Comparison of the Kneader and the Twin Screw Extruder in the Compounding of TPV Materials

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Kenneth W. Russell has more than 30 years of experience working with polymer processing and resin companies delivering results in new product development, process improvement, scale-up and customer technical support. Kenneth's expertise includes polyolefin polymerization, polymer compounding, reactive extrusion, and film extrusion. Kenneth has transferred product developments and processes into Europe, India and China from the US while maintaining product equivalency between locations utilizing the tools of continuous process improvement and statistical process control.

Kenneth is certified as a CPlasT from the Society of Plastics Engineers. He has earned a BS in Chemical Engineering from Rutgers University in Piscataway, NJ, a MS in Chemical Engineering from Auburn University, AL. and a Master of Engineering Management from Lamar University in Beaumont, TX.

Over the course of his career, Kenneth has worked for major compounding and resin companies including JM Huber Polymer Services, Chevron Phillips, PolyOne, Celanese and Solvay. He has been consulting for over 5 years as an expert in process improvement, product development, new process development, operator process training and as a resin subject matter expert.

Outline

- Introduction
- Materials
- Equipment
- DOE
- Tape extrusion & Testing
- Results
  - Mechanical properties
  - Morphology

Introduction

- Parker Hannifin Fluid Connector Group
  - Thermoplastic Vulcanizates (TPV)
  - High temperature hose applications
- Initial formulations developed on torque rheometer
  - Mixing head attachment
- Scaled to 26 mm twin screw extruder
  - Samples for testing
  - Process development for future production

Introduction (con't)

- Ideal TPV properties
  - Mechanical properties of elastomer
  - Processability of thermoplastic

- Early formulations
  - Excellent physical properties
  - Poor processability/ high viscosity

- Adopted Design of Experiments methodology

Materials

Thermoplastic:

Polyamide 12 – Arkema

Specific Gravity: 1.031

MVR:51 cm^3/10 min

Elastomer:

Type-1 FKM – Parker O-Ring and Engineered Seals Division

Specific Gravity: 1.91

Durometer: 60 Shore A

Process

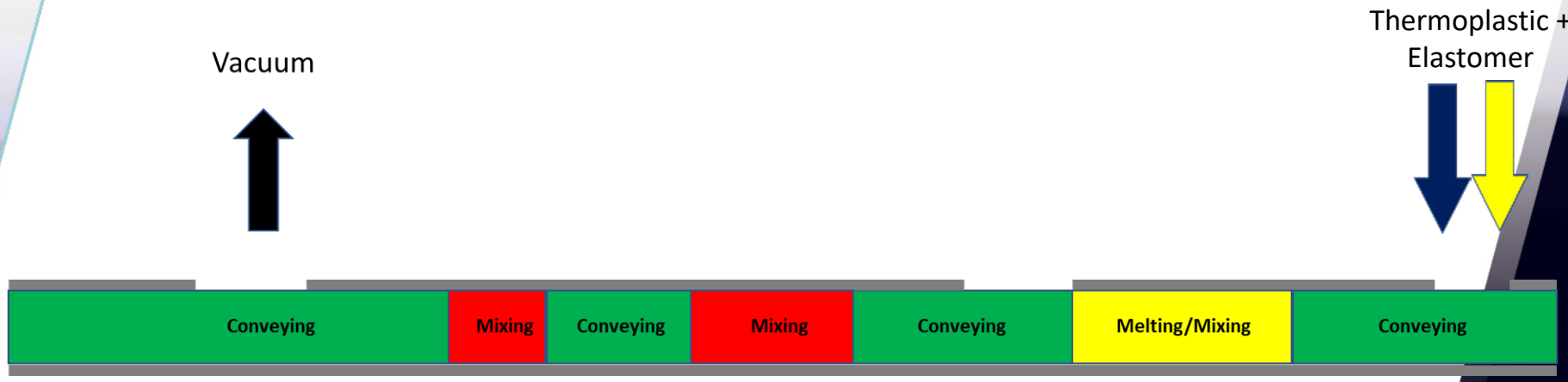
ZSK-26 Set-up

- Coperion ZSK-26 MEGA twin screw extruder
  - 10 barrel/40 L:D
- 4 K-Tron LIW feeders
- Strand Cut Pelletizer
- -24 in. Hg vacuum

