

## Procedure for Technical Analysis of the Cause of Volvo FH 12 Road-Train Trailer Gearbox Failure

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**Abstract:** