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CAREER EPISODE 1

a) Introduction:

- 1.1 The episode is developed to demonstrate my understanding of material engineering and its chemical reactions by carrying out an eight-semester project named "Comprehensive Studies on Termination of Hydroxyl Polybutadiene by Modifying EPDXY Resin". All the experimental activities were conducted in National Aerospace Laboratories from February 2005 to May 2005. During this tenure, I was studying Bachelor of Engineering Degree from SJCE College of Engineering.

b) Background:

- 1.2 Research has shown that epoxy resins are superior compared to thermosets because of their well-balanced properties at an extremely low cost. Furthermore, it can ensure better mechanical strength at maximum temperature, resistance, good flame, and fewer smoke quantities emissions with comparatively minimum toxicity during incineration, hence making it the most preferable material in the aerospace industry. But, epoxy resin is not very tough and brittle. For this purpose, many materials are introduced that can be blended with thermosets (especially with the epoxy resins) to improve this toughness without even impairing significantly thermal and mechanical properties. Such materials are liquid rubber,
- 1.3 This project was intended to improve the epoxy resin's toughness with the help of liquid rubber, i.e. HTPB (Hydroxyl-terminated Polybutadiene). The main focus was to toughen the properties of Epoxy resin because it is extremely an important and preferable material in commercial and aerospace applications. This project was done by identifying chemical reactions between HTPB and Epoxy by carrying out Infrared Spectroscopy and DSC studies. For this purpose, we selected different blending compositions of HTPB and Epoxy to conduct improvement studies (toughness) by considering glass transition temperature (T_g) and blend's processability.
- 1.4 For studying toughness, it was decided to use woven-glass fabric reinforced composites by adding HTPB (0-4%) to the resin so that it can productiny

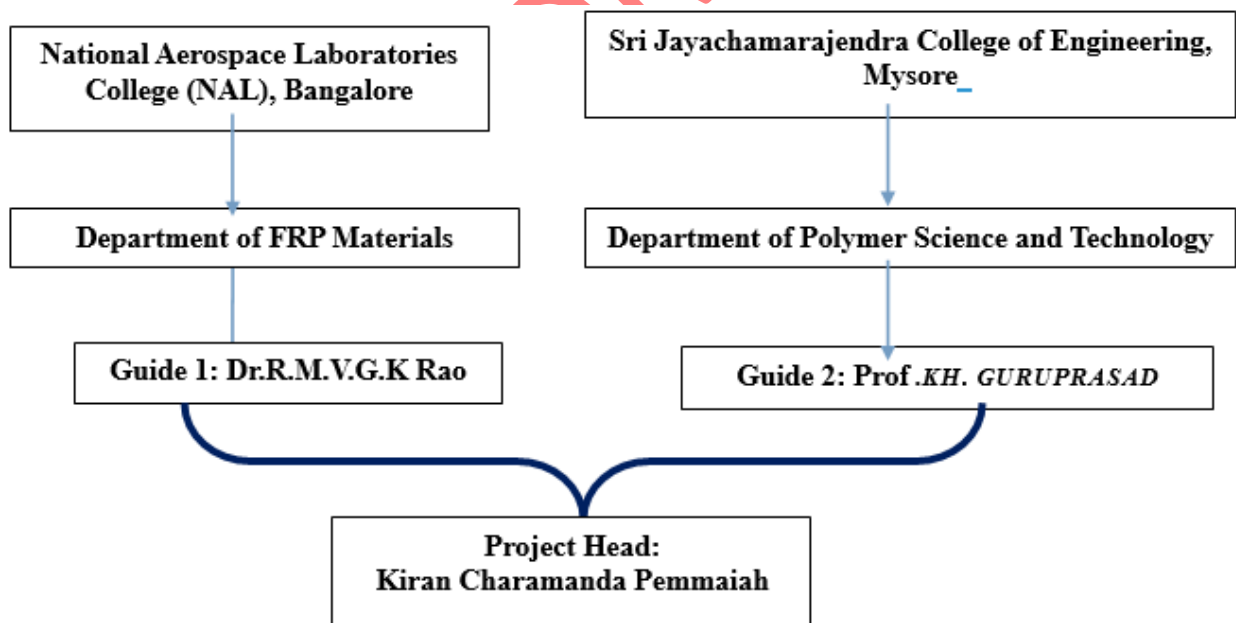


elastomer particles. Thus, it enhanced the mechanical properties of resin along with impact strength. Moreover, the addition of HTPB produced a blend of elastomer-epoxy and it reduced mechanical properties. Lastly, this project involved the identification of dispersion of rubber particles by performing SEM analysis.

1.5 I was working on the following tasks to carry out experimental work.

- Involved in carrying out background study in composite to understand toughness by resin modification.
- Performed a literature review by studying epoxy toughness with various elastomers.
- Selected the materials and explained their description.
- Conducted experimental work including preparing prepolymer and laminate and its curing.
- Determined the composite material properties including flexural, Tg (expand), and strength of HTPB by modifying Epoxy Laminates.
- Optimization of concentration of HTPB by improving fracture toughness.
- Prepares a report on experimental work by discussing its results.

1.6 Organizational Structure:



c) Personal Engineering Activities:

1.7 First, I performed a detailed study on composite materials (light in weight) currently used in the aerospace industry. The research has shown that maximum resins like₂ Phenolic, Epoxy, Polyester, etc. are used in making FRP composites. I noticed

that many international types of research were conducted on common resin matrix materials, i.e. epoxy due to its lowest cost and excellent mechanical properties. In addition, I studied a few articles showing the use of carbon fiber, aramid fibers, and glass fibers as reinforcement in FRP composites. Therefore, in this project, I decided to work on epoxy (resin matrix) along with glass fiber (reinforcement). I also reviewed the chemical reaction between glass fiber and epoxy. Also, I noticed that all international material studies used various methods to toughen epoxy matrix using ETBN and CTBN reactive rubbers.

- 1.8 Then, I developed an MSWord report showing the limitations of the previous research and then presented my proposal along with a list of materials that would be used to get accurate results. Furthermore, I also included a schedule of this project showing project activities (material selection, experimental work, SEM analysis, results, etc.) with their deadlines to complete each task on time. I submitted it to the project head and discussed it with the Aerospace Lab engineer (Guide 1) to get guidance.
- 1.9 Afterward, I selected the required materials to fabricate the composite laminates, i.e. I first opted for eight mill twill glass fiber due to its relatively great toughness properties with a density of 2.54 g /cc and thickness of 6 to 7 Kg /mm². It is comprised of aluminum calcium borosilicate glass along with less than 1% alkali content. Then, for epoxy resins, I selected diglycidyl ether of bisphenol-A-based epoxy resin of the following molecular structure.

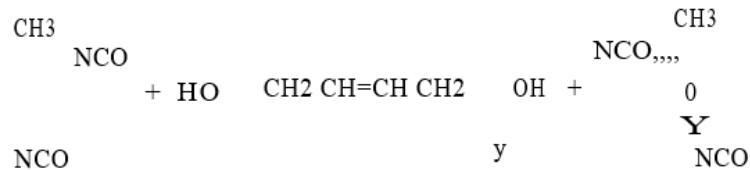


I procured epoxy resin (Araldite LY556) from Huntsman Materials (India) Pvt. Ltd of the following specifications, i.e. Hydrolysable chlorine of 0-400, Gel time at 60°C (200- 270 min), Viscosity at 25°C (10,000-12,000 cps), etc. Next, I selected reactive elastomeric material i.e. HTPB due to Poly butadiene which has the minimum glass transition temperature, especially for elastomeric materials. The elected HTPB has a viscosity of 8000 cp with a molecular weight of 3500 and an acid value of <1. Afterward, I opted for Toulene-diisocyanate (TDI) as a catalyst, i.e. 2,4-di-iso-cyanato toluene which acted as a modifier due to its bifunctional nature and can react with HTPB's hydroxyl groups. In addition, I also worked with TBAI which is a catalyst and can react with TDI-linked epoxy resin with HTPB. The selected TBAI has a molecular formula of (n—Bu)₄NI. Afterward, I chose Stannousoctoate which has the chemical name stannous 2-ethyl-hexanoate with a molecular formula of C₁₆ H₃₀O₄Sn. It was also used as the main catalyst which can reach TDI with HTPB. Lastly, I opted for Hardener HT 972 which has the chemical name 4,4-diamino Diphenylmethane. It was a crosslinker that created three-dimensional epoxy resin crosslinks.

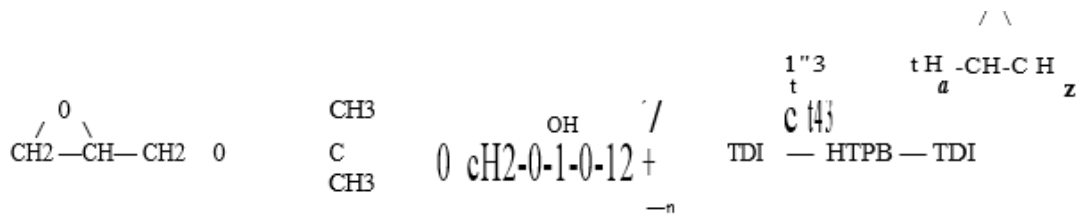
- 1.10 After material selection, I started the preparation of the prepolymer. For this, I first divided the whole process into two-phase, i.e. development of chemical reactions for modifying HTPB and linking it subsequently with the epoxy resin. So, I³

performed chemical reactions by using HTPB of 1 mole with TDI of two moles using a catalyst (stannous octoate) with the epoxy resin. During the processing of the typical HTPB reaction (1,2,3,4,5, & 7 %), I added Epoxy resin and TDI with stannous octoate (a few drops) in a round bottom two-necked flask and made it fit with a thermometer and stirrer. Firstly, I ensured the reaction was conducted at $30 \pm 1^\circ\text{C}$ (room temperature) with continuous stirring (20 to 25 minutes). Secondly, I added TBAI (2.25% of the epoxy resin) catalyst which was heated at 160°C for around 1 hour and 45 minutes. After, I made it cool at room temperature and left this solution for 24 hrs. Then, I prepared various blends considering the following proportions during LY556 modification.