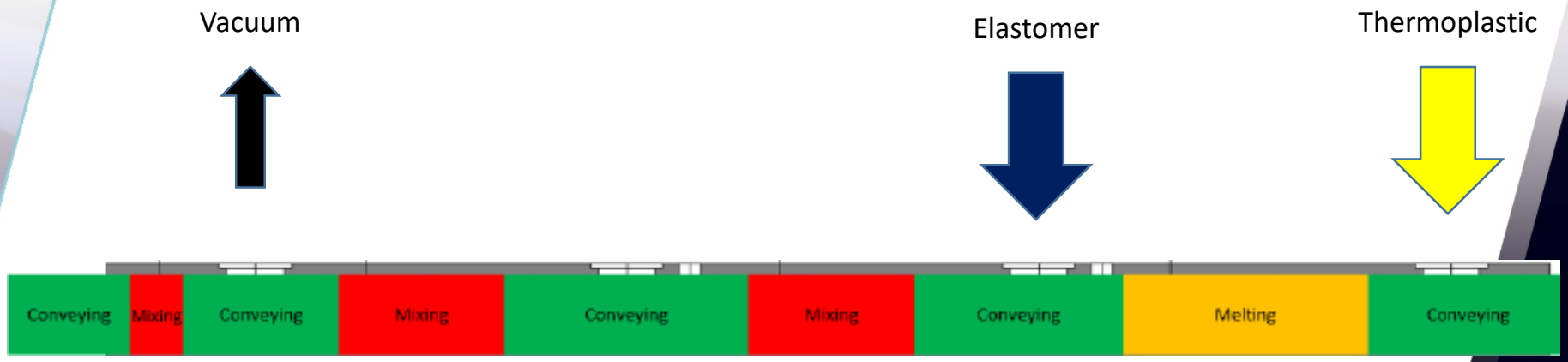
BUSS Kneader Set-up

- BUSS Kneader Model: MX 30-22 F40-6
  - 30mm kneader 22 L:D
  - 40mm discharge screw 6 L:D
- 2 Brabender LIW Feeders
- Strand Cut Pelletizer
- -10 in. Hg vacuum

Screw/Rotor configuration (Twin Screw layout)



Screw/Rotor configuration (Kneader layout)



Design of Experiments

Factor	Low	High	Mid
Temperature	Kneader: 185C/195C/205C TSE:	Kneader: 215C/225C/235C TSE: 230C Flat	Kneader: 200C/210C/220C TSE
Rubber Content	46.6 volume %	60.0 volume %	53.3 volume %
Rotor/Screw Speed	150 RPM	250 RPM	200 RPM

Trial observations

- Process ran very smoothly in a steady state fashion
- Transitions from one condition to the next proceeded in a smooth fashion and lined out quickly
- Rubber content from 40 vol% up to 70 vol% tested
- 70 vol% rubber easily achieved with kneader
  - Highest rubber content produced
  - Not previously achievable on the twin screw
- Demonstrated effects of:
  - Rotor speed vs. Feed Rate
  - Effect of Barrel temps vs MFI, Tensile Strength, Modulus
- In general, low barrel temperatures seemed to provide a more smoothly operating process.

Operational Observations

Twin Screw Extruder

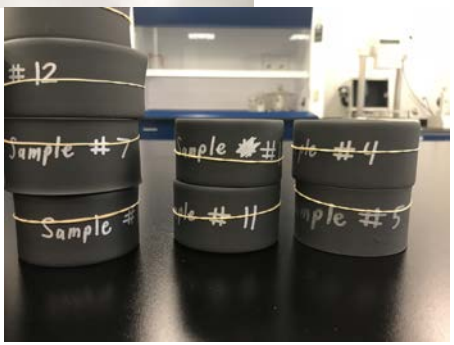
- Barrel temperatures limited
  - Can only run high temp set
- Total processing rate: 14.8 kg/hr
- Torque: 67 – 90%

