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Minimizing ZnO usage in rubber vulcanization

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2 Example of ZnO use in tires (NR-based tire belt skim compound)

(Citation: The Rubber Formulary, Noyes Publications, USA)

Formulation (phr)	Compound
NR	100
Zinc oxide (primary activator)	7
Stearic acid (secondary activator)	1
Hexamethoxy methyl melamine (HMMM) (primary accelerator)	2
N,N'-dicyclohexyl-2-benzothiazole sulphenamide (DCBS) (secondary accelerator)	0.7
Sulphur	5
Total amounts of chemicals in the cure system	15.7: 5phr S/10.7 phr curatives

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Solution to reduce ZnO usage in tires

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Combine ZnO with a sulfur-bearing accelerator into a single additive component

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Coating ZnO with the accelerator to produce a single powder

4 Materials and chemicals

Materials:
Standard Malaysian rubber (NR) (98 wt% 1-4-cis content) with a Mooney viscosity of 89 units.

Chemical curatives:

- Tetramethyl thiuram disulfide (TMTD) (a sulfur-donor accelerator)
- zinc oxide (activator)
- No stearic acid (secondary activator) is used
- No secondary accelerator is used.

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ZnO was treated with different amounts of TMTD from 35 mg/g to 400mg/g in an organic solvent to produce powders

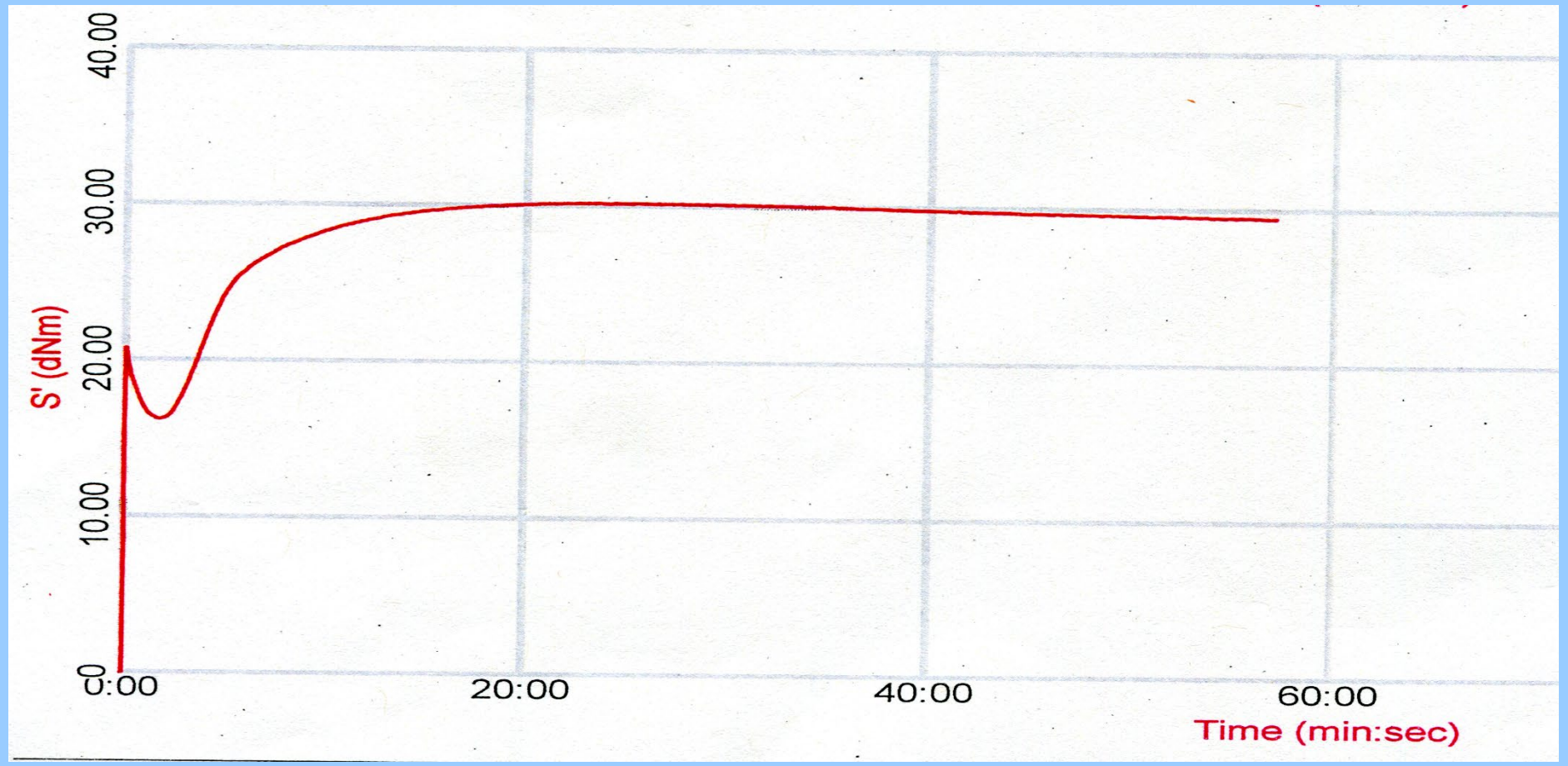
The powder with 400mg/g (TMTD/ZnO) gave a good cure and was selected for further work.

At 1.48 phr of the powder, TMTD/ZnO: 0.42phr/1.06phr
At 12 phr of the powder, TMTD/ZnO: 3.43phr/8.57phr
At 20 phr of the powder, TMTD/ZnO: 5.72phr/14.28phr

To reduce ZnO content in the powder, use a more efficient sulfur-donor accelerator

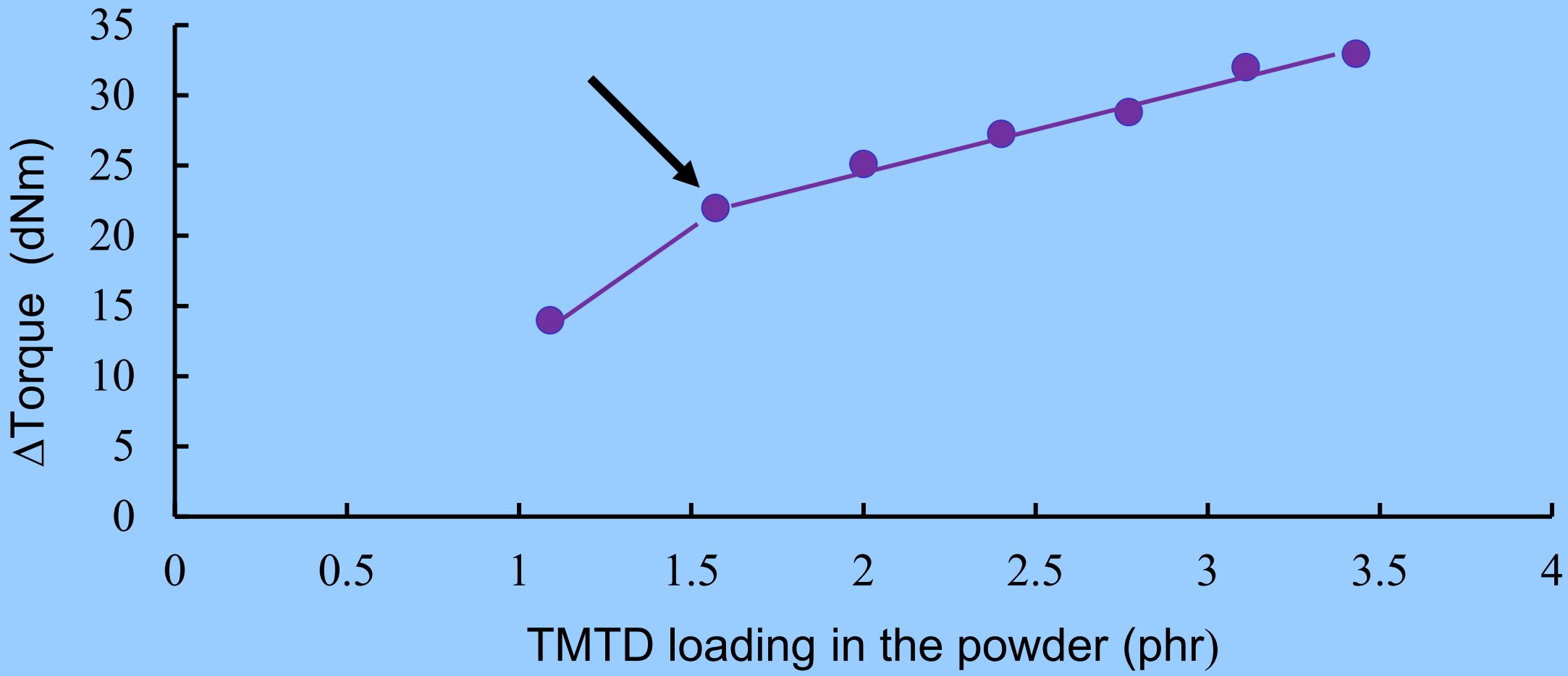
- The procedure for preparing the powder is fully described in reference 1.

6 Typical torque versus time trace from which Δtorque is calculated at 160°C



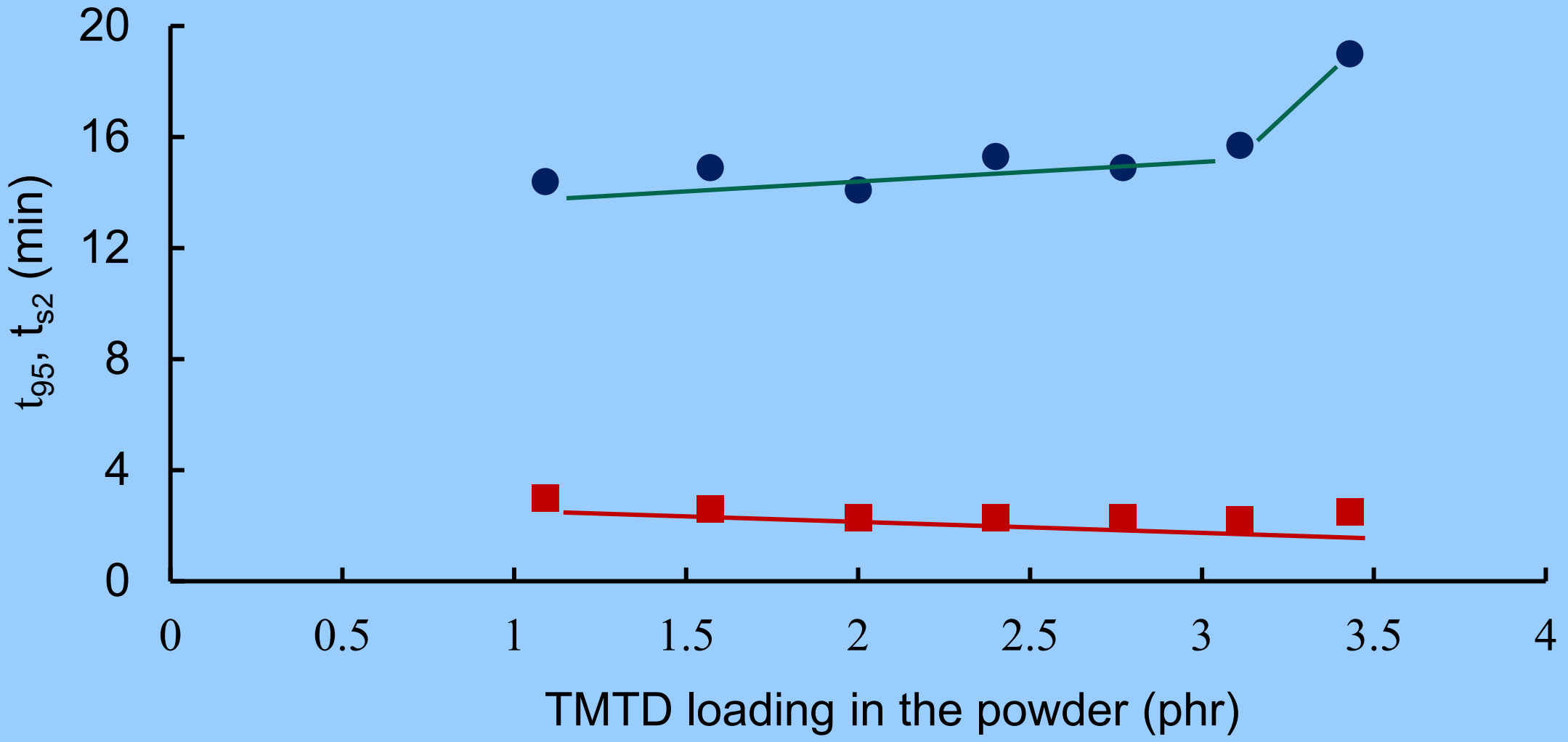
Data for the rubber with 1.09 phr TMTD in the powder

7 Effect of an increasing loading of TMTD in the powder on the ΔTorque of the rubber. For this powder, the optimum TMTD in the powder is 1.57phr