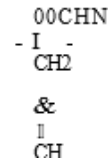
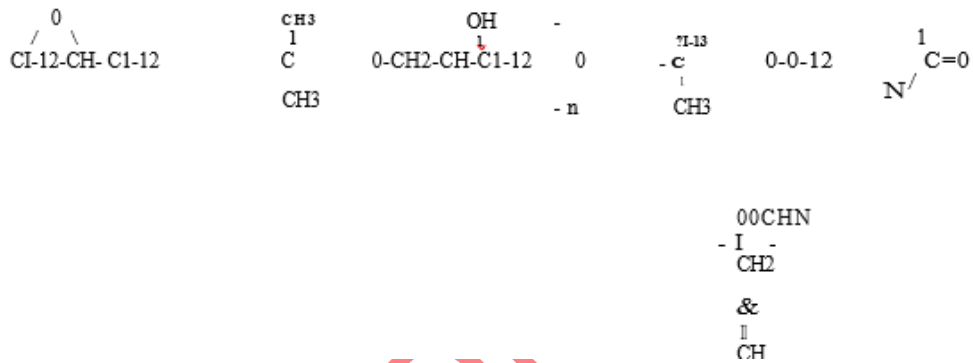
Materials	1%	2%	3%	4%	5%	7%
LY556	100	100	100	100	100	100
HTPB	1	2	3	4	5	7
TDI	0.0994	0.1988	0.2982	0.3977	0.4971	0.696
TBAI	2.25	2.25	2.25	2.25	2.25	2.25



Australia



@ 160°C , TBAI CATALYST



1.11 Next, I did the characterization of the prepolymer using IR spectroscopy. It was done to improve mechanical behavior with epoxy resin toughness by modification of HTPB. To achieve the required toughness, I had to perform resin curing to get a homogeneous structure by introducing a flexible configuration to the frame structure of epoxy resin or when the cured resin maintains a microdomain dispersed structure. In either of the toughening mechanisms, the flexibility and the matrix must interact chemically. Therefore, I studied the existence of chemical interaction using the IR spectrum, detected using Burker-Fourier transform IR spectrometer. Spectra's of epoxy and epoxy mixed with HTPB (different %s) were taken smearing the samples on the top of KBR pellets. I then cured these pellets in a hot air oven. IR spectrum of cured epoxy and epoxy mixed with HTPB (different %s) was then detected. I studied it to identify whether chemical interaction between epoxy and HTPB takes place.

1.12 To conduct this study, I fabricated laminate using the hand lay-up method with hot press curing. To start this process, I prepared a laminate setup by cutting Bi-directional glass fabric (2*2 twill weave) to get nine layers of laminate with the size of 300x 300mm. After this, I mixed the computed amount of⁵

hardener and resin (100:28) in a bowl and placed the first bi-directional glass fabric layer on a Teflon sheet, and coated it with a resin-hardener mixture. Then, it was properly squeezed to ensure excess mixture. I repeated this procedure for nine layers and then placed this Teflon sheet over this. I kept spacer bars having a thickness of 2mm and placed them on 4 sides of the mold plate. Next, I placed the upper mold on the spacer's top and transferred the whole mold to a compression machine called a hydraulic press. This machine applied pressure using its plates and cured the laminates. The lay-up was then post-cured to relax residual stresses.

- 1.13 Next, I performed different testing on this cured laminate, i.e. thermal analysis and toughness test. For thermal analysis, I used TA Instruments 2910 DSC to perform the DSC studies to identify the curing schedule and evaluate Tg alterations with different rubber concentrations. DSC in the Dynamic model was employed to calculate the enthalpy related to the curing process and to fix the curing schedule. For this, I noted the down weight of 5-15mg of uncured sample and placed it in an inert cell made of aluminum. They were placed on the sample platform of a DSC cell disk. I measured 50-300°C with a 10°C/min heating rate under a nitrogen atmosphere. For determining glass transition temperature 25-30mg of cured sample was placed in the DSC cell disk.
- 1.14 After this, I conducted fracture toughness testing as per ASTM STP 876. This test was done to study the characterization of delamination behavior which is a fundamental issue in evaluating laminated composite structures for durability and damage tolerance. For this, I prepared double cantilever beam specimens of 140X25X2 mm dimensions from the cured epoxy, and modified epoxy laminates were employed to determine fracture toughness value (G_{ic}). Then, I introduced a crack of 50mm length at the mid-portion of the specimens, while being cured, by using a PTFE sheet. I applied loads through aluminum tabs fixed to the ends of the DCB specimen using cyanoacrylate adhesive. After I placed DCB specimens in a tensile test machine on displacement control with a low pulling speed of 0.5 mm/min and the crack was allowed to grow by a small distance of 5mm. I determined Mode I fracture toughness (G_{ir}) using the following equation:

$$\text{Energy Release Rate, } G_I, \text{ J/m}^2 = \frac{3P^2 B}{2(a + A)} I$$

Where P is a critical load, A is a crack length, B is the thickness of the specimen, A is a Displacement, and I is a Crack length correction factor. I plotted values of G_{ic} as a function of crack length 'a' (mm) to produce a resistance (R) curve.

- 1.15 Also, I also flexural test using specimens of 127 x 12.7mm with a thickness of 2mm at a support span of 40mm at a crosshead speed of 2mm/min. I measured the deflection by measuring the motion of the loading nose relative to the supports. Then, I plotted a load-deflection curve for determining the modulus. The slope of the initial linear portion of the curve provided flexural modulus and flexural strength (S) as measured using the relation: $S = \frac{3PL}{2BD^2}$. Then, I performed impact testing because the impact



properties of the composite material are directly related to the overall toughness of the material.

1.16 After completing this experimental work, I analyzed the results of prepolymer characterization using the infrared spectroscopy technique, i.e. in the first phase of a reaction, it was noticed that isocyanate presence skyrocketed at 2269 cm^{-1} . But with the procedure in reaction, I observed that this peak of isocyanate disappeared completely because, in the first phase of the reaction, I noticed formulation of urethane linkage (stable) because of a chemical reaction between HTPB and TDI. This reaction was monitored with the help of FTIR. Then, I noticed the appearance of this peak again because of the generation of the urethane linkage at 1738 cm^{-1} along with viscosity increase of a reaction mixture due to confirmed development of pre-polymer (TDI-HTPB-TDI) in the epoxy medium. Whereas in the second phase, I decided to enhance the temperature up to 160°C , and then the catalyst was added i.e. TBAI (tetra butyl ammonium iodide) at a rate of 2.25 parts/100 parts of resins causing generation of the oxazolidone linkage, and it caused a substantial upsurge in the reaction's viscosity and peak's intensity at 1756 cm^{-1} .

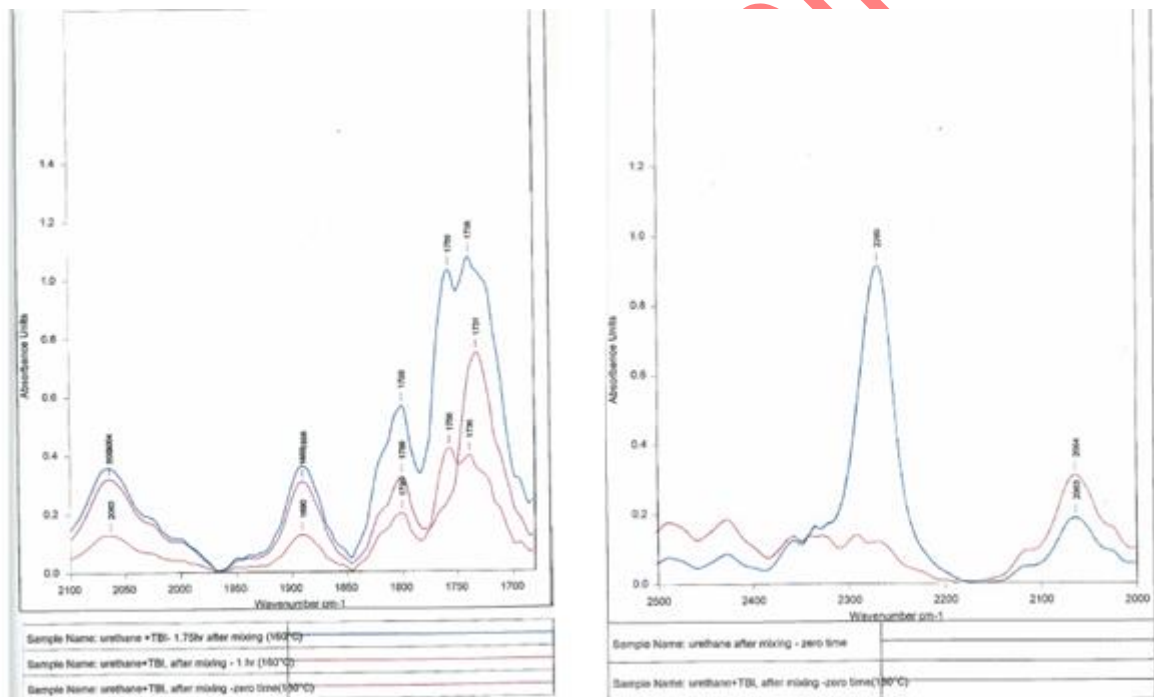


Figure 1 IR Peaks

1.17 Then, I analyzed the thermal analysis results. The below results show decrease in temperature of glass transition by increasing HTPB in the epoxy resin. It is known that the addition of HTPB in epoxy can decrease crosslinking density along with softening of the matrix but reduces the temperature of glass transition. Hence, I noticed from that graph a reduction in T_g by increasing the content of HTPB. Also, I observed dispersion of rubber particles at a lower concentration within the epoxy, developing strong interfacial adhesion among them. Whereas, by

using increased rubber content, I noticed an increase in particle concentration within the matrix. But, this phenomenon reduced the value of T_g because rubber particles decreased both crosslinking density as well as matrix flexibility.

