



# *RECYCLED TIRES IN THERMOPLASTICS: A VALUE-ENHANCED SOLUTION TO SUSTAINABILITY*

Scrap Tire Recycling Conference

Haikun Xu | Greenville, SC, December 4-5, 2019

REDEFINING RUBBER  
REDEFINING RUBBER

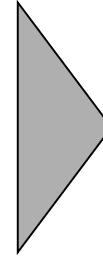
## Krauss Maffei Brands

Broad technology portfolio for a wealth of applications

Machines, technologies, products and applications

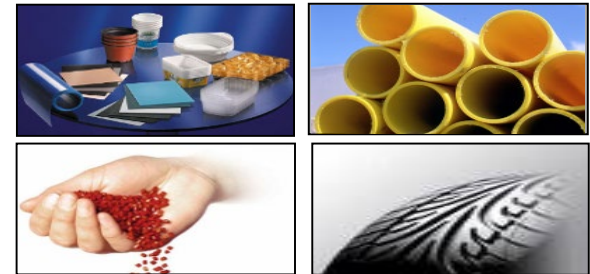
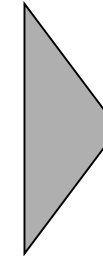
### IMM

Injection Moulding Technology



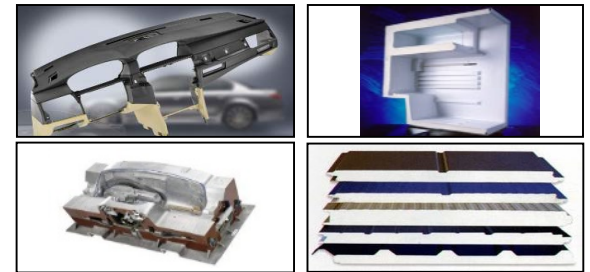
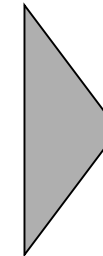
### EXT

Extrusion Technology



### RPM

Reaction Process Machinery





REDEFINING

RUBBER

Rubber Recycling | Crumb Rubber Infill  
Thermoplastic Elastomer Compounding

*Make a  
Greener  
World!*

**Entech Inc.** is a full service tire recycling facility. Production facilities located in northern Indiana.

**Jomar Inc.** sister company, provides us with highly-engineered production equipment.

**Paxco Inc.** Entech's owned trucking company provides prompt, reliable transportation service.



**Paxco Inc.**

# Entech = A Commitment to Sustainability!



## Products

- Crumb Rubber Infills
- Sports Surfaces
- Rubberized Asphalt
- Rubber Rock
- MRP



Last year we recycled:

105,000

Tons of Tires

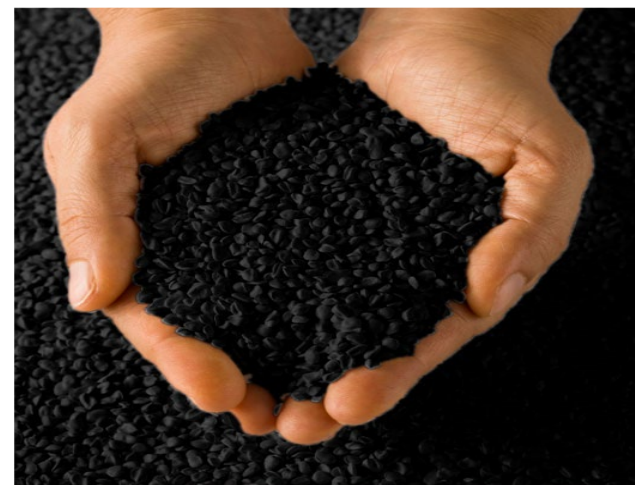
of Tires

# What is Micronized Rubber Powder?

- Fine, dry, powdered elastomeric rubber particles
- Most often from end-of-life tire material
- **Free of foreign particulates** (metal, fiber, etc.)
- Typically range from **180  $\mu\text{m}$  to 50  $\mu\text{m}$**
- **3<sup>rd</sup> generation** of post-consumer tire processing products



1<sup>st</sup> generation: shredded tire rubber chips  
(typically 1 inch or larger)



2<sup>nd</sup> generation: crumb rubber  
(usually 1/2-1/8 inch)

# Why MRP? Find High Values.

## Performance

Durability

Flexibility

**Weather resistance**

**Crack resistance**

**Impact resistance**

Sound dampening

Anti-skid

Compatibility

## Applications

Tire

Compounding

Injection-molding

Extrusion

Asphalt



**MRPs inherit all the good properties of tire rubber.**

[1] "Study on Powder Utilization of Waste Tires as a Filler in Rubber Compounding", Jin Kuk Kim, R. P. Burford. *Rubber Chemistry and Technology*. 1998

[2] "The Use of Recycled Tire Rubber to Modify Asphalt Binder and Mixtures," United States Department of Transportation, Federal Highway Administration, Sep. 2014.

# Future MRP Uses: Find Higher Values

Plastic/MRP compounds  
↓  
Injection molded/extruded products  
↓  
Consumer/Construction/Transportation markets