Kneader

- Able to run complete temperature DOE
- Total Processing rate = 7.5 kg/hr
- Torque: 40 – 66%

Product Testing

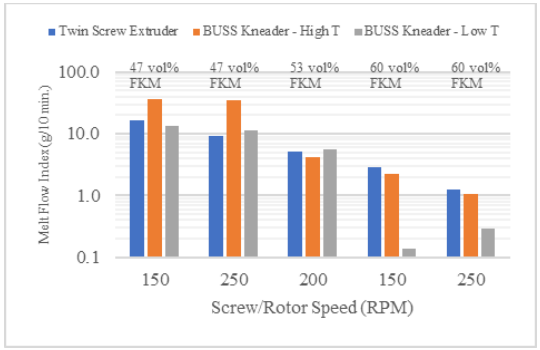
Fabrication of test specimens



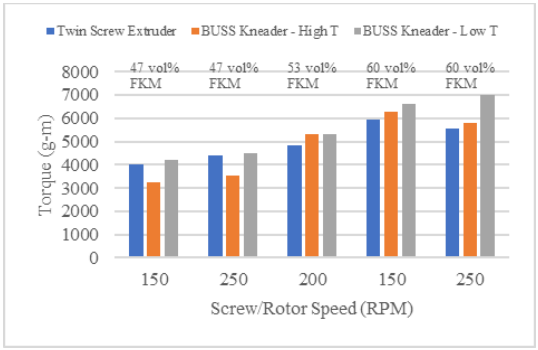
- Material is extruded into tape
  - RS5000 torque rheometer
  - ¾” single screw extruder head
  - 2” Tape die
  - 50 RPM
  - Barrel Temp: 230℃
  - Die Temp: 240℃
- Tensile specimens die cut from tapes

Processability

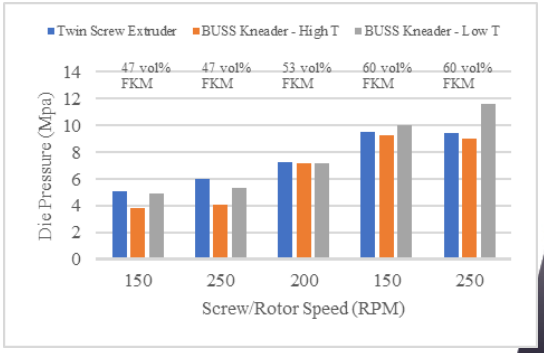
Melt Flow (230°C, 21.5 kg) (g/10 min)



Extruder Torque (gram-meter)

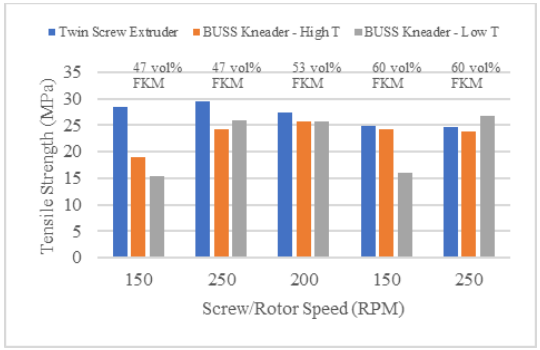


Die Pressure (MPa)

