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EEVC Brussels, Belgium, October 26-28, 2011
Maschinenelemente und Entwicklungsmethodik
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History and development trends of flywheel-powered vehicles as part of a systematic concept analysis

1. Aims of the thesis

In order to successfully achieve a *systematic analysis* it was necessary to work out the following steps:

- Acquiring historic and recent data
- Analyzing trends of technical specifications
- Creating a classification / categorization for flywheel powered vehicles
- Creating the actual assessment strategy
- Applying the assessment strategy to three specific examples
- Interpreting the results

2. Trend analysis

The following parameters were analyzed over time

● Maximum rotational speed ● Energy content ● Energy density

→ Outliers were identified and discussed plus development intervals defined

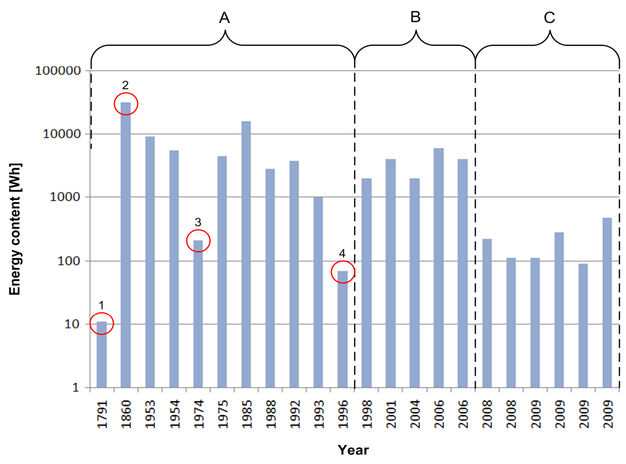

Fig.1: Trend of the energy content of flywheel hybrid vehicles and development intervals

A) Striving for high energy content – The goal is the plug-in flywheel vehicle

B) Upward trend is not based on technical achievements but the change in application (Commercial vehicles, public transportation)

C) One tries to take advantage of the high power density of flywheels in hybrid drive trains (highly dynamic surge power unit – „Booster“)

3. Influencing parameters

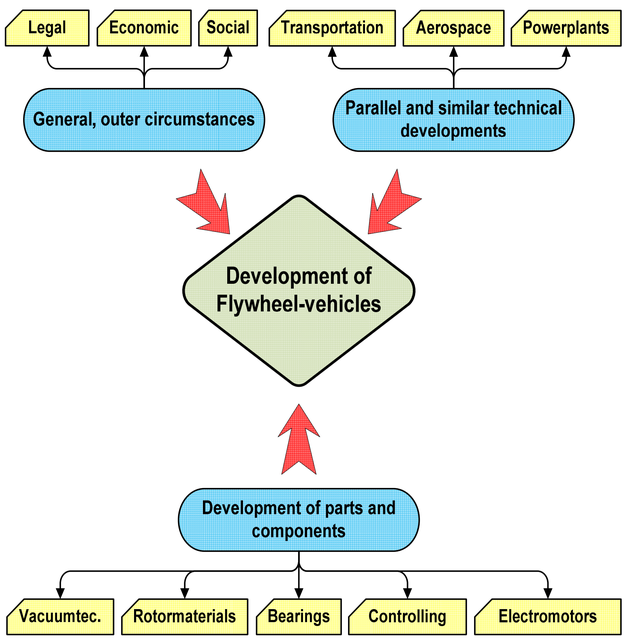

Fig.2: Influences on the development of flywheel hybrid vehicles

The correct and critical interpretation of Figure 2 with its listed factors and their interactions holds the explanation of *why* the development of flywheel-powered vehicles has taken such a discontinuous path. Therefore, actual examples have been assigned to each *parameter* and if possible quantified and statistically validated.

