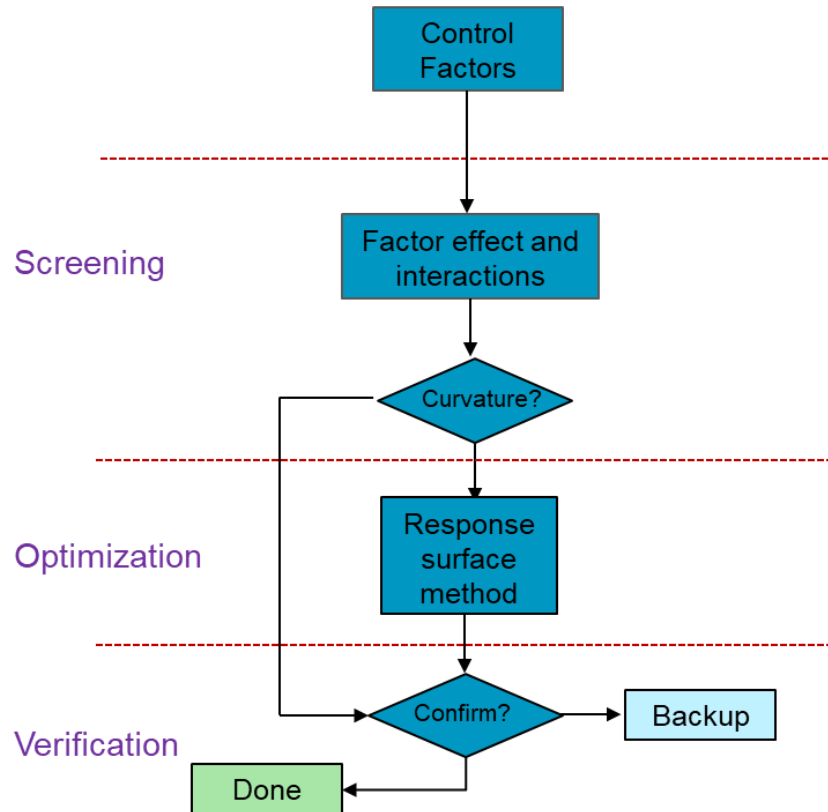


Supplementary Materials: Defining Key Factors in Carbon Black-Filled NR/BR Compounds for Balancing Aircraft Tire Tread Properties

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Scheme S1. The flow chart of design of experiments (DOE) in this research.

Table S1. The design of experimental run for screening.

No.	A: BR Type	B: T. mixer (°C)	C: Rotor speed (rpm)	D: Filler mixing time (min)
1	LCB-BR	100	60	10
2	HL-BR	100	120	2
3	HL-BR	75	90	6
4	LCB-BR	50	60	10
5	LCB-BR	75	90	6
6	LCB-BR	100	120	2
7	LCB-BR	75	90	6
8	LCB-BR	50	120	2
9	HL-BR	75	90	6
10	HL-BR	75	90	6
11	LCB-BR	50	60	2
12	HL-BR	50	60	10
13	LCB-BR	100	60	2
14	LCB-BR	50	120	10
15	LCB-BR	100	120	10
16	HL-BR	100	60	10
17	HL-BR	100	120	10
18	HL-BR	50	120	10
19	HL-BR	100	60	2
20	HL-BR	50	120	2
21	LCB-BR	75	90	6
22	HL-BR	50	60	2

