NEW DEVELOPMENTS IN ELEVATOR TECHNOLOGY: PLANETARY TRANSMISSIONS

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ABSTRACT

This paper describes the development of a new planetary gear transmission for lifts. The development goals are set out and the resulting gear characteristics described fully. The new gears are shown to be an improvement on the conventional worm gears.

1. INTRODUCTION

Drive systems for cable operated elevators have seen no radical changes since their conception well in the last century. Torque from an electric motor has been directed through a worm gear transmission to the drive sheeve for cable-cabin movement. This type of drive system offers a relatively high gear ratio that could be realized with simple technology and the system was self-braking. However, only one-speed worm gears with an efficiency of less than or equal to fifty percent are self-braking. Where efficiency is more than or equal to fifty percent self-braking more or less does not exist.

The disadvantages of worm gear transmissions have also been clear. Mechanical efficiency is very low. Internal friction levels of the worm gear transmission create high operating temperatures. The gearing must be adjusted for wear. Variation in cabin speed can only be realized by a high number of sheeve diameters.

Previous development attempts to replace worm gear technology with either spur or planetary gear transmission failed because of gear play, vibration, excessive noise or the physical size of the transmission design.

This paper has been edited to conform to the format of *Elevator Technology 5*.

The Zahnradfabrik Passau GmbH is one of Europe's major manufacturers for driveline components used in construction and agricultural machinery. For more than twenty years the Zahnradfabrik Passau has been producing one hundred and eighty thousand planetary gear systems per year. They have an enormous "know how" in the field of gearing technology and production of highly specialized planetary gear systems.

The decision of Zahnradfabrik Passau to take up the development of a planetary transmission for elevators was supported by the experience they have gained in the field of precision transmissions.

2. DEVELOPMENT OF A NEW ELEVATOR TRANSMISSION

The development goal for the new elevator transmission was to create a planetary transmission that would set the future pace of the industry. Project targets were a transmission family with-
First: increased working efficiency,
Second: absolute operational safety,
Third: superior travel comfort,
Fourth: reduced maintenance requirements and
Fith: a far more compact than the existing transmissions available.

After extensive research the elevator transmissions Ecolift RME two hundred and ten, Ecolift RME three hundred and ten and Ecolift RME four hundred and ten with a two stage, planetary design were conceived. These transmissions meet the most stringent working requirements of the industry. The close geographic relationship to Loher in Ruhstorf, lower Bavaria lended itself to a close engineering cooperation during the development of the Ecolift family.

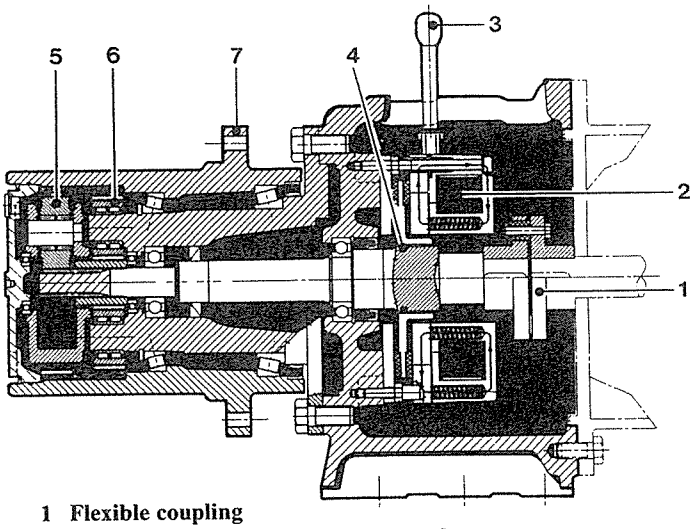


Figure 1: Construction of planetary gear

3. TECHNICAL DESCRIPTION

The construction of this planetary gear is shown in figure one and will be explained below by means of this drawing.

A torsionally flexible coupling [one] with no radial play connects the electric drive motor to the transmission. The high speed first planetary stage [five] has helical cut gears. Power is transmitted to the sun gear of the second planetary stage [six] across the planetary carrier.

