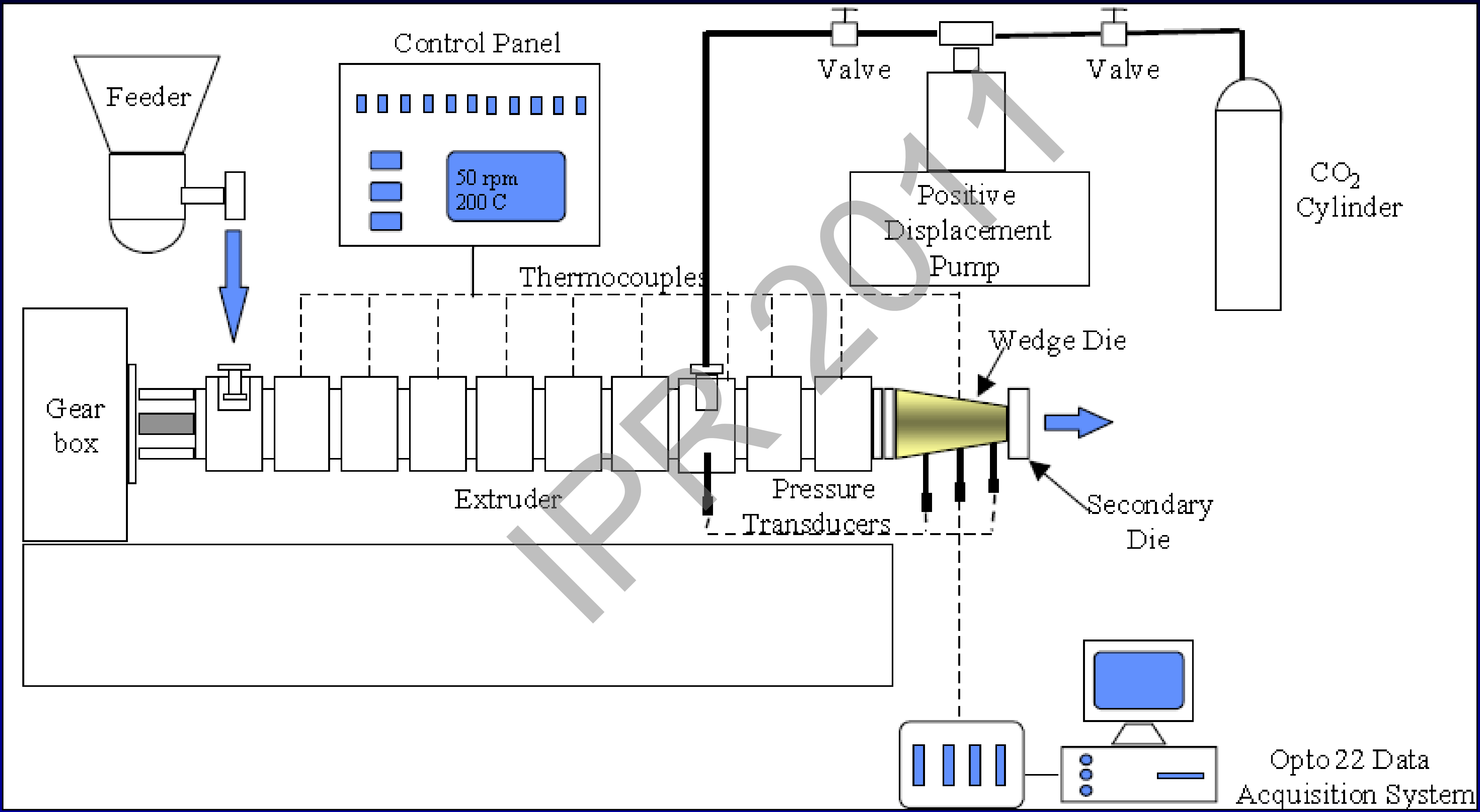
A Statistical Study Of The Compatibility And Curing Of Devulcanized Rubber And Polypropylene