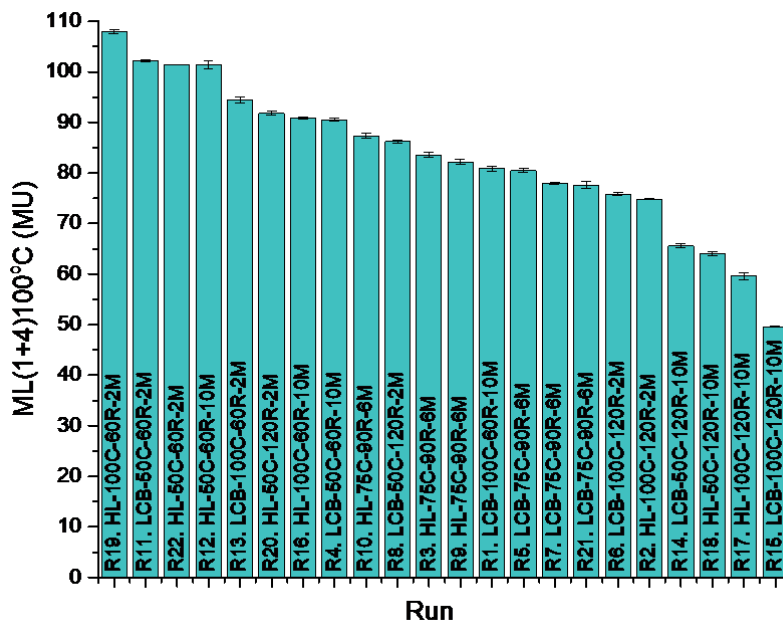


Figure S1. The response of MV of all experimental runs.

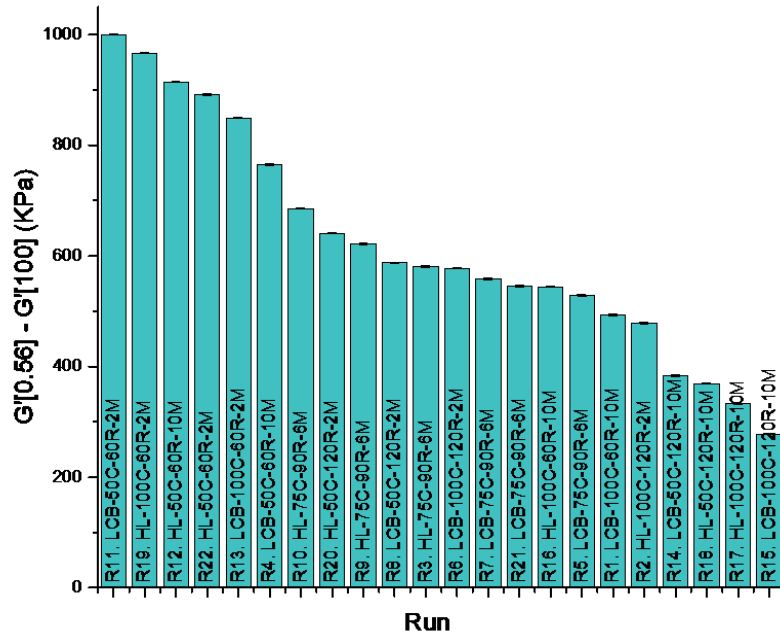


Figure S2. The response of Payne effect of all experimental runs.

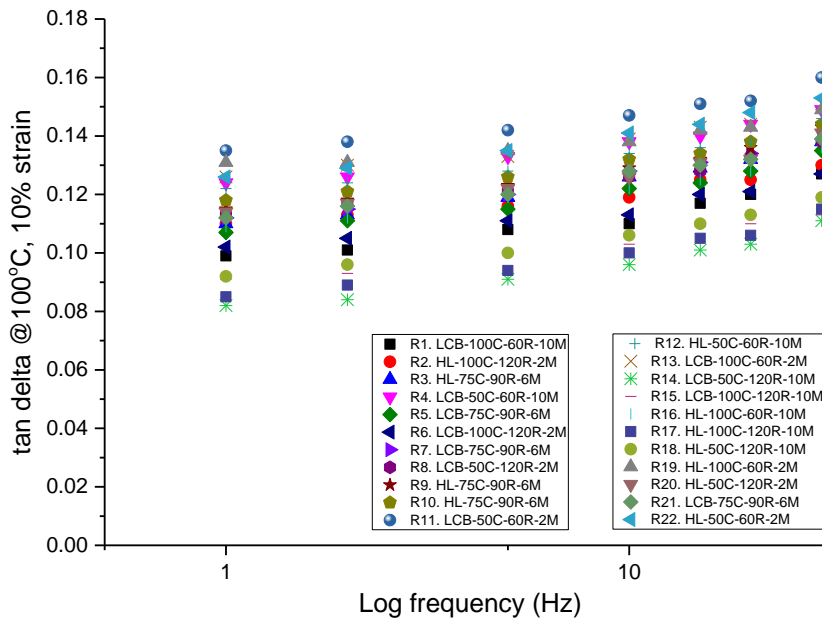


Figure S3. The response tan delta at 100 °C, 10% strain measures, with a frequency sweep from 1 to 30 Hz.

