

strategy&

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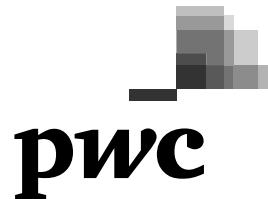
June, 16th 2015



Innovation trends steel 2015



- Analysis of patent publications in steel and its implications -



Agenda

Management summary

Innovation trends steel 2015

Management summary „Innovation trends steel 2015“

Shorter innovation cycles and more demanding applications require an integrated steel research and development (1/2)

The dynamics within steel research and development growth rapidly. This is the key result of the new study “Innovation trends steel 2015” conducted by Strategy& consulting on behalf of the German Wirtschaftsvereinigung Stahl.

Strategy& observes that customer requirements on today’s steel applications become more and more demanding. Its properties like stability, ductility and many others show values that never existed before. This enables leaps of innovations for the products of the steel processing industry. Therewith steel is the driver of technical advancements with in the economic growth areas of energy supply, infrastructure, mobility and resource and energy efficiency.

The novel dynamics of steel innovations are reflected within the steel relevant patents of

German, European and World intellectual property organizations as well. In 2014 nearly 4.300 new steel patents relevant for Germany have been published compared to only 2.000 in the early 90s. Furthermore, the compound annual growth rate for patent publications has doubled from 3% to 6% per year. The patent analysis show as well that the duration for a patent publication decreased by 20%. At the same time the complexity of new patents has increased constantly. This means that patents are registered more often across multiple production steps or even across value chains. Innovation cycles are shrinking and intensifies the innovation competition.

Another implication of the patent analysis shows that a substantial part of new patents belong to steel processing (about one third). Construction

Management summary „Innovation trends steel 2015“

Shorter innovation cycles and more demanding applications require an integrated steel research and development (2/2)

part-specific solutions or novel material interconnection technologies for composite materials are respective examples. But the increasing dynamics take place across all production steps. The most dynamic area, with a compound annual growth rate of 7%, is the area of hot and cold forming. This is the link between the material and the customer application. It shows that novel steel grades in combination with the processing are developed to market readiness considering industrial scale challenges.

To cope with shrinking innovation cycles and increasing requirements an integrated steel research and development is necessary more than ever, concludes Strategy&. The composition of local research and corporate development, the close collaboration between steel producer and steel processors as well as the tight

interdisciplinary research and development networks belong to this integrated research and development. The study reveals that the steel country Germany has already such a tight network. Today more than 69 research institutes and cooperation with many partnerships exists. Thereby the number of cooperation has increase steadily over the last years. On these grounds Germany is responsible for about one third of new steel patents each year.

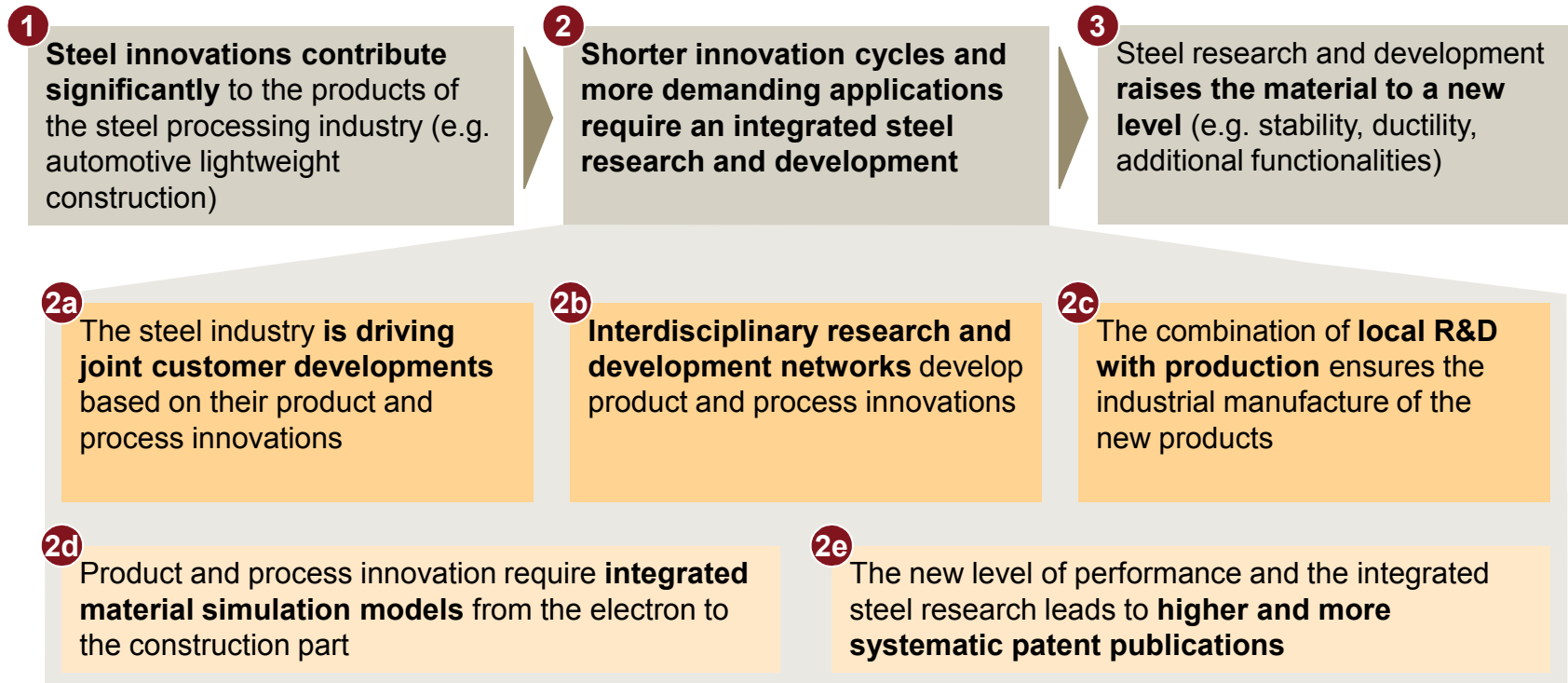
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“Innovation trends steel 2015”

