Advances in Twin Screw Compounding Technology

Extrusion technology from micro to production scale
Advances in Twin Screw Compounding Technology

Agenda

Introduction
- Development of Dr. Collin GmbH

Compounding in Pharmaceutical Applications
- Material screening ZK12 and ZK16
- Production of drug loaded polymers

Pellet Production in Polymer Development
- Twin-screw extruders
- Pelletizing lines

Compounding in Foam Investigation

Direct Extrusion of Cast film and Sheet
Development of Dr. Collin GmbH

Milestones

1972
- Establishment of Dr. Collin Systementwicklung as a sole proprietorship
- First patent filed for modular calendare systems
- Shipment of first 3-roll calendare

1974
- Expansion of product line to roll mills, presses, single-screw extruders and compoanders

1975
- Conversion from sole proprietorship to Dr. Collin GmbH

1977
- Relocation of company from center of Munich to Weissenfeld, to the east of Munich. Offices and assembly operations now at the same location.

1979
- Shipment of first automated measuring roll mill

1982
- Relocation to newly built offices and assembly building in Ebersberg

1985
- First coextrusion line

1991
- First water-cooled blown film line with 7-layer blown film die

1993
- First coextrusion line for catheter tubing

1994
- Construction of new building with test / demonstration area and laboratory
Development of Dr. Collin GmbH

Milestones

1995
- First pharmaceutical calander for production of pills and tablets
- Introduction the first optical film inspection system

1998
- 50th employee hired
- Introduction of the Teachline Series

2001
- Construction of first 2-gap monoaxial stretching line.

2004
- Introduction of 9-layer feedblock for cast film

2007
- First blown film line with turning bar system
- Rotating blown film die
- First calander for optical film with pivoting 3rd roll

2008
- Shipment of MDO-600S pilot line for monoaxially stretched film and sheet

2009
- Introduction of TDO stretching frame
- Introduction of laboratory-scale spinning line

2010
- Introduction of Mini-Compoander Series
Development of Dr. Collin GmbH

Dr. Collin GmbH today

- A team of about 90 highly motivated employees with expertise in the following areas creates customer-specific solutions
  - Sales and marketing
  - Process technology
  - Mechanical engineering
  - Electrical / electronic engineering
  - Assembly
  - Service
- Approx. 4500 individual machines and systems in use worldwide
- Export share approx. 80%
- Worldwide sales and service network
Compounding Technology

Fields of application for twin-screw extruders

Co-rotating extruders
- Melting, mixing and homogenizing of
  - Polymers, polymer blends
  - Liquids and high-viscosity pastes
  - Mineral-based and organic fibers and fillers
  - Dispersion of pigments
- Outgassing of volatile components
- Continuous reactive extrusion
- Preparation of pill / tablet mixtures
- Direct extrusion

Counterrotating extruders
- Compounding and processing of temperature- and residence time-critical materials
- Characterization of the processing behavior of PVC blends
- Determination of specific energy for scale-up

Throughput ranges
- 50 g/h to 1500 g/h Micro-compounder Series
- 300 g/h to 3000 g/h Teach Line ® Compounder Series
- 2.5 kg/h to 100 kg/h ZSK Series

Collin® co-rotating extruders are quickly converted to counterrotating extruders through quick and easy replacement of the transfer gearbox
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Compounding in Pharmaceutical Application
Stages in pharmaceutical product development

- **Research**: 10000 substances, Batch size 5-50g, Throughput 0,05 kg/h – 1,6 kg/h
- **Pre clinical**: 100 substances, Batch size 50g – 1,5kg, Throughput 1 kg/h – 7 kg/h
- **Clinical Phases**: Phase 1, 5 substances, Batch size 10kg -50kg, Throughput 10 kg/h – 100 kg/h
- **Production**: Application for admission, 2 substances, Batch size 10kg – 50kg, Throughput 10 kg/h – 100 kg/h
Compounding in Pharmaceutical Application
Extrusion in pharmaceutical processes