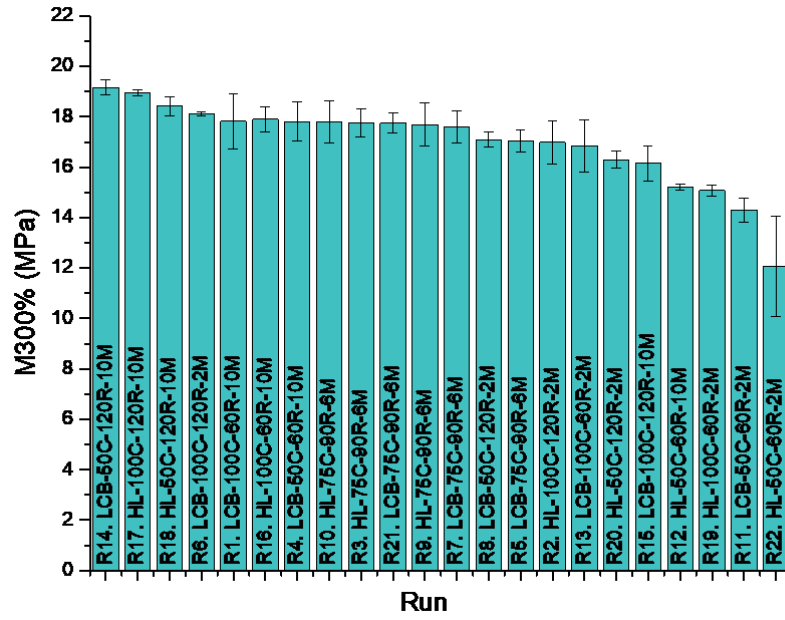


Figure S4. The response of M300% of all experimental runs.

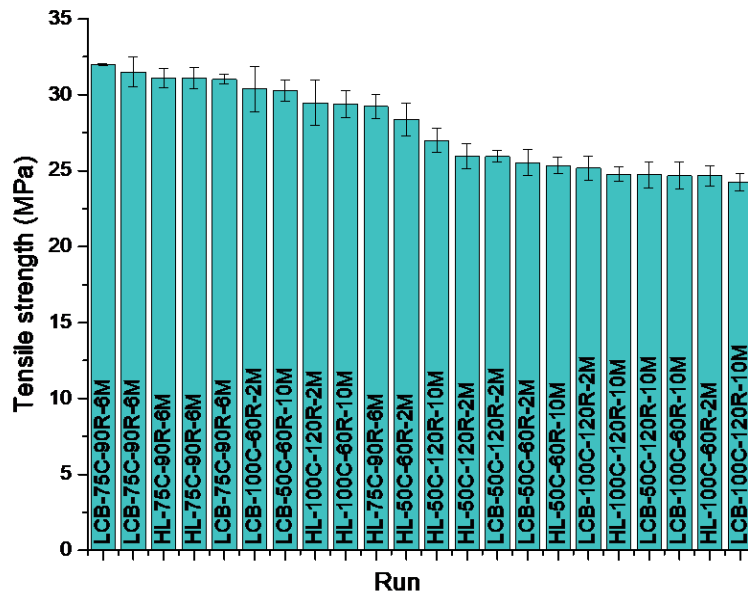


Figure S5. The response of tensile strength of all experimental runs.