P. Mutyala, C. Tzoganakis
Department of Chemical Engineering, University of Waterloo, Ontario, Canada

IPR -2011, UW, ON

DEVULCANIZATION



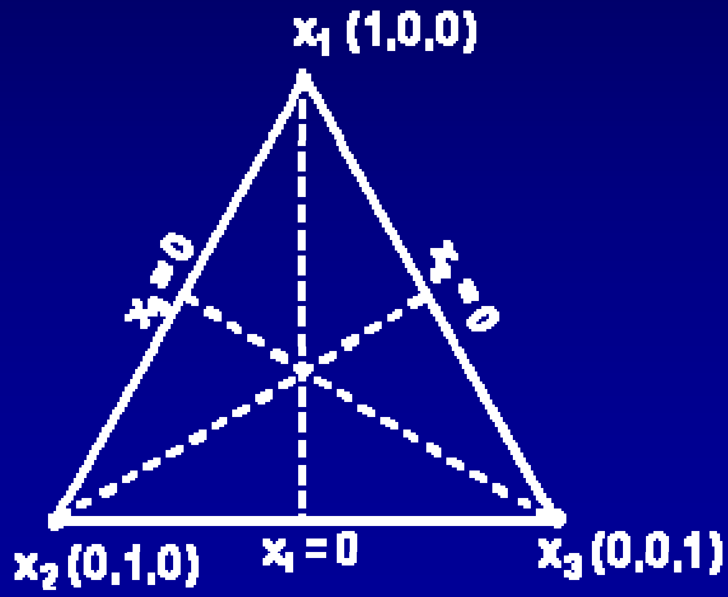
* *C. Tzoganakis, "Method of Modifying Crosslinked Rubber", Patent Number US 7189762 B2, March 13, (2007)*

Outline

- Introduction
- Objectives
- Experimental
- Results
- Conclusions

Introduction

- Review of work on blending devulcanized rubber and plastics
- Role of compatibilizers
- Cure compatibilization
- Mixture designs



Objectives

To statistically evaluate:

