

The ZF Automatic Transmission 9HP48 Transmission System, Design and Mechanical Parts

Lutz Gaertner and Michael Ebenhoch
ZF Friedrichshafen AG

ABSTRACT

With the 8HP transmission generation, ZF established a model range on the market offering considerable progress in terms of fuel savings, power-to-weight ratio, and functionality. A front-transverse transmission derived from the 8HP transmission generation gear set concept leads to higher design costs and to an unfavorable design, contradicting the very restricted installation spaces for front-transverse transmissions.

With the transmission concept of the 9HP48 transmission, the advantages of the 8HP transmission generation were successfully transferred to a front-transverse transmission design and, at the same time, all restrictions regarding the installation space were solved. Thanks to its number of gears the high efficiency and the reduced drag torque, the 9HP48 transmission delivers fuel savings of up to 16 percent compared with today's standard 6-speed automatic transmissions with front-transverse installation.

The publication gives a detailed description of the mechanical design of the 9HP48 transmission. By means of a new gear set concept with 4 planetary gear sets and 6 shift elements, the requirements regarding high efficiency and a large total spread that are important for achieving fuel savings and comfort can be realized at low gear steps. For the first time, two positive locking dog clutch shift elements are applied alongside an axially parallel vane cell pump to reduce the drag torques. In order to achieve compatibility between the transmission's design and the installation spaces of typical front-transverse vehicles, a completely new transmission architecture is used. In addition to the new architecture, the achievement of installation targets is facilitated by two dog clutches, two planetary gear sets nested on top of each other, and multi-disk clutches, as well as a new torque converter design.

In addition, the 9HP48 transmission is designed according to a modular principle. As a result, the basic transmission can be supplemented depending on the requirements and customer wishes. Thus, different starting elements and all-wheel drive applications can also be implemented at optimal cost in the restricted installation space conditions of front-transverse passenger cars.

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1. INTRODUCTION

With a 75 percent market share (see Figure 1), vehicles with transversely installed front-mounted engines represent the most common drive concept in the world.

With the 8HP transmission generation, ZF has established a model range on the market that offers considerable progress with regard to fuel savings, power-to-weight ratio, and functionality. However, the gear set concept of the 8HP transmission generation is predestined for the longitudinally installed standard transmission design. A derivation as a transverse transmission leads to higher design costs and an unfavorable design that contradicts the very restricted installation spaces in the area of front-transverse transmissions.

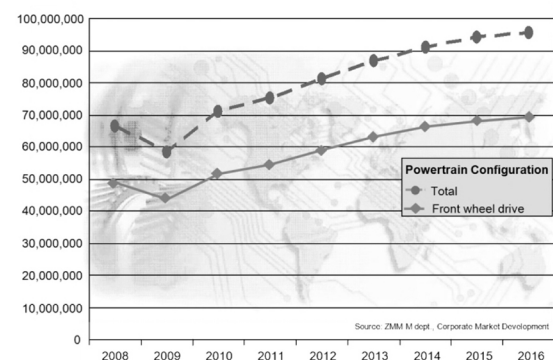


Figure 1. Transmission volumes worldwide

The pressure placed upon the transmission's cost and size is even higher due to the fact that vehicles with transversely installed front-mounted engines are particularly prevalent in the cost-sensitive market of compact and mid-size cars.

Against this background the development of the 9HP48 front-transverse transmission began with the search for a suitable installation space-specific gear set concept.

2. TRANSMISSION SYSTEM

The prerequisite for the new gear set concept is that it must be possible to implement it in the installation spaces of the 6-speed transmissions established on the market. When it comes to size, the transmission length of the transverse transmissions is extremely important. However, the high requirements in terms of high gear spread, high number of gears, small gear steps, and high efficiency at low drag torques must also be fulfilled.

Experience obtained during the search for gear set concepts has demonstrated that the higher requirements in terms of gear spread and number of gears can only be realized with additional shift elements or gear sets. During the search for a gear set concept new approaches were necessary in order to resolve the associated contradiction between additional components, installation space, reduced drag torques, and a cost reduction.

As a result the criterion with respect to the constructability of clutches and gear sets in a radial, nested manner became essential. Only gear set concepts that facilitate clutches and gear sets arranged on top of each other possess sufficient potential to contribute to the solution. However, this generates restrictions in terms of the possible stationary gear ratios of the gear set and the connection of the individual components with each other.