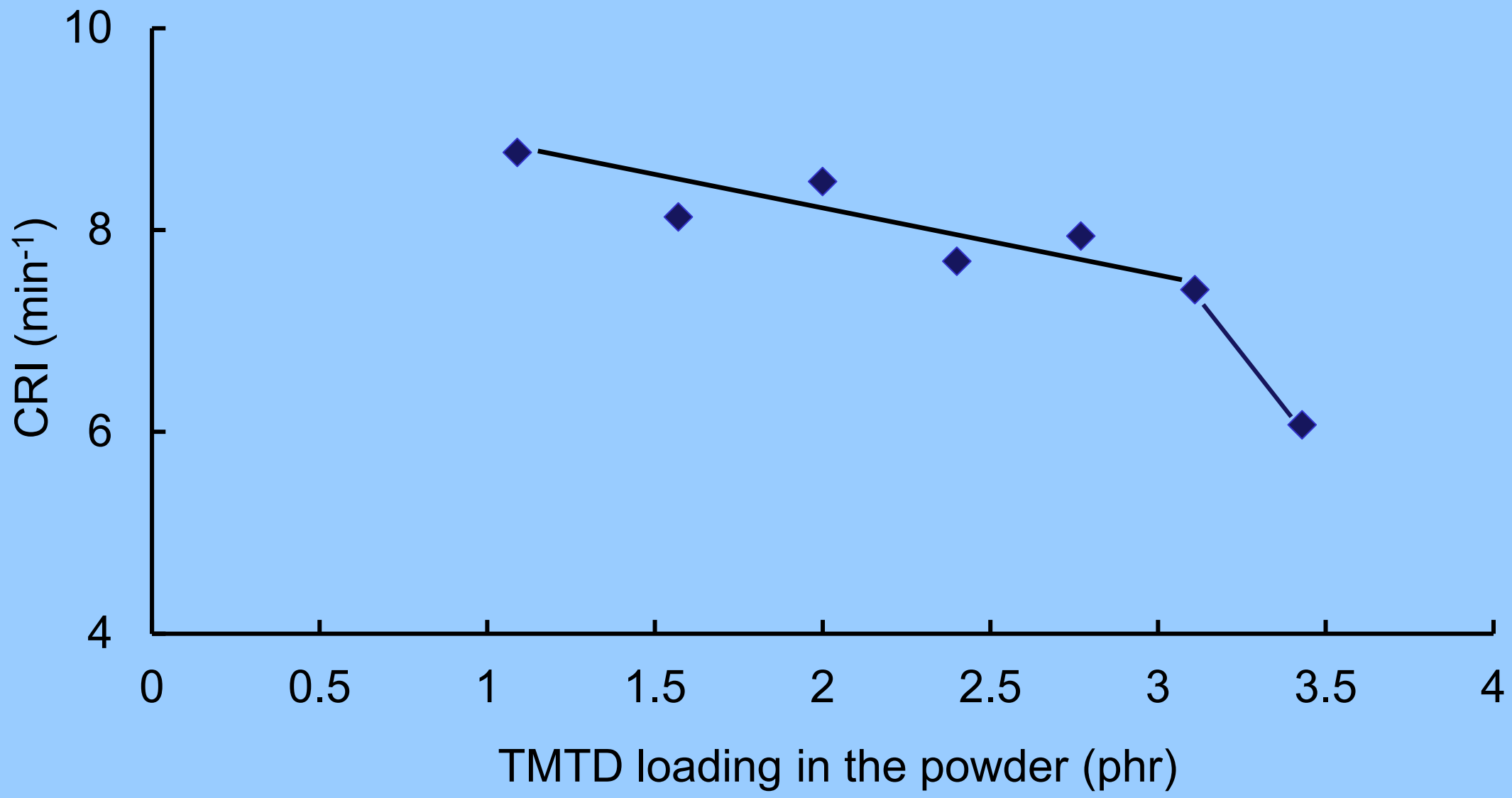


ΔTorque is the difference between the maximum and minimum torques on the cure trace of the rubber and indicates crosslink density changes. Each point is a compound tested.

8 Effect of an increasing loading of TMTD in the powder on the scorch and optimum cure times of the rubber



9 Effect of an increasing loading of TMTD in the powder on the cure rate index of the rubber



10 Conclusions

- ZnO coated with a sulfur-bearing accelerator offers the following benefits:
- Reduces excessive use of ZnO;
- Eliminates use of elemental sulfur;
- Eliminates use of secondary accelerator;
- Eliminates use of secondary activator;
- The cure cycle is controlled by changing the TMTD loading in the powder and **all the chemicals react together at high temperature.**
- **Other benefits are**:
- Highly cost-effective when a single chemical is used instead of 5;
- Less harmful to health, safety and environment;
- Lesser use of chemicals improves efficiency of rubber mixing with chemicals and rubber compounding.

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Summary
Our proposal to reduce ZnO in tires

- Combine ZnO with a sulfur-bearing accelerator to produce one single component (a powder) to vulcanize rubber

12 References

- 1 – Ali Ansarifar, Kornkanok Noulta, Saad h Sheikh, Xujin Bao, George W Weaver and K G Upul Wijayantha. The Perfect Cure, Tire Tech. Inter., April 2019, pp 90-94.

- **Additional references**
- 2 – A Ansarifar, K Noulta, G W Weaver, K G U Wijayantha. Rubber Fibres Plastics International, Vol.14, September 2019, pp184-188.
- 3 – A Ansarifar, K Noulta, G W Weaver, K G U Wijayantha. Rubber Fibres Plastics International, Vol. 16, February 2021, pp30-34.

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Thank you for your attention

Any Qs?