**Benefits:**  
Cost-effective solution  
Superior performance  
Stable supply sources  
Sustainability

Market > Recycle > Product **MRP** Performance < Recycle < Motivation



**Collaborated efforts should be utilized to add more values**

## **Vertical Solution**

Tire recycling

**Paxco Inc.**

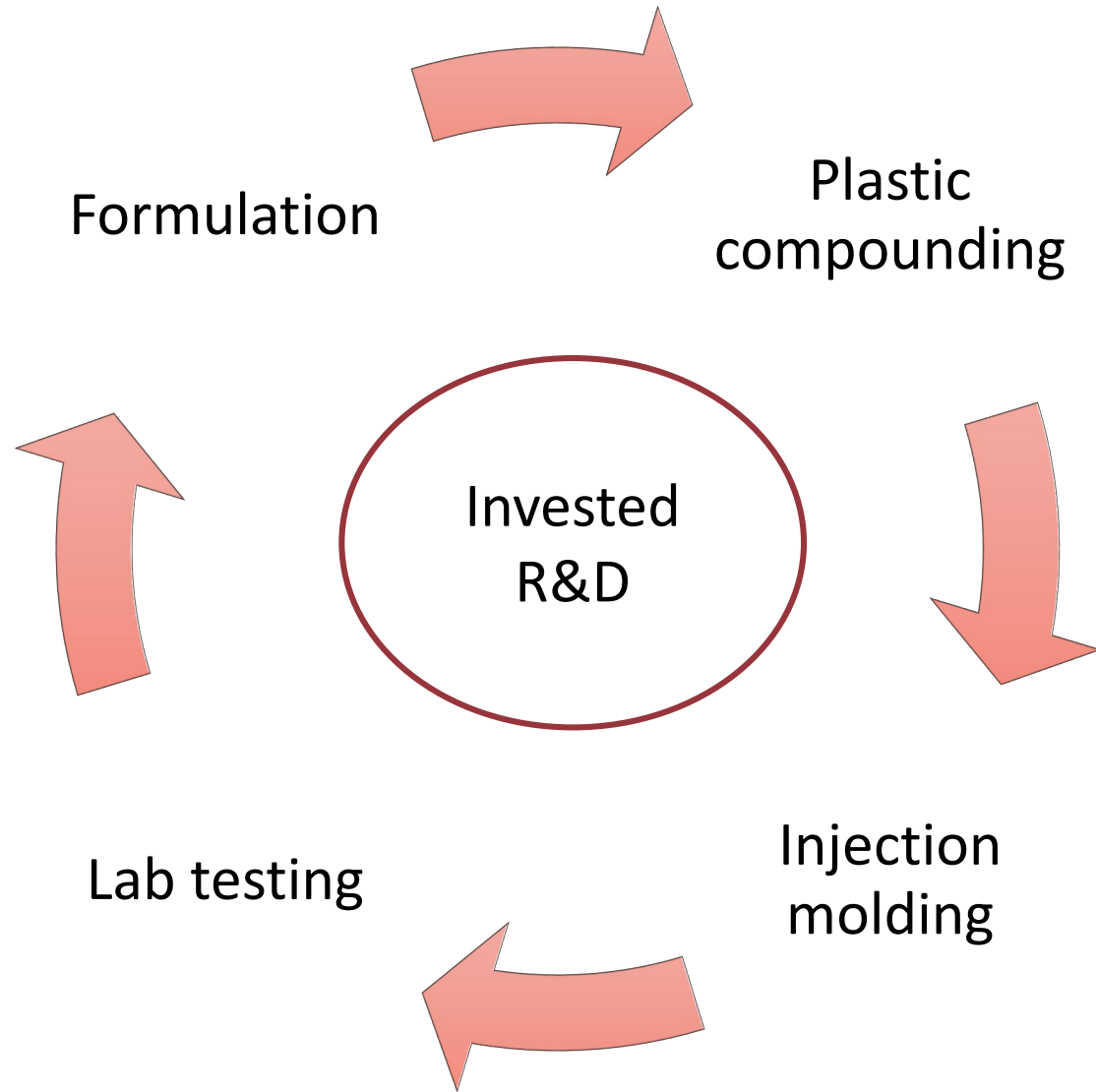
Trucking fleet

Production



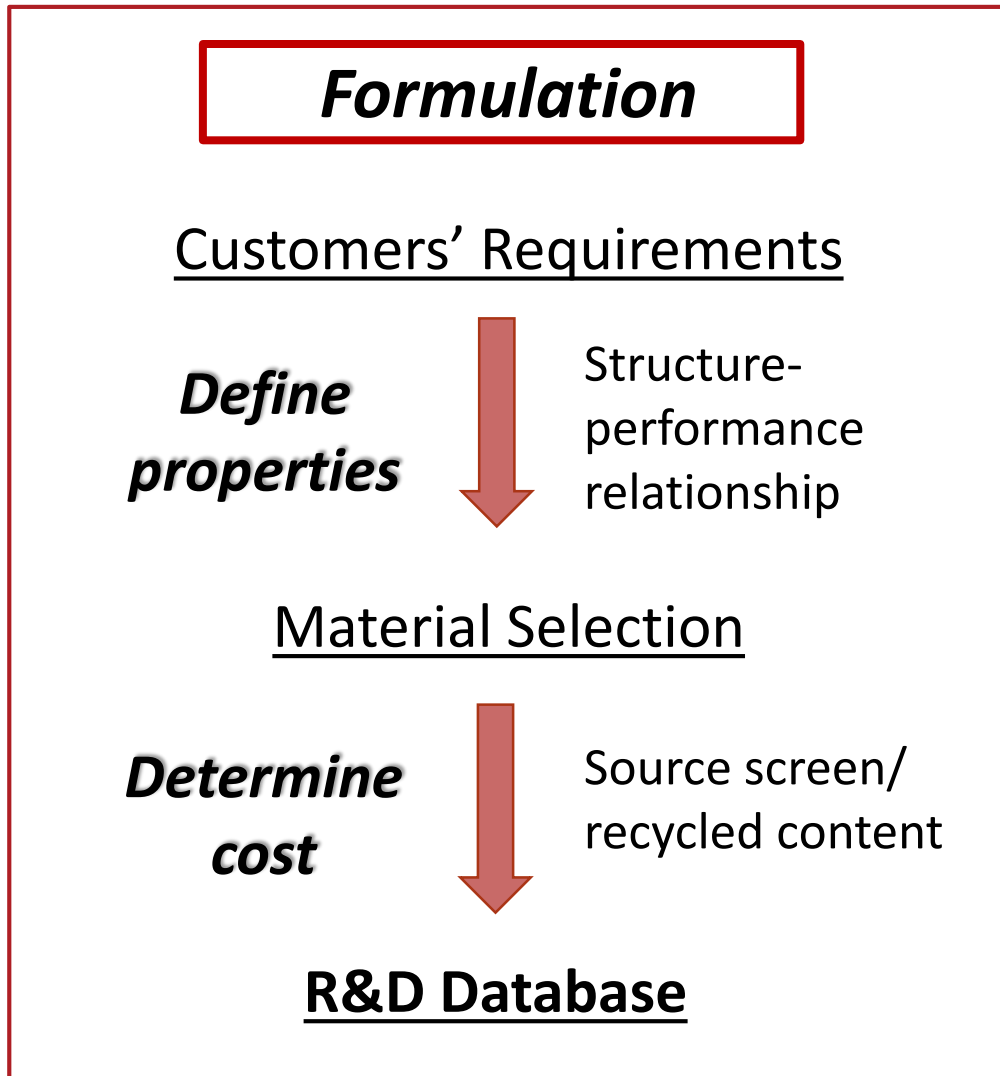
Shredders/  
grinders

MRP





# How is MRP Used in High-value Molded/Extruded Products?



Entech Resins															
	Material	Density (g/cm <sup>3</sup> ) ASTM D792	Hardness (Shore A) ASTM D2240	Melt Flow ASTM D1238		Tensile Properties (50 mm/min) ASTM D412/ASTM D638				Flexural Properties ASTM D790		Izod Impact ASTM D256		Total Recycled Content / Post-consumer (wt %)	
				MFR g/10min (230C, 2.16kg)	MFR g/10min (230C, 10.00kg)	Tensile Strength (MPa)	Elongation @ break (%)	Yield Strain (%)	Yield Stress (Mpa)	Tensile Modulus (Mpa)	1% Secant Modulus (MPa)	Flexural Strength (MPa)	Impact Strength at 23C (J/m)		Break Type at 23C
Non-MRP-filled Compounds	TM 03-16-01	0.895	95	33		24.8	57	6.6	24.8	375	969	31.0	90	C	100/0
	TM 03-16-02	0.896	94	24		23.8	49	6.4	23.8	371	825	26.2	105	C	100/0
	Oflex 96	0.921	96	15		20.9	57	7.3	20.9	286	636	20.5		NB	100/0
	Oflex-70/30	0.897	97	12	219	20.0	76	8.1	20.0	247	588	18.9		NB	100/0
	TM 03-16-05	0.898	97	9	150	18.0	106	10.3	18.0	175	486	15.8		NB	100/0
	Oflex 95	0.924	95	5	100	15.8	126	16.6	15.8	95	371	11.3		NB	100/0
	TM 03-16-06	0.899	96	3	65	14.5	320	22.4	14.4	65	325	10.7		NB	100/0
	TM 03-16-07	0.899	95	2	36	13.9	477	29.0	13.9	48	256	8.7		NB	100/0
	TM 03-16-08	0.900	94	1	22	12.8	447	36.8	12.3	34	224	7.9		NB	100/0
	TM 03-16-09	0.899	93		13	12.3	433		10.9	21	175	6.3		NB	100/0
	TPE-90	0.896	91	<1	9	10.4	470			24	105	4.2		NB	100/0
	TPE-85	0.900	85	<1	18	9.1	382			43	69	2.8		NB	100/0
MRP-filled TPE Enhancement	CRTPE-95	1.056	96	3	53	10.2	29	8.0	9.2	43	328	9.2	122	P	100/50
	CRTPE-85	0.969	85	<1	12	8.7	294			39	76	2.7		NB	100/30
	TM 10-15-54	0.937	81	<1	5	7.2	285			31	47	2.0		NB	90/20
	CRTPE-78		78	<1	5	6.9	419	31.4	2.8	9				NB	60/60
	TM 10-15-59	0.987	75	<1	2	5.8	258			18	38	1.4		NB	90/40
	CRTPE-70	0.990	70	<1	3	5.4	341			11	19	0.9		NB	80/35
	TM 10-15-61	0.976	64	<1	3	4.5	346			9	18	0.8		NB	70/40
TM 10-15-33	0.980	61	<1	5	4.3	477			6	18	0.6		NB	60/40	

