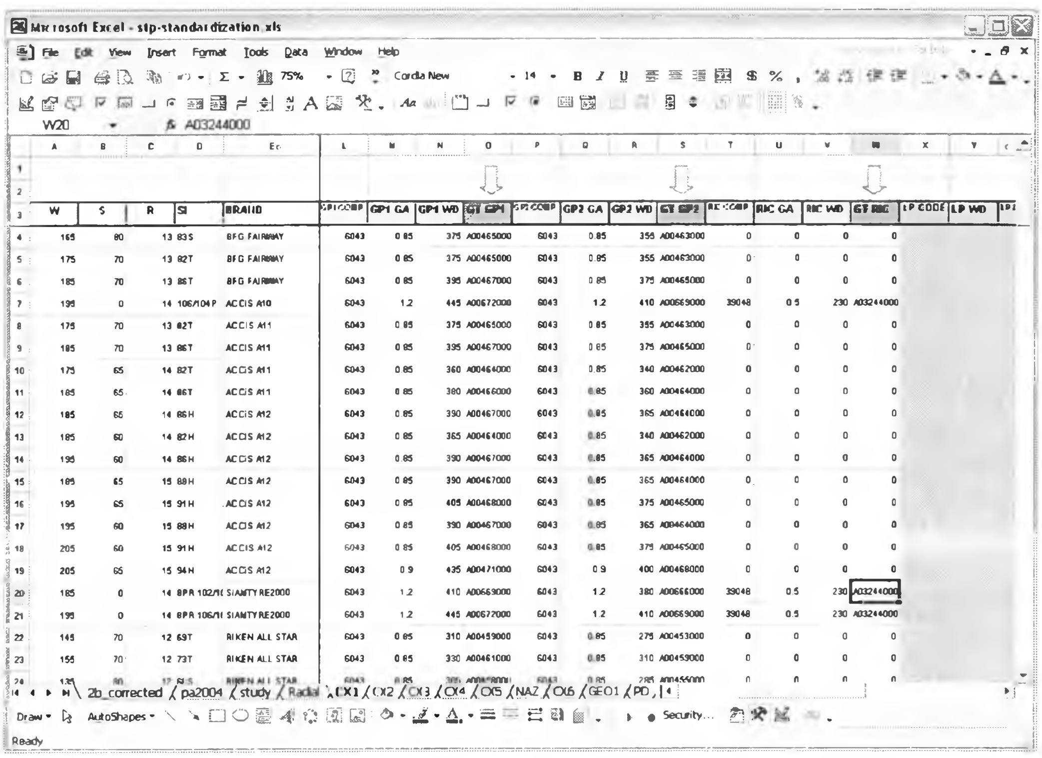


Figure 3.4 Data base for Radial Tire Components with Coding

3.6.2 Pros vs. Cons Analysis: Data base for Radial Tire Components

<u>Pros</u>
- User-friendly
- Less development period
- Low development cost
- Fully compatible with the current spec system

<u>Cons</u>
- Not suitable for further data base development

3.7 Application Software for C&C and Design Retrieval

3.7.1 Application Design

As the application software for issuing tire specification and the data base of radial tire components have been constructed on MS.Excel, therefore, the application for C&C and design retrieval are constructed on MS.Excel with the support of Visual Basic modules. The source code of Visual Basic is shown in Appendix C.

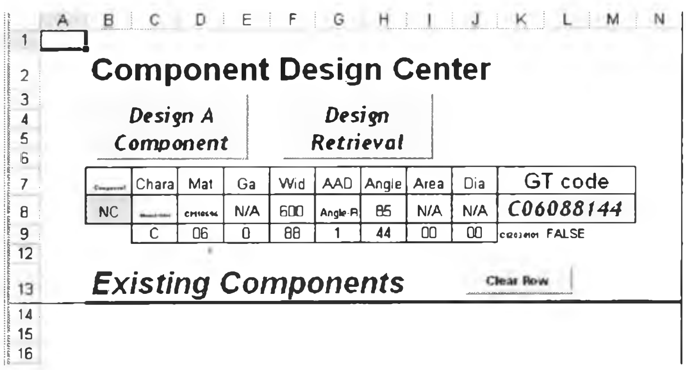


Figure 3.5 Application Software for C&C and Design Retrieval

3.7.2 Pros vs. Cons Analysis: Application for C&C

<u>Pros</u>
- User-friendly
- Less development period
- Low development cost

<u>Cons</u>
- Manual input the new design

3.7.3 Pros vs. Cons Analysis: Application for Design Retrieval

<u>Pros</u>
- User-friendly
- Less development period
- Low development cost

- Maximize possibility of "HIT"

<u>Cons</u>

- System takes long time to retrieve data