TEXTILTECHNIK

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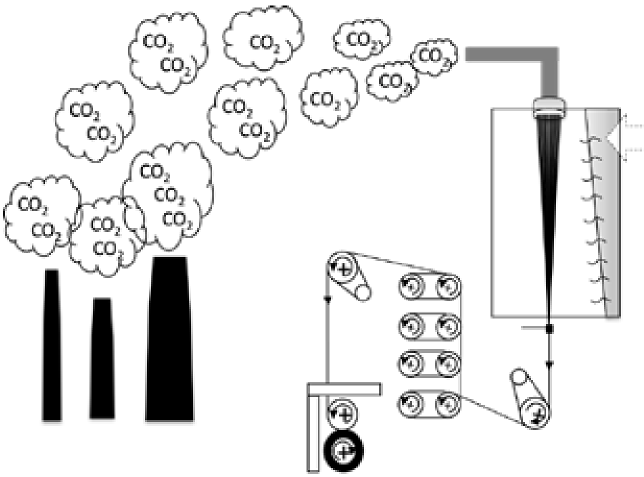
# Melt spinning of carbon dioxide based thermoplastic polyurethane

Pavan Kumar Manvi




SHAKER VERLAG

**„Melt Spinning of Carbon Dioxide Based Thermoplastic Polyurethane“**

**„Schmelzspinnen von thermoplastischem Polyurethan auf Kohlendioxid-Basis“**

Von der Fakultät für Maschinenwesen
der Rheinisch-Westfälischen Technischen Hochschule Aachen
zur Erlangung des akademischen Grades eines

**Doktors der Ingenieurwissenschaften**

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**Pavan Kumar Manvi**

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Major part of scientific content of this thesis is based on results from projects “Dream Products“ and “Cross-linkable $CO_2$-Polyether polyols – Cro$CO_2$PETs”. Parts of this thesis are also based on student theses under my supervision. A bibliography of student theses is given in chapter 17.

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## Abstract

Developing sustainable processes and products that create “sustainable growth” and “low carbon footprint” are the future concerns of the European industry. Thermoplastic polyurethanes from carbon dioxide based raw materials are recently developed by the company Covestro AG, Leverkusen, Germany. This is an innovative solution to support sustainable production with the potential to be established as an alternative to conventional polyurethanes. Therefore, this PhD thesis is aimed at developing a melt spinning process for carbon dioxide ($CO_2$) based thermoplastic polyurethane (TPU) to identify textile applications. The melt spinning process is successfully developed at technical scale at a winding speed of 2500 m/min, which is the highest ever winding speed known for polyurethane filaments in any spinning process. Filament spinnability is tested for a fineness range from 156 dtex to 1240 dtex, which is successfully completed. Melt spun elastic filaments are evaluated regarding their technical and economic aspects. The filaments have a tensile strength equivalent to the industrial benchmarks. Elongation is lower than the benchmark and therefore a scope analysis is made to analyse the feasibility for implementation in industrial products. Melt spun elastic filaments can be used in the majority of elastic textile products. However the whole range of applications cannot be covered. From an economical point of view, melt spun carbon dioxide based thermoplastic polyurethane filaments are 50 – 60 % cheaper than conventional solution polyurethane filaments. The much lower price shows the high potential of melt spun carbon dioxide based thermoplastic polyurethane filaments in the textile market. Further efforts are required to improve the filament elongation to cover the whole range of elastic textile applications.

## Kurzfassung

Die Entwicklung nachhaltiger Prozesse und Produkte für ein "nachhaltiges Wachstum" und einen "geringen $CO_2$-Fußabdruck" ist ein zentrales Zukunftsanliegen der europäischen Industrie. Thermoplastische Polyurethane aus kohlenstoffdioxidbasierten Rohstoffen wurden von der Covestro AG, Leverkusen, Deutschland entwickelt und sind ein innovativer Lösungsansatz zur Unterstützung der nachhaltigen Produktion mit dem Potential zur Etablierung als Alternative zu konventionellen Polyurethanen. Die vorliegende Promotionsarbeit ist gezielt auf die Entwicklung eines Schmelzspinnverfahrens für thermoplastisches Polyurethan (TPU) auf Basis von Kohlenstoffdioxid ($CO_2$) zur Identifizierung des Potentials für Textilanwendungen ausgerichtet. Der Schmelzspinnprozess wurde erfolgreich im technischen Maßstab mit einer Wickelgeschwindigkeit von 2500 m/min entwickelt. Dies ist die höchste bekannte Wickelgeschwindigkeit für Polyurethanfilamente bei Betrachtung sämtlicher Spinnverfahren. Der Prozess wurde auf einem Feinheitsbereich von 156 dtex bis 1240 dtex erfolgreich getestet. Schmelzgesponnene elastische Filamente wurden hinsichtlich ihrer technischen und wirtschaftlichen Aspekte bewertet. Die Filamente zeigen eine mit den Benchmark-Werten vergleichbare Zugfestigkeit. Da die Dehnung im Vergleich zum Benchmark geringer ausfällt, wird eine Machbarkeitsstudie für schmelzgesponnene Filamente zur Untersuchung der Einsetzbarkeit in industriellen Produkten durchgeführt. Schmelzgesponnene elastische Filamente können im Großteil der elastischen Textilprodukte verwendet werden, die gesamte Bandbreite an Anwendungen kann jedoch nicht abgedeckt werden. Aus ökonomischer Sicht sind die TPU-Filamente auf Kohlenstoffdioxid-Basis um 50 – 60 % preiswerter als herkömmliche Polyurethanfilamente. Der niedrige Preis deutet auf das große Potential der schmelzgesponnenen elastischen Filamente auf dem Textilmarkt hin. Weitere Forschungen sind erforderlich, um die Filamentdehnung zu verbessern und um den gesamten Bereich der elastischen Textilanwendungen abzudecken.

# Content