The extrusion process is appropriate to:
- Drug incorporation into vehicle materials
  - Waxes, cellulose, starch, polymers
- Degassing of volatile parts in the recipe
- Pelletizing of premixes for pills
- Continuous forming of pills
- Coating of drug loaded tapes for transdermal applications
- Production of coextruded drug loaded strands for subcutaneous implants
- Production of mono and multilayer and mono and multi lumen tubes for catheters
- Production of mono and multilayer films for infusion bags
Compounding in Pharmaceutical Application

Extrusion in pharmaceutical processes

Benefits of the extrusion
- Optimal Homogenization
- Wide range of process temperatures (RT to 300°C)
- Accurate temperature control in each heating zone
- Short residence times in each processing unit
- Short times for production changes
- Self cleaning twin screws
- Steady-state, continuous process
- Reliable process with maximum reproducibility of the quality
Compounding in Pharmaceutical Application

Microcompounders ZK12 and ZK16

Fields of application

- Compounding of extremely small batches in research and development
- Throughput ZK12: 50 – 600 g/h
- Throughput ZK16: 100 – 1200 g/h
- Used in the pharmaceutical and plastics industries
- Extremely easy and fast cleaning
- Extremely fast material changes
- Ergonomically designed process control system with touch screen
- Incorporation of active ingredients into carriers such as wax, cellulose, starch, etc,
- Outgassing of volatile components
- Pelletizing of tablet pre-mixtures
- Continuous forming of tablets
Compounding in Pharmaceutical Application

Microcompounders ZK12 and ZK16

Processing unit

- Processing length 24D or 36D
- Modular construction using 12D elements
- Infeed element provided with C-flange
- Quick uncoupling from gearbox for cleaning purposes
- Each element has two heating / cooling zones
- Barrel elements are provided with ports for side feed and outgassing
- Each heating zone has four heater cartridges and thermocouple
- Each zone is provided with ports for air cooling
- Fully encapsulated mechanism holds the heater cartridges and thermocouples
- Modular multi-element screw for all compounding tasks
Compounding in Pharmaceutical Application

Analysis of Degradation of PLA (Joint Project University Munich, EVONIK, Collin)

Target of the Project
- Incorporation of Hydroxylapatit (HA) into absorbable PLA
- HA supports bone growth, faster absorption of the PLA

Problem
- Compounding parameters are not yet investigated
- Material cost 2500€/kg
- Variation of Screw Speed, temperature, filling degree of HA and filling degree of the Compounder
- With a standard laboratory batch size of 1kg it is about 140,000 € material cost for trials

The ZSK12 needs only 100g per batch, which means only 14,000€ for the trials
Compounding in Pharmaceutical Application

Microcompounders ZK12 and ZK16

Downstream equipment

- Roll mill for film
- Calander for tablet molding
- Water bath with pelletizer
- Conveyor belt for air cooling
Compounding in Pharmaceutical Application

Pelletizing Lines

- The compounders can be combined with cooling belts and pelletizers to complete pelletizing lines.

- Various types of cooling belts can be offered.
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Direct Extrusion of Cast film and Sheet
Pellet Production in Polymer Development

Pelletizing lines with Series ZK25TL, ZK25 and ZK35

ZK25TL
- Screw lengths 18D and 24D
- Barrel element length 6D
- Throughput range 300 g/h to 5000 g/h
- Water bath and pelletizer for pellet production

ZK25
- Screw lengths 24D to 42D
- Throughput range 1.5 kg/h to 15 kg/h
- Maximum speed 460 rpm
- Maximum torque 90 Nm
- Determination of specific energy possible when equipped with gravimetric metering units
Pellet production in Polymer Development

Pelletizing lines with the Series ZK25TL, ZK25 and ZK35

- Screw diameter 35 mm, length 56D
- Maximum speed 700 rpm
- Throughput up to 100 kg/h
- Melt pump with pressure / speed control
- Four gravimetric metering units for solids
- Three temperature-controlled gravimetric liquid metering units with protective gas blanket
- Available as strand pelletizer or underwater pelletizer
- Ergonomic layout of controls with touch screen for operation and display of all process parameters
- Software for recording and documenting all experimental conditions
- Fast material changes thanks to quick and easy cleaning
Pellet production in Polymer Development

Pelletizing lines with the Series ZK25TL, ZK25 and ZK35

Fast cleaning and screw conversion

- Motorized shifting of drive unit simplifies screw pulling
- Barrel elements rest on a rail for fast and easy access
Pellet production in Polymer Development