## ***Injection Molding***

Carefully Tailored Compounds

***Process Parameters***



Shot size, pressure, temperature, cooling time

Finished Parts

***Determine Process costs***



Machine size, Cycle time

**Production**



**Krauss Maffei 1200 Ton**



**Van Dorn 400 Ton HT EL**



**Boy 35 Ton Proscan Alpha**

## Lab Testing

Plastic Compounds/Parts

**Key  
properties**

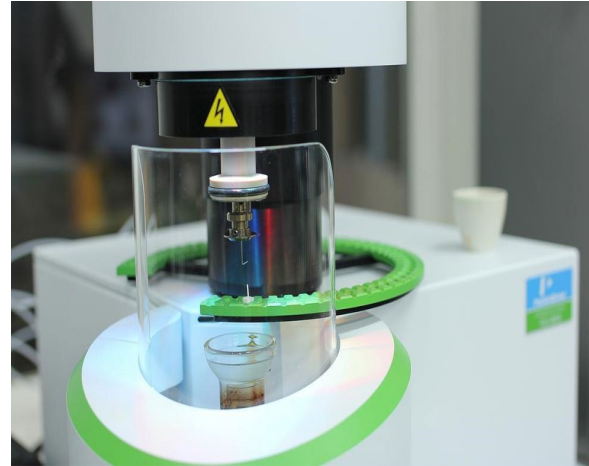
ASTM methods,  
testing procedures

Analysis/Interpretation

**Qualification  
/Quality**

Structure-  
Property-  
Performance

QC standards



**TGA**



**Camsizer**



**Hardness**



**Tensile/Flexural**

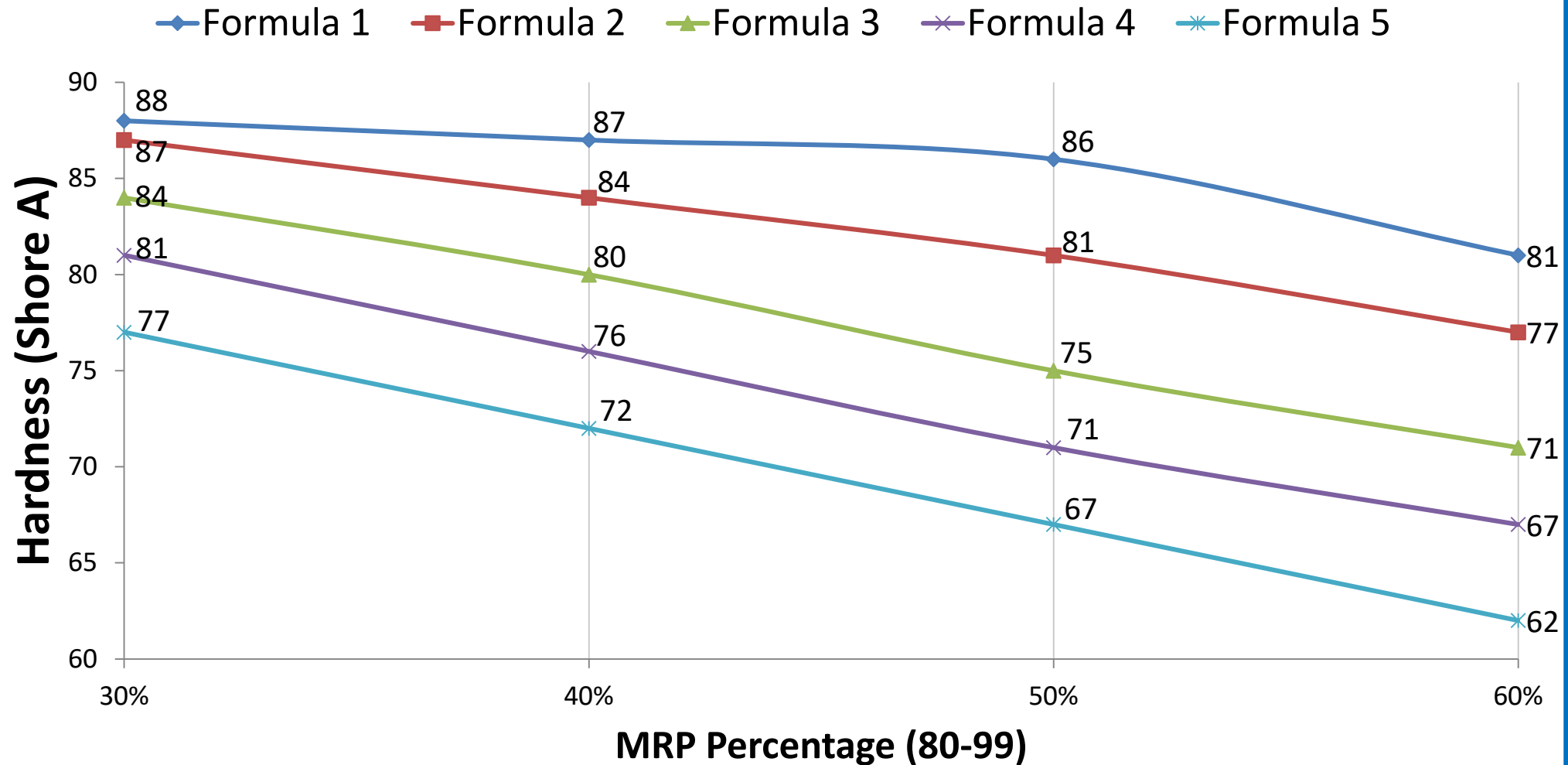


**Izod Impact**



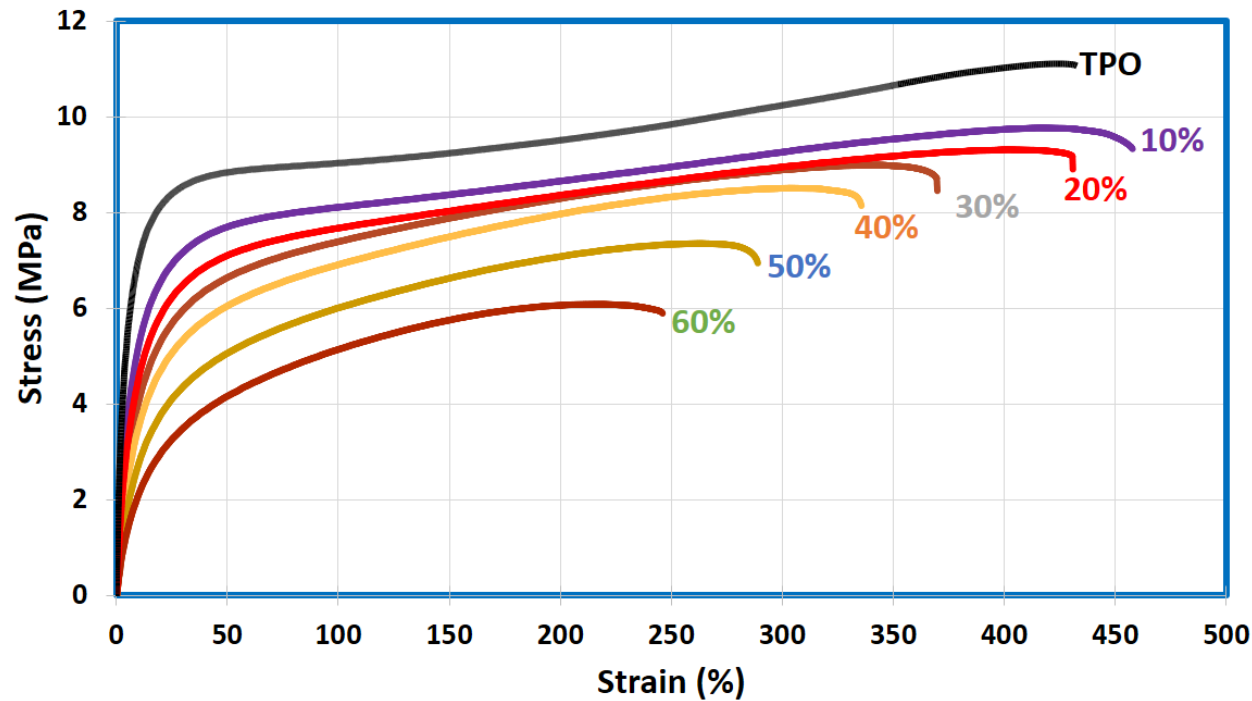
**MFI**

## Hardness vs MRP Percentage



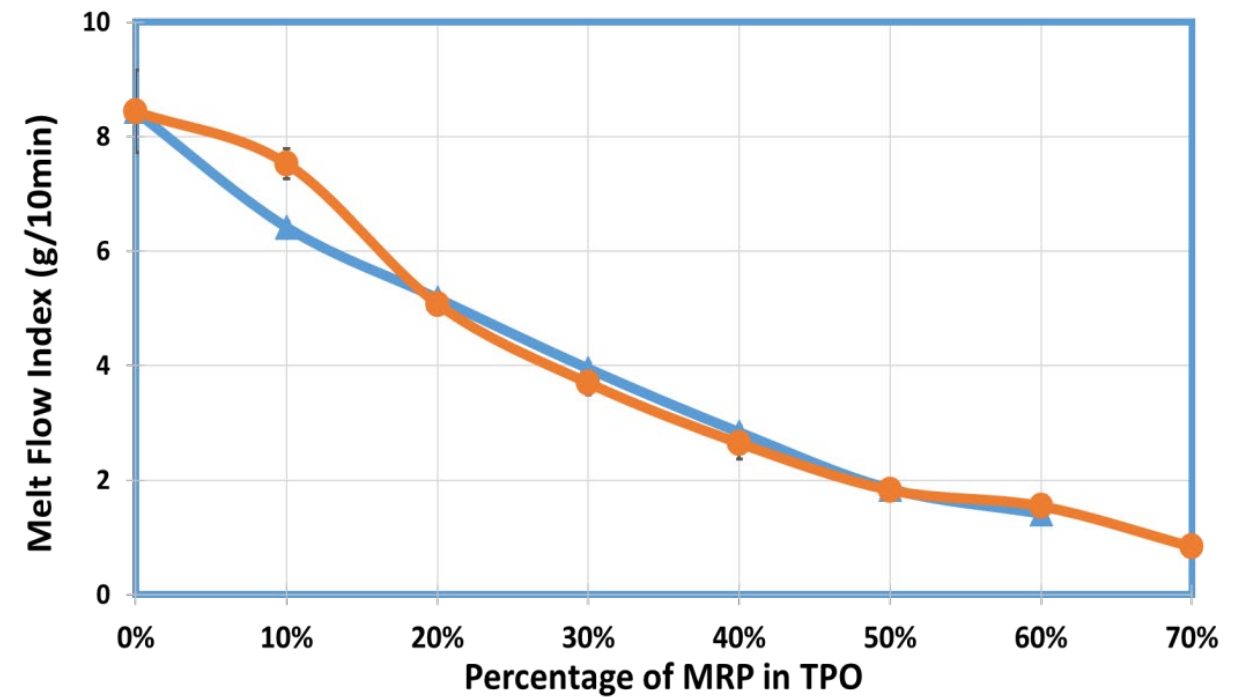
# Comparison of Properties on MRP/TPO Compounds

(No Compatilizer)