1. **The compatibility between devulcanized rubber and Polypropylene (PP)**

2. **Compatibilizing efficiency of sulphur curing**

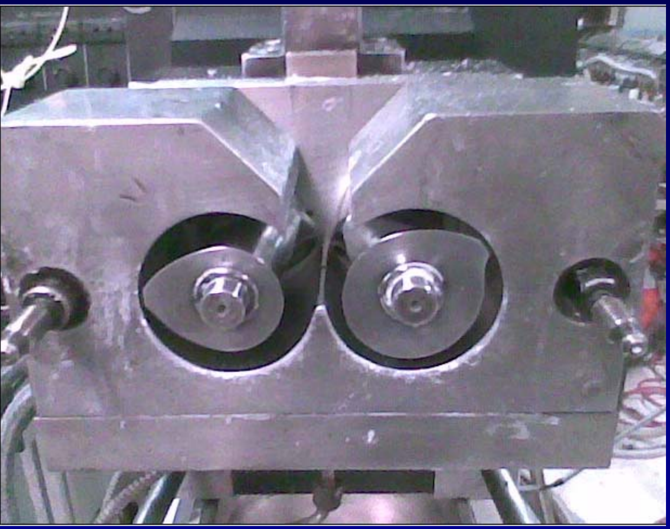
Experimental

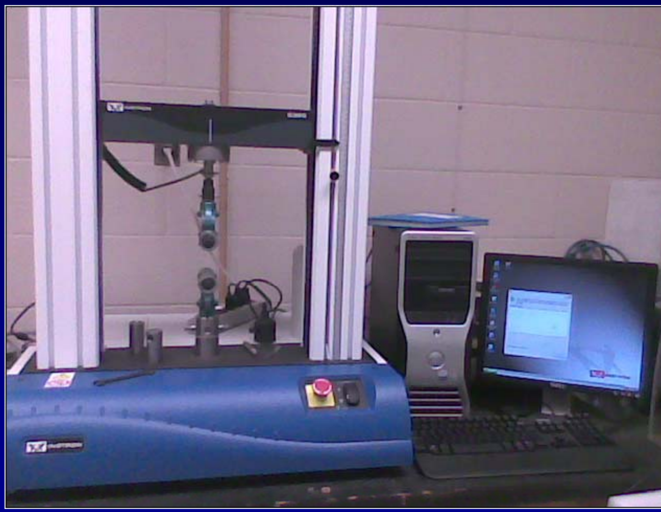
A. Materials:

- **PP - PP31KK01 (MFI=5), Lyondell Basell, North America , TS 24 MPa and EB of 7%**
- **Devulcanized Rubber- Tread based, TS= 9 MPa and EB of 388%**
- **Sulphur (S) and zinc oxide (ZnO) are supplied by Sigma Aldrich and Fischer Scientific respectively.**
- **Stearic acid (St. A) and TBBS are supplied by Western Reverse Chemical Co.**
- **Dicumyl Peroxide (DCP)-99% was by Sigma Aldrich.**