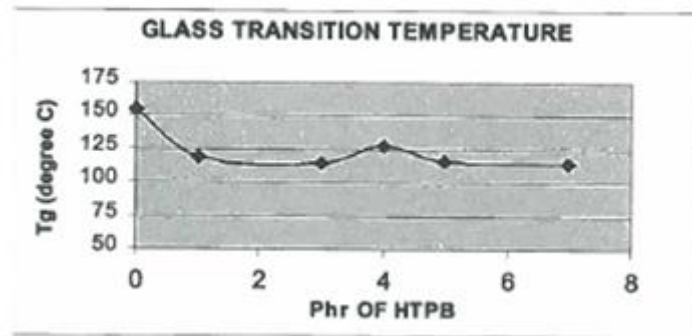


Figure 2 Temperature of Glass Transition

Table 1 G_{ic} calculations for 4 PHR-HTPB MODIFICATION

CRACK LENGTH (mm)	LOAD P (N)	DISPLACEMENT 8 (mm)	CI13 [(mm/NI)/3]	G_{ic} (J/m ²)
50	52.20	15.98	0.68	476.60
55	59.34	23.38	0.74	756.70
60	53.39	27.03	0.80	752.80
65	48.78	30.01	0.85	731.80
70	46.05	34.77	0.91	768.30
75	43.27	39.09	0.97	780.60
80	42.20	44.42	1.02	833.10
85	40.47	48.32	1.06	837.90
90	28.94	54.76	1.23	655.70
95	31.69	59.35	1.23	752.20
100	35.02	72.29	1.27	844.80
105	32.15	77.55	1.34	934.80
110	31.69	83.40	1.38	960.90
115	30.60	88.40	1.42	954.70
AVERAGE G_{ic} VALUE				734.90

1.18 From the graph, I noticed that modified Epoxy exhibit had higher fracture toughness as compared to non-modified epoxy resin. So, I obtained the optimum G_{ic} (fracture toughness) with a rubber of 4phr. This optimized content of rubber dopped down impact strength and elastomer particles enhanced the fracture energy (initiation) by 55%. Furthermore, I noticed the formation of a heterogeneous system due to 4phr HTPB molecules which developed domains in the epoxy



system. But, above 4 phr, epoxy resin blocked a rubber phase creating a homogeneous blend consequently reducing a fracture toughness due to an increase in the size of the rubber domain. Also, at maximum elastomer concentration, I noticed that the rubber completely reacts with the epoxy, thus making it flexible instead of toughening. The phase transfer from particle to homogeneous blend is expected

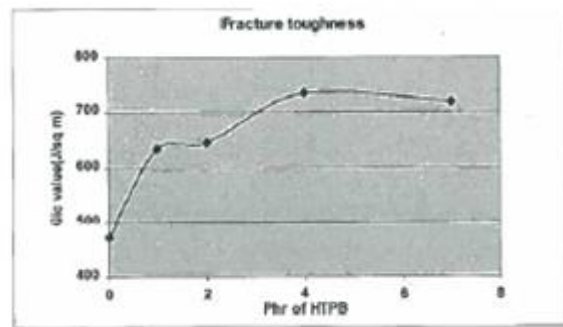


Figure 3 Fracture Toughness

1.19 I also analyzed all experimental results which showed improvement in Epoxy toughness using FRP laminates. I also checked and developed chemical reactions using my engineering knowledge. I followed instructions given by Guide 1 and Guide 2 to avoid all kinds of errors as per ethical standards and submitted a full report showing detailed results with graphs and reactions.

1.20 I prepared an oral presentation on my research work using MS-PowerPoint and explained my project in front of the project head who appreciated this innovative work. Moreover, I communicated with the supervisor and teammates throughout the experimental work to obtain accurate results.

d) Summary:

1.21 In this project, I performed experiments, testing, data analysis, and material characterization to improve epoxy fiber's toughness by introducing FRP. This project developed my understanding of material properties and chemical reactions. I also learned how to blend different materials at a required proportion to obtain a better result.

CAREER EPISODE 2

e) Introduction:

2.1 The aforesaid career episode is based on the project which was an important part of my Master's of Technology Degree in Polymer Science & Technology obtained from Sri Jayachamarajendra College of Engineering (SJCE). This research project is called "Experimental work on the Tread Based Green Compound for Radial Truck Tyres". In this project, I was responsible to investigate the properties of the silica (non-inorganic petroleum material) by varying its amount to prepare truck radial tread compound for commercial purposes because it would help decrease the usage of fuel and resistance of a tyre. This project was done for JK Tyre and Industries Ltd from February 2009 to May 2011.

f) Background:

2.2 The carbon black has been used extensively by tyre industry as a reinforcing filler, but after the emergence of using the green tyre concept, many industries have replaced carbon black with Silica due to its chemical and physical properties in reducing the tyre's rolling resistance.

2.3 This project focused on developing a Tread base compound using silica by optimizing levels of silica in "Tread Base" in such a way that required properties of the base compound would retain, i.e. low heat and low hysteresis build-up. However, it was extremely difficult for me to replace entirely carbon black with Silica because of poor interaction between natural rubber and silica, and thus, it required special equipment to ensure proper mixing. Therefore, in this case, it was decided to use coupling agents such as Silanes to disperse silica in rubber.

2.4 Furthermore, this project involved analyzing the chemical properties of silica and few chemical reactions were developed in a controlled manner. So, before carrying out experimental work, it was necessary to understand the chemistry of Silica -silane reactions to ensure an appropriate chemical bond between silica and natural rubber.

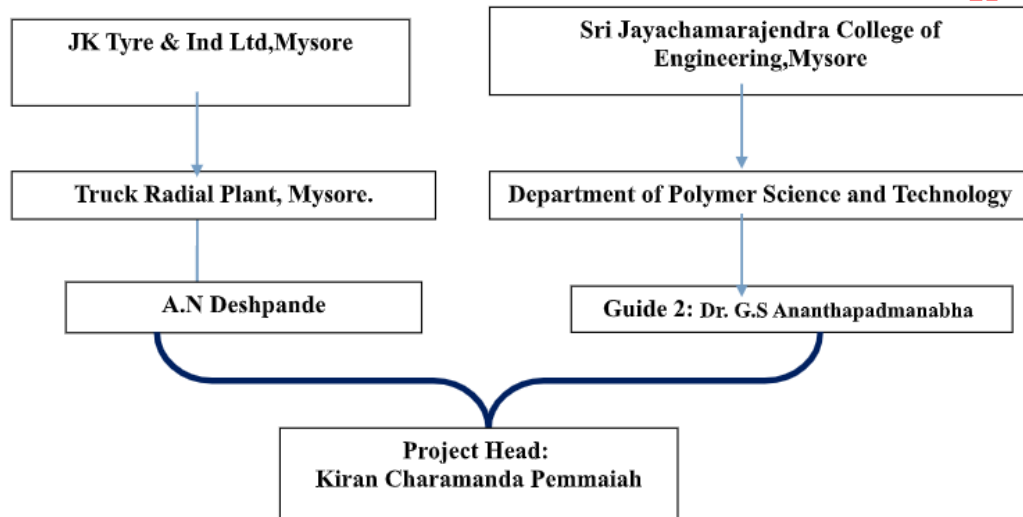
2.5 During this tenure, I carried out the following required duties to achieve the milestone.

- Involved in the background history of silica to understand material properties and their chemistry.
- Understood behavior of inorganic material in the rubber compound.
- Analyzed the chemical processing of a polymer composite material.



- Used material characterization technique to select the appropriate materials.
- Prepared silica tread material by using its different proportions.
- Involved in the mixing of silica compounds using three processes, i.e. masterbatch, re-mill, and final batch.
- Involved in the induction meetings conducted in the industry and reported the progress to the radical plant manager.

2.6 Organizational structure:



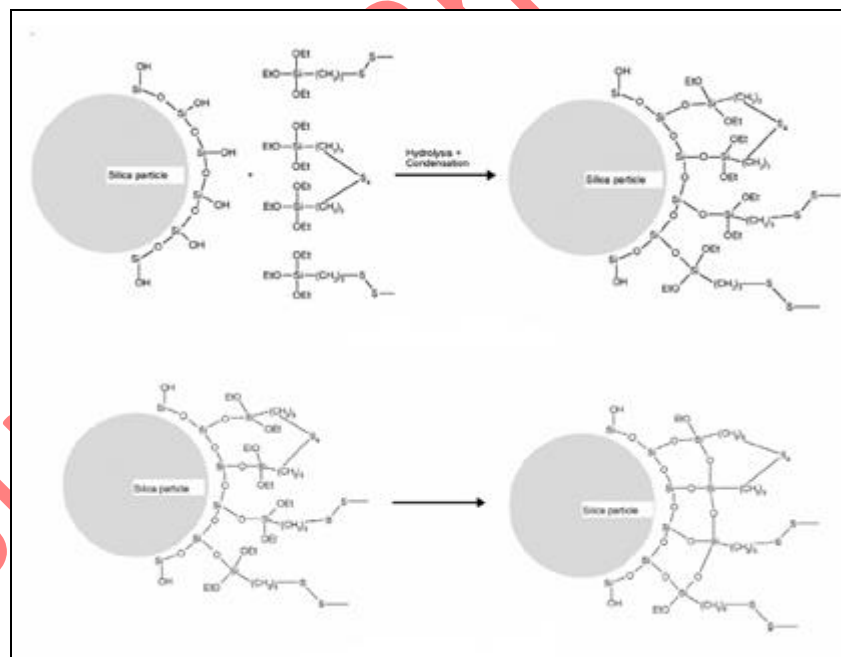
g) Personal Engineering Activities:

2.7 For the literature survey, I checked some latest international articles showing experimental work and analysis of using silica as a non-inorganic material in tyres. I found out that for passenger tread compound only highly dispersible silica was used in the 1990s, however, this compound proved challenging in terms of processing. Then, a silica/silane filler system was introduced to dramatically increase wet traction along with a reduction in rolling resistance. From this research, I noticed that overall performance was significantly improved by blending carbon black and adjusting the quantity of crosslinking system and silane. However, here, I noticed that introducing silica as a treadwear compound also turned out good in comparison with carbon black-filled compound. During this research tenure, I also didn't find a lot of data on the usage of tread compounds by only using silica. Therefore, I decided to work on the "Tread Base Compound" to decrease hysteresis in tyres.

2.8 Then, I arranged a meeting with the supervisor to discuss my work plan with the supervisor and co-supervisor around 25 to 30% of rolling resistance occurred in tyre of passenger trucks or cars. This tread component whenever comes in contact with the road controls tyre's rolling resistance. The two main components of tread are the base and tread cap. Hence, I explained that I plan to design a Tread base compound with minimum heat built-up, excellent dynamic properties, and low rolling resistance.

2.9 After approving my idea, I started studying the material properties and chemical behavior of silica technology. I first studied the amorphous precipitated silica properties which are distinguished by their physical properties, particle characteristics, and chemical composition. I analyzed that physical properties are most important in silica, including pH determined as a 5% aqueous slurry, loss density and tapped density, viscosity, turbidity, refractive index, light-scattering properties, and/or sedimentation rate by ultracentrifugation. Also, these silica particles are characterized by specific surface area as determined by the adsorption of nitrogen gas by the BET method. Since I decided to highly dispersible silica in the project, so, I analyzed the interaction between the silane coupling agent and silica rubber (TESPT). I found out about the use of silica in combination with bifunctional organosilanes, particularly bis (triethoxysilyl propyl) tetrasulfide. I noticed that there are two factors responsible for the properties achieved with these two product groups.

1. Triethoxysilyl groups of TESPT react with silanol groups of silica during compounding liberating ethanol.
2. The rubber reactive group of silanes (tetrasulfane) has a strong tendency to form tofiller bond during the curing of rubber.