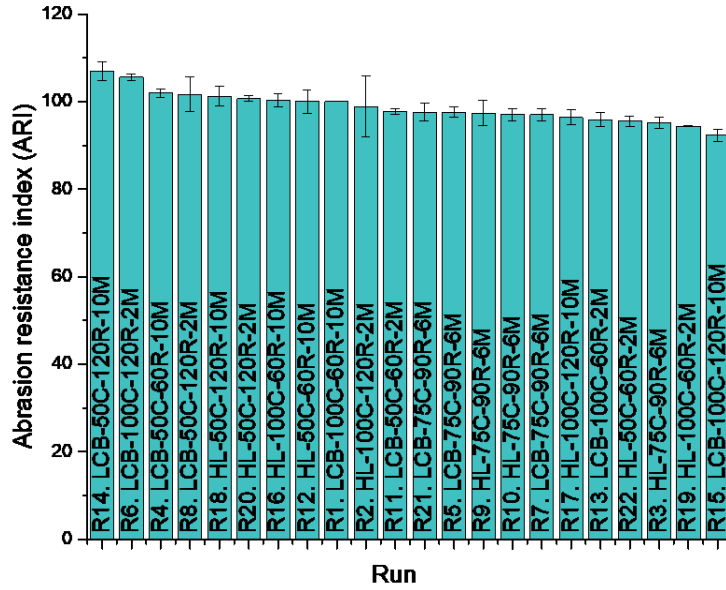


Figure S6. The response of ARI of all experimental runs.

Table S2. Results of DOE screening.

No.	A: BR type	B: T mixer (°C)	C: Rotor speed (rpm)	D: Filler mixing time (min)	Y1: ML(1 + 4), 100 °C (MU)	Y2: Payne effect (KPa)	Y3: tan delta (-)	Y4: M300 % (MPa)	Y5: Tensile strength (MPa)	Y6: ARI (%)
1	1	1	-1	1	80.9	493.51	0.120	17.8	24.7	100
2	-1	1	1	-1	74.8	478.52	0.127	17.0	29.5	99
3	-1	0	0	0	83.6	580.87	0.132	17.8	31.1	95
4	1	-1	-1	1	90.5	764.36	0.144	17.8	30.3	102
5	1	0	0	0	80.5	529.10	0.122	17.1	32.0	98
6	1	1	1	-1	75.8	577.66	0.121	18.1	25.1	106
7	1	0	0	0	77.9	558.61	0.134	17.6	31.0	97
8	1	-1	1	-1	86.2	587.57	0.128	17.1	25.9	102
9	-1	0	0	0	82.2	621.67	0.136	17.7	31.1	97
10	-1	0	0	0	87.3	685.88	0.138	17.9	29.2	97
11	1	-1	-1	-1	102.2	1000.48	0.152	14.3	25.5	98
12	-1	-1	-1	1	101.4	914.29	0.138	15.2	25.4	100
13	1	1	-1	-1	94.4	849.53	0.144	16.8	30.4	96
14	1	-1	1	1	65.6	383.49	0.103	19.2	24.7	107
15	1	1	1	1	49.6	278.10	0.110	16.1	24.3	92
16	-1	1	-1	1	90.9	543.86	0.133	17.9	29.4	94
17	-1	1	1	1	59.6	332.26	0.106	19.0	24.8	96
18	-1	-1	1	1	64.1	369.04	0.113	18.4	27.0	101
19	-1	1	-1	-1	108	966.21	0.143	15.1	24.7	94
20	-1	-1	1	-1	91.8	641.03	0.132	16.3	26.0	101
21	1	0	0	0	77.6	545.49	0.132	17.8	31.5	98
22	-1	-1	-1	-1	101.4	891.03	0.148	12.1	28.4	96

$$Effect = \frac{\sum Y_+}{n_+} + \frac{\sum Y_-}{n_-} \quad (1)$$

$$SS = \frac{(n_+ + n_-)}{4} \times (Effect)^2 \quad (2)$$

$$MS = \frac{SS}{df} \quad (3)$$

$$F \text{ value} = \frac{MS}{MS_{residual}} \quad (4)$$

where:

Y_+ : the results of observed response in level +1

Y_- : the results of observed response in level -1

n_+ : the total number of experiments in level +1

n_- : the total number of experiments in level -1

ANOVA:

