1 Introduction

Einleitung

The climate change due to human activities is one of the most important issues endangering the environment [PARR08]. Climate change is caused by an accumulation of green house gases in the atmosphere [CROW00]. Approximately three quarters of global green house gas emissions are attributed to carbon dioxide CO_2 [OLIV17]. Due to the prevalence of combustion engines, the transportation sector accounts worldwide for about a quarter of the total CO_2 emissions with a major part of this share caused attributed to cars [INTE17].

In order to reduce CO_2 emissions from cars, legislative limits have been imposed on maximum permissible CO_2 emissions [YANG17]. A further tightening of the current regulations is expected in the future (Figure 1.1a). In complying with the regulations, the average CO_2 emission values can be seen to decrease (Figure 1.1b). So far, the major enablers of CO_2 emission reduction are enhanced combustion engines accompanied by a simultaneous increase in engine power output [MOCK17].

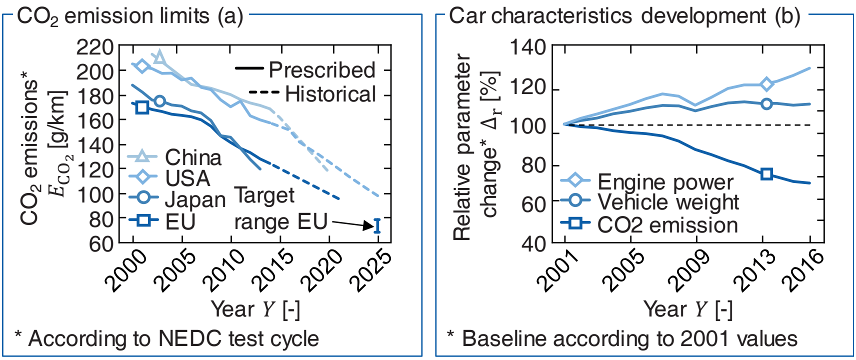

Figure 1.1: Historical and prescribed limits on maximum CO_2 emissions from passenger cars [INTE14] (a), car characteristics development [MOCK17] (b)

Historische und vorgeschriebene Grenzwerte für maximale CO_2-Emissionen von PKW (a), Entwicklung von PKW-Eigenschaften (b)

Lightening the weight of cars is a means of reducing their fuel consumption and the resulting CO_2 emissions [HELM06]. It is estimated that a 1 % weight reduction of a car decreases fuel consumption by 0.7 % [CHEA10]. There is ongoing effort into light weighting structural car components, but this is offset by features that increase weight and by the introduction of heavier car classes [HEYW15]. As a consequence, the average car weight remained nearly constant over the last decade (Figure 1.1b). A more radical approach to lightweighting is needed to tap into the fuel saving potential.

Most of the current lightweighting advances are achieved by substituting conventional steels with alternatives such as high-strength steels, aluminum, magnesium and composite materials [MACK14]. Amongst others, a sub-class of composite materials, carbon fiber reinforced plastics (CFRP), offers the highest weight-saving potential for automotive applications [FRIE13]. So far, the high prices of CFRP components limited their applications mostly to sport cars (e.g. AUDI R8, BMW i8) or to luxury vehicles (e.g. AUDI A8, BMW 7). Although, the recent example of the Toyota Prius demonstrates the feasibility of CFRP applications in a larger market segment. Furthermore, the total demand for CFRP composites in the automotive industry is predicted to steadily increase in the future, becoming the largest market segment per weight by the end of 2020 [SAUE17].

The further growth of CFRP usage in the automotive industry depends on whether CFRP components find a way into high-volume applications. If automotive grade carbon fiber prices decline steadily [SLOA16b], the development of repair and recycle as well as transformative technologies for mass manufacturing CFRP components will be necessary [SLOA16a]. The transformative technologies should aim at automation, cycle time and cost reduction of CFRP components for CFRP components fabrication processes [MAZU16]. An investigation of one potentially transformative technology for CFRP components manufacturing is addressed in this thesis.

CFRP components are manufactured to near-net shape by means of molding [KRIS13]. In order to fulfill the final geometric and functional requirements, near-net shape CFRP components must, however, undergo a finishing step [WANG95]. This involves trimming the outer workpiece contour and creating holes or openings [YASH13]. Currently, machining and abrasive water jet cutting technologies are used for this purpose [HADD14]. Given a possible transition to the mass production of CFRP components, shearing could potentially make CFRP finishing more cost-efficient and productive than the current state-of-the-art. This hypothesis is based on an analogy with sheet metal working in the automotive industry, where shearing is the most widely used technology for trimming and piercing of structural car body components [KLOC13].