Against the backdrop of the requirements in terms of installation space and drag torque reduction, the option of utilizing a dog clutch as a shift element also obtained new significance. However, the possible functionality of the dog clutch has significant effects on the selection of the gear set concept.

Alongside these criteria that were additionally highlighted for the transverse transmission, the boundary conditions that basically applied to the transmission system, such as equal component torque load, speed factors, etc. also had to be observed.

The transmission synthesis was started in selected search fields under these boundary conditions (see Figure 2).

The following gear set concept for the 9HP48 transmission was selected from hundreds of possible systems (see Figure 3) by means of a systematic selection process that also accounted for the evaluation and weighting of a comprehensive criteria catalog of the search field which lead to about 15 million variants.

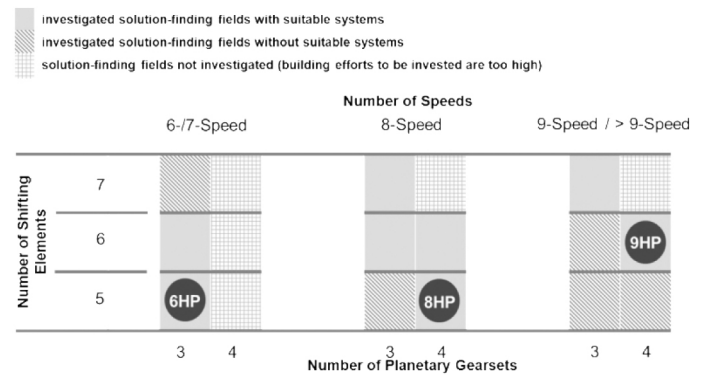


Figure 2. Search fields with assessment

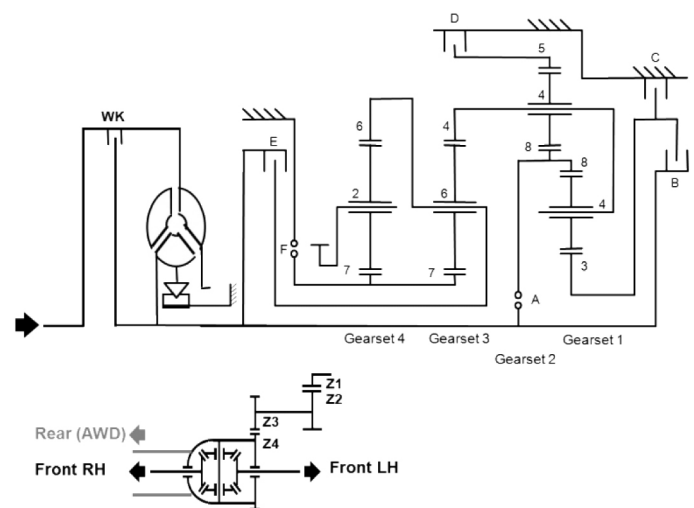


Figure 3. Transmission schematic 9HP48

The selected gear set system is characterized by the significant properties named below.

Four multi-disk shift elements and two dog clutch shift elements are used for the shift elements. Of the multi-disk shift elements, two are designed as a brake and two as a clutch. The two dog clutch shift elements only perform one shift each and can be easily installed in the center of the transmission, below gear set 1 respectively the center bearing. All simple shifts can be performed by changing two shift elements (see Figure 4).

The selection of suitable ratios on the gear sets enabled gear set 1 and gear set 2 to be arranged on top of each other. As a result, only three gear set levels are included in the installation length of the transmission. Despite this restricted ratio selection, it is possible for the selected system to exhibit a large total spread of 9.823 what is important for reducing consumption at favorable gear steps and good efficiencies (see Figure 5).