Analysis of patent publications in steel and its implications



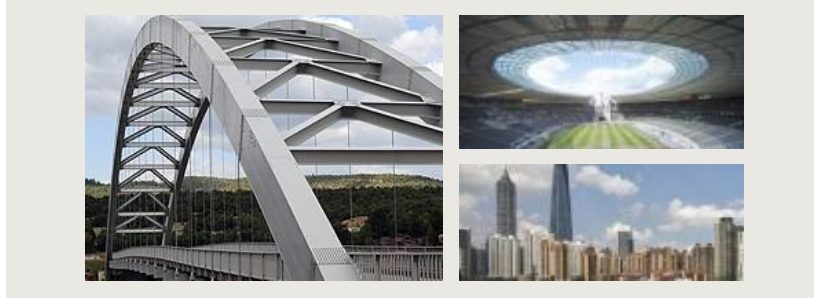
Steel innovations contribute significantly to the products of the steel processing industry

① The steel industry is the key to our future wealth

Energy supply



Urbanization & infrastructure



Mobility



Resource & energy efficiency



These innovations improve products and processes in all key growth areas

1 Growth areas: Applications of steel innovations (examples)

Energy supply

- Innovative **steel materials** and **catalysts** increase the effectiveness of the fuel cell
- Innovation in **non-oriented electrical steel** increase the energy efficiency of electric motors

Urbanization & infrastructure

- **Novel steel composites** enable resource and nature-friendly construction of bridges (e.g. Saale-Elster-Bridge)

Mobility

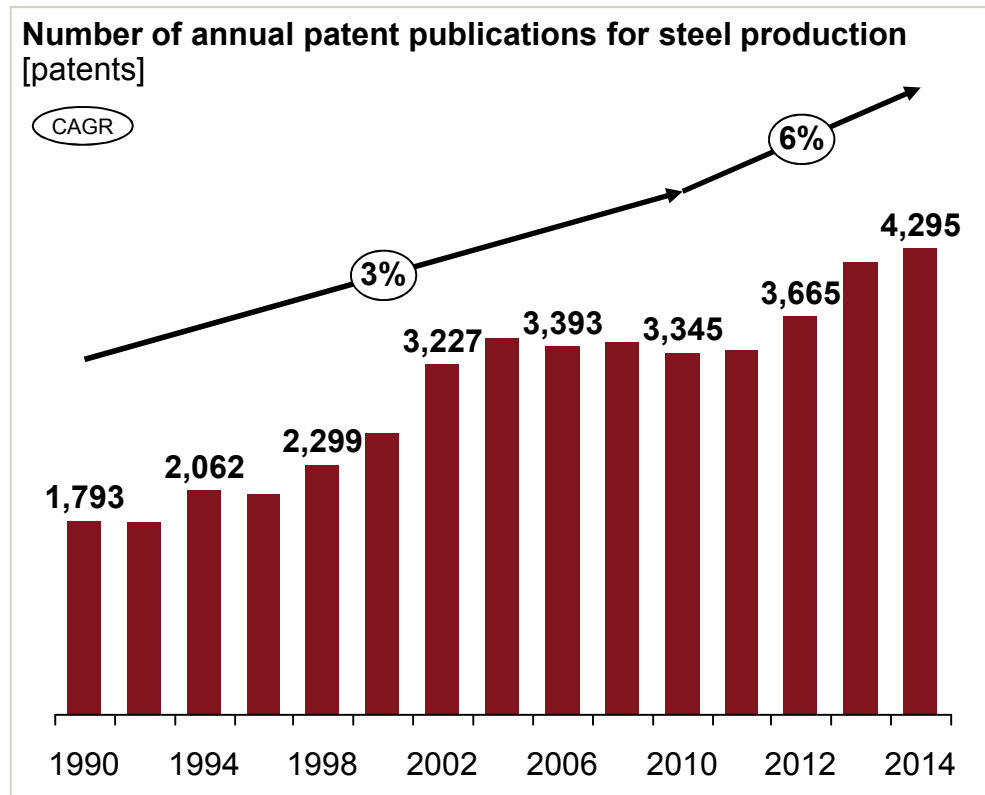
- Innovative **multiphase steels and composites** increase the energy efficiency and safety of automobiles (e.g. carbon fiber steel, aluminum-steel composites)
- Innovations in **manganese alloyed steels** leads to longer lifetimes of wearing parts (e.g. highly wear resistant, non-magnetic)