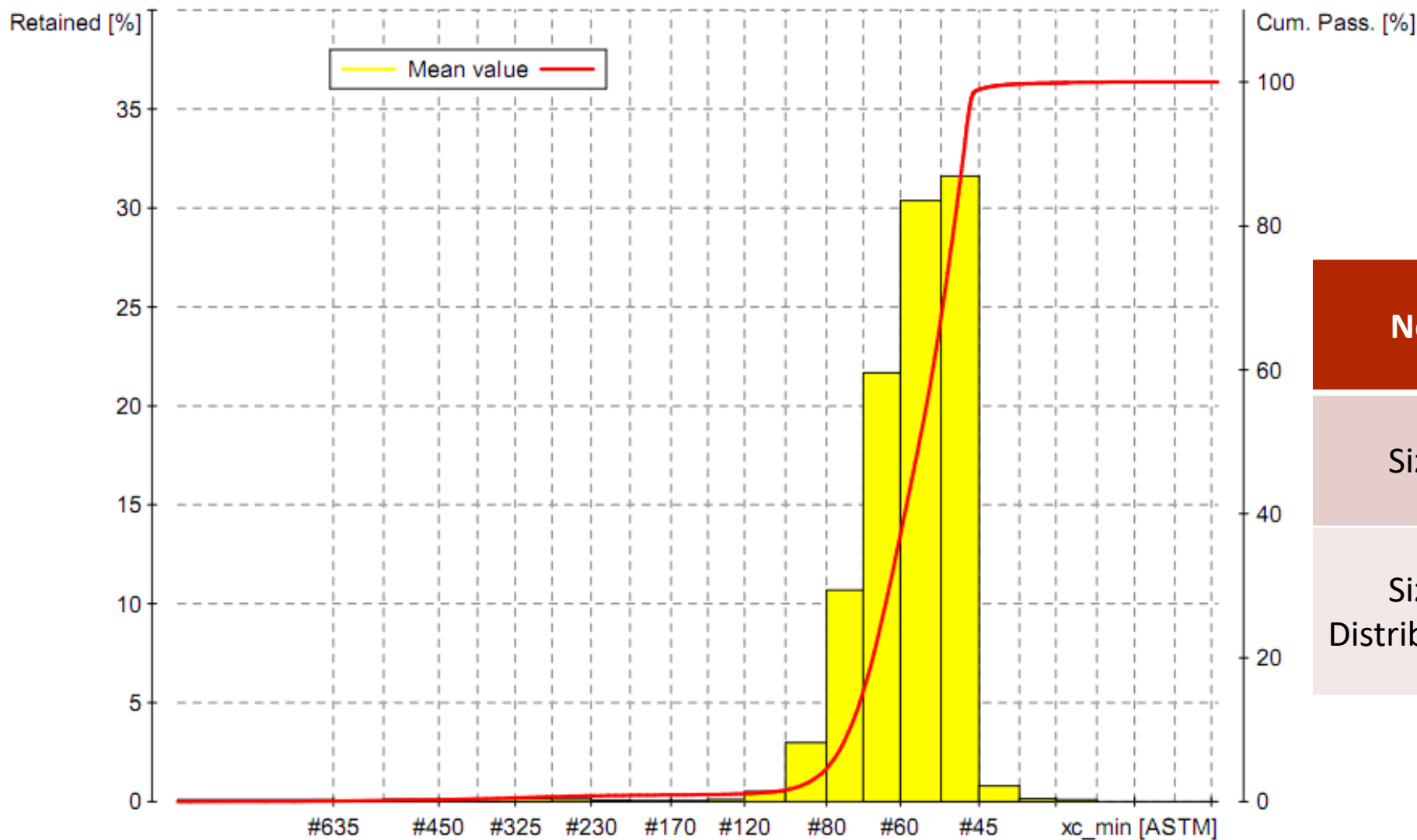
↓ strength    elastomer ↑  
 ↓ modulus    behavior

▲ No compatilizer    ● 5% compatilizer



↓ MFI

# Size and Size Distribution Analysis on MRP

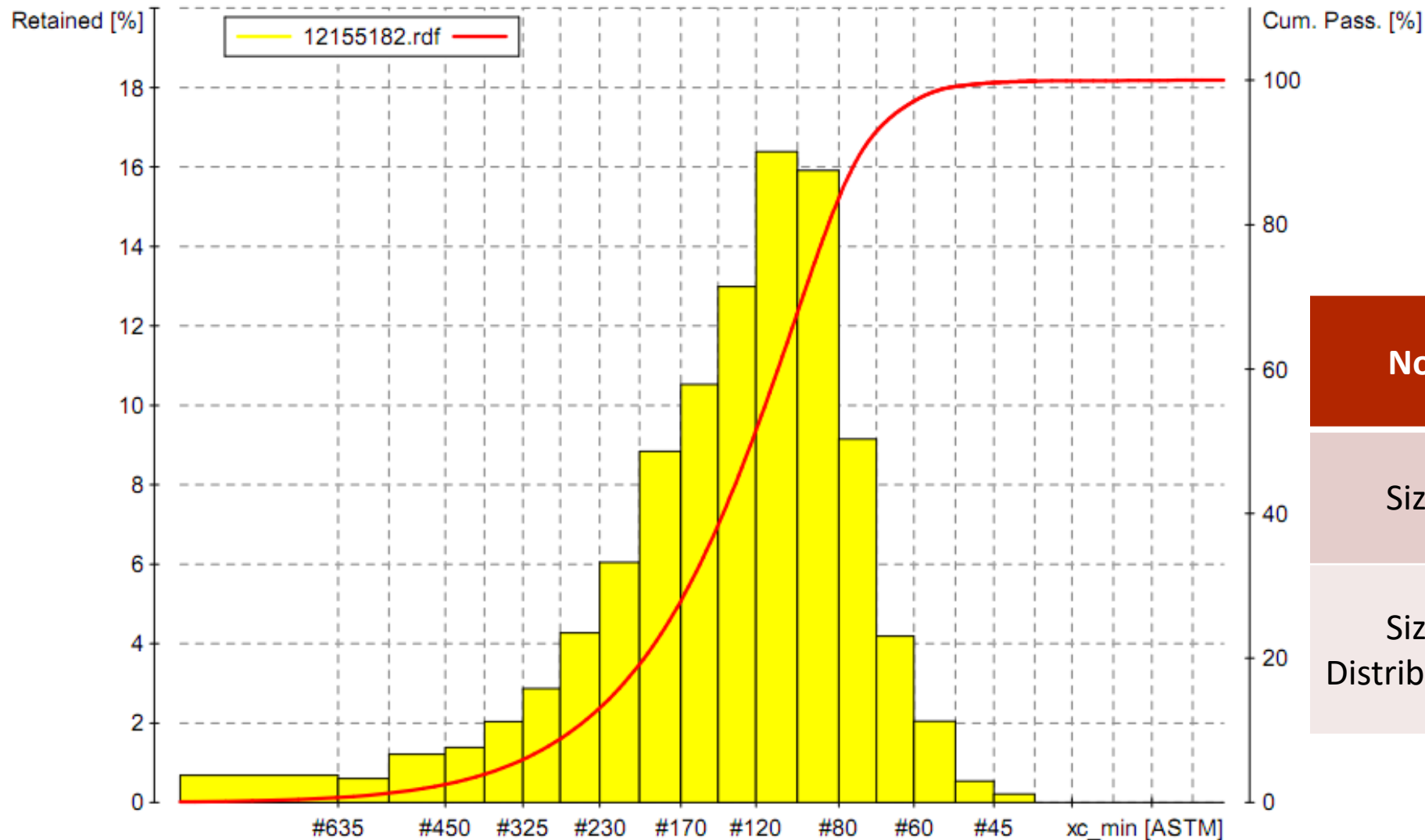


## Summary:

No.	40-80 mesh
Size	177-420 $\mu\text{m}$
Size Distribution	0.3% > 420 $\mu\text{m}$ 98.1% 177~420 $\mu\text{m}$ 1.6% < 177 $\mu\text{m}$

The size and size distribution analysis of the **40-80** mesh-size rubber powder (MRP).

# Size and Size Distribution Analysis on MRP



## Summary:

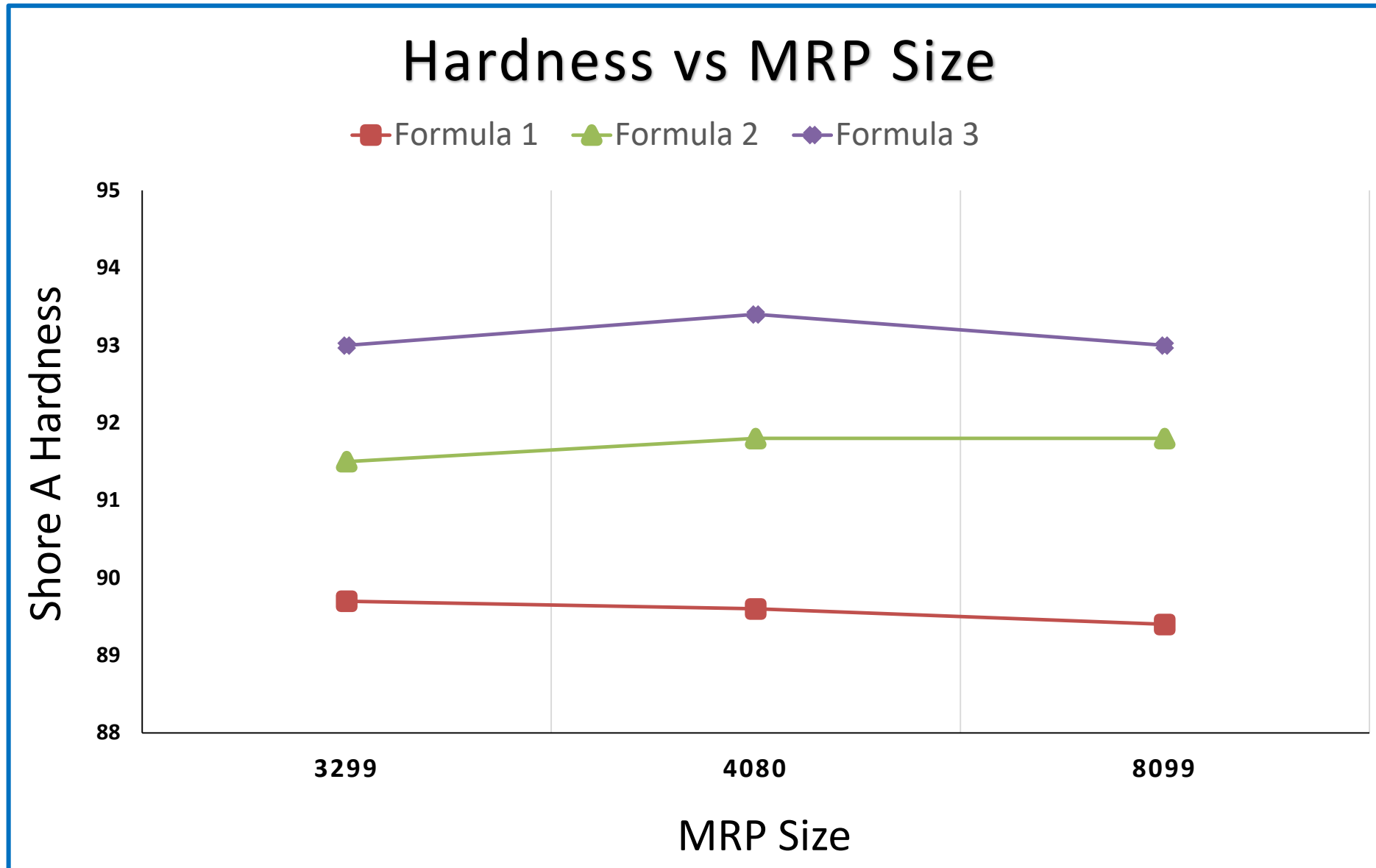
No.	80-99 mesh
Size	$\leq 177 \mu\text{m}$
Size Distribution	~10% 177 $\mu\text{m}$ ~40% 105 $\mu\text{m}$ ~50% <105 $\mu\text{m}$

