

Rolling Element Bearings - Discussion round table -Wrap up -

Dr. Hannes Grillenberger

- 1 Discussion format
- 2 Impressions of the discussions
- 3 Attendance, feedback and outlook
- 4 Technical results

5 discussion tables

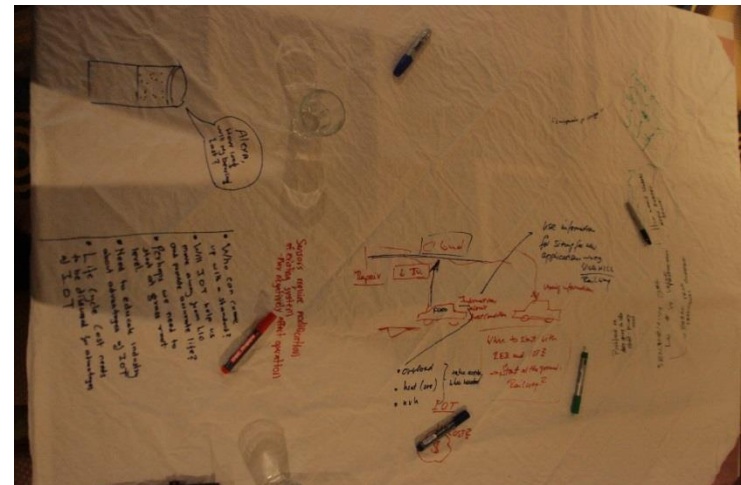
- ▶ topics fixed in advance
- ▶ host moderates an open discussion
- ▶ 4 discussion rounds of 20 minutes
- ▶ obligatory to switch tables after discussion round
- ▶ notes should be written in the table *only*

Format intents to:

- ▶ encourage open discussion
- ▶ *active* role of participants
- ▶ new views on the topics
- ▶ networking

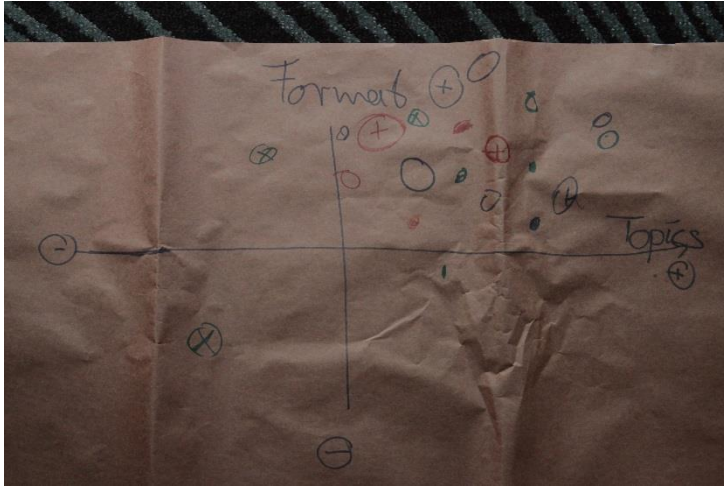
Format intents not to:

- ▶ find closed answers on the topic
- ▶ hold lectures
- ▶ *passive* entertainment of participants