Pelletizing lines with the Series ZK25TL, ZK25 and ZK35

Recipe entry in percent

Recipe entry as absolute values
Pellet production in Polymer Development

Pelletizing lines with the Series ZK25TL, ZK25 and ZK35

Throughput control
Pressure / speed control
Coupling of metering (degree of screw fill)
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Compounding in Foam Investigation

Polymer foams

Applications

- Packaging
- Furniture
- Sandwich core material
- Insulation (thermal, acoustical)
Compounding in Foam Investigation

Polymer foams

Foam structures

- **closed cell foams**
  - applications:
  - foam extrusion, particle foams
  - thermal insulation, packaging, ...

- **open cell foams**
  - applications:
  - foam extrusion, solving of second phase, etc.
  - acoustical insulation, household, ...

- **microcellular foams**
  - applications:
  - foam injection moulding, foam extrusion
  - thermal insulation, automotive, ...

- **structural foams**
  - applications:
  - foam injection moulding
  - automotive, weight saving, ...
Compounding in Foam Investigation

Polymer foams

Tailoring foam properties

nucleating agents
micro scaled - nano scaled - soluble

blowing agents
chemical - physical - combinations

blends, compatibilized blends
two polymer materials - block copolymers

second phase materials
toughness modifier - core-shell particles - Janus particles

processing techniques
batch foaming - foam extrusion - foam injection moulding
Compounding in Foam Investigation

Polymer foams

Blowing agents

Physical blowing agents

Gases: supercritical state
- nitrogen
- carbon dioxide

Liquids:
- alkanes: pentane
- water
- organic solvents with low boiling point

Chemical blowing agents

decomposition at elevated temperature
- anorganic
- carbonate, hydrogencarbonate
- carbon dioxide + water
- endotherm

new approach: combinations of organic liquids, CO₂ and organic liquids, combinations of chemical and physical blowing agents

advantage: foaming of blends, special polymers

anorganic
organic
azo compounds
nitrogen
exotherm
Compounding in Foam Investigation

Foaming with CO$_2$

Foaming Line

- Compounding / Aeration
  - Twin-screw extruder ZK 25 – 42D
  - Throughput 10 kg/h

- Cooling Extruder
  - Single screw E45 – 30D
  - Water cooled

- Extrusion Die
  - Single layer 3 x 30mm

- Calibrator
  - Working width 200 mm
  - Maxim Thickness 60 mm
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Direct Extrusion of Cast Film and Sheet

MDO stretching lines

MDOII 600 for separator film

- Extrusion
  - Twin-screw extruder ZK 35 – 40D
  - Throughput 50 kg/h
- Single-layer die
  - Width 600 mm
  - Gap 0.3 mm to 1.5 mm
- Chill roll
  - Working width 650 mm
  - Roll diameter Ø 252 mm / 252 mm
- Stretching unit
  - Roll width 600 mm
  - Preheat unit - 3 rolls
  - Stretching unit - 4 rolls – gap 1
  - Annealing unit - 2 rolls
  - Stretching unit 4 rolls – gap 2
  - Cooling unit - 3 rolls
Cast film and sheet

MDO stretching lines

Winder  |  MDO II  |  Chill roll

MDOII 600 for separator film
- Touch screen controls
Final Considerations

Basic approaches to materials development

Basic development and screening
- Small quantities for testing
- Frequently expensive materials
- Large number of tests
- Basic assessment of processing behavior
- Scale-up not necessary

Small, high-precision machines
- Throughput 30 g/h to 3000 g/h

Near-production-scale development
- Product properties close to those of final product
- Test in subsequent processes (print, welding, etc)
- Minimal testing costs
- Scale-up necessary

Economical materials development
- Optimized machine sizes for every stage of materials development reduces material costs considerably
- Production lines require a long time to reach thermal equilibrium
- The availability of production equipment for development test is usually very limited, resulting in long development times
- Development on a pilot system means
  - Cost efficiency
  - High versatility
  - Short development times
  - Shorter “time to market”

Pilot production lines
- Throughput 30 kg/h bis 300 kg/h