Due to the novelty of this approach, there is a lack of knowledge on the technological and economic potential of CFRP shearing technology. In order to address this issue, the interdependencies between the shearing process parameters and the resulting workpiece and process characteristics will be investigated from technological, mechanical and economical standpoints in this thesis. This contributes substantially to the understanding of CFRP separation mechanisms during shearing and lays a foundation for the further development of this potentially transformative technology for the mass production of CFRP components.

Einleitung

Der Klimawandel ist eines der wichtigsten Probleme, welches die Umwelt gefährdet [PARR08]. Der Klimawandel wird durch eine Ansammlung von Treibhausgasen in der Atmosphäre verursacht [CROW00]. Ungefähr drei Viertel der globalen Treibhausgasemissionen sind CO_2-Emissionen zugeschrieben [OLIV17]. Aufgrund der globalen Bedeutung von Verbrennungsmotoren macht der Verkehrssektor weltweit etwa ein Viertel der gesamten CO2-Emissionen aus, wobei ein Großteil dieses Anteils auf Autos entfällt [INTE17].

Um die CO_2-Emissionen von PKW zu reduzieren, wurden gesetzliche Grenzwerte für die maximal zulässigen CO_2-Emissionen festgelegt [YANG17]. Die Grenzwerte werden in Zukunft weiter verschärft, vgl. Abbildung 1.1a. Durch die Einhaltung der Vorschriften verringern sich die durchschnittlichen CO_2-Emissionswerte, vgl. Abbildung 1.1b. Bis heute sind die Verbesserungen in Verbrennungsmotoren, die mit einer gleichzeitigen Erhöhung der Motorleistung einhergehen, die wichtigsten technologischen Befähiger für die Reduzierung von CO_2-Emissionen [MOCK17].

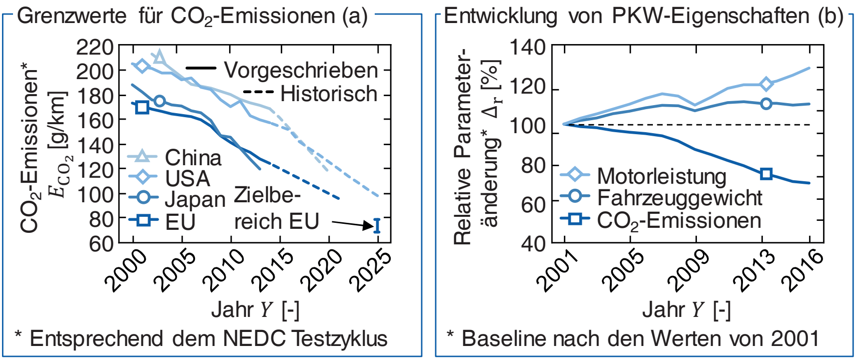

Abbildung 1.1: Historische und vorgeschriebene Grenzwerte für maximale CO_2-Emissionen von PKW [INTE14] (a), Entwicklung von PKW-Eigenschaften [MOCK17] (b)
Historical and prescribed limits on maximum CO2 emissions from passenger cars (a), car characteristics development (b)

Der Leichtbau von Pkw bietet eine weitere Möglichkeit, den Kraftstoffverbrauch und die daraus resultierenden CO_2-Emissionen zu reduzieren [HELM06]. Schätzungsweise führt eine Gewichtsreduzierung eines Autos um 1 % zu einem um 0,7 % reduzierten Kraftstoffverbrauch [CHEA10]. Jedoch werden die fortwährenden Leichtbauoptimierungen von strukturellen Fahrzeugkomponenten durch neues gewichtssteigerndes Zubehör und die Einführung schwererer Fahrzeugklassen überlagert [HEYW15]. Infolgedessen blieb das durchschnittliche Fahrzeuggewicht in den letzten zehn Jahren nahezu konstant, siehe Abbildung 1.1b. Daher ist ein radikalerer Ansatz für den automobilen Leichtbau erforderlich, um dessen Potenzial zur Kraftstoffeinsparung auszuschöpfen.