Outlook

Feedback

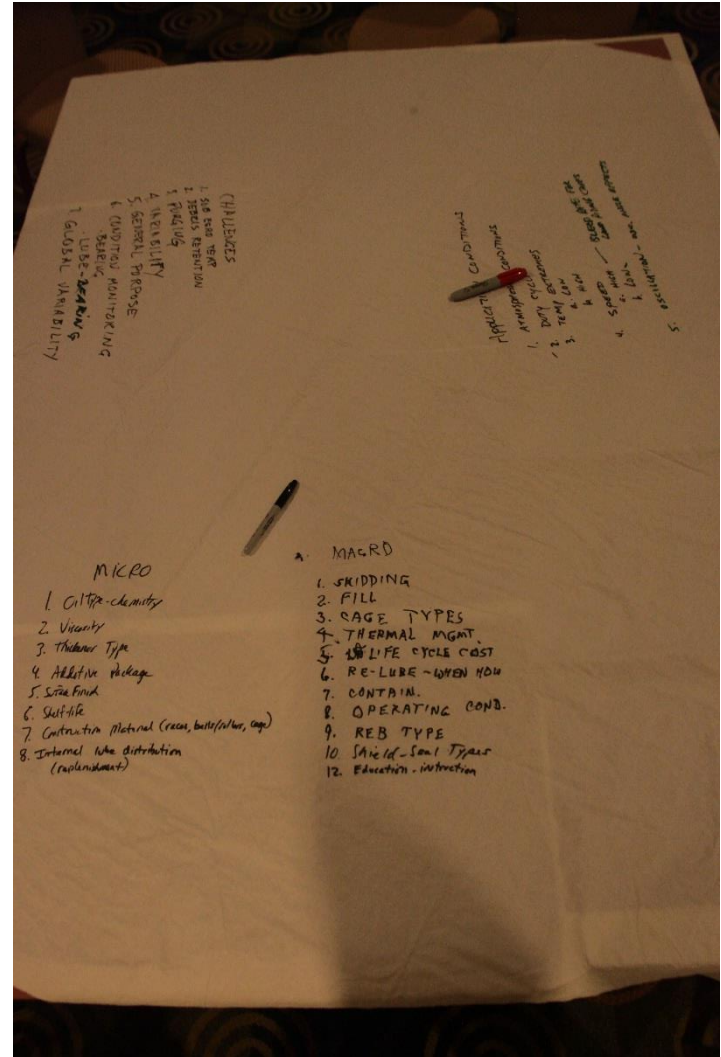
- ▶ positive feedback on topic and format selection from attendees and hosts
- ▶ high attendance
 - ▷ 40 people before the exhibitor break
 - ▷ condensed discussion after (3 tables)
- ▶ good networking (connect)
- ▶ different views on topics generated (learn, achieve)

- ▶ Wrap up to be uploaded on STLE home page
- ▶ REB Business Meeting:
 - ▷ Discussion round tables should be continued on the next STLE annual meetings
 - ▷ Topics should be integrated in the program beforehand
 - ▷ maybe joint DRT with other technical committees
 - ▷ call it differently to make it more appealing, e.g. 'Scientific networking event'
- ▶ more topics and maybe run them only twice
- ▶ 'take care of exhibitor break' and venue
- ▶ include a short introduction round at begin of each discussion

Dr. Robert Gresham

STLE Director of Professional Development

What Factors Influence Grease Behavior in REB?



What Factors Influence Grease Behavior in REB?

Approach:

Define the factors by category, then analyze the result:

Macro Factors

Examples: type of bearing, type of grease, application, environment, sealing, installation, maintenance, etc.

Micro Factors

Examples: grease composition, contaminants, tribofilms, etc.

Application factors

Examples: temperature extremes, load, speed, etc.

Challenges

Examples: bearing life, condition monitoring (bearing and grease), global variation

Observations:

- 1. There are a very large number of variables that affect bearing life for any given application and set of operating conditions.**
- 2. Aside from consideration of all the variables, there is also the problem of global variation in both the bearing and the grease for any given bearing design.**
- 3. Predicting bearing life based on fatigue, absent consideration of all the other variables, is actually pretty good.**
- 4. As a result, it is difficult to select the right bearing for the right job with absolute certainty.**

Conclusions:

1. The fundamental problem is that predicting bearing life and performance is still based on statistical probability considering as many variables as practicable.
2. What is needed is a more deterministic method(s) of measuring bearing life, both in terms of design and also in use.

Notes on the table

► Challenges

- ▷ sub zero temp
- ▷ debris retention
- ▷ purging
- ▷ variability
- ▷ general purpose
- ▷ condition monitoring
 - ▷ bearing
 - ▷ lube – bearing
- ▷ global variability
- ▷ electric current

► Micro

- ▷ oil type – chemistry
- ▷ viscosity
- ▷ thickener type
- ▷ additive package
- ▷ surface finish
- ▷ scuff – life
- ▷ conduction material (races, rolling elements, cage)
- ▷ internal lube distribution (replenishment)