Silica silane reaction

2.10 After studying chemical properties and interactions, I decided to use Silica as reinforcement in place of Carbon black either completely or partially. Also, silica is considered an inorganic material so it would decrease the footprint on the environment. But, I noticed that the interaction of carbon black with rubber is entirely via physical adsorption, so this would produce restrictions on the viscoelastic properties of tire material (composite). This week's interaction between rubber and carbon black can enhance the compound's viscous compound along with an increase in rolling resistance and heat¹²

build-up of the tire. Hence, I provided a solution of introducing filler material in this rubber compound by creating chemical bonding between them because this appropriate bond between rubber and filler would improve both physical properties and dynamic mechanical. However, it was another challenge to introduce silica material into a rubber compound because the rubber compound in Tread base is non-polar whereas silica is polar, consequently it was difficult for me to blend the two materials. So, I eradicated this issue with the use of a silane coupling agent because it can develop chemical bonds between silica and rubber compound. For this purpose, I decided to develop different formulations by gradually reducing carbon black and using silica as a substitute in each formulation. Then, I decided to add a Silane coupling agent in these silica formulations as so to promote chemical bonding between natural rubber and silica.

2.11 After deciding on the main agent of this project, I conducted a material study to select the best material which would be used in the experimental work. I first opted for natural rubber by studying its chemical structure and physical properties which are shown below. This was a Polyisoprene which is a "synthetic natural rubber" that is synthesized commercially from an isoprene monomer.

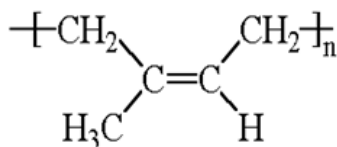


Figure 4 NR Structure

After this, I selected zinc oxide in higher quantities because it has a reinforcing effect on rubber compounds and improves thermal conductivity and heat resistance, and also improves resistance to tear, abrasion and flexing. Then, I elected stearic acid because it is an activator for accelerators, which functions by forming zinc soap which in turn activates the accelerators. Next, I selected 6 PPD type anti-degradant because it offers excellent resistance to rubber vulcanizates against degradative forces such as ozone, flex cracking and fatigue, oxidative heat aging, and metal-ion catalyzed oxidative aging.

Chemical name	N-1, 3-dimethyl butyl-N'-phenyl paraphenylenediamine
Chemical structure	
Appearance	Dark purple pastilles
Specific gravity at 25°C	1.0
Melting point, ball and ring	48°C
Heat loss	0.3%
Solubility	Soluble in acetone, ethyl alcohol. Moderately soluble in hydrocarbon solvents. Insoluble in water
Classification	Discoloring and staining type antidegradant

Also, I used TMQ of chemical name (Polymerized 2,2,4-trimethyl-1,2-dihydroquinoline) is an anti-degradant to provide long-term protection in rubber articles.

2.12 Afterward, I selected PVI Prevulcanisation inhibitor for IR, NR, NR-BR blend, SBR, NR-SBR, SBR-BR blends, etc. it is an effective scorch inhibitor with almost all types of accelerators and in all types of Sulfur cured 'dienerubber based compounds. Also, I used TBBS of chemical name (N-tert-Butyl-2-benzothiazolesulfenamide) which comes under the category of Sulfenamide accelerators. Hence, I selected the following materials and equipment for this project:

MATERIALS	
Materials	Source
SIR(Natural Rubber)	Indonesia
Zinc Oxide	Pondy Oxides
Stearic acid	VVF Ltd Taloja
6PPD	Kumho Petro chemical
TMQ	Merchem Ltd, Cochin.
Micro Crysallinet Wax	Rhein Chemie.
Silica	Degussa(Evonik).
X50'S(Coupling agent)	Degussa(Evonik).
N339 Carbon Black	Continental Carbon.
RM Sulfur	Jaishil Sulphur & Chemicals Ltd.
TBBS	Flexsys.
PVI	NOCIL Ltd.

Sr. No.	Equipments	Model / Manufacturer
1	a) Master Mixer (Intermix) b) Final Mixer (Tangential)	a) GK320, Harburg Freudenberger, Germany b) GK 270, Harburg Freudenberger, Germany
2	Rheometer	MDR2000, Alpha Technologies USA
3	Rubber Process Analyzer	RPA 2000 from Alpha Technologies, USA
4	Mooney Viscometer	MV2000, Alpha Technologies USA
5	Hardness Tester	Wallace
6	Tensile Tester	Zwick Roell, Germany
7	Dynamic Mechanical Analyzer	DMA, VA4000 from M/s Metravib, France
8	Heat Build up	Goodrich Flexometer
9	Rebound resilience tester	Zwick 5019, Germany

2.13 After this, I started experimental work by Base Truck formulations carrying

preparing a series of the Radial Tread different silica amounts. In this present¹⁵



work, I correspondingly reduced the Carbon Black amount by varying amounts of Silica. Also, in the mixture, I added a coupling agent called X50'S comprised of the following composition at 16 percent of silica for each 100 Silica.

Table Tread Base Formulation (Radial)

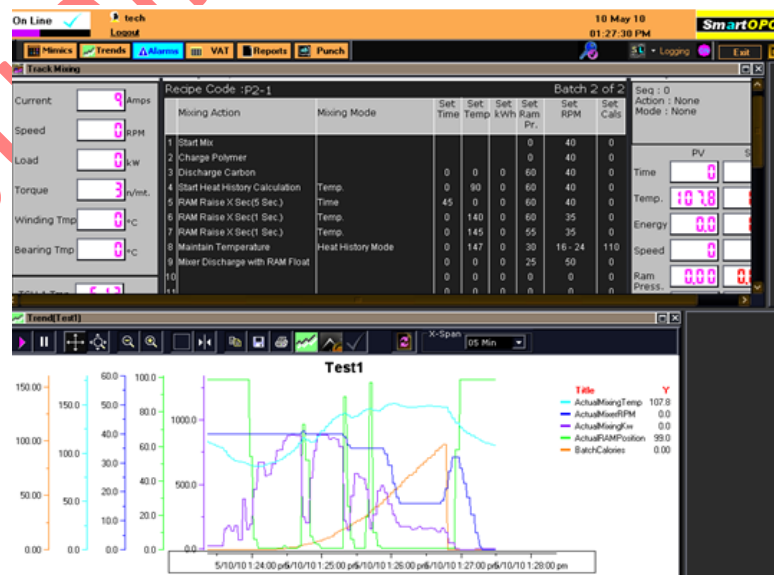
SILICA TRUCK RADIAL TREAD BASE FORMULATION	P1	P2	P3	P4
NR	100	100	100	100
ZNO	3-4	3-4	3-4	3-4
STEARIC ACID	2-3	2-3	2-3	2-3
6PPD	1	1	1	1
TMQ	1	1	1	1
MC WAX	1	1	1	1
SILICA	5	15	25	38
N339	33	23	13	0
X505(COUPLING AGENT)	0	2.4	4	6.08
SULPHUR	1-2	1-2	1-2	1-2
PVI	0-0.200	0-0.200	0-0.200	0-0.200
TBBS	1.2-2	1.2-2	1.2-2	1.2-2

I mixed all selected compound ingredients by using three main processes, i.e. Masterbatch /Mastication, Remill, and Final batch process. The masterbatch, refill mixing, and mastication was done by using GK 320 intermix whereas final mixing was performed using tangential mixer GK 270. Finally, I developed the following figure showing the mixing procedure, i.e. I created four formulations for the Tread base compound, such as P₁, P₂, P₃, and P₄ which were mixed at different formulations. Out of these, I considered P₁ as a control/ standard/tread base compound, whereas in the remaining base compound, I kept on increasing the amount of silica congruently decreasing the overall carbon black.

Table Mixing Procedure

MIXING PROCEDURE					
COMPOUND	MASTICATION	MASTER 1	MASTER 2	REMILL	FINAL
P1		NR-100	MASTER 1	MASTER 2	REMILL
		ZINC OXIDE	ANTIDEGRADANTS		SULFUR
		STEARIC ACID	N339-15		TBBS
		N339-18			PVI -
P2	NR-100	MASTICATION		MASTER 2	REMILL
	SILICA-15	ZINC OXIDE			SULFUR
	X50S-2.4	STEARIC ACID			TBBS
		N339-23			PVI
		ANTIDEGRADANTS			
P3		NR-100	MASTER1	MASTER 2	REMILL
		SILICA-25	ZINC OXIDE		SULFUR
		X50S-4	STEARIC ACID		TBBS
			N339-13		PVI
		ANTIDEGRADANTS			
P4	NR-100	MASTICATION		MASTER	REMILL
	SILICA-12	SILICA-26		ZINC OXIDE	SULFUR
		X50S-6.08		STEARIC ACID	TBBS
				ANTIDEGRADANTS	PVI

2.14 Next, for comparison of the Silica mixing curve (silica-silane reaction), I noticed that it would be difficult for me to maintain silica -silane mixing's temperature plateau, which was a necessary step to carry out the silica-silane chemical reaction, so the temperature should have remained for 60 seconds at 145°C. So, I overcome this problem by maintaining the temperature plateau using loop control of mixer rpm.



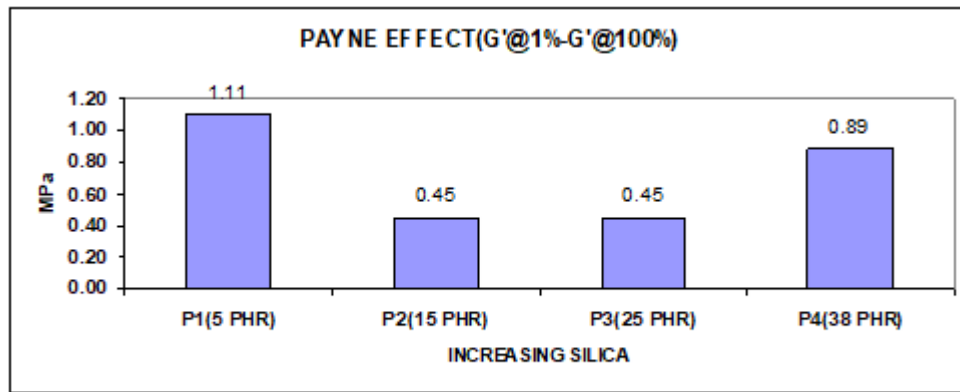
Mixing Curve for Silica-Silane Reaction

2.15 After completing formulation work, I started analyzing the properties of the material, i.e. I first opted for Rheometric properties. Here, I noticed that by increasing the silica level, all other parameters like t90, t40, and scorch time were also increased. This was due to the acidic nature of silica which adsorbs basic accelerators over its surface and on the other hand, it provided less accelerator for curing reactions. That's why both the current rate and scorch time were increased.