Experimental

B. Procedure:





Mixing: Rheomix 3000 attached to Haake Rheocord 90 , 180°C, 80 rpm

DR, PP, ZnO, St. A, Curing package

Molded - 180 °C, 40,000 psi

Instron tensiometer

Experimental

C. Experimental design -Constrained Mixture Design

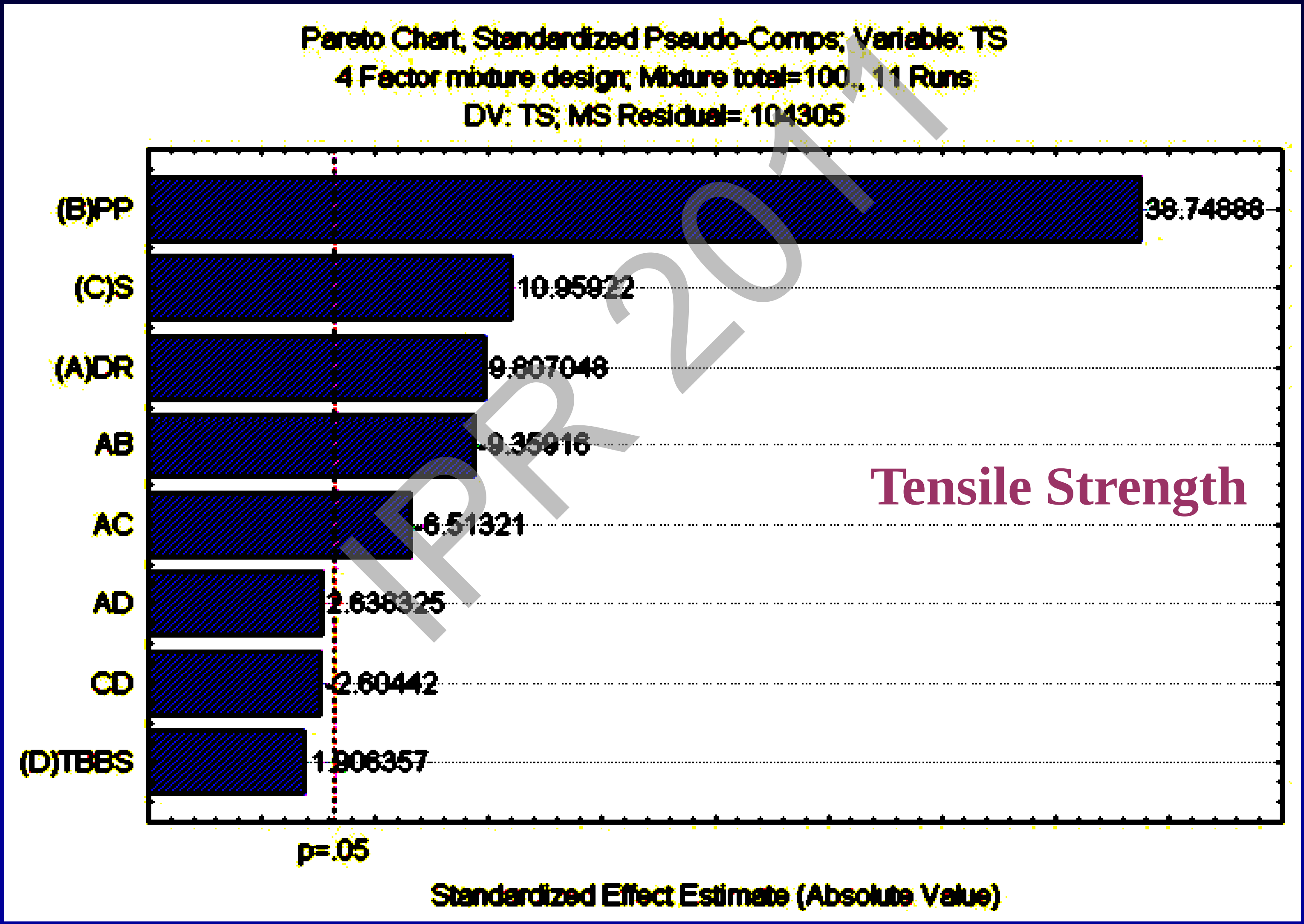
- Variables and constraints – DR: 40% - 80%, PP: 20%- 60%, S: 0.5%-4%, TBBS: 0.5%- 4%.
- ZnO and St. A were assumed to be sufficient for the ranges in which the experiment was carried out and hence were kept constant
- Another set: 3% DCP and 2% S added to the blends DR: PP 60:40, 70:30 and 80:20.