► Macro

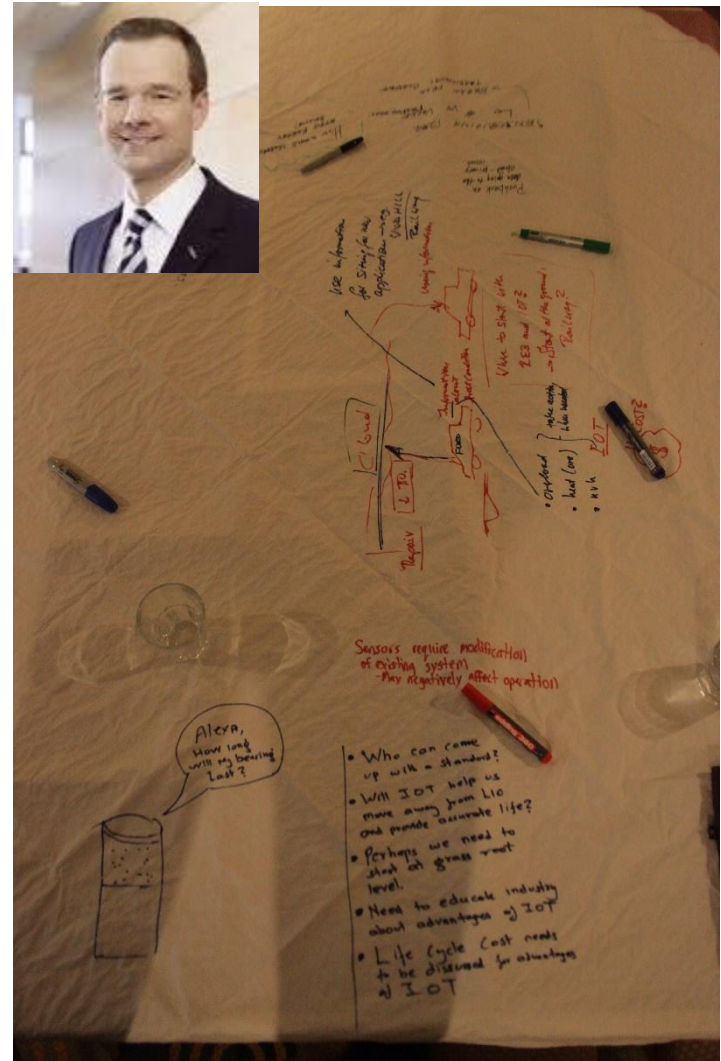
- ▷ skidding
- ▷ fill
- ▷ cage types
- ▷ thermal management
- ▷ life cycle costs
- ▷ re-lube → when, how?
- ▷ contain
- ▷ operating conditions
- ▷ REB type
- ▷ shield – seal type
- ▷ education – introduction

► Application conditions

- ▷ atmosphere conditions
- ▷ duty cycle
- ▷ temp extremes (low / high)
- ▷ speed
 - ▷ high (bleed rate for load riding cages) / low
- ▷ oscillation – osc. angle effects
- ▷ NVH
- ▷ no grease → water turbines → new materials

View of host – Rainer Eidloth

- ▶ Will additional cost for sensors at Bearings accepted?
 - Life cycle cost of Sensors and sensorized Bearings. should be discussed with customers.
- ▶ Who owns the gathered data of sensorized Bearings?
 - Share information / data will support all competitors more than fencing and protection own data stock.
- ▶ Is better condition monitoring with sensorized REB all?
 - Next to better efficiency / life time of bearing, the right dimensioning according application requirements will pay off.
- ▶ Where to start with REB and Internet of Things?
 - Start at the grass root, low hanging fruits could be railway.

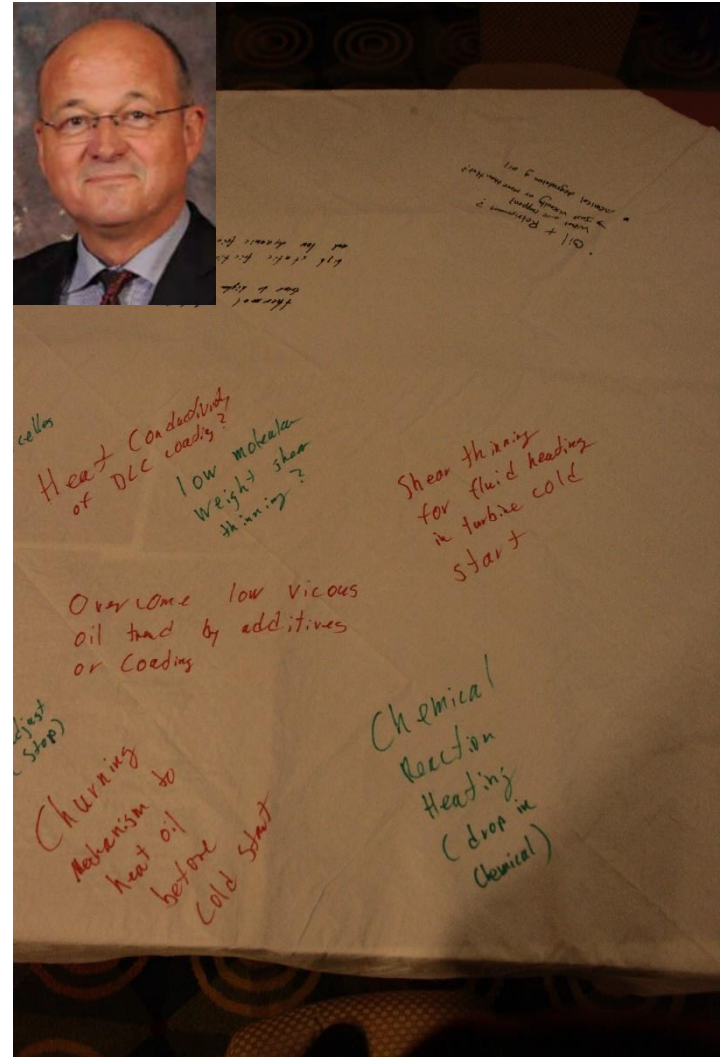


Notes on the table

- ▶ Alexa – how long will my bearing last?
- ▶ who can come up with a standard?
- ▶ will IoT help us move away from L_{10} and provide accurate life?
- ▶ perhaps we need to start at grass root level
- ▶ need to educate industry about advantages of IoT
- ▶ Life cycle cost needs to be discussed for advantages of IoT
- ▶ Sensors require modification of existing system
- ▶ may negatively affect operation
- ▶ how would sensors affect energy balance?
- ▶ sensorizing REB → \$ vs. value proposition
 - ▷ break from traditional construct
- ▶ Life cycle cost through analysis
- ▶ pushback on data going to the cloud – privacy issue
- ▶ where to start with IoT at REB → start on the ground → Railway?
- ▶ Overload, heat, NVH → take action when needed
- ▶ use information for siting for new application → e.g. windmill, railway



- ▶ ionic liquids need to be looked at with respect to structure / EHL relationship
- ▶ low molecular weight shear thinning
- ▶ additive influence on EHL film?
- ▶ low temperature start up too high viscosity
- ▶ molecular bond breaking and re-bonding, miscelles?



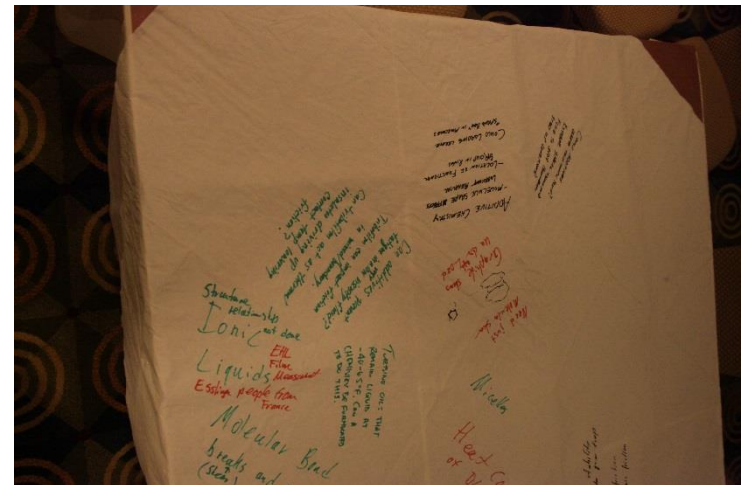
The chemical factor in EHL

Notes on the table

SCHAEFFLER

- ▶ could additives create citriouc fluid? – extreme shear thinning fluid to avoid boundary start up conditions?
- ▶ additive chemistry
 - ▷ Molecule shape affects lubricant behavior
 - ▷ location of functional group in rings
 - ▷ could loading create 'spring break' in molecules?
- ▶ graphite shears under load – need molecules just shear
- ▶ micelles
- ▶ Can additives prevent fatigue in a very low viscosity fluid?
- ▶ Tribo-film can impact friction in mixed/boundary
- ▶ Can tribo-film act a thermal insulator driving um contact temp lowering friction?
- ▶ turbine oils that remain liquid at -40-65°F. Can a chemistry be formulated to do this?
- ▶ Structure relations not to done
- ▶ ionic liquids
- ▶ EHL Film measurement → Esslingen people from France
- ▶ Molecular band breaks (shear) and readjust (stop)
- ▶ Churning mechanism to heat oil before cold start
- ▶ overcome low viscosity oil tread by additives or coating
- ▶ shear thinning for fluid heating in turbine cold start

- ▶ low molecular weight shear thinning?
- ▶ oil + refrigerant – what will happen:
 - ▷ just viscosity or more than that?
 - ▷ chemical degradation of oil
- ▶ thermal stability tread to higher gear temp
- ▶ high static friction and low friction

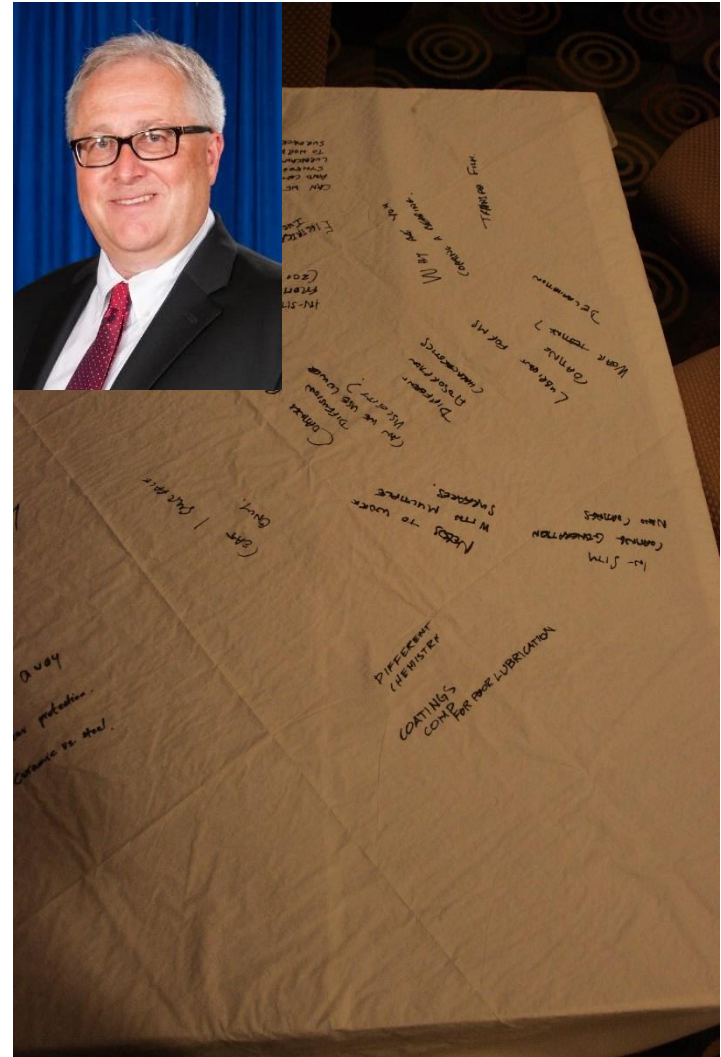


Technical take-aways

- ▶ Coatings are often designed around existing lubricants which may limit selection of coating
- ▶ Oils may need to work with multiple surfaces including both coated and non-coated
- ▶ Insulating effect of coatings may increase heat in contacts and reduce effective film thickness
- ▶ How about lubricants that lay down their own coating in-situ
- ▶ Adsorption of additives will be different.

Overall feedback on session

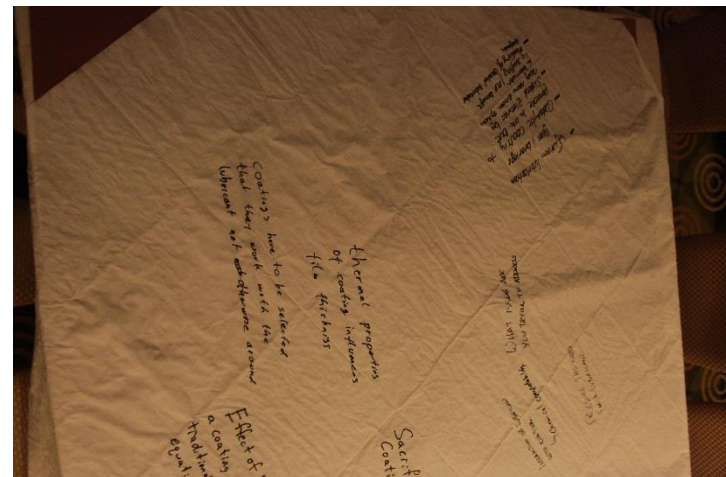
A good idea that should be repeated. Suggest that the planning occurs earlier so that the topics can be included in the program schedules and advertised ahead of time. Also finish the discussion at the first break or introduce new topics after the break.