- Center point (CP) was not calculated because CP only used for check curvature and repeatability
- The effect of each factor and its interaction on each response was calculated using Equation 1.
- Sum of square (SS) of each factor and its interaction on each response was calculated using Equation 2.
- Mean of square (MS) of each factor and its interaction on each response was calculated using Equation 3.
- F-value of each factor and its interaction on each response was calculated using Equation 4.
- F-value must be compared to the reference distribution of F (F-ref).
- F-ref can be obtained from the table of F distribution for 0.1% (Anderson & Whitcomb, DOE simplified: Practical tools for effective experimentation, Appendix 1.6).
- From the table, F distribution for 0.1% (there is only a 0.1% chance that an F-value this large could occur due to noise), F-ref was 8.956.
- If F-value > 8.956 → reject null hypothesis (H_0).
- Null hypothesis (H_0): There is no difference or no effect of the parameters being studied by default—null is valid until we have enough evidence to reject the hypothesis.
- Alternative hypothesis (H_1): There is a systematic effect present.
- Error level α = probability to incorrectly reject H_0 .
- $\alpha = 0.05$ (having 5% probability of incorrectly rejecting the null).
- p -value is obtained from the computer program that calculates the probability of obtaining a sample “more extreme” than the ones observed in the data, assuming H_0 is true. The p -values are reported on a scale of 0 to 1. p -value < 0.05 = statistically significant.

Table S3. Example of ANOVA calculation for MV (ML(1 + 4)100 °C) in the DOE screening.

Source	Effect	Sum of square (SS)	Degree of freedom (df)	Mean square (MS)	F-value	p-value	Remark
Model		4379.52	10	437.95	28.87	< 0.0001	significant
A: BR type	-5.85	136.89	1	136.89	9.02	0.0149	significant
B: T. mixer	-8.65	299.29	1	299.29	19.73	0.0016	significant
C: Rotor speed	-25.28	2555.30	1	2555.30	168.47	< 0.0001	significant
D: Filler mixing time	-16.5	1089.00	1	1089.00	71.80	< 0.0001	significant
AB	-2.3	21.16	1	21.16	1.40	0.2678	not significant
AC	2.58	26.52	1	26.52	1.75	0.2187	not significant
AD	-1.55	9.00	1	9.00	0.59	0.4609	not significant
BC	-3.33	44.22	1	44.22	2.92	0.1219	not significant
BD	-1.5	9.00	1	9.00	0.59	0.4609	not significant
CD	-5.93	140.42	1	140.42	9.26	0.0140	significant
Residual		136.51	9	15.17			

Pareto chart:

- t-value effect of each factor and its interaction on each response is calculated by the following formula:

$$t \text{ value} = \frac{|Effect|}{\sqrt{MS_{residual} \times \left(\frac{1}{n_+} + \frac{1}{n_-}\right)}} \quad (5)$$

- t-value is compared to t-value limit from t-distribution table (Anderson & Whitcomb, DOE simplified: Practical tools for effective experimentation, Appendix 1.1).
- From the two-tailed t-table with df = 10 and $\alpha = 0.05$, t-value limit is 2.228.
- If t-value > 2.228 → statistically significant.
- The t-value effect of each factor and its interaction on each response is shown in the Pareto chart.

Table S4. The results of DOE optimization for all responses.

No.	A: Rotor speed (rpm)	B: Filler mixing time (min)	Y1: ML(1+4) 100 °C (MU)	Y2: Payne effect (KPa)	Y3: tan delta	Y4: M300% (MPa)	Y5: Tensile strength (MPa)	Y6: ARI (%)
1	95	8	70.4	380.20	0.114	14.9	26.1	108
2	95	10.8	66.4	313.70	0.108	14.3	27.3	103
3	70	10	81.6	535.02	0.131	14.1	27.2	89
4	120	10	58	280.00	0.1	15.4	25.0	95
5	95	5.2	79.5	552.94	0.128	13.4	26.1	111
6	70	6	90.5	739.77	0.144	12.5	27.3	97
7	120	6	67.1	349.17	0.109	15.0	26.9	102
8	95	8	71.5	384.45	0.113	15.0	26.2	111
9	95	8	71.3	376.96	0.112	15.0	25.9	102
10	60	8	92.6	743.39	0.143	12.7	27.6	101
11	130	8	58.1	259.59	0.098	15.7	24.3	92