Experimental

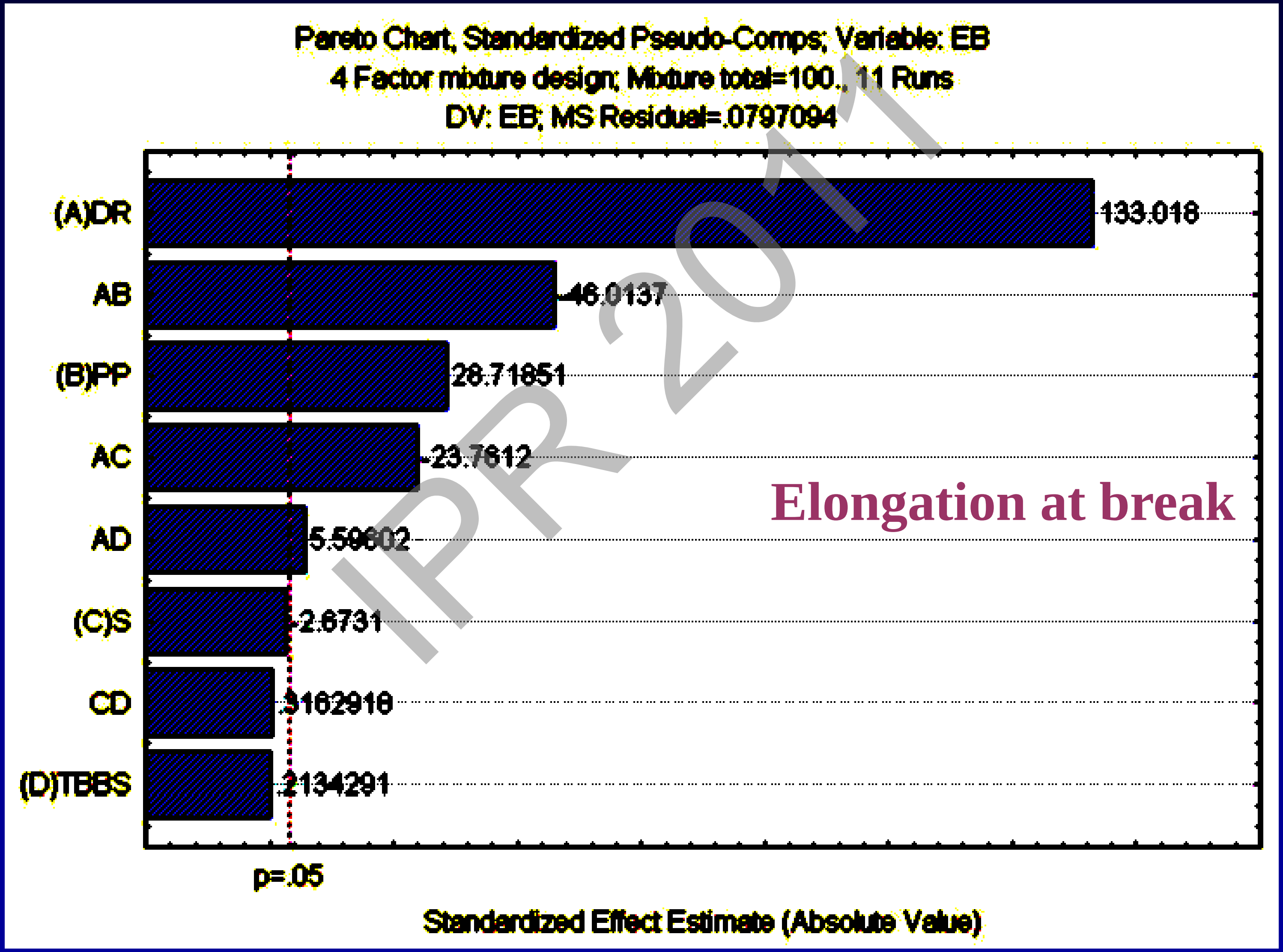
Data points

Experiment No.	1	2	3	4 *(3)*	5	6	7	8	9
Components									
DR %	75.50	40.00	40.00	57.75	40.00	79.00	72.00	40.00	75.50
PP %	20.00	52.00	59.00	37.75	55.50	20.00	20.00	55.50	20.00
Sulphur %	0.50	4.00	0.50	2.25	4.00	0.50	4.00	0.50	4.00
TBBS %	4.00	4.00	0.50	2.25	0.50	0.50	4.00	4.00	0.50
ZnO %	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
St. A %	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15

Results and Discussion



Results and Discussion



Results and Discussion

If x = DR content %, y = PP content %, z = S content %)

- **TS: Dosages of DR, PP, sulphur (S) and interactions between <u>'DR + PP'</u> and <u>'DR + S'</u> seem significant.**

  TS = + 3.0*x + 11.9*y + 46.9*z - 9.89*x*y - 36.50*x*z + 14.79*(-.012)*x - 148.06*(-.012)*z - 0.1

- **EB: Dosages of DR, PP and interactions between 'DR+ PP', and <u>'DR+ S'</u> seem significant.**