Speed	Brake		Clutch		Dog clutch		Gear Ratio	Gear Transition
	C	D	B	E	F	A		
R		●	●		●		-3,830	Total 9,823
N		●			●			
1		●			●	●	4,713	
2	●				●	●	2,842	
3			●		●	●	1,909	
4				●	●	●	1,382	
5			●	●		●	1,000	
6	●			●		●	0,808	
7		●		●		●	0,699	
8	●	●		●			0,580	
9		●	●	●			0,480	

Figure 4. Shift pattern 9HP48

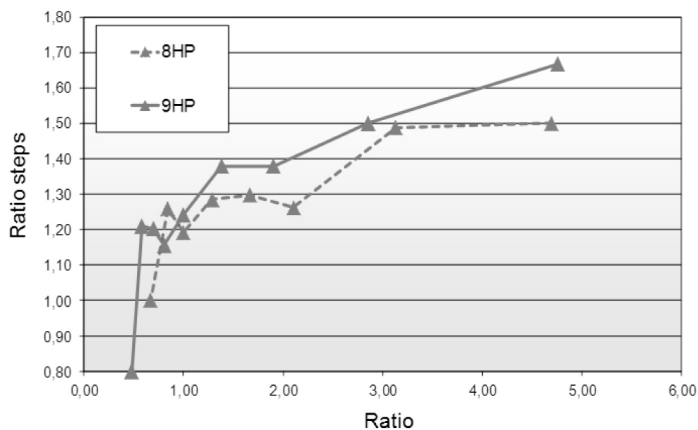


Figure 5. ratio steps 9HP48

Thanks to this selection of the ratios it was also possible to ensure a balanced speed and torque splitting within the transmission required for a space and weight-optimized overall construction. No high speed and torque factors occur thanks to the specific kinematic design and the coupling of the gear sets. For this reason, no unnecessarily large dimensioning of components (shafts, gear sets and clutches) is required and a harmonic transmission design is possible. The speed and torque factors are illustrated in [Figures 6.1 and 6.2](#).

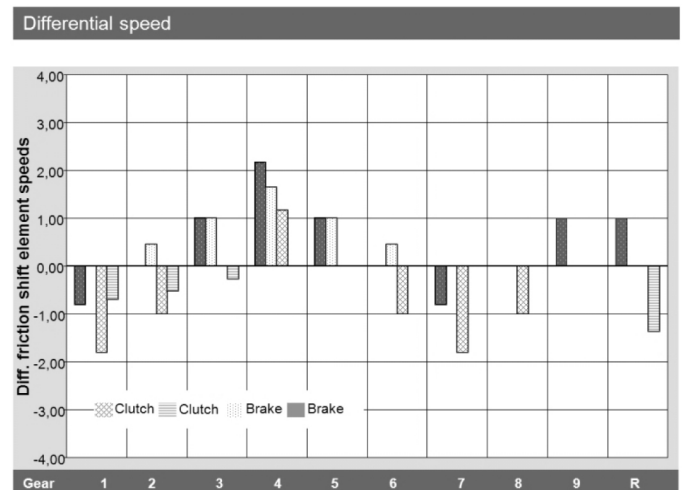


Figure 6.1. Speed level factorial

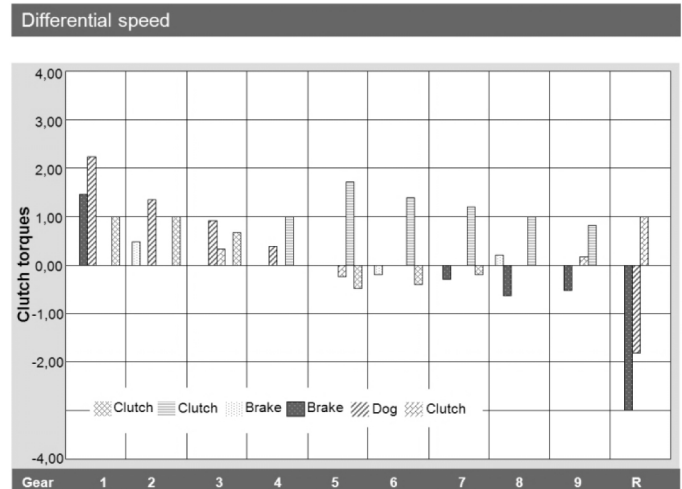


Figure 6.2. Speed level factorial

The essential system features are summarized in the following list:

- 9 Gears
- Overall ratio 9.823
- Harmonic step range with small gear steps and high efficiency
- 4 gear sets
 - 6 shift elements
 - 2 multi-disk brakes
 - 2 multi-disk clutches
 - 2 dog clutches