The connection between transmission and sheave seven was arranged so that the load is applied between the two tapered roller bearings.

The planetary gears are arranged externally which has two extremely important advantages:
First: Wear can be checked easily after removing the external cover, and
Second: This arrangement allows for extremely easy maintenance.

Special attention was given to smooth speed rise for travel comfort. Numerous measurements were carried out on these installed transmissions to insure jerk-free operation. The broken line in this figure shows the nominal speed: the measured speed follows the theoretical speed very exactly.

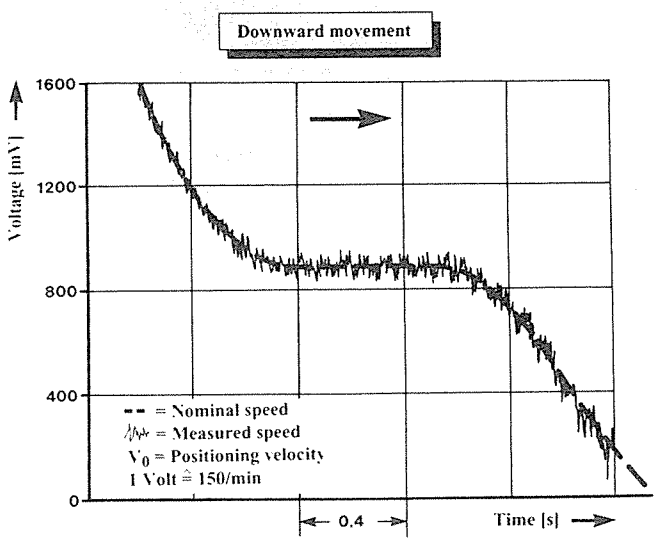


Figure 2: Motor speed curve

4. WORKING EFFICIENCY AND ENERGY COSTS

The planetary gear design offers highly improved mechanical efficiency of ninety-eight percent! The efficiency of a worm gear transmission is approximately

The higher mechanical efficiency of Ecolift transmission makes possible the use of smaller electro motors. Energy savings of thirty to fourty percent can be realized. For example the Ecolift RME three hundred and ten offers savings of approx. twenty thousand German Marks in energy cost over conventional transmissions across the service life. For the calculation of energy costs an average price of zero point three German Marks per kilo Watt hour was taken as a basis.

Calculations are based on the following load cycle :
- period of use: ten hours per day
- duration of use: fourty percent
- period of operation: five point five days per week
- mean shifting frequency: oen hundred and fifty travel cycles per hour
- maximum shifting frequency: two hundred and fourty travel cycles per hour.

The advantage of cost saving is clear. There are other problems looming on the horizon also The elevator operator is facing a serious future energy problem, the restricted supply of peak current. European electric supply companies plan to limit the available starting currents to maximum two point five times of the nominal drive motor current consumption. Two of the first pioneers in such restrictive policies are Switzerland and the city of Hamburg, Germany. Drive systems with worm gear technology require a starting current typically four times higher than nominal. The new RME transmissions require less start-up current than these new stringent requirements.

Regarding the comparison of sizes the advantage of Ecolift (blue line) against a common worm gear system (red line) is obvious. Ecolift planetary transmissions have a compact physical size. The comparison between ZF-Ecolift and a conventional transmission show a space saving capability of over fourty percent. The reduced size is especially advantageous in tight applications.

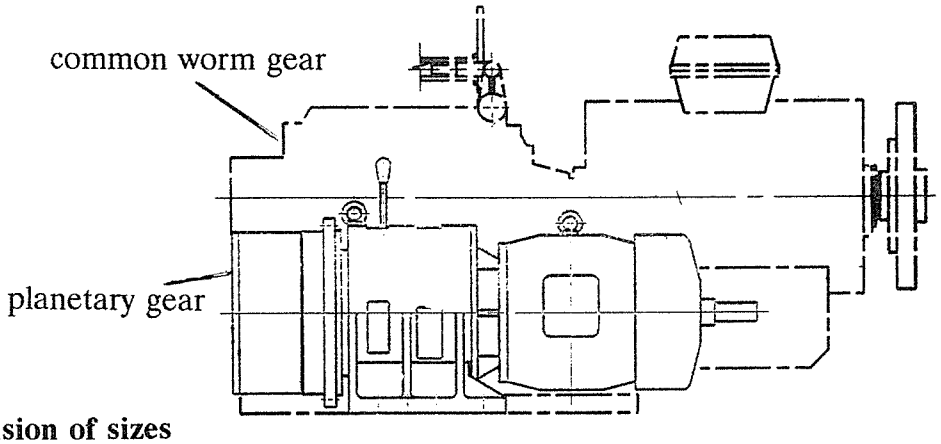


Figure 3: Comparision of sizes

5.DOUBLE WRAP

Double looping of cable is possible without an additional support bearing by arrangement of the sheave between two pre-stressed idler wheels.

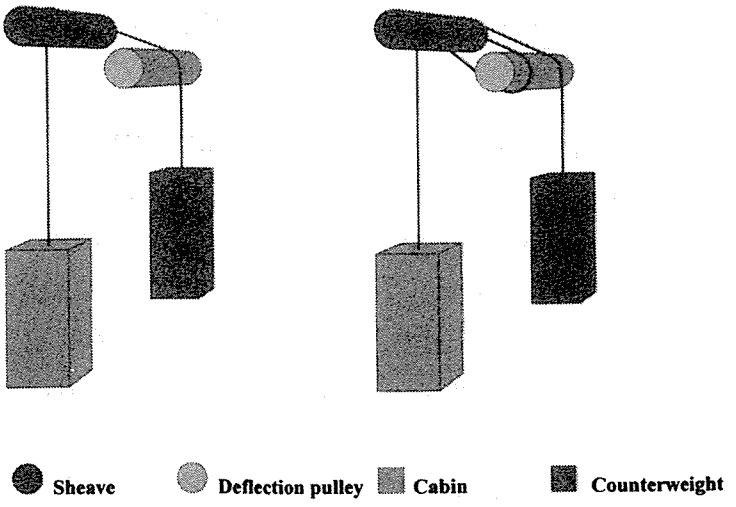


Figure 4: Double wrap arrangement

6. MOTOR SPEEDS

The elevator transmission Ecolift is suitable for motor speeds of one thousand, one point five thousand (standard speed) and three thousand rounds per minute.

In frequency transformer operation, cabin velocity can be increased and decreased with respect to standard speed.

This simple speed adjustment potential makes possible a standardization of transmission ratios and limits the number of drive sheeves to an absolute minimum.

7. NOISE LEVEL

Special helical gear tooth designs were introduced with tolerances less than half of standard planetary gear sets to minimize gear play within the complete system. All gears are ground and honed to assure quiet operation and reduce wear to an absolute minimum.

Sound proof chamber tests have shown a noise levels no higher than sixty-three dba for Ecolift RME two hundred and ten at speeds as high as three thousand rounds per minute in either right or left operation.

8. WEAR

The Ecolift planetary transmissions are essentially wear-free. No wear could be found after one point six million cycles during tower testing. Testing is being continued.

A service life as shown in figure five results from the load cycle and a motor of six point eight kilo Watt with a torque of maximum of one hundred and eight Newton meters.

The following is taken as a basis:

- **Period of use:** 10 hours/day
- **Duration of use:** 40 %
- **Period of operation:** 5.5 days/week
- **Service life:** 15 years
- **Shifting frequency:** aver. 150 shiftings/hour
  max. 240 shiftings/hour

This results in:

- L_h = 10 x 5.5 x 52 x 15 x 0.4 = 17,160 hours
- L_t = 17 160 : 2 = 8,580 hours/tooth flank
- L_l = 17 160 x 150 = 2 574,000 load cycles

These calculations are proved by a test bench load run

Figure 5: Service life of the transmission

9. MAINTENANCE

ZF-Ecolift's design and operational characteristics reduces maintenance time to an absolute minimum. Even in continuous operation with two hundred and fourty shiftings per hour and maximum load, the transmission is just lukewarm and allows extremely easy maintenance without cool-down time. Maintenance down time will thus be reduced to a minimum.

Inspection of the planetary gear sets is easily done by simply removing the end plate of the planetary transmission. All gears are visable and readily available for inspection and measurement.

10. LUBRICATION AND BIO OILS

The compact planetary design and low operating temperature require only a minimum of lubricating oil. The smallest member of the Ecolift family, the RME two hundred and ten has a total oil volume of only one point three liters. RME three hundred and ten needs three point five liters, RME four hundred and ten only five liters. The low operating temperatures also allow the use of ecologically friendly biological oils. Disposal or recycling costs are held to an absolute minimum. Furthermore, the transmission can be fully loaded immediately, no starting time is required.
In comparison, a typical worm gear transmission requires up to twenty-five liters of lubricating oil. Especially in heavy duty operations, synthetic oils have become standard to high operating temperatures. Disposal costs of these synthetic oils are highly problematic and costly.

11. OPERATIONAL SAFETY

Operational safety has been the utmost design criteria. TÜV-Bayern gave its approval for this transmission in a declaration on twentieth June eighty-eight, with the following words: "The drive system is in accordance with

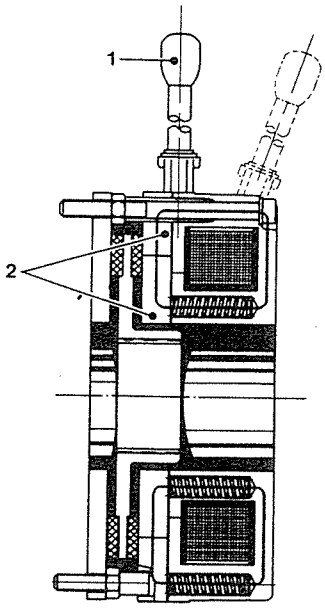
the technical regulations for elevators (TRA two hundred) TRA two hundred and twenty to two hundred and twenty-nine as well as the European Elevator Standard DIN EN

eighty-two." Even during catching tests with crashing cabin and springing counter weight the transmission was not damaged at all.

The gearing in Ecolift transmission offers the ultimate in safety. Model dependent, at least three planetary gears are always in constant mesh. If a gear tooth breaks and is cast off, the transmission will emit noise to show that a malfunction has occured. If a broken tooth is not cast off, the transmission will experience a blockage.

Ecolift transmissions are equipped with a dual circuit disc brake system designed by a well known German manufacturer. Each circuit is capable of one hundred and thirty Newton meters braking force. This braking system has been approved by the Examining Board of the German Elevator Committee.

The dual circuit disc brake system is integrated in the stator housing. It is equipped with a manual release [three]. Inspection ports have been integrated into the housing for maintenance checks.



Brake torque: max. 130 Nm per circuit
Voltage: 190 V (direct v.)
Power: 150 W

- Electro magnetically released pre-loaded with springs
- Requirements acc. to TRA 227 are met through
  - split armature plate
  - internal and external pressure springs
- In case of power failure it is possible to release brake manually

1 Manual release of brake
2 Split armature plate

Figure 6: Dual circuit disc brake

12. APPLICATIONS

Further to the above described transmission there are another two transmission sizes available.

The table shows the allocation of the most important data to the individual transmission sizes according to the selection size "load capacity". Special versions are being constructed for use in explosive atmospheres.

Transmission			Lift			
Type	Power max kW	Ratio i	Load capacity kN	Velocity *) m/s	Sheave ø mm	Speed rpm
RME 210	6.8	38.77	630	0.63 to 1.25	460 to 680	920 or 1500
RME 310	19.5	38.70 or 44.10	1000	0.63 to 1.6	460 to 740	920 or 1500
RME 410	35.0	22.60 or 35.33	1600	1.6 to 2.5	460 to 800	1500

*) Suspension 1:1

13. CONCLUSION

The Ecolift transmissions from Zahnradfabrik Passau are a major break through in elevator technology. They have been designed with the requirements of the industry in the fore front by specialists - for specialists. Ecological thinking, safety, and modern design backed by the ZF name insure a good choice for future elevator design.

Patent

For this drive system patent was issued as per the letter dated twenty-fourth of June ninety-three from the European Patent Office.