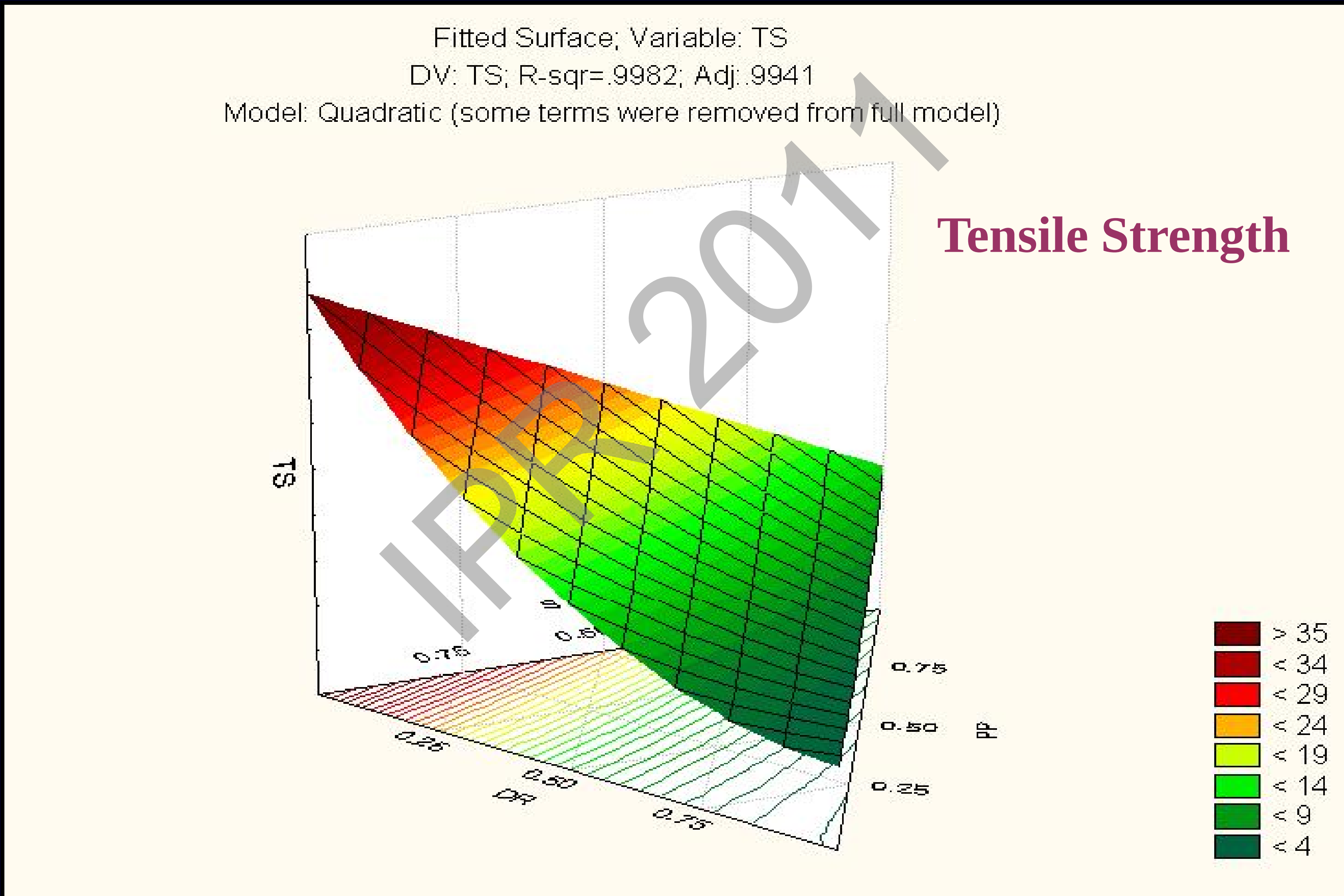
  EB = + 35.6*x + 7.7*y - 10.0*z - 42.49*x*y-16.42*x*z + 27.4*(-.01)*x + 15.7*(-.012)*z - 0.0