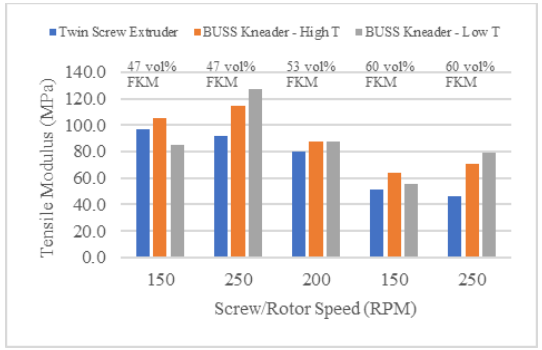


Tensile Properties

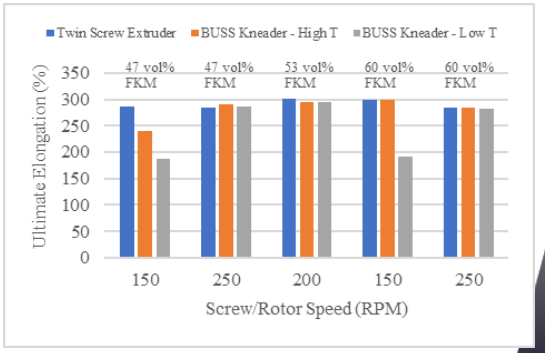
Tensile Strength (MPa)



Tensile Modulus (MPa)

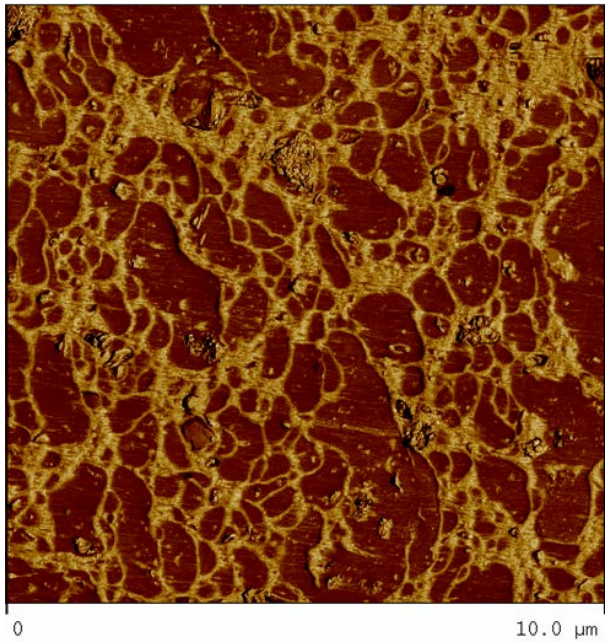


Elongation (%)

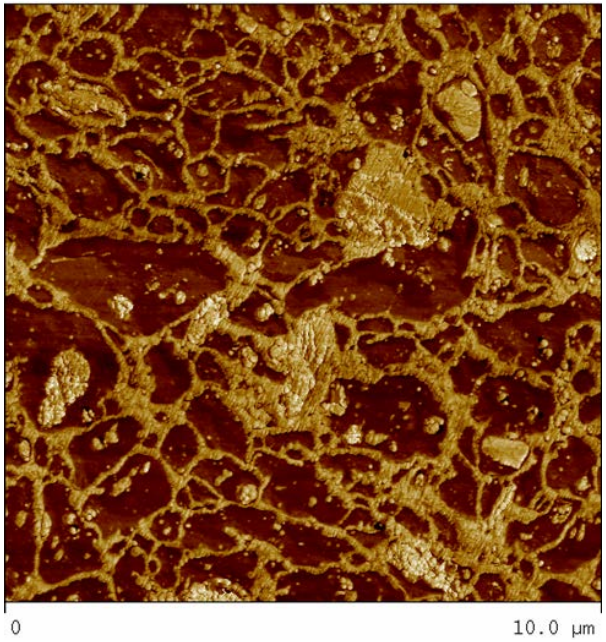


Morphology 70 vol% rubber

Twin Screw Sample



Kneader Sample



Conclusions

- Both the twin screw and the kneader are capable processes for producing TPV products
- The kneader provided a larger operating window with lower torque values.
  - Lower processing temperatures
    - Less potential degradation
  - Potentially higher rubber content
- Product properties were similar
  - Twin screw material had slightly higher strength, slightly lower modulus
- Morphology appears to be similar
  - Rubber dispersion key factor

Next Steps

- New product developments continue
  - Product screening on Torque rheometer
  - Scale-up to twin screw for sample generation, testing and prototype volumes
  - Testing on kneader for promising formulations
- Scale up to commercial operation – 2019
  - Determine which process provides best operation, highest quality product and most economic production
  - Explore options for large scale sampling and production.

Thank You!