One particular example of this analysis which falls under the category of *general, outer circumstances* and the *economic parameters* is shown in figure 3. Note:

- More than **50 flywheel vehicles** in total
- Current decade expected to bring up even more developments
- **Categorization** of vehicles necessary

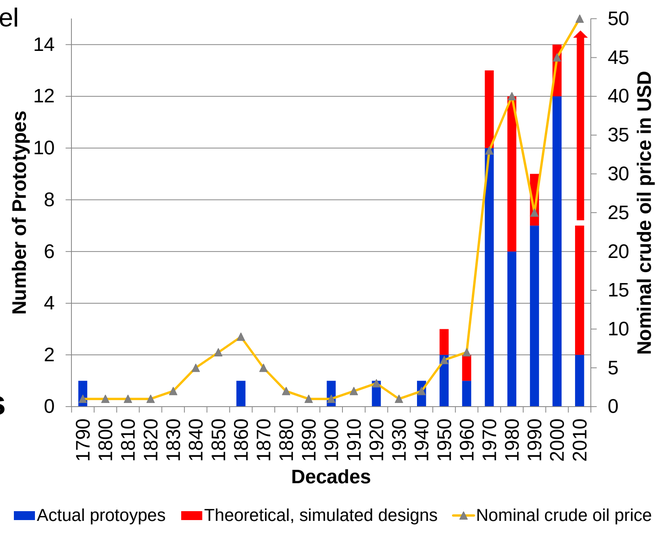

Fig.3: Comparison of development activity of flywheel-powered vehicles and crude oil price over time

4. The flywheel hybrid assessment strategy

- Unmistakability (clear scheme)
  - Transparent
  - Repeatable
- Objectivity
- Universal validity (applicable to all flywheel-powered vehicles)
- Advertence of all relevant parameters (*holistic approach*)
- Emphasis on the flywheel technology

- *Short description of the vehicle concept*
- *Abstraction*
- *Loss analysis*
- *Application of assessment- and rating tools*
  1. *Mod. Camelot-Method*
  2. *Morphological Matrix*
  3. *Value-Benefit-Analysis*
- *Conclusion*
  1. *SWOT-Analysis*

5. Analysis Examples

The *assessment strategy* was applied to three examples of flywheel-vehicles, each having a different hybrid structure and each one using a different technology to transfer the energy to the flywheel-unit