Results and Discussion

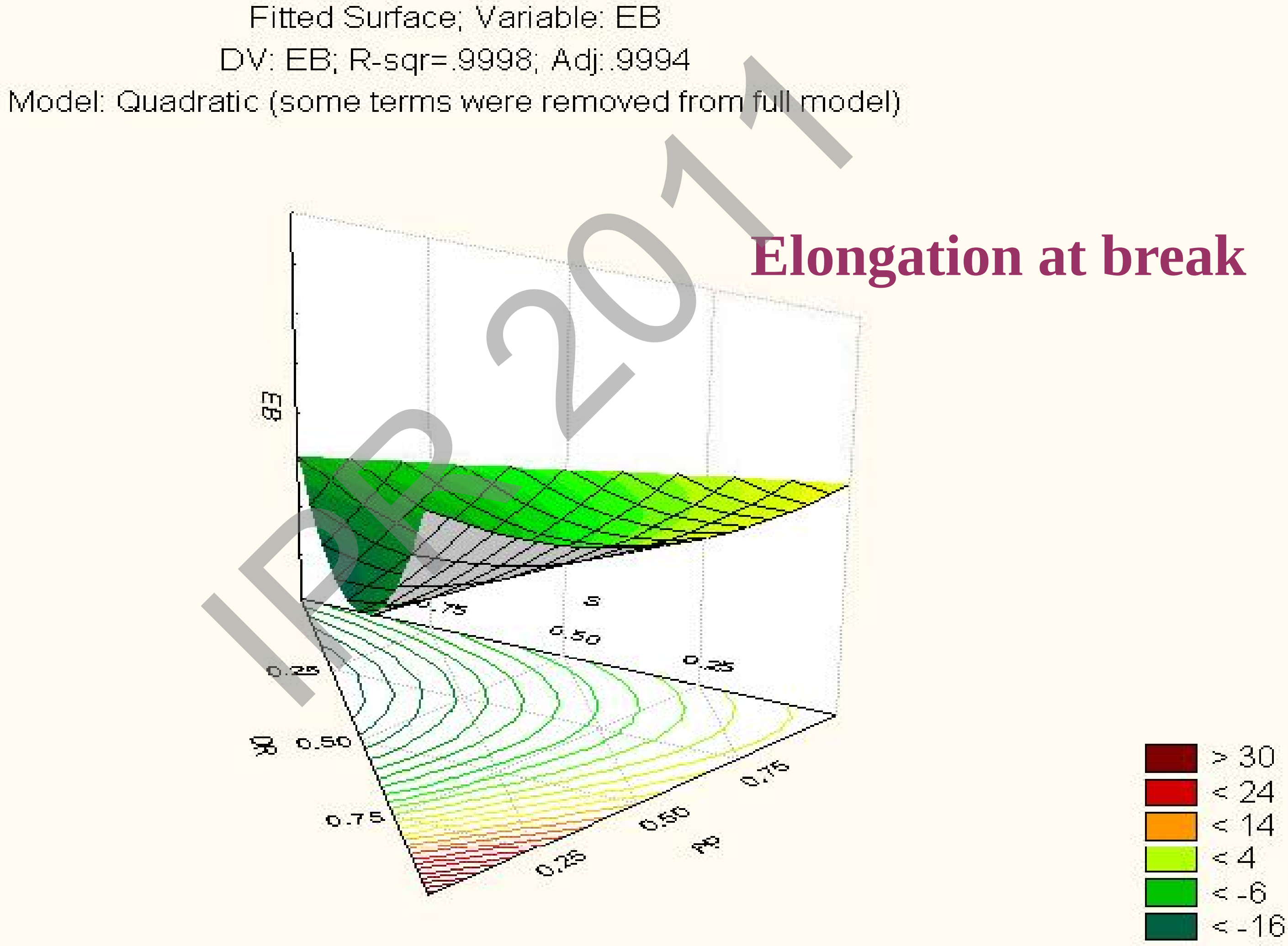
- **The significant negative influence of DR+PP on TS and EB - a statistical representation of the 'incompatibility' between DR and PP phases.**

- **The negative influence of 'DR + S' on both TS and EB - Sulphur cure system is not an effective compatibilizer.**