Resource & energy efficiency

- Material innovations in **extremely pressure-resistant injectors** increase efficiency of diesel engines
- Innovative **near-net-shape casting** enables an energy-saving production and new applications of steel
- **Innovative steel application** account for 80% of modern wind turbines

The development of patent publications since 2010 shows a new growth dynamic

② The material steel is not yet exhausted



New dynamic

- Since 2010, growth has doubled to **over 6%**
- The German share is about **one-third**

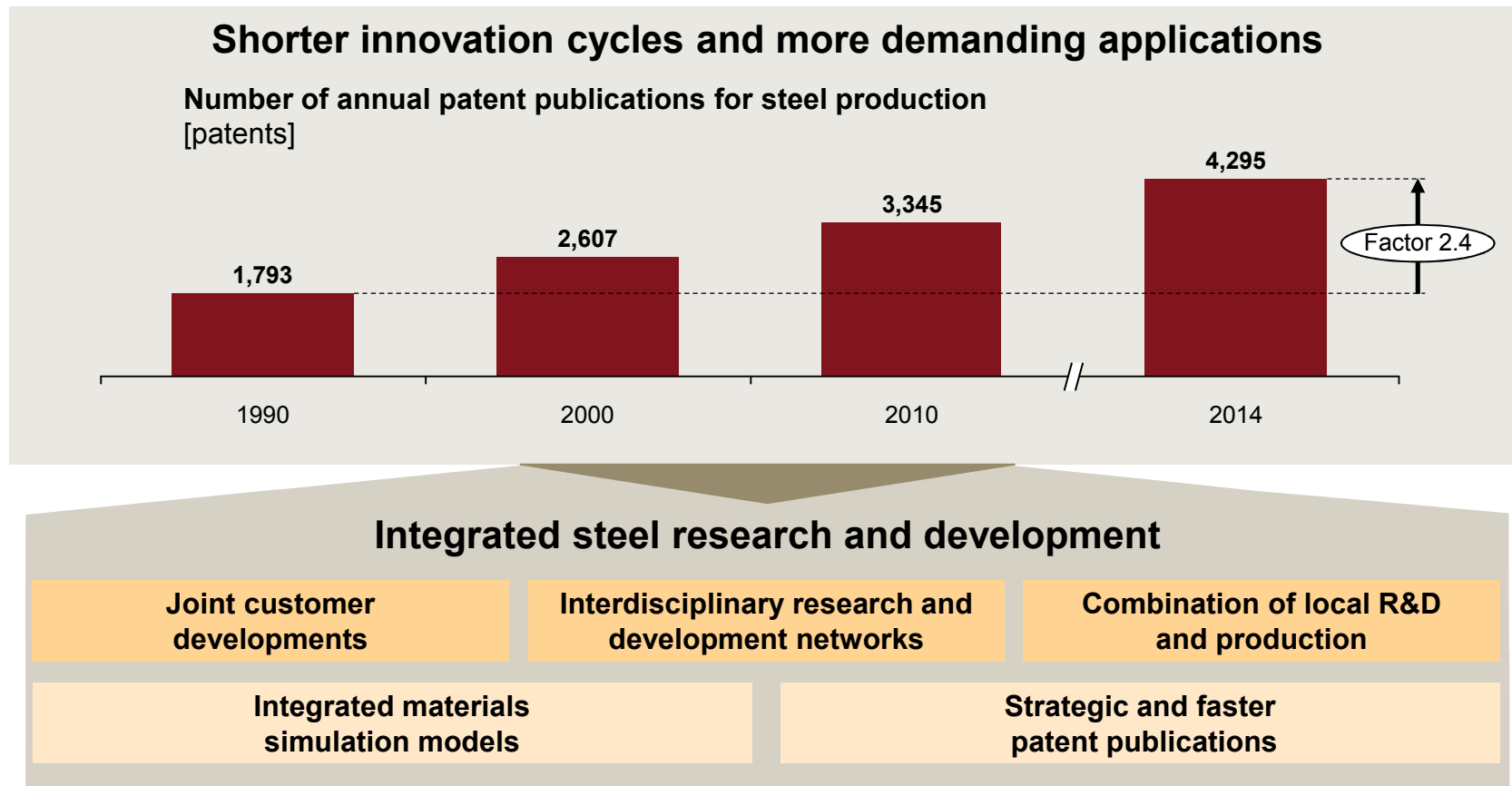
Drivers are:

- **Lighter and safer steel** in the automotive industry
- The exit from nuclear energy requires **new materials for production, storage and distribution** of electricity
- **Infrastructure and mobility** in big cities and metropolitan areas

Source: Strategy&, German Patent Office (DPMA), European Patent Office (EPO), World Intellectual Property Organization (WIPO)
IPC classes: B21B, C21B, C21C, C21D, C22B, C22C (comparable to Strategy& study 2011)

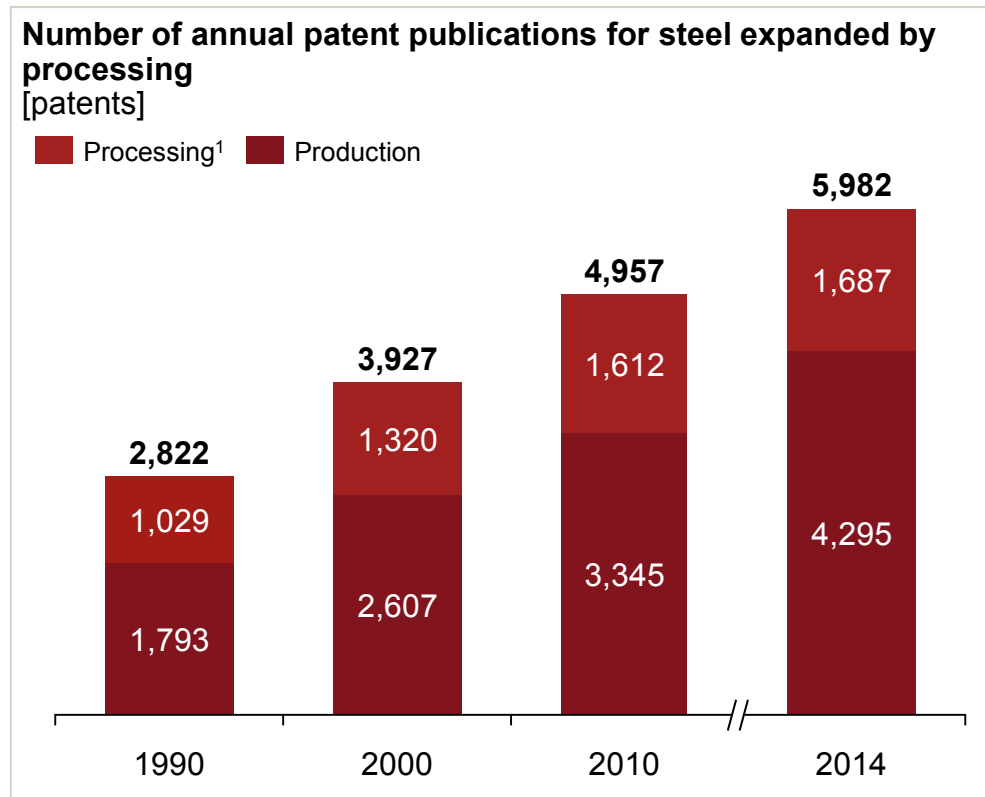
Shorter innovation cycles & new applications require an integrated steel research and development

2 Implications of the new growth dynamic



The steel industry drives customer developments based on their product and process innovations

2a 1/3 of the innovations takes place in processing



Co-Innovation with customers

- Innovations in **steel processing** have a direct **impact on customer's process**
- High frequency of **new steel grades**
- Integration of complex **alternative materials** (e.g. aluminum, carbon) in the application)
- Usage of new **connection technology**
- **Construction part-specific** customer solutions accelerate process innovation

Source: Strategy&, German Patent Office (DPMA), European Patent Office (EPO), World Intellectual Property Organization (WIPO)

IPC classes: B21B, B21C, B21D, B21F, B21H, B21J, B21K, B21L, C21B, C21C, C21D, C22B, C22C, C23C, C23D, C23F, C23G, C25C, C25D

1) Processing is for example: forging, pressing, machining, molding, coating, etc.

Requirements of the end users drive active innovation strategies of steelmakers

2a Shorter development cycles

New customer requirements drive...

- **Lightweight construction increases** (driven by the automotive industry)
- **Multi-material mix rises its influence** (result of the lightweight constructions)
- **Construction part specific solutions are expected by customers** (new customer's requirement)
- **Material properties become more complex** (high and dedicated requirements)
- **Shorter innovation cycles in the aluminum sector** (increasing competition)



... active steel innovation strategies

- **Completely new steel grades** (outside the current state of technology)
- **A long-term R&D strategy** (not only aiming a short-term marketability)
- **Systematic innovation management** (efficient & effective)
- **Development of innovations on their own and with a higher frequency** (adapted to the customers and the competitors)

Source: Strategy&, Interviews

Research and development networks form an important basis for product and process innovations

2b The steel research network in Germany has a unique density

Research & DevelopmentSteel ProductionSteel processing & application

Development of the research network steel in Germany

Illustrative

- More than 69 research institutes, centers and alliances

• In recent years, a variety of research and development alliances were newly established

• For example, various concept developments for the automotive industry

▲ Integrated steel mill
● Electro-steel plant

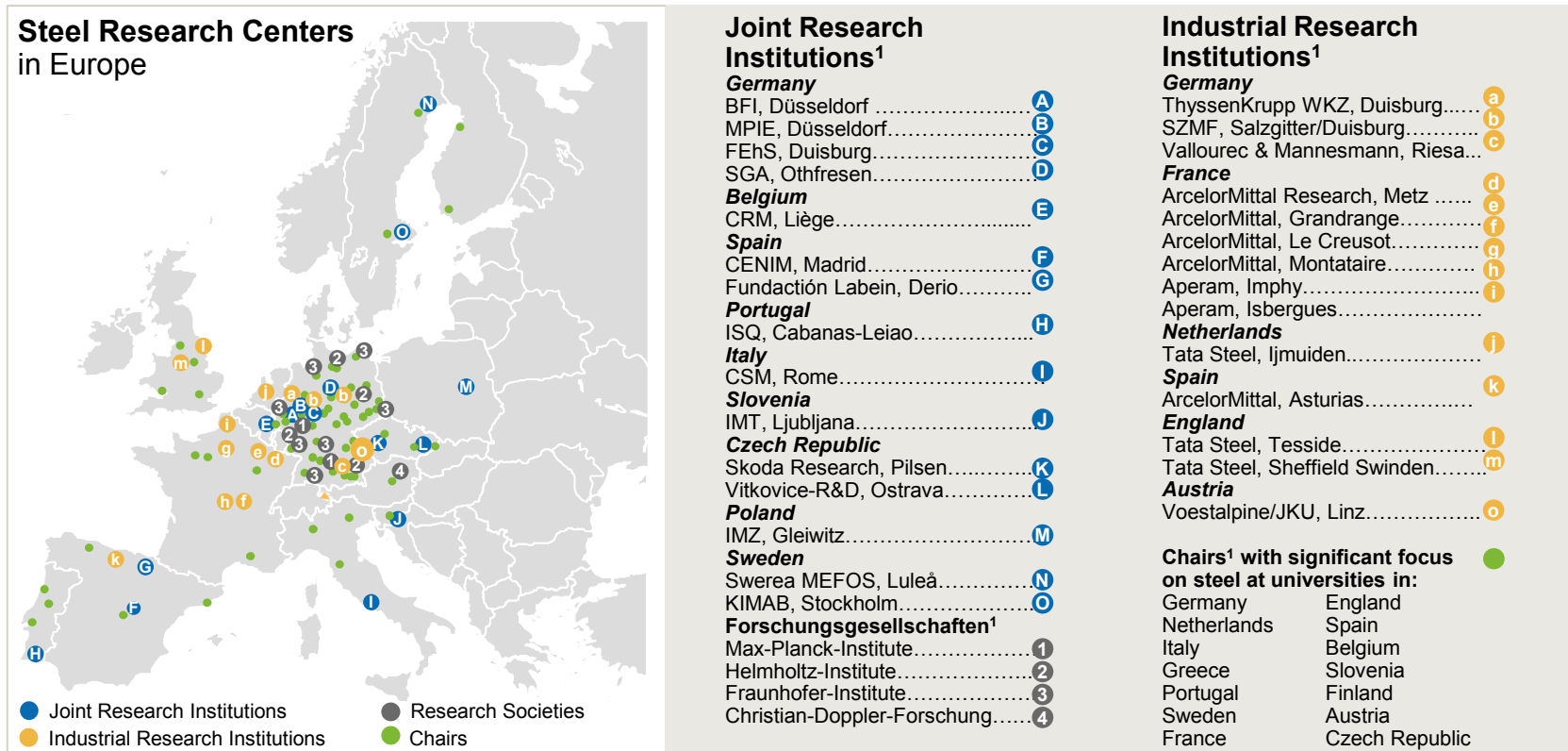
Advantage Germany

- The **steel research network in Germany** has a **unique density**
- Moreover there is an **increasing number of partnerships** between research, steel manufacturers and processors
- The **close cooperation** between science and industry within this network creates a **high innovative strength**
- This network thus contributes to the **innovative strength of the industry in Germany** – today and tomorrow

Source: Strategy&, Interviews

The integration of local R&D with production ensures the industrial production of the new products

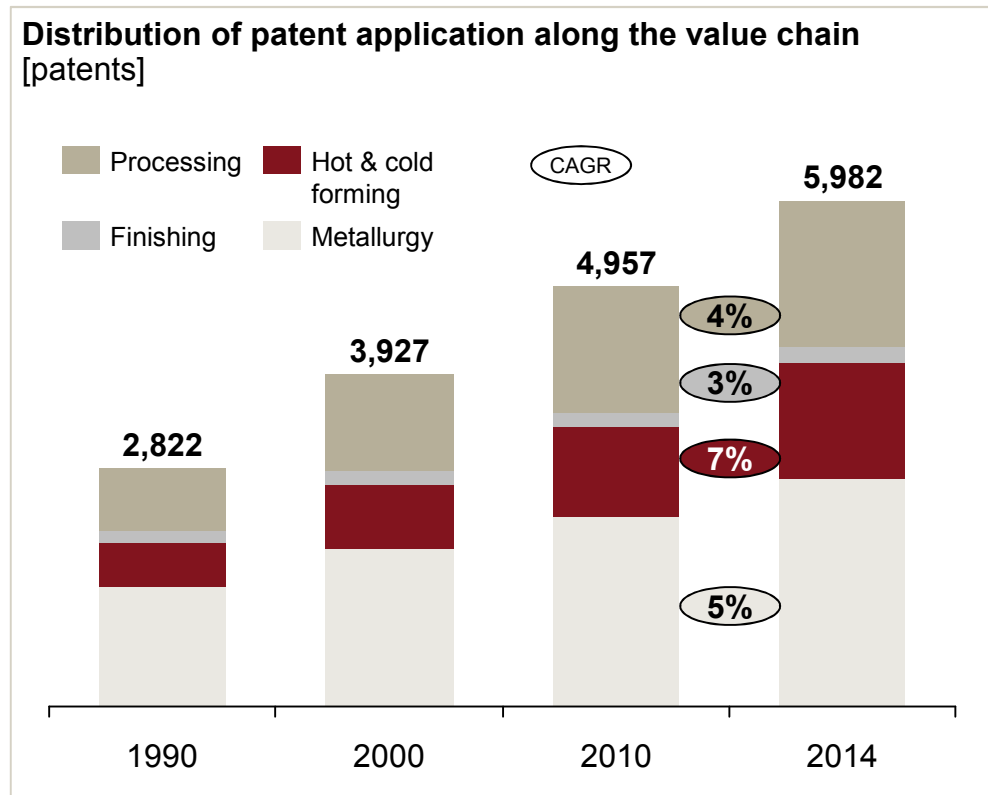
2b Research network steel in Europe



1) Selection
Source: Strategy&, Interviews

The steel industry integrates product & process innovations to enhance material properties and efficiency (1/2)

2c Innovation in product and manufacturing processes go hand in hand



Product- & process integration

- Hot & cold forming is the **link between metallurgy and semi-finished goods**
- Hot & cold forming shows the **strongest growth and is innovation driver**
- Steel grades and process engineering are **brought to market maturity under industrial conditions within production**

Source: Strategy&, German Patent Office (DPMA), European Patent Office (EPO), World Intellectual Property Organization (WIPO)
 IPC classes: B21B, B21C, B21D, B21F, B21H, B21J, B21K, B21L, C21B, C21C, C21D, C22B, C22C, C23C, C23D, C23F, C23G, C25C, C25D

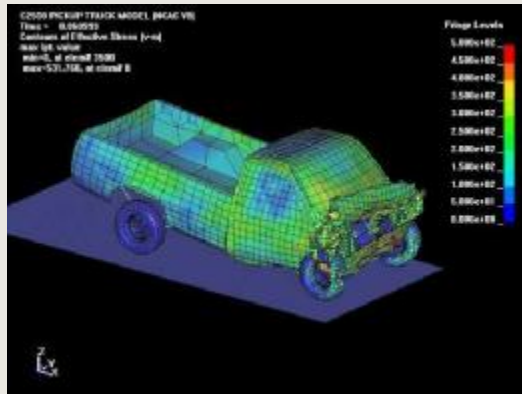
The steel industry integrates product & process innovations to enhance material properties and efficiency (2/2)

2c Examples: Product & process innovations

Simulation models

complement the experimental research...

Example: Crash test simulation



Material properties and behavior is simulated down to the level of electron configurations.

Process innovations

enable the production of innovative specialty steels in industrial scale.

Example: Near-net-shape casting

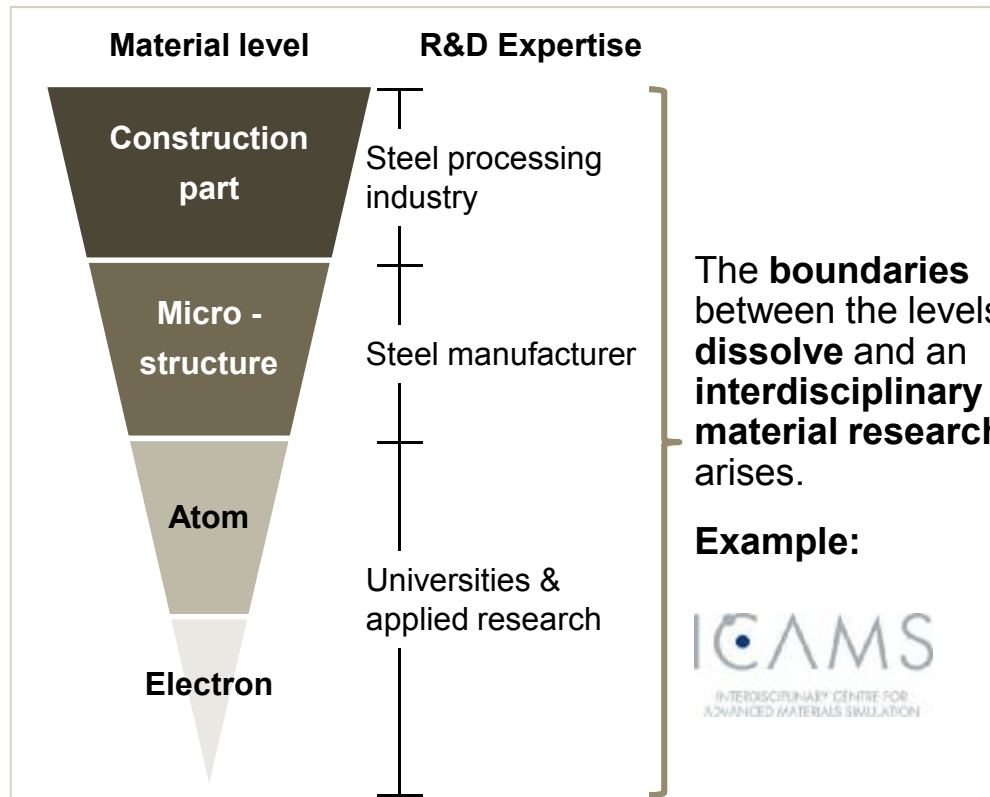


Conserve resources, with the possibility to produce novel physical properties in the material.

Source: Strategy&, ICAMS, MPI, Interviews

Product & process innovation require integrated material simulation models from electron to the construction part

2d Material levels & expert domains dissolve



Integrated research

- **Transfer of special steel properties** into customer components and functions
- Establishment of international **databases on the behavior of steel structure and phases**
- Calculation of **atomic structures and microstructures** in the manufacturing process
- **Integration of material simulation models** across traditional boundaries

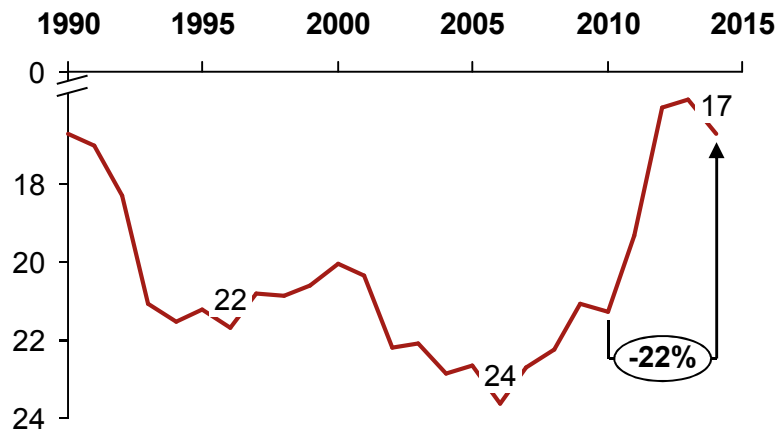
Source: Strategy&, ICAMS, MPI, Interviews

The new performance level of the material leads to a faster but more complex registration of patents

2f Systematic patent registration

Increasing pace

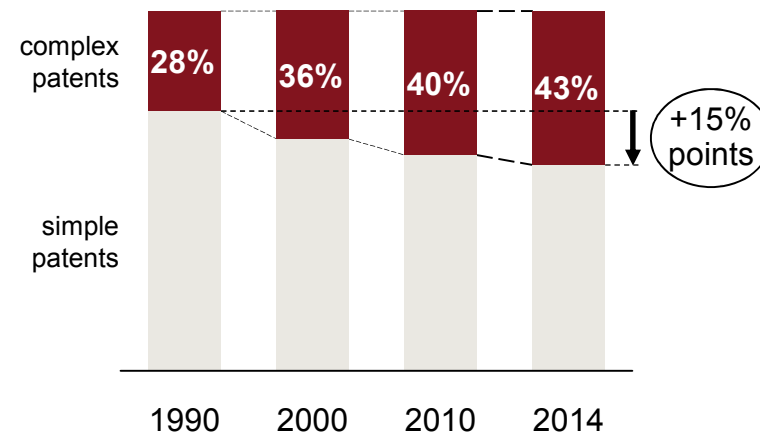
Ø Duration of patent registration to publication [months]



The **pace** of publication has increased by **22% since 2010**. The **research level** is clearer and can therefore be detected earlier.

Increasing complexity

Share of complex vs. simple patents¹ [%]

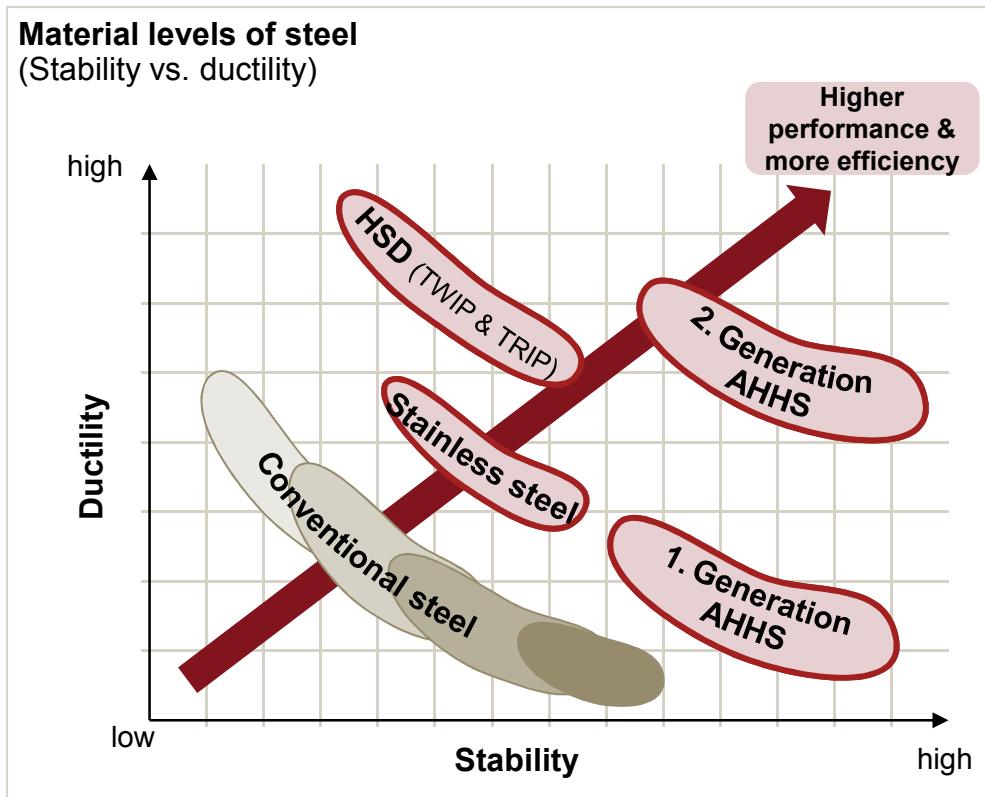


The **complexity** of patent registrations as well as of patents **increases steadily**.

Source: Strategy&, German Patent Office (DPMA), European Patent Office (EPO), World Intellectual Property Organization (WIPO)
 IPC classes: B21B, B21C, B21D, B21F, B21H, B21J, B21K, B21L, C21B, C21C, C21D, C22B, C22C, C23C, C23D, C23F, C23G, C25C, C25D
 1) complex application: patent nomination in more than one IPC class, simple application: patent nomination in one IPC class only

Integrated steel research and development raises the material steel therefore to a new performance level

③ Steel research: Higher functionality by using less resources



Materials on a new level

- Higher stability ensures **safety and resource efficiency**
- Higher ductility ensures the **operational utilizability and process cost efficiency**
- Higher levels fulfill additional functions to **improve energy efficiency** and the general **effectiveness factors**
- Modern steel materials are **sustainable and recyclable**

AHHS: Advanced High Strength Steels; HSD: High Strength and Ductility; TWIP: Twinning-induced plasticity; TRIP: Transformation-induced plasticity
Source: Strategy&, Interviews

Shorter innovation cycles and new applications require an integrated steel research and development

Summary

- 1 The number of annual patent publications has doubled over the past 4 years**
- 2 1/3 of the innovations takes place at the interface between steel manufacturer and the application with the customer**
- 3 R&D integrated with production, drives innovation within the growth are #1: Hot & cold forming**
- 4 The steel research network in Germany has a unique density**
- 5 The complexity of patents in Germany increases steadily**

Source: Strategy& Interviews

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June, 16th 2015

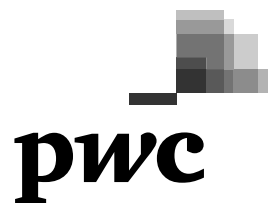
Final document



Appendix



“Innovation trends steel 2015”



Strategy & allocation of IPC categories along the value chain

2a Description IPC Allocation

Level of value chain	IPC-Category	Description
Metallurgy	C21B	<ul style="list-style-type: none"> Extraction of iron or steel
	C21C	<ul style="list-style-type: none"> Processing of pig-iron, e.g. producing steel
	C22C	<ul style="list-style-type: none"> Alloys
	C22B	<ul style="list-style-type: none"> Pretreatment of raw materials
Hot & cold forming	C21D	<ul style="list-style-type: none"> Change in the physical structure of ferrous metals; General devices for heat treatment of ferrous or non-ferrous metals or alloys; Making metal malleable by using decarburization, tempering or other treatment methods
Finishing	C25, C, D	<ul style="list-style-type: none"> Electrolytic or electrophoretic processes
Processing	B21, B, C, D, F, H, J, K, L	<ul style="list-style-type: none"> Rolling metal, production of forged or pressed products etc.
	C23, C, D, F, G	<ul style="list-style-type: none"> Coating metallic material

IPC = International Patent Classification

Your contact persons

strategy&
Formerly Booz & Company



*PwC Strategy& (Germany) GmbH
Anna-Louisa-Karsch-Straße 2
10178 Berlin
Telefon: +49 (0) 30 88705 855
Fax: +49 (0) 30 88705 800
Mobil: +49 (0) 1702238855
Nils.Naujok
[@strategyand.pwc.com](mailto:Nils.Naujok@strategyand.pwc.com)*



Dr. Nils Naujok
Vice President

Ingo Schill
Principal, Management Consulting



Friedrich-Ebert-Anlage 35-37
60327 Frankfurt am Main

Telefon: +49 69/9585-5353

Mobil: +49 160 3681895

E-Mail: ingo.schill@de.pwc.com