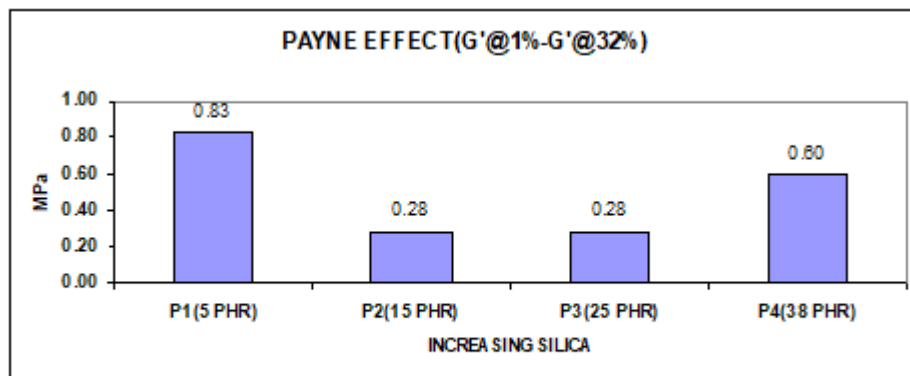
Table Rheometric Properties

Rheometric Properties @160°C for 15 min				
Properties	P1	P2	P3	P4
MIN TQ (lb.in)	2.40	1.74	1.68	2.37
MAX TQ (lb.in)	14.54	12.20	11.80	12.76
ts2 (m.m.)	4.12	4.20	4.39	4.41
Tc10 (m.m.)	3.64	3.35	3.60	2.72
tc40 (m.m.)	4.73	4.85	4.98	5.49
tc90 (m.m.)	6.65	6.70	6.73	7.48
Mooney Viscosity (MU) ML(1+4)100°C	62	58	57	84
Payne Effect_1 (G'@1% - G'@32%)	0.83	0.28	0.28	0.60
Payne Effect_2 (G'@1% - G'@100%)	1.11	0.45	0.45	0.89

Meanwhile, I also observed the Payne effect by developing a graph showing torsional modulus difference versus increasing phr of silica at 100 percent strain and decreasing the difference of torsional modulus up to around 25 phr. I knew that minimum a Payne effect, then better would be polymer for filler interaction. From the graph, I noticed that silica-silane interaction was performed better upto 25 phr in natural rubber and represents a minor Payne effect. But, by increasing silica loading, i.e. at 38 phr, I observed that a Payne effect was also escalated indicating there's more filler-filler interaction instead of silica silane interaction in natural rubber. I concluded that a decrease in Payne effect to at least silica loading of 25 phr turned out a better polymer-filler interaction. But, increasing silica loading to 38 phr, indicated poor filler interaction, which means the compound's viscosity of the compound decreases up to 25 phr but beyond 25 phr the viscosity increases indicating poor silica Natural Rubber interaction.



Plot of Payne Effect (G'@1%-G'@100%) Vs Silica loading



Plot of Payne Effect (G'@1%-G'@32%) Vs Silica loading

2.16 After this, I analyzed the physical properties for various silica loading of Truck Radial tread base compounds. I noticed a 100% decrease in modulus due to an increase in the silica level and there were significant changes up to 25 phrin 300% modulus, however, I observed a drastic reduction from 10.3 MPa to 7.3 MPa at silica loading of 38 phr. It was also due to the acidic nature of silica which adsorbs the accelerators over its surface. Furthermore, it also resulted from a reduction of crosslink density due to the availability of fewer accelerators for vulcanization. Hence, I concluded that at 38 phr silica only 300% modulus was reduced to the maximum extent and it could be eradicated through the ultrafast accelerator. On the other hand, in dynamic mechanical properties, I observed the below two figures which indicated an increase in silica level but it decreases Tan Delta in all three temperatures up to 25 phr silica loading and then increases at 38 phr level of silica. This is because the elastic component of the tread base compound increases and the viscous component decreases up to 25 phr silica loading. Hence, the total ratio from viscous modulus to elastic modulus was also reduced causing minimum values of Tan Delta.

2.17 In the starting phase of this project, I adopted safety approaches by planning all required chemicals and then studied the MSDS sheets to understand the chemical reactions of the component and their safe handlings. Moreover, while choosing equipment, I focused on ASTM standards to select the appropriate equipment and properties of the specimen, such as ASTM D 5289 for moving Die Rheometer, and ASTM D 412 for tensile properties, ASTM D5992 for dynamic mechanical analyzer, etc.

2.18 Since this project was done for JK Tyre and Industries so I attended meetings called by plant radical plant manager (A.N Deshpande) to discuss my research work outcomes and seek his guidance to achieve the defined results. I selected and procured all materials under his guidance by considering cost as a significant factor. Furthermore, I was also instructed by the manager to attend induction meetings at the workplace along with the lab manager and lab tour guide to understand safety standards and proactive measures which need to be implemented while working with chemicals. Also, I learned different ways to handle spill kits and proper disposal methods of chemical waste. Therefore, during my research work, I abided by and implemented the H&S protocol.

2.19 I performed experimental work in the laboratory of the industries with the help of the lab manager and discussed all possible results to avoid errors. I followed ethical regulations to work as per instructions given by the lab manager and never used any chemical or product without his permission. Furthermore, I also kept in mind industry standards to avoid penalties. I also provided innovative solutions using my extensive knowledge in material engineering, i.e. I encountered difficulties during the mixing process of natural rubber and silica in an internal mixer due to reaction time and temperature, i.e. it was decided to start silica-silane reaction from 140 °C to 150° so that silica's hydroxyl groups made abundant with the ethoxy group. But it was taking extra time which was breaking the sulfide bonds in silica while mixing. Therefore, I had to brainstorm to select an optimum level for rebound resilience and hardness of the elastomeric material. I suggested increasing silica content because the rate of vulcanization would decrease rubber content, which means due to the acidic nature of silica it would absorb a basic accelerator, hence producing accelerator's scarcity needed for crosslinking reactions. It would also decrease the hardness and modulus of a composite rubber material. In addition, I also introduced an ultrafast accelerator TBzTD to enhance a crosslink density.

h) Summary:

2.20 I completed experimental work on time and provided all results in the form of graphs and tables so that the co-supervisor and supervisor can understand my work. I accomplished my research requirements and created a thesis document on it. It gave me industrial working experience and polished my skills.

CAREER EPISODE 3

a) Introduction:

20



3.1 For this episode, I decided to explain a casestudy that was developed to check the high viscosity of steel skim compounds to represent my understanding of material properties and their compositions. The project was named “Cure Pro Insoluble sulfur (10% oil treated)Adoption in High Viscosity Steel Skim Compound of Truck Radial Tire” conducted from February 2019 to February 2021. This project trial was done at an Indiantire company for truck radial tires during my internship tenure at Eastman Chemical. I completed this projectand it was a commercial success.

b) Background:

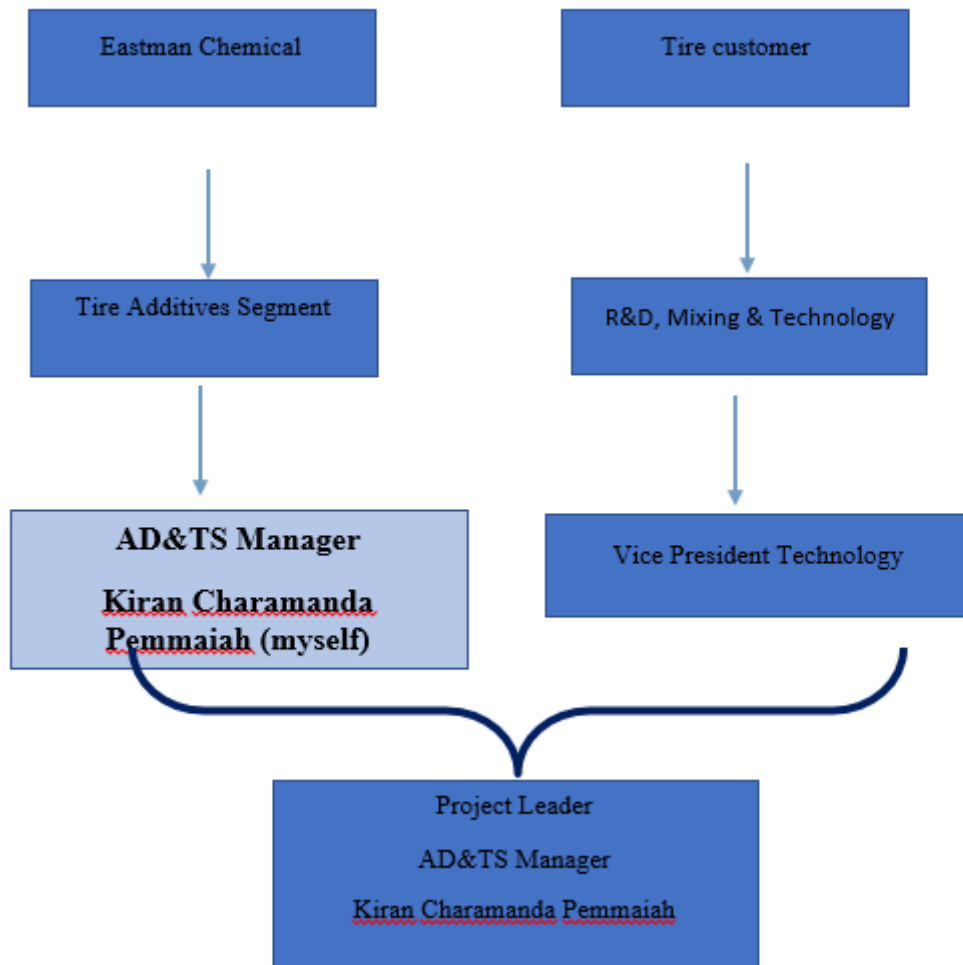
3.2 Insoluble sulfur is widely used in radial tires for vulcanization of the rubber material. The commonly used insoluble grades are OT 20 (20 % oil treated) and OT 33 (33 %oil treated). In the current project, a new grade of insoluble sulfur, Cure Pro (10 % oil treated) was introduced to the tire customer. This product has the highest thermal stability and best dispersion in the existing insoluble sulfur grades. The customer was using OT 33 grade for truck radial compounds, so this project is a comparison of Cure Pro(10 % oil treated) against OT 33 (33 %oil treated) and ultimately replacing OT 33 with Cure pro.

3.3 The project’s objective was to introduce Cure Pro (10 % oil treated) insoluble sulfur in steel skim truck radial compound at the tire customer by replacing OT 33 (33 %oil treated) sulfur with Cure Pro(10 % oil treated) insoluble sulfur in truck radial compounds along with a demonstration of tensile strength,dispersion and thermal stability benefits and demonstration of equal or better tire performance

3.4 I was performing the following duties in the project, i.e.

- Arrange a meeting with the tire customer and give a technical presentation on Cure Pro(10 % oil treated) insoluble sulfur.
- Working with R&D of Tire customers and collecting R&D samples for evaluation.
- SubmittingTDS(Technical datasheet), specification, and MSDS to the tire customer.
- Providing technical expertise in rubber compound missing and testing.
- Troubleshooting any issues arising from mixing and processing
- Planning and scheduling plant trials, testing, and processing.
- Made comparisons between insoluble sulfur ‘OT 33’ and ‘Cure pro and developed an experimental setup.
- Responsible for B96 mixing/processing and analyzed the results of tensile dispersion.
- Optimizing the B96 compound with cure Pro.
- Analyzed the tensile properties of the B96 Trail compound.