Results and Discussion

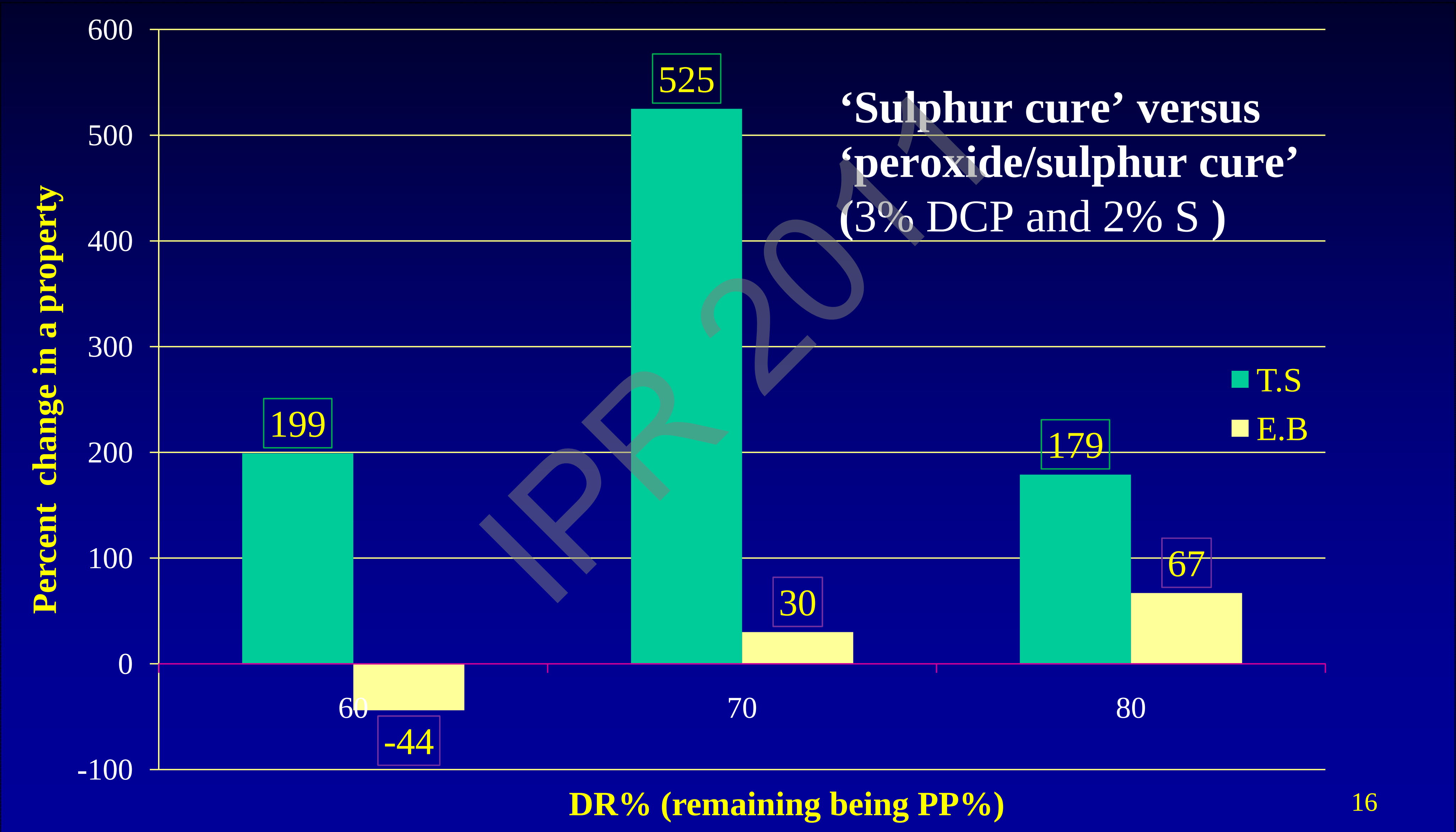


Results and Discussion



Elongation at break

Results and Discussion



Conclusions

- A mixture design approach can be used to analyze the compatibility between phases in a thermoplastic elastomer.

- DR and PP matrix have been proven statistically to be mutually incompatible. Sulphur cure system has been shown to be ineffective as a cure compatibilizer.

- Peroxide/ sulphur cure system has shown promising properties and a better option as a cure compatibilizer.