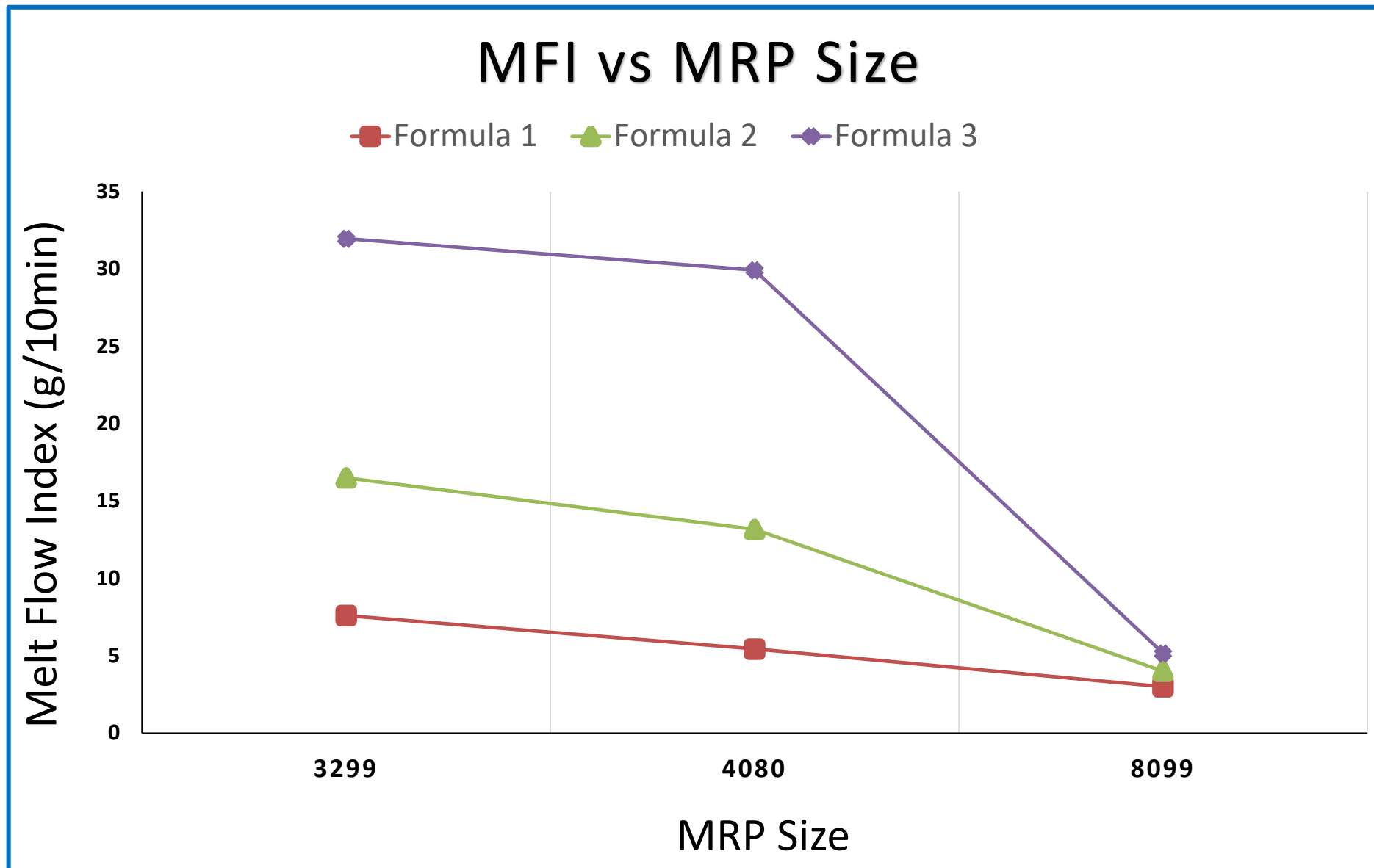
The size and size distribution analysis of the **80-99** mesh-size rubber powder (MRP).

