Systematic development and analysis of continuously variable transmissions with INNER POWER SPLIT for mobile machinery

Marco Ramm

RWTH Aachen University / R&D Tractor Drivetrain – CVT / CLAAS Industrietechnik GmbH

✉: Halberstädter Str. 15-19, Paderborn (Germany) ☎: +49 5251 705-5310 Email: Marco.Ramm@CLAAS.com

Motivation

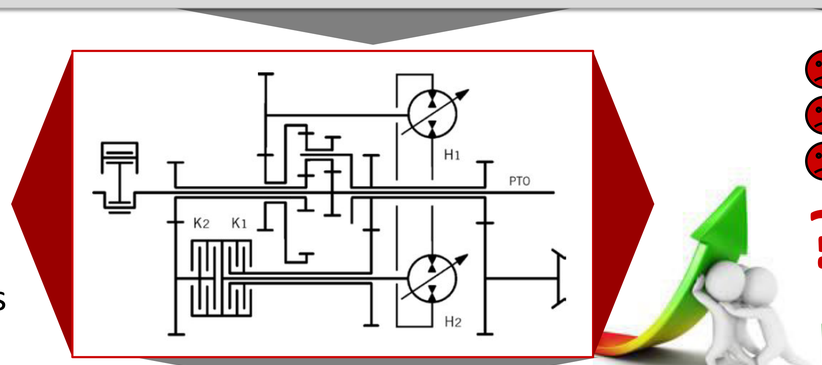
** = IVT = Infinite variable transmission*

Engine Power	P = 120 kW … 400 kW	P < 100 kW
Transmission technology	IVT* with hydrostatic-mechanical power split	Power shift transmission or hydrostatic IVT*

Institute at RWTH Aachen University - Prof. G. Jacobs -

Industrial cooperation partner: Rexroth Bosch Group

(OUTER) POWER SPLIT
High expense for integration due to needed quantity of transmission elements

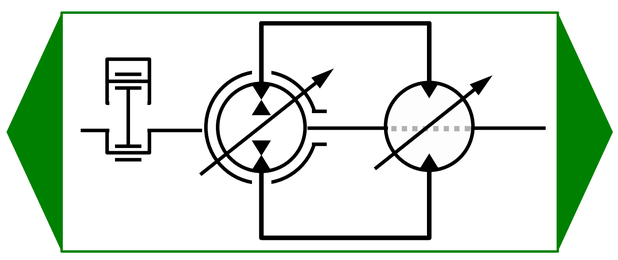


- Less comfort (PS-trans.)
- High fuel consumption
- Low maximum speeds

? **IMPROVEMENT METHOD ➔ (Outer) power split transmissions unsuitable for small machines (high costs, needed space,...)**

! **NEW IMPROVEMENT METHOD FOR SMALL MACHINES ➔ Transmission with INNER power split (IPS)**

- IVT enables high comfort and automation of tractor & implement
- Low fuel consumption due to power split technology

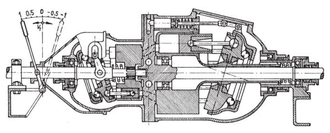


Special hydrostatic variator which enables additional inner mechanical power flow

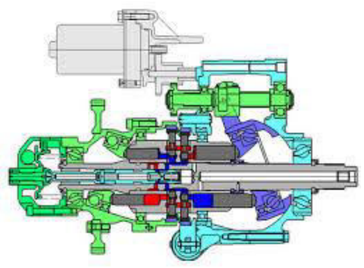
Situation, Analysis & Synthesis

Relevant IPS transmissions

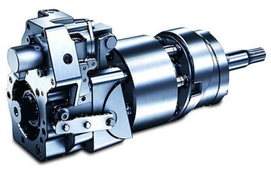
Patent from RENAULT (→ 1906) for automotive



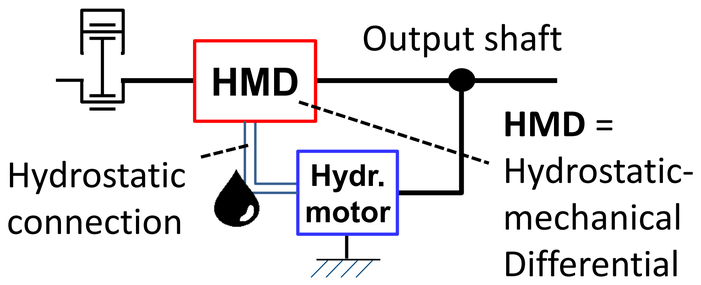
HONDA with „HFT “ P = 45 kW (→ 2000) for motorbicycles



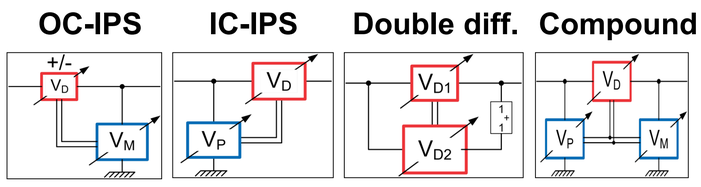
YANMAR with „i-HMT“ P < 39 kW (→ 2015) for tractors



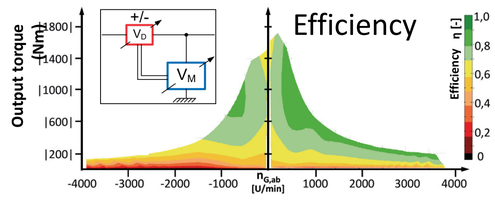
Analysis and Abstraction



Synthesis of IPS transmission concepts



Simulation based analysis of IPS transmission concepts

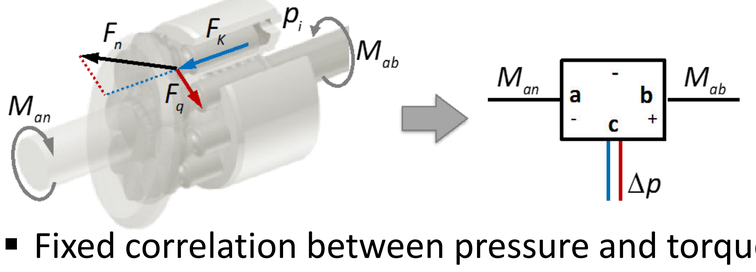


- Approx. 20 % better efficiency of IPS than hydrostatic transmission possible
- Complex IPS transmission design: no standard hydrostatic technology

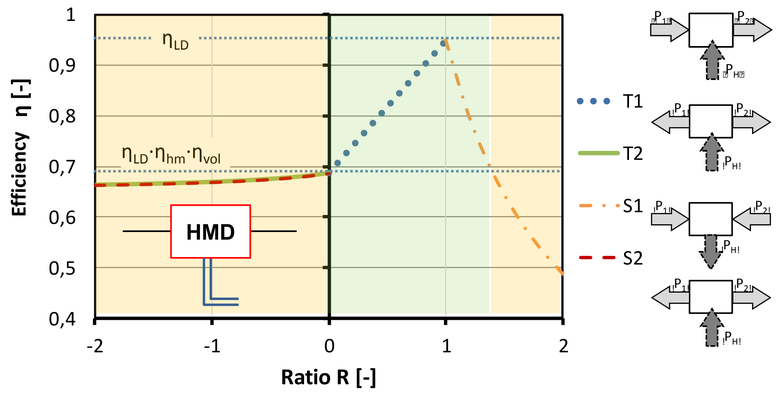
➔ **For economical usage: new design of IPS transmission needed**

Development of an economical approach to improve drivetrains for small vehicles

Analysis of hydrostatic-mechanical differential (HMD)

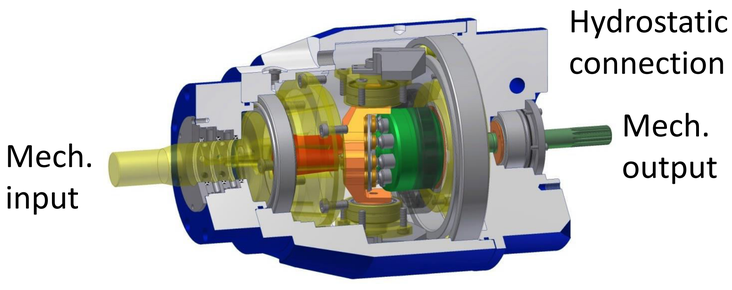


- Fixed correlation between pressure and torque at input and output shaft
- Independent speed of input and output shaft



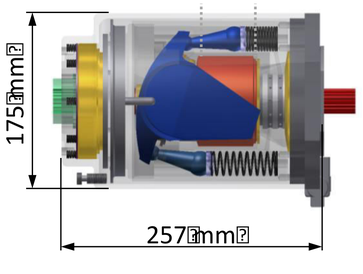
- Internal friction of pump comp. with effects on efficiency (circulating efficiency in HMD)

Design and test of “isolated” variable HMD for modular IPS concept

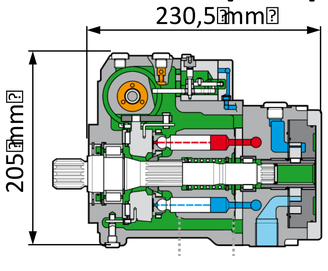


- New design enables usage of standard pump components in HMD
- Variable wobble plate without reset forces

HMD



standard pump



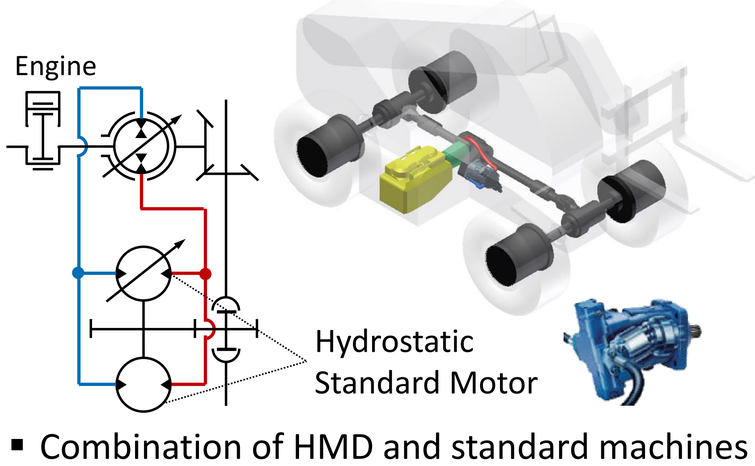
- HMD has similar size than hydr. standard units
- **8 patent applications during PhD-period**

Development of modular IPS concept

Offset IPS transm.
HMD & bent axis

Coaxial IPS transm.
HMD & swash plate

Variable integration of HMD and standard motors for IPS transmission



- Combination of HMD and standard machines
- **Modular IPS concept enables an easy improvement of hydrostatic transmissions**