3.5 Organizational Structure:



c) Activities:

Personal Engineering

3.6 I researched insoluble sulfur which is being used in the tire industry for a very long time for the vulcanization of rubber to give rubber its desired properties. I reviewed many research articles on the use of insoluble sulfur which showed that it is an appropriate material because it helps the tire to have a good performance on roads. Moreover, from the research, I studied that traditionally OT 20 (20% oil treated) and OT 33 (33% oil treated) were used to enhance tire performance. So, I arranged a discussion meeting with the R&D team on this new grade 'Cure Pro' which is 10% oil-treated insoluble sulfur. For this purpose, I went through the technical data of Cure Pro such as thermal stability, dispersion data, and tensile data. These data were generated by our R&D lab, so it was accountable to run the trials in our tire customer plant and commercialize this product.

3.7 Before initiating the trial work, I attended a group meeting consisting of a total of six members (internal team) and our tire customer to discuss the work methodology and predicted results. Also, I was given 222 kg of material by the R&D department of our tire customer. Moreover, the TDS

(Technical datasheet), specification, and MSDS were given to the tire customer before the R&D evaluation. In this phase, I developed the following working plan showing details of multiple plant trials and specialized sophisticated testing conducted.

3.8 Then, I selected a few materials to carry out plant trial work, i.e. sulfur because it has raw rubber molecules that are entangled but can move relative to each other. On sulfur cross-linking the molecules are tied together making the rubber elastic, tough and harder. Then, I did a comparison of Rhombic sulfur vs insoluble sulfur and made the following conclusion:

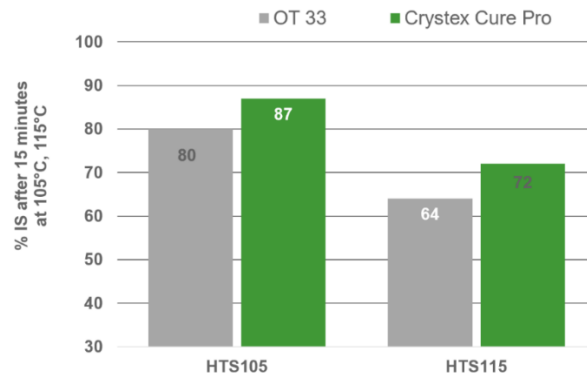
1. Normal rubber makers sulfur, with 8 sulfur atoms in a ring structure, has limitations when used at higher concentrations in rubber compound (more than 1.5phr)
2. To overcome the limitations of normal sulfur, I decided to use insoluble sulfur (polymeric sulfur) because it offers the following advantages:
 - Prevents sulfur migration and bloom during rubber processing, thereby maintaining green tack
 - Maximizes inter ply/layer adhesion
 - Reduces defects in process/service
 - Improves production efficiencies

3.9 Next, I also did chemical properties comparison and thermal stability comparison between insoluble sulfur 'OT 33' and 'Cure pro.

Table 2 Chemical Properties comparison

SPECIFICATIONS		OT 33	Cure Pro
PROPERTY	TEST METHOD	LIMITS	LIMITS
Appearance	FF97.5	Yellow powder	Brownish-yellow powder
Insoluble sulfur (on total sulfur), %	FGr98.1	90.0 Minimum	90.0 Minimum
Total sulfur content, %	FM98.1	66-68	88.0-91.0
Ash, %	FGr98.3	0.05 Maximum	0.05 Maximum
Total binder content, %	FM98.1	32- 34	9.0-12.0
Acidity (as H ₂ SO ₄), %	FAC98.1	0.05 Maximum	0.05 Maximum

From the comparison, I noticed that Cure Pro has better thermal stability at 105°C and 115°C. I developed the following graph showing %IS(% insoluble sulfur) retained after subjecting both insoluble sulfurs at 105 and 115 for 5 minutes, so I concluded that Cure pro has higher % IS retention at both temperatures.



Lastly, I conducted a storage area comparison between insoluble sulfur 'OT 33' and 'Cure pro', which showed that Cure pro occupies 21% less area, is cost-effective, and economical as compared to OT 33 because of less oil in the product.

3.10 After the material selection and comparison, I developed an experimental setup to perform the mixing of Cure Pro and OT 33 in a 270 L Kobelco mixer. Two trials were conducted in the 'B96' truck radial skim compound. In the current trials, B96 R is referred to as OT 33 (control) and B96 T/F is referred to as cure pro

Trial 1

5 batches of cure pro were mixed followed by 5 batches of OT33 (control)

1. Control B96 was mixed (6 batches) using a standard cycle
2. B96T/F mixed very fast compared to B96 R(20-25 sec faster)
3. I kept an effective mixing time of 65-70 sec for B96 T/Fas compared to 75 sec for B96 R.
4. Cure Pro (10 batches) followed, however, the higher shear resulted in over-temperature concerns (spiking up to 120C on mixer T/C), so the cycle was shortened to control the temperature
5. Not enough mixing time for the Cure Pro B96T/Fcompound to have a homogenous mix and the sulfur dispersion was poor. This is because of friction created by lower oil content in cure pro compared to OT 33.
6. This 20" shorter cycle caused inhomogeneity in the dropped batches
7. Calendaring was poor resulting in wire visibility and un-uniform coating.
8. Subsequent processing of batches #10 & #9 resulted in 'cold' & poorly broken-down rubber being presented to the calendar.
9. Bare wire due to poor rubber flow in the nip was unacceptable

Trial 2 (optimized)

To minimize friction, 1 pHR6PPD,I shifted the anti-oxidant to final mixing in B96 T/F because it would give sufficient time for the B96 T/F compound to have a²⁴

homogenous mix. With this modification, not only B96 R compound was having a good sulfur dispersion but also was mixing 15 sec faster compared to the control compound B96 R



Figure 5 Trial 1: Mixing Power curve-control B96 R

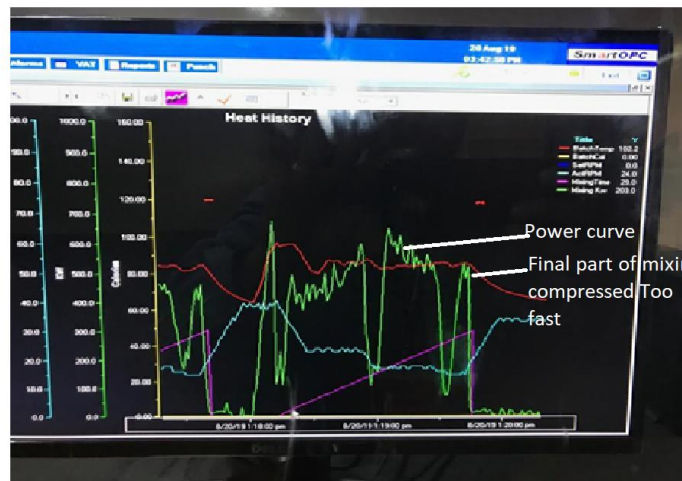


Figure 6 Trial 1: Mixing Power curve-control B96 TF(too fast mixing)



Figure 7 Trial 2: Mixing Power curve-control B96 TF optimized with 1 PHR 6 PPD

3.11 After this, I analyzed the results using Keyence Optical Microscopy and obtained the following results.

1. The size of particle count was less than 100 μm do not impact the tensile properties of the rubber
2. Particle count of particle sizes was between 100 and 200 μm having a possible impact on the tensile properties of rubber
3. Particle counts of particle sizes above 200 μm have a probable impact on the tensile characteristics of rubber. I noticed a higher particle count in this region which will likely harm rubber mechanical properties and will likely result in lower alpha and beta Weibull parameters generated from tensile dispersion
4. These guidelines are ultimately dependent on curing temperatures and kinetics.

3.12 Now considering the concept, I deduced that for Trial 1, B96 T/F has better sulfur dispersion than B96 R.

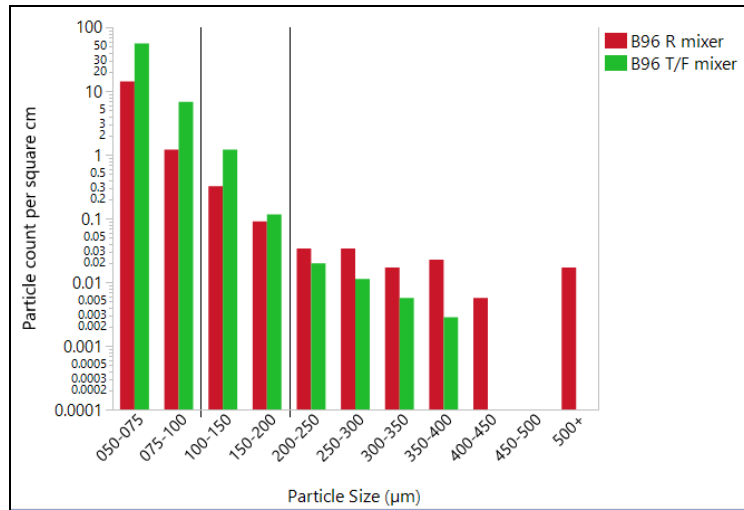
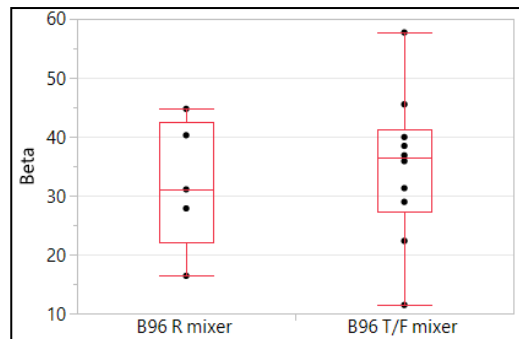
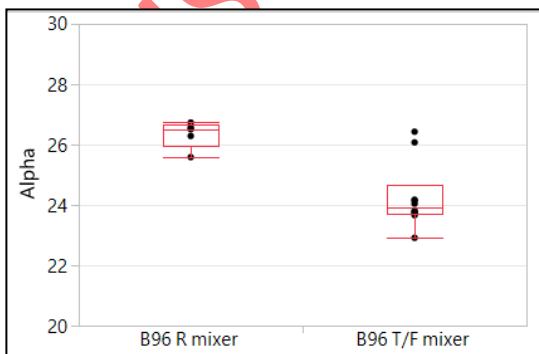
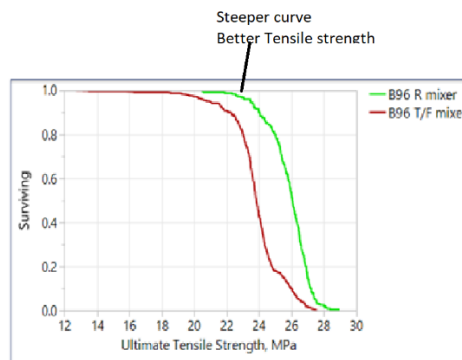


Figure 8 Trial 1: Keyence Microscopy particle size distribution

Then, I performed tensile strength analysis-survival plot (Weibull statistics) for Trial 1, I observed that the B96 R has a steeper curve indicating a lower number of tensile failures in the lower values of tensile strength. Furthermore, I found out that the B96 R mixer is statistically different from than B96 T/F mixer for Alpha whereas the B96 R mixer and B96 T/F mixer were statistically the same for Beta. Also, I noticed that the pooled survival plot showed a distinct separation between the two samples. Thus, from this analysis, I concluded that B96 R has better tensile because B96 T/F was mixing fast and had poor homogeneity of chemicals during final mixing.