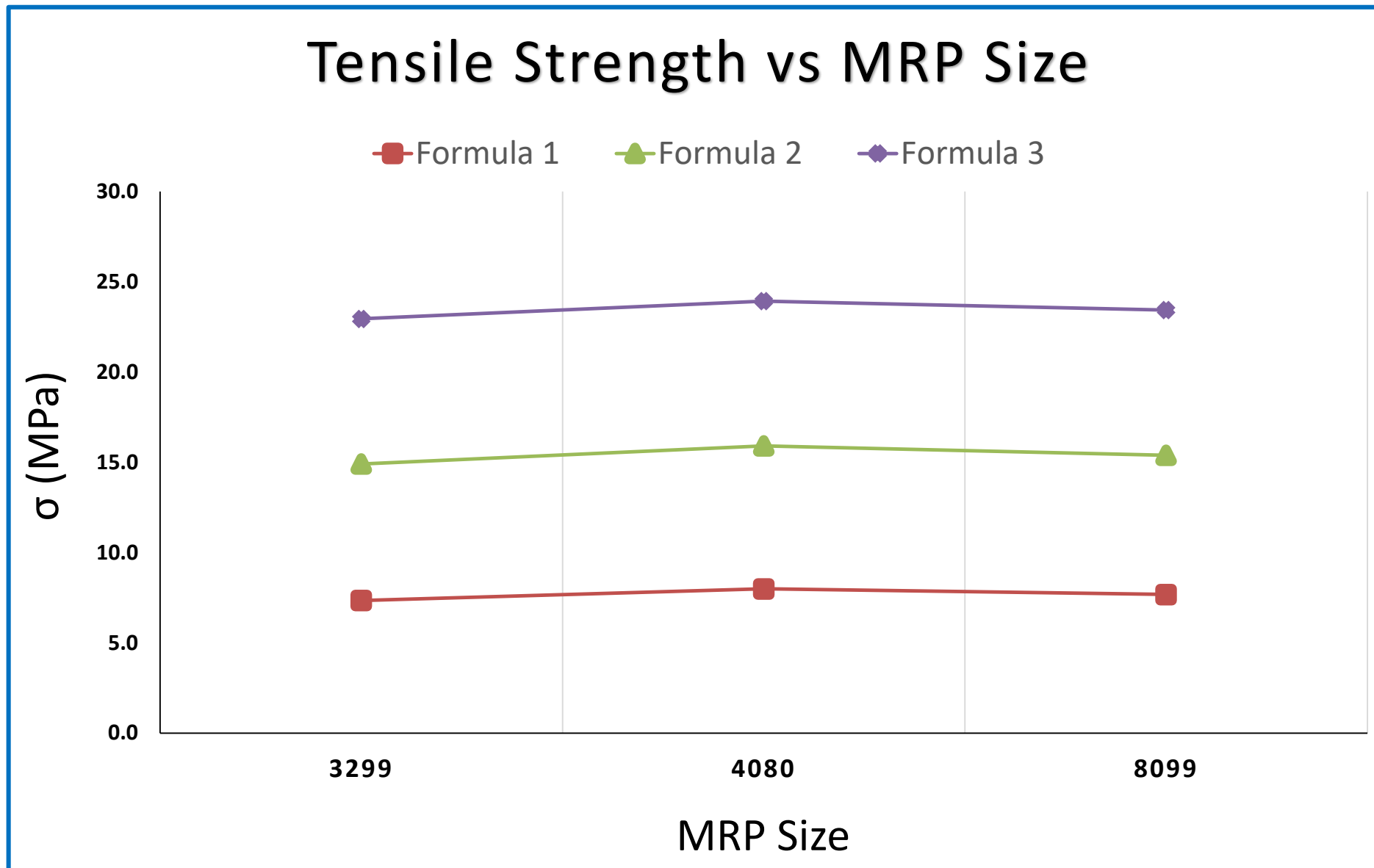
# Effect of MRP Size on the Properties

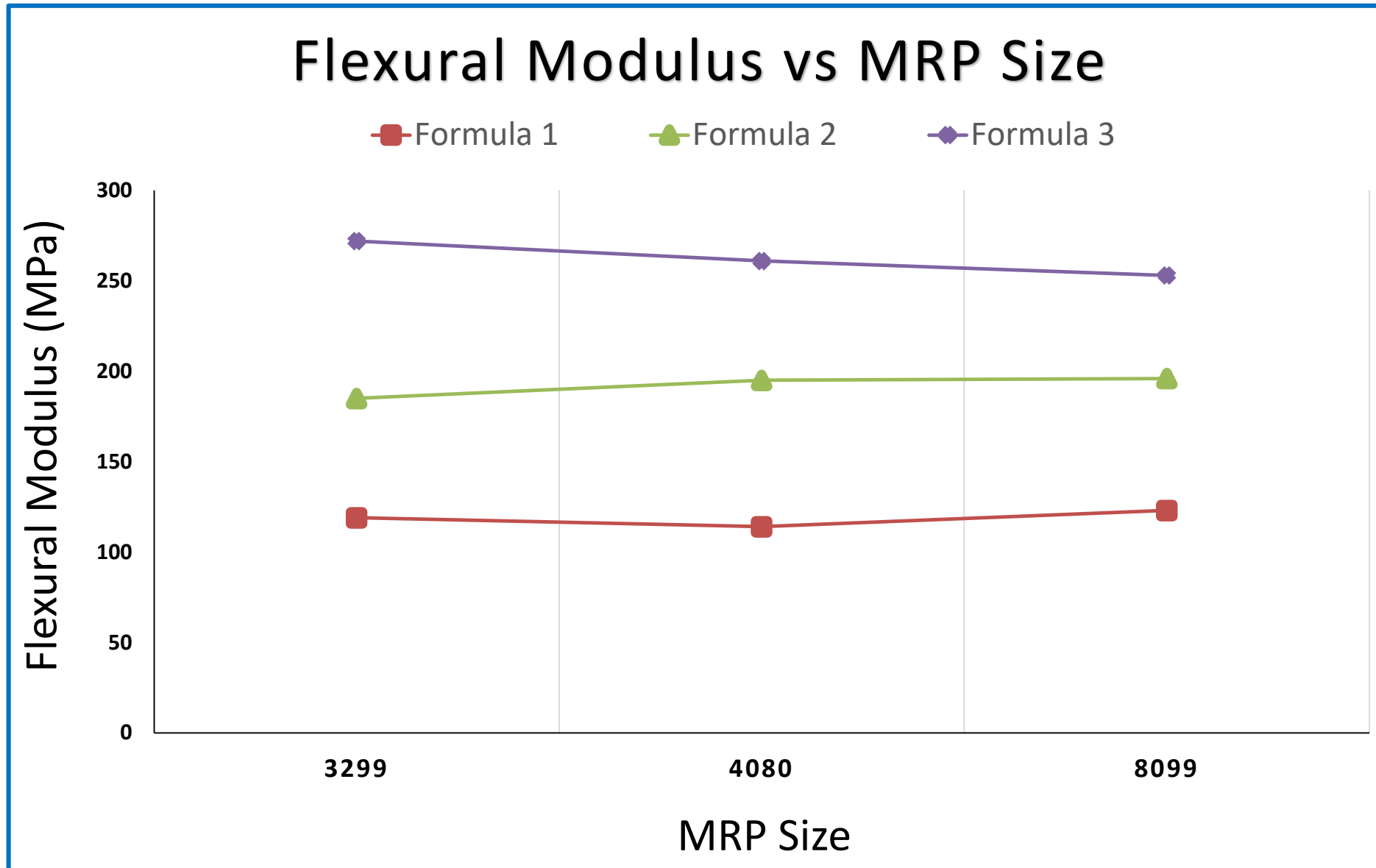
Material (Batch #)	Hardness	Melt Flow	Tensile Properties (50 mm/min)					Flexural Properties ASTM D790 Izod Impact				ASTM D256	Formula	
	ASTM D2240 Shore A	ASTM D1238 MFR g/10min (230C, 10 kg)	Tensile Strength (MPa)	Elongation @ break (%)	Yield Strain (%)	Yield Stress (Mpa)	Tensile Modulus (Mpa)	Modulus @ 100% ε (Mpa)	Flexural Modulus (MPa)	1% Secant Modulus (MPa)	Flexural Strength (MPa)	Impact Strength (J/m)	Break Type at 23C	MRP/TPO-D/PP
3299	02-17-10	87	3	6.7	199			6.0	75	72	2.7	NB	50/50/0	
	02-17-11	90	8	7.4	183			7.0	119	116	4.0	NB	50/40/10	
	02-17-12	92	17	7.6	100	83.7	7.6	9	185	176	5.6	NB	50/30/20	
	02-17-13	93	32	8.0	47	39.6	8.0	20	272	256	7.7	NB	50/20/30	
	02-17-14	94	59	8.6	26	20.3	8.6	42	407	372	10.6	186	P	50/10/40
	02-17-15													50/0/50
4080	11-16-41	86	2	6.7	189			5.9	78	76	2.8	NB	50/50/0	
	01-17-10	90	5	8.0	194			7.2	114	109	4.0	NB	50/40/10	
	01-17-11	92	13	7.9	137			7.8	195	175	5.5	NB	50/30/20	
	01-17-12	93	30	8.0	67			94	261	240	7.4	NB	50/20/30	
	02-17-25												50/0/50	
8099	09-15-11	86	3	7.3	212			6.2				NB	50/50/0	
	02-17-05	89	2	7.7	255			6.6	123	119	4.3	NB	50/40/10	
	02-17-06	92	3	7.7	213			7.1	196	178	5.7	NB	50/30/20	
	02-17-07	93	5	8.1	77	60.4	8.1	13	253	239	7.2	NB	50/20/30	
	02-17-08	94	10	8.7	36	29.9	8.7	29	394	351	9.9	NB	50/10/40	
	02-17-09	95	15	8.9	19	15.6	8.9	57	502	440	12.0	106	P	50/0/50

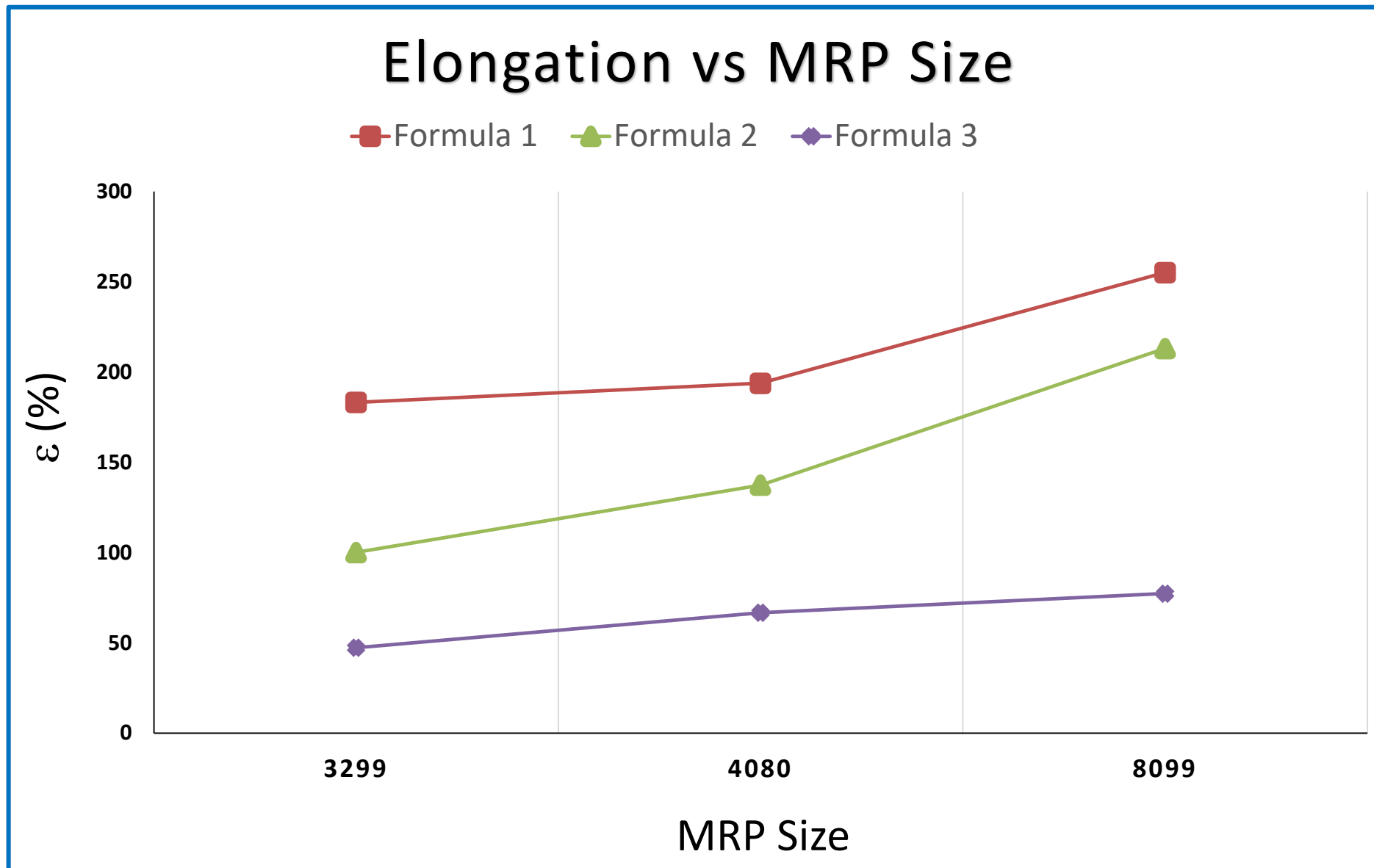












**Projects that Make Sense**



**Appropriate Applications**



# Wheel Chocks



**Purpose:** Injection molding grade TPO compounds.

**Injection Molding:** high pressure, low MFI, high clamp tonnage, long cycle times.

**Key Properties:** Good strength, excellent crack resistance and impact resistance, especially at low temps.

**Application scenario:** **thick bulky parts**, requires some surface improvement, can load high percentage of MRP.

**Great example for parts of highly recycled content.**



# Wheel Chock: Comparison

## Substantial Surface Improvement!





# Dust Pans

**Purpose:** Injection molding grade PP compounds

**Formulation:** 32 mesh MRP/ Recycled PP

**Compounding:** co-rotating intermeshing twin screw extruder

**Application Scenarios:** [typical thin parts](#), requires rigidity and toughness, can load medium percentage of MRP.

**Advantages:** Combined properties of MRP/PP. Recycle content 100%.



# Sump Basins

**Purpose:** Injection molding grade PP compounds

**Formulation:** Postconsumer TPO/ Recycled PP

**Compounding:** co-rotating intermeshing twin screw extruder

**Application Scenarios:** large parts with deep draw ratio, requires rigidity and toughness, can load medium percentage of MRP.