Notes on the table

- ▶ system lubrication
 - ▷ gears/ bearings
- ▶ catalytic coating to generate in-situ-DLC
- ▶ Sintered zirconic by using nano zircon spheres in lubrication
 - ▷ scuffing / M.P. benefit
- ▶ modelling of coated lubricated surfaces
- ▶ what issue are you trying to address
- ▶ thermal properties of coating influences film thickness
- ▶ coating have to be selected that they work with the lubricant not otherwise around
- ▶ effect of having a coating on the traditional modeling equations
- ▶ sacrificial coatings
- ▶ heat protection
- ▶ wear protection
- ▶ ceramic vs steel
- ▶ different chemistry
- ▶ coating from poor lubrication
- ▶ in-situ coating generation - nano coatings
- ▶ needs to work with multiple surfaces
- ▶ coat one surface only
- ▶ coating prevents diffusion – can we lower viscosity

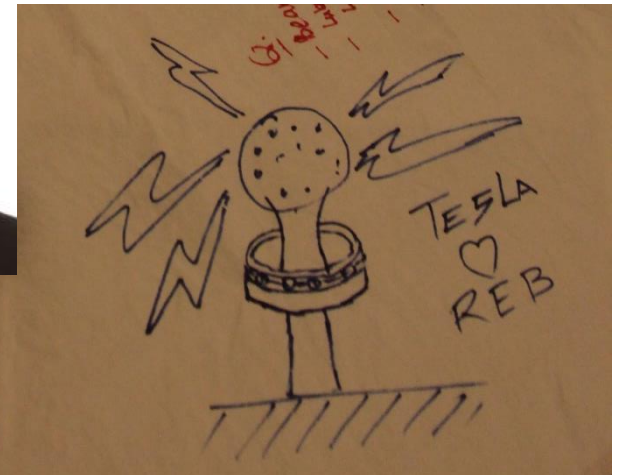
- ▶ different adsorption characteristics
- ▶ why are you coating a bearing?
- ▶ lubricants forms coating
- ▶ wear testing
- ▶ delamination
- ▶ in-situ films formed from ZrO_2 nano particles (200nm +)
- ▶ can we design lubricant and component to be synergistic. current lubricants are designed to work with steel surfaces – reactive?
- ▶ interaction of coating with lubricant – chemical compatibility
- ▶ reduce the need for a lubricant



Notes on the table - 1

- ▶ how many different funds?
- ▶ high cost need low cost operation
- ▶ REBs become even more important in electric vehicles. IC engines have no/few REBs. Electric motors have at least two. Need long life efficient high speed REBs with high reliability over a wide range of operating conditions → grease development needed
- ▶ high speed index is not an issue– spindle bearings have higher $n \cdot dm$. The task is in automotive industry to realize high $n \cdot dm$ without extra cost
- ▶ what is the cost of the mpj of PEVs (pure electric vehicles)
- ▶ PEV concept can mean fewer bearings
- ▶ idea: using the bearing as a part of the circuit
- ▶ why is high speed necessary?
- ▶ Questions:
 - ▷ bearing speed?
 - ▷ lube properties (electrical) L_{10} life
 - ▷ heat generation – life problem?
 - ▷ use right grease
 - ▷ ACBB vs TRB
 - ▷ coolant as lubricant
- ▶ will designs of REB + materials need to change? – lower friction – energy generation – lower loads? – conductive grease

- ▶ Automotive + REB industry will have to go through a learning cycle → need for design guidelines accepted by everyone
- ▶ larger weight will lead to increased loads to every bearing position such as suspension bearings, wheel bearings
- ▶ REB should educate the automotive industry
- ▶ Questions: will the number of REB increase → depends on the design of PEV (pure electric vehicle)



Notes on the table - 2

- ▶ Challenges:
 - ▷ electric currents / electromagnetic fields
 - ▷ costs
 - ▷ lubricant (grease)
 - ▷ high DN
 - ▷ noise behavior
 - ▷ low inductive materials
- ▶ grease can be a limiting factor of the life time of the bearings
 - ▷ need for high speed greases
 - ▷ how to overcome the additional costs?
 - ▷ alternative designs of bearings (pockets @ cages)
- ▶ Implications for power generation through solar/wind/etc.
- ▶ Cost structure depending on the business model of the mobility provider → REB industry should develop a new business model
- ▶ due to $DN \sim 10^6$ → new concepts for the lubrication of the drive train
 - ▷ e.g. using the coolant of the batteries for the bearings
 - ▷ grease lubrication probably inappropriate
 - ▷ Transformer oil as coolant and lubricant
- ▶ Gearbox or large motors?
- ▶ remove gearbox → motor with wide speed range