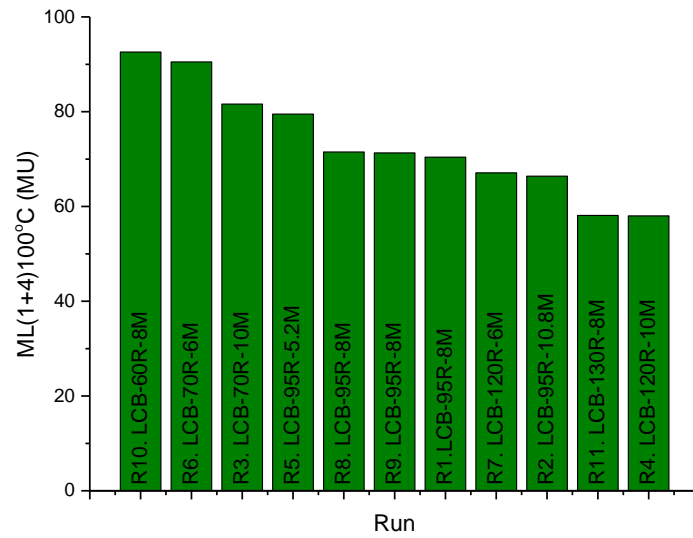


Figure S7. The results of MV in DOE optimization.

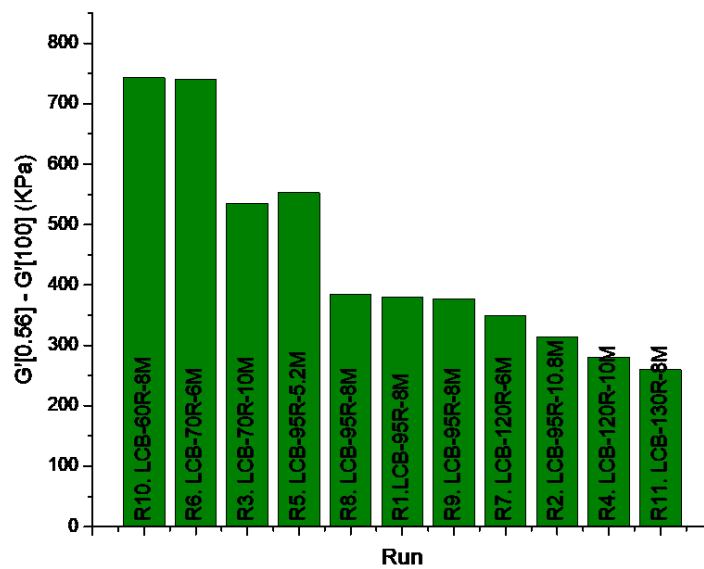


Figure S8. The results of the Payne effect in DOE optimization.

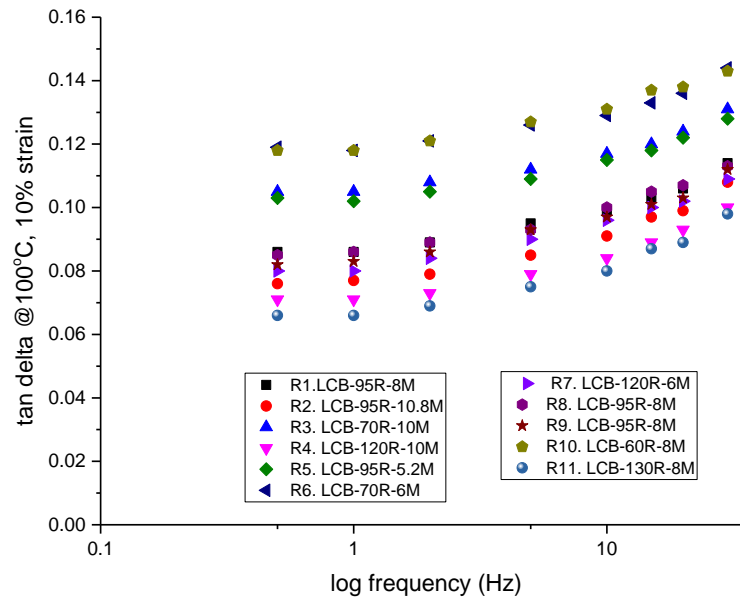


Figure S9. The results of tan delta in DOE optimization.

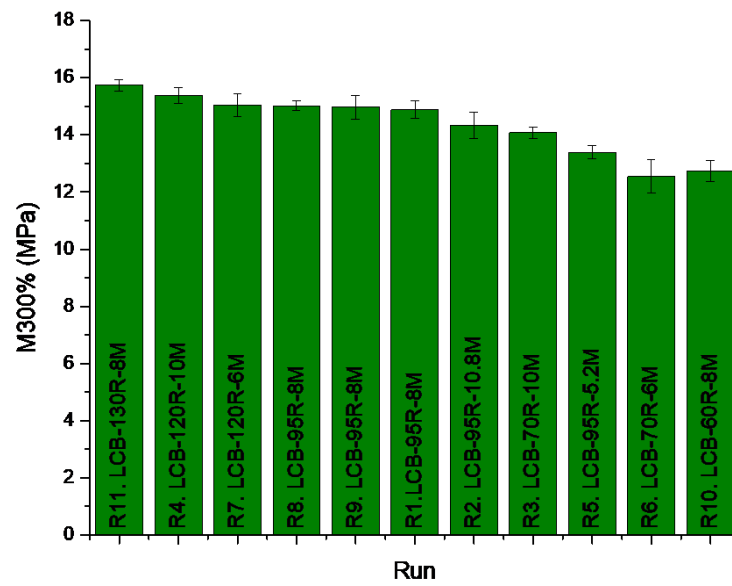


Figure S10. The results of M300% in DOE optimization.

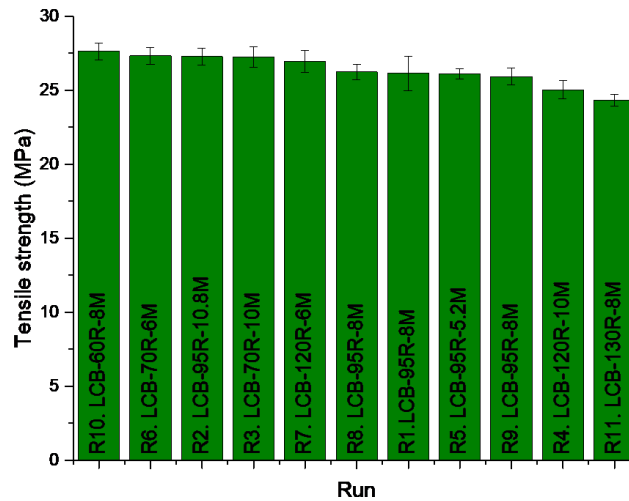


Figure S11. The results of tensile strength in DOE optimization.

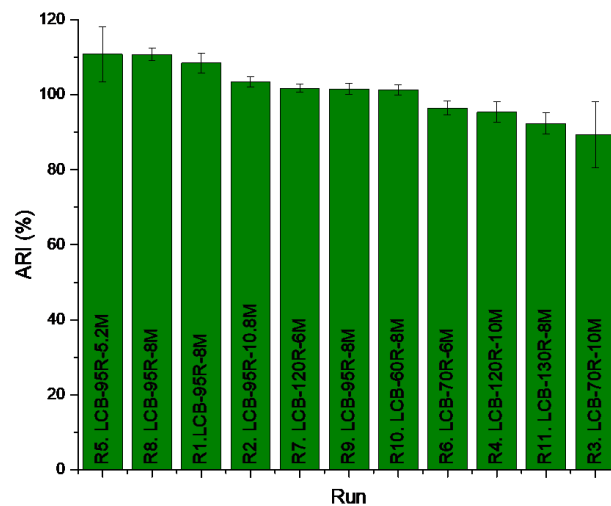


Figure S12. The results of ARI in DOE optimization.

Table S5. Example of ANOVA calculation for MV(ML(1 + 4)100 °C) in DOE optimization.

Source	Sum of square (SS)	Degree of freedom (df)	Mean square (MS)	F-value	p-value	Remark
Model	1341.76	8	167.72	488.50	0.0020	significant
A: Rotor speed	595.12	1	595.12	1733.37	0.0006	significant
B: Filler mixing time	85.80	1	85.80	249.92	0.0040	significant
AB	0.02	1	0.02	0.029	0.8802	not significant
A ²	22.02	1	22.02	64.13	0.0152	significant
B ²	4.26	1	4.26	12.40	0.0721	not significant
A ² B	0.063	1	0.063	0.18	0.7098	not significant
AB ²	0.65	1	0.65	1.88	0.3036	not significant
A ² B ²	0.015	1	0.015	0.043	0.8545	not significant

Note: p -value < 0.05 = statistically significant.