Connecting Letters Report			
Level			Mean
B96 R mixer	A		26.34
B96 T/F mixer	B		24.28

Levels not connected by same letter are significantly different.

Connecting Letters Report			
Level			Mean
B96 T/F mixer	A		34.84
B96 R mixer	A		32.07

Levels not connected by same letter are significantly different.

Figure 9 Trial 1: Survival plot of Tensile strength

3.13 After this, I checked ultimate tensile strength and concluded the following results:

- B96 R mixer is statistically different from B96 T/F mixer for average ultimate tensile strength.
- B96 R is better in average ultimate tensile strength with a lowerrange.

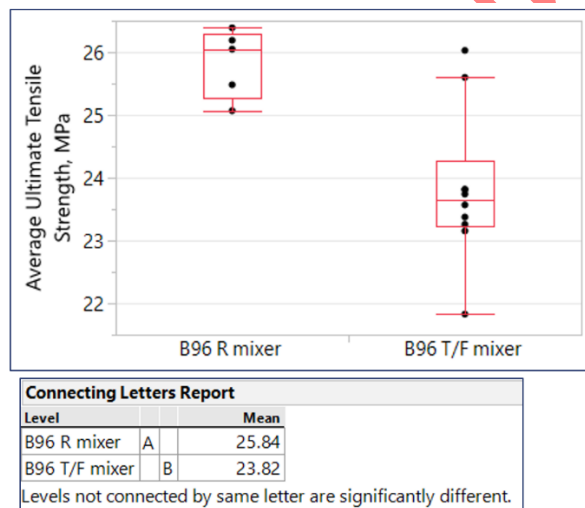


Figure 10 Trial 1: Ultimate Tensile Strength

3.14 After this, I analyzed the optimized results of Trail 2– Keyence Microscopy. I noticed that B96 T/F has better sulfur dispersion than B96 R, which means the result is the same as trial 1

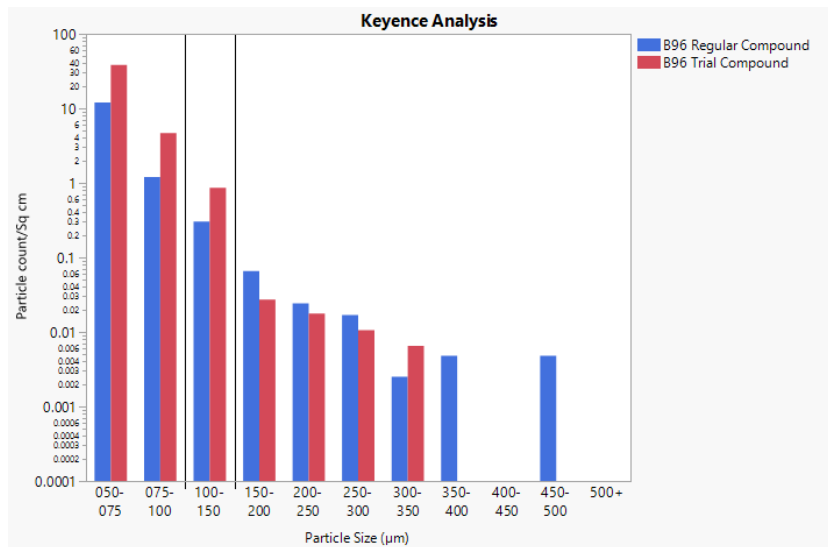


Figure 11 Trial 2: Keyence Microscopy

For Trial 2 Thermal stability: I tested % Soluble sulfur (%SS) using High-Performance Liquid chromatography technique (HPLC) after the mixing and calendaring process. For B96 T/F (Trial), I noticed that % SS was well below a bloom threshold level and lower than B96 R (Regular). This means less amount of insoluble sulfur is converted to soluble sulfur indicating better thermal stability of the B96 T/F compound

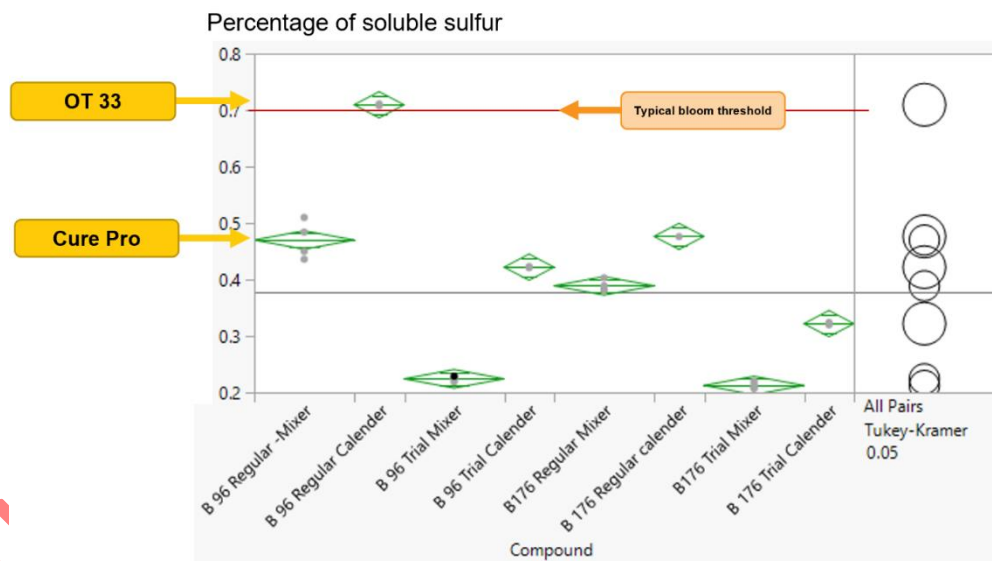


Figure 12 Trial 2: Thermal stability (% soluble sulfur after mixing and calendar)

3.15 Then, I analyzed the results of the tensile strength analysis-survival plot (Weibull statistics) for Trial 2 and noticed the following outcomes.

1. Higher α and β indicate better dispersion
2. B96 R (Regular)(OT 33) is statistically different from than B96 T/F Trial(Cure Pro)

I concluded that the B96 T/F Trial(Cure Pro) has better in tensile properties than B96 R Regular(OT 33). This indicated better Consistency in tensile properties which will reflect in better CpCpk values.

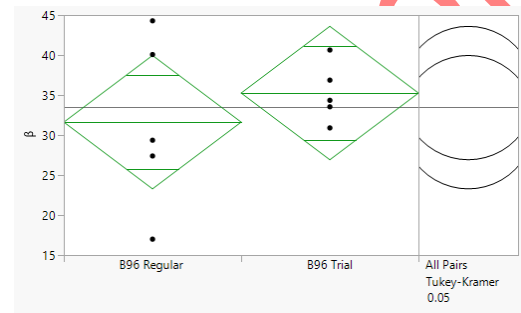
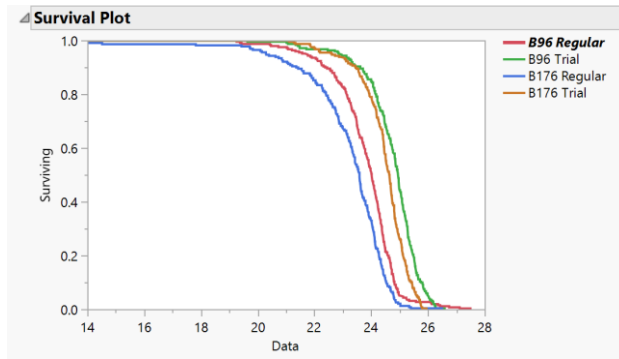


Figure 13 Trial 2: Weibull plot of Tensile Strength

3.16 Now for ultimate tensile strength-Trial 2, I obtained the following results:

1. B96 R, Regular is statistically different from B96 T/F, Trial for Average Ultimate Tensile Strength.
2. B96 T/F Trial is better in average ultimate tensile strength with the lowest range.

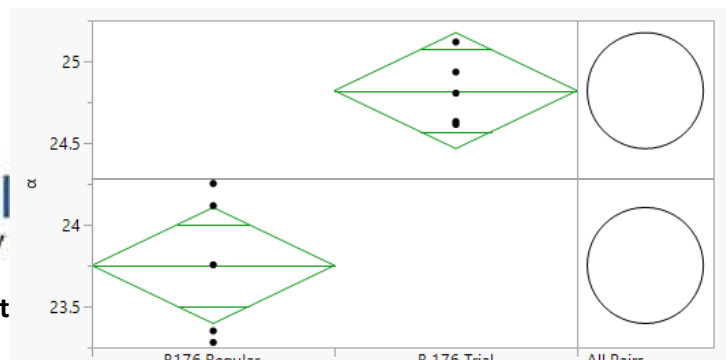
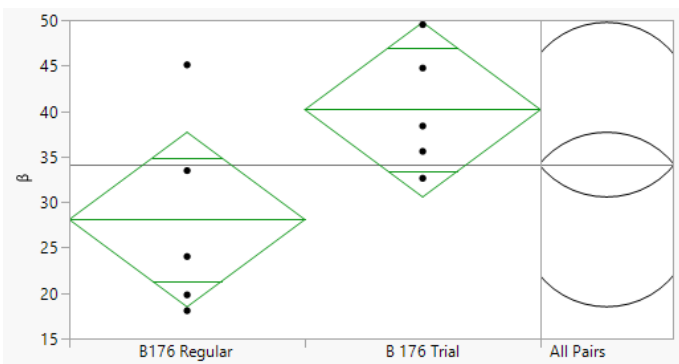
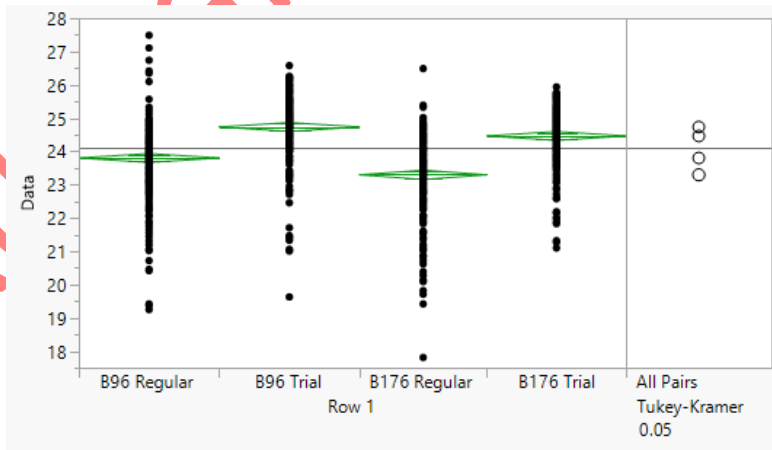


Figure 14 Trial 2: Ultimate Tensile Strength

Hence, I concluded the following learnings from this case study.