**Advantages:** Impact-improved “non-break” PP. Recycle content 100%.

# Associated Costs: Compounding Costs



## Hypothetical Compounding Cost Calculation #1

Cost Item	Description	Cost	Cost Per Month	Price Per Pound
Labor	Wages, FICA, Benefits, Etc.	30.00/ Hour	\$15,000	\$0.05
Electricity	Electricity at 10 cents/kWh	\$9.60/ Hour	\$3,840	\$0.01
Machinery Amortization	1 Million \$ Line, 5 yrs @ 4.5% Int.	\$18,643/ Month	\$18,640	\$0.07
Machinery Maintenance	Full line maintenance	\$1,200 per week	\$5,160	\$0.02
			Compounding Cost Per Pound	<b>\$0.15</b>

Pounds Per Hour	700
Hours Per Month	400
Pounds Per Month	280,000

# Associated Costs: Compounding Costs

## Basic 80 Durometer Compound for an Injection Molded Wheel Chock

Cost Item		Price Per Pound	Percentage of final Compound	Price Per Pound in Final Compound
Compounding Expense		\$0.15	100%	\$0.15
Materials:	Recycled PP/TPO/PE	\$0.35	60%	\$0.21
	MRP 40	\$0.22	40%	\$0.09
Packaging Cost		\$0.03	100%	\$0.03
			Subtotal	\$0.48
			Overhead/Margin @ 30%	\$0.14
			<b>Price Per Pound</b>	<b>\$0.62</b>

## Ideal for...

Exterior

High Impact

Cold Temps

Crack Resistance

Resilience

Surface Grip

## Key Benefits

1. Lower costs for TPE
2. Improve performance/  
Increase value
3. Add sustainability



# Where is it not economically viable?

- **Recycled, Granulated PE/PP/TPO (regrind) normally floats between \$.30 and \$.50.**
- **If regrind will perform acceptably in an injection molding application, it's not likely that an MRP filled resin will be competitive, because while MRP is relatively low cost, it costs money to mix it into the plastic regrind.**



## Challenges and Possibilities

MRP size reduction

Odor reduction

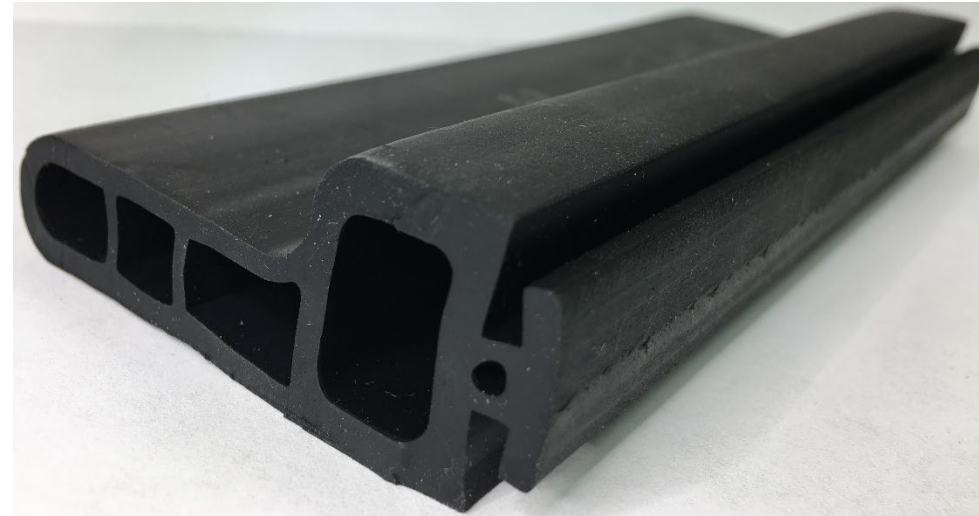
Engineering control

Sheet extrusion

Profile extrusion

Thermoforming

Rotational Molding



**Innovation and exploration are necessary!**

- **Injection molded parts requiring a soft “rubbery” feel**
- **Parts that must resist cracking from impact or deformation**
- **Where expensive TPE compounds are currently in use**
- **Soft parts requiring a high recycled content**

# Surface Finish Improvement Adds More Possibilities

# Surface Finish of TPO/MRP Parts is a Challenge!



**TPO**

**10% MRP**

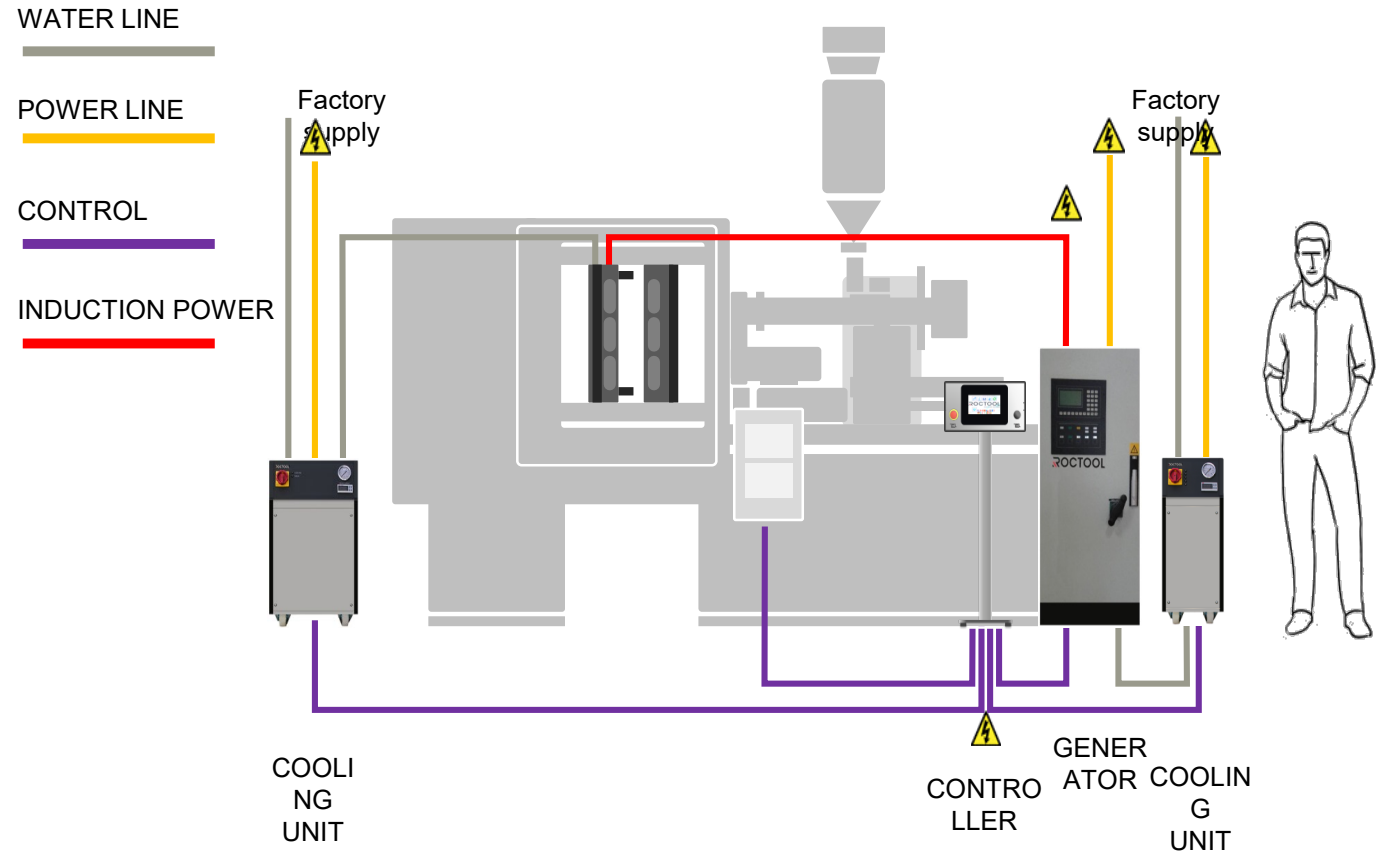
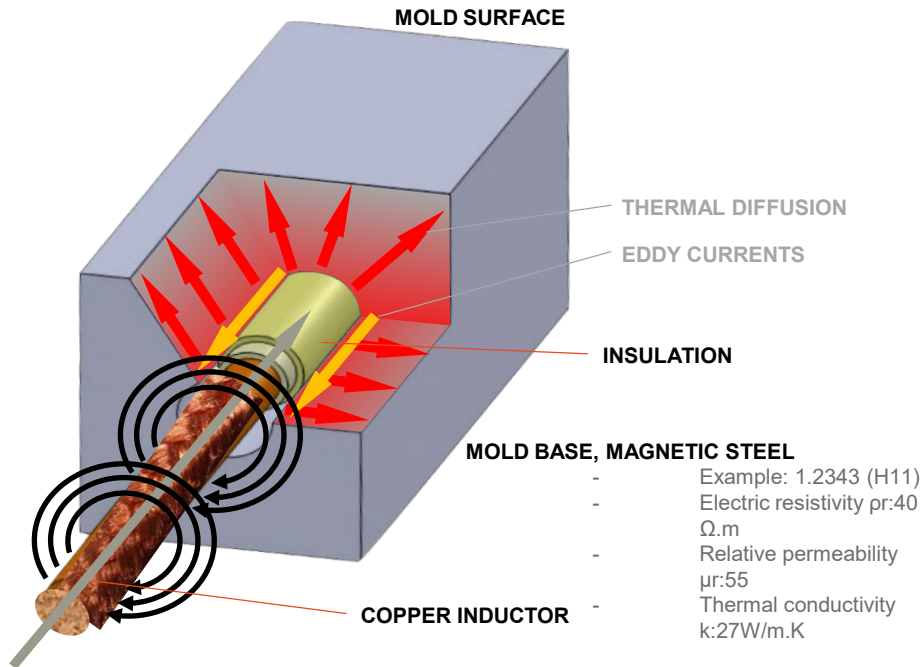
**20% MRP**

**30% MRP**

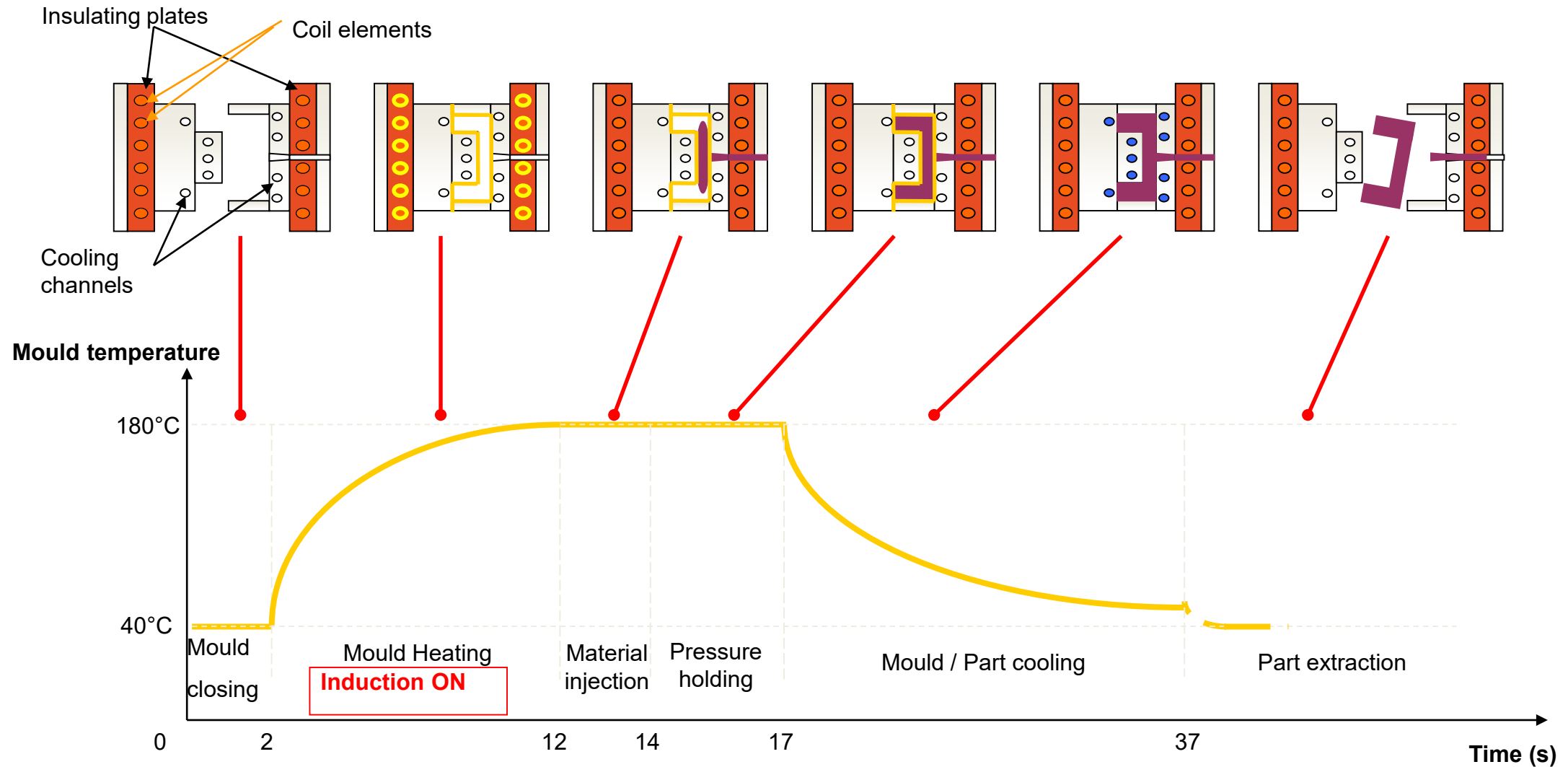
**40% MRP**

**50% MRP**

## Roctool Heat & Cool System for Injection Molding



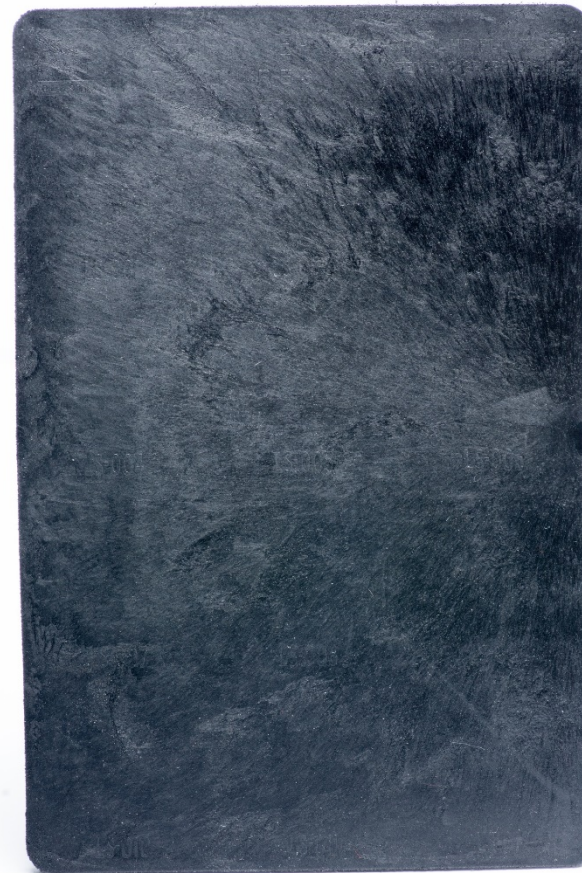
## Roctool Heat & Cool Cycle for Injection Molding



# Breakthroughs on Surface Finish of MRP-filled Parts



(top) 8099 MRP-filled resin  
(bottom) 4080 MRP-filled resin  
(left) conventional injection molding  
(right) induction-heated molding



(a) Conventional mold



(b) Induction-heated mold

**These are 50% MRP-filled samples!**



- **R&D efforts** are greatly needed for this field of study.
- **Working together** (collaboration and joint efforts) will facilitate the advancement of the industries.
- **Sharing knowledge and technologies** will accelerate and advance the industries further.

## Free Project Evaluation Vertical Integration

- Compounding
- Injection Molding
- Extrusion
- Testing Capabilities

**ABOUT ENTECH**

OUR PATH TO THERMOPLASTIC ELASTOMER EXPERTISE

entech TPE

**RESINS**

Resin	Color	Grade	Weight	Volume	Temperature	Shrinkage	Modulus	Strength	Elongation	Impact	Hardness	Other
1000	Black	1000	1.00	1.00	100	10	100	100	100	100	100	
2000	Black	2000	1.00	1.00	100	10	100	100	100	100	100	
3000	Black	3000	1.00	1.00	100	10	100	100	100	100	100	
4000	Black	4000	1.00	1.00	100	10	100	100	100	100	100	
5000	Black	5000	1.00	1.00	100	10	100	100	100	100	100	
6000	Black	6000	1.00	1.00	100	10	100	100	100	100	100	
7000	Black	7000	1.00	1.00	100	10	100	100	100	100	100	
8000	Black	8000	1.00	1.00	100	10	100	100	100	100	100	
9000	Black	9000	1.00	1.00	100	10	100	100	100	100	100	
10000	Black	10000	1.00	1.00	100	10	100	100	100	100	100	



**Request Your Sample**



**OUTDOOR PLAY**



**HANDLES**

Thank you!  
Questions?



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Email: [info@entechtpe.com](mailto:info@entechtpe.com)

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Thank you very much!

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