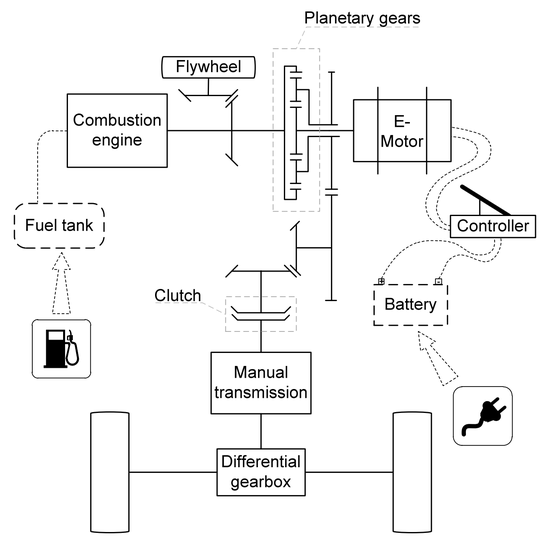

Fig.4: *VW T2* flywheel hybrid, Aachen 1976

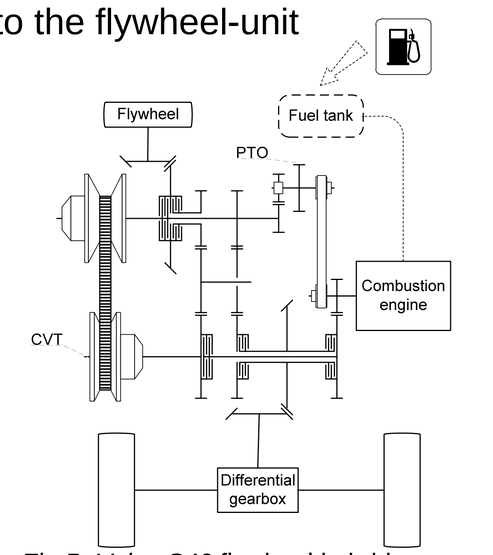

Fig.5: *Volvo S40* flywheel hybrid, Eindhoven 1996

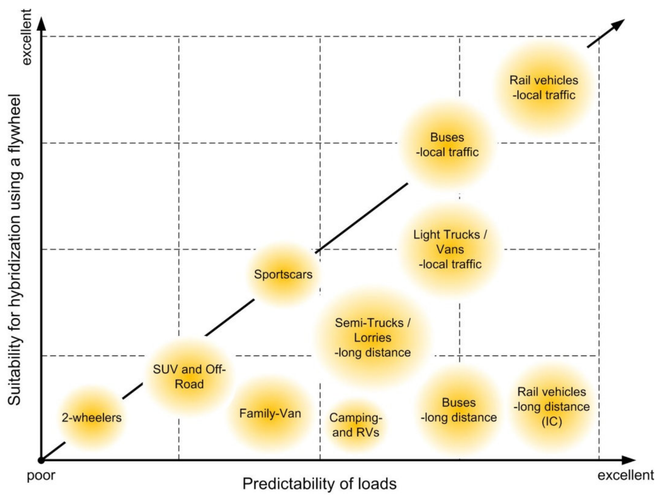

Fig.6: Suitability of vehicles for flywheel application

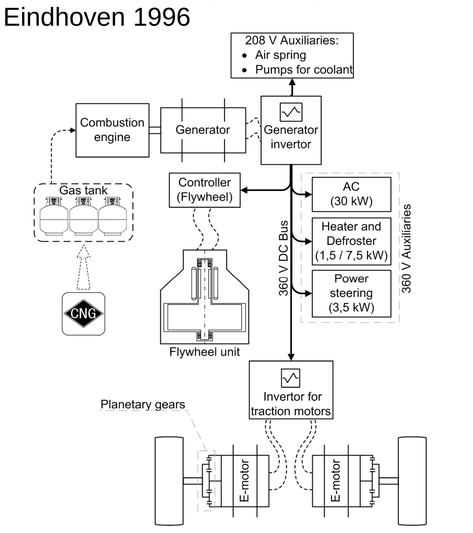

Fig.7: Advanced Technology Transit Bus, Austin, 2001

6. Conclusions

- **Public transportation** is most suited for flywheel application.
- Mechanical systems currently still reach higher degrees of efficiency but their potential is limited.
- Current trend: **Electric energy transfer** → potential advantages:
  - Additional value through electrification of the auxiliaries
  - Less limited arrangement of components
  - Advantages in controlling and adjustment with active safety
- The design of a flywheel storage unit *always* results in a **multidimensional optimization problem**.

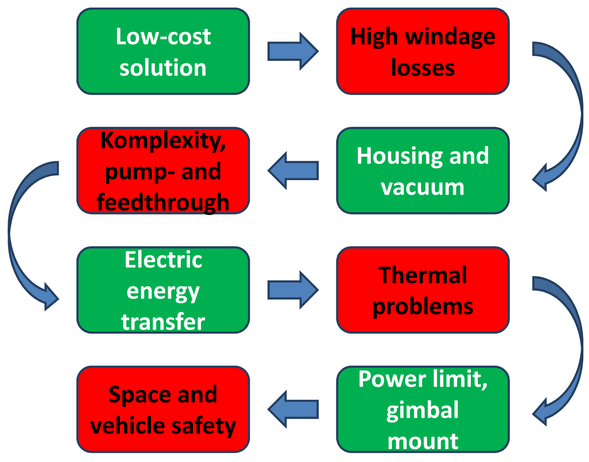

Fig.8: trade-offs during flywheel optimization

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