- Each compound has to be treated differently while optimizing the mixing cycle.
- Parameters such as viscosity, mixing power curve, and temperature have to be considered while mixing.
- Compounding ingredients and calendaring process requirements also should be considered while optimizing the mixing cycle
- There is a threshold beyond which cycle time reduction will have a major effect on the quality of the compound mix

3.17 I was involved in the project meetings called by the manager to discuss trial details and experimental work results. I focused on following ethical work regulations to communicate properly with each member involved in this experimenting work. Moreover, I stick to the company's regulations to avoid any illegal activity. I showed coordination with my teammates to obtain the desired objectives of the project

3.18 After completing an experiment, I gave a presentation on the work by dividing slides into different sections, including trial summary, Keyence results, analysis, graphs description, and learning lessons. The work was presented in front of the manager, supervisor, and other senior members who appreciated my contribution and engineering skills. Then, I prepared a report containing all details and an attached sheet showing the trial summary table.

d) Summary:

3.19 In this project, I was able to replace OT 33 insoluble sulfur I (B96 R, Regular/control) with cure Pro (B96 T/F, Trial) by optimizing the mixing parameters (Trial 2). I was able to achieve better thermal stability, dispersion and ultimate tensile strength using Cure Pro insoluble sulfur in B96 truck radial tire steel skim compound

Summary Statement

Competency Element	A brief summary of how you have applied the element	Paragraph in the career episode(s) where the element is addressed
PE1 KNOWLEDGE AND SKILL BASE		
<p>PE1.1 Comprehensive, theory-based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline</p>	<p>My project involved studying of material properties, experimental work, toughen the properties of Epoxy resin by selecting different blending compositions of HTPB and Epoxy to conduct improvement studies (toughness), characterization of the prepolymer, developing a Tread base compound using silica by optimizing levels of silica in “Tread Base” by retaining required properties of the base compound would retain, and introducing Cure Pro (10 % oil treated) insoluble sulfur in steel skim truck radial compound. I performed these work by utilizing comprehensive material engineering knowledge and standards.</p>	<p>1.12, 1.13, 1.14, 1.15, 2.13, 2.14, 2.15, 3.10, 3.11, 3.12</p>

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<p>PE1.2 Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline</p>		1.14
	I determined Mode I fracture toughness (Gir)	1.15
	I measured the slope of the initial linear portion of the curve provided flexural modulus and flexural strength (S)	
	I analysed the chemical processing of a polymer composite material.	
	I selected a few materials to carry out plant trial work,	2.15
		3.8, 3.9

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<p>PE1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline</p>	<p>I did the characterization of the prepolymer using IR spectroscopy and then fabricated the laminate using the hand lay-up method.</p> <p>I performed experimental work by preparing a series of the Radial Tread Base Truck formulations carrying different silica amounts</p> <p>I developed an experimental setup to perform the mixing of Cure Pro and OT 33 in a 270 L Kobelco mixer.</p>	<p>1.11, 1.12</p> <p>2.13, 2.14</p> <p>3.10, 3.11</p>
<p>PE1.4 Discernment of knowledge development and research directions within the engineering discipline</p>	<p>I performed a detailed study on composite materials (light in weight) currently used in the aerospace industry.</p> <p>I studied some latest international articles showing experimental work and analysis of using silica as a non-inorganic material in tyres.</p> <p>I reviewed many research articles on the use of insoluble sulfur which showed that it is an appropriate material</p>	<p>1.7</p> <p>2.7</p> <p>3.6</p>

PE1.5 Knowledge of contextual factors impacting the engineering discipline	I performed material study to select the required materials to fabricate the composite laminates.	1.9
	I studied the material properties and chemical behavior of silica technology to use Silica as reinforcement in place of Carbon black either completely or partially.	2.9, 2.10
	I conducted a material study to select the best material which would be used in the experimental work.	
	I selected a few materials to carry out plant trial work and chemical properties comparison and thermal stability comparison between insoluble sulfur 'OT 33' and 'Cure pro.	2.11, 2.12
		3.8, 3.9

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<p>PE1.6 Understanding of the scope, principles, norms, accountabilities, and bounds of contemporary engineering practice in the specific discipline</p>	<p>I conducted fracture toughness testing as per ASTM STP 876. This test was done to study the characterization of delamination behavior.</p>	1.14
	<p>I focused on ASTM standards to select the appropriate equipment and properties of the specimen</p>	2.17
<p>PE2 ENGINEERING APPLICATION ABILITY</p>		

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PE2.1 Application of established engineering methods to complex engineering problem solving

I performed a fracture toughness testing to check the characterization of delamination behavior which is a fundamental issue in evaluating laminated composite structures.

1.14

2.10

I noticed that interaction between rubber and carbon black can enhance the compound's viscous compound along with an increase in rolling resistance and heat build-up of the tire, I provided a solution of introducing filler material in this rubber compound by creating chemical bonding between them.

2.14

During comparison of the Silica mixing curve (silica-silane reaction), I noticed that it would be difficult for me to maintain silica -silane mixing's temperature plateau, I overcome this problem by maintaining the temperature plateau using loop control of mixer rpm.

2.19

I encountered difficulties during the mixing process of natural rubber and silica in an internal mixer due to reaction time and temperature



<p>PE2.2 Fluent application of engineering techniques, tools, and resources</p>	<p>I used TA Instruments 2910 DSC to perform the DSC studies to identify the curing schedule and evaluate Tg alterations with different rubber concentrations</p>	<p>1.13</p>
		<p>1.16</p>
	<p>I analyzed the results of prepolymer characterization using the infrared spectroscopy technique.</p>	<p>1.17</p>
		<p>2.14</p>
	<p>I performed thermal analysis to check decrease in temperature of glass transition by increasing HTPB in the epoxy.</p>	<p>2.15</p>
<p>PE2.2 Fluent application of engineering techniques, tools, and resources</p>		<p>3.10, 3.11</p>
	<p>I developed the Mixing Curve for Silica-Silane Reaction.</p>	
	<p>I developed the graphs to observe the Payne effect showing torsional modulus difference.</p>	
	<p>I conducted two trials in the 'B96' truck radial skim compound and analyzed the results.</p>	

<p>PE2.3 Application of systematic engineering synthesis and design processes</p>	<p>I performed comprehensive studies on termination of hydroxylPolybutadiene by Modifying EPDXY Resin.</p> <p>I performed experimental work on the tread based green compound for radial truck tyres.</p> <p>I determined cure pro insoluble sulfur (10% oil treated) adoption in high viscosity steel skim compound of truck radial tire</p>	<p>1.11, 1.12, 1.13, 1.14, 1.15, 1.16, 1.17, 1.18</p> <p>2.13, 2.14, 2.15, 2.16</p> <p>3.10, 3.11, 3.12, 3.13, 3.14, 3.15, 3.16</p>
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<p>PE2.4 Application of systematic approaches to the conduct and management of engineering projects</p>	<p>I managed the work in the initial phase by making reports showing research findings and attending communication meetings.</p> <p>I stick to the industrial standards while analysing experimental work to get the optimum results.</p> <p>I was involved in the planning and scheduling plant trials, testing, and processing</p>	<p>1.7, 1.8, 2.7, 2.8, 3.6.</p> <p>2.19</p> <p>3.7</p>
<p>PE3 PROFESSIONAL AND PERSONAL ATTRIBUTES</p>		

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PE3.1 Ethical conduct and professional accountability	I followed instructions given by Guide 1 and Guide 2 to avoid all kinds of errors as per ethical standards.	1.19
	I adopted safety approaches by planning all required chemicals and then studied the MSDS sheets to understand the chemical reactions.	2.17
	I followed ethical regulations to work as per instructions given by the lab manager and never used any chemical or product without permission	2.19

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PE3.2 Effective oral and written communication in professional and lay domains	I attended meetings called by plant radical plant manager (A.N Deshpande) to discuss my research work outcomes.	2.8, 2.18
	I was involved in the project meetings called by the manager to discuss trial details and experimental work results.	3.17
	I prepared progress reports to communicate the research work.	1.19, 3.18

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<p>PE3.3 Creative innovative and proactive demeanor</p>	<p>I analyzed the results of prepolymer characterization using the infrared spectroscopy technique.</p> <p>I selected PVI Prevulcanisation inhibitor for IR, NR, NR-BR blend, SBR, NR-SBR, SBR-BR blends, etc. it is an effective scorch inhibitor with almost all types of accelerators.</p>	<p>1.16</p> <p>2.12</p>
<p>PE3.4 Professional use and management of information</p>	<p>I underwent detailed research in each project to collect the best material which was then used to performed experiments.</p> <p>I managed all project details by making reports.</p> <p>I prepared presentations containing all details and an attached sheet showing the trial summary table.</p>	<p>1.7, 1.9, 1.10, 2.7, 2.9, 2.10, 3.6</p> <p>1.19</p> <p>3.18</p>

<p>, PE3.5 Orderly management of self, and professional conduct</p>	<p>I developed schedule of this project showing project activities (material selection, experimental work, SEM analysis, results, etc.) with their deadlines to complete each task on time.</p> <p>I arranged a meeting with the supervisor to discuss my work plan with the supervisor and co-supervisor.</p> <p>I developed the following working plan showing details of multiple plant trials and specialized sophisticated testing conducted.</p>	<p>1.8</p> <p>2.8</p> <p>3.7</p>
<p>PE3.6 Effective team membership and team leadership</p>	<p>I communicated with the teammates throughout the experimental work to obtain accurate results.</p> <p>I showed coordination with my teammates to obtain the desired objectives of the project</p>	<p>1.20</p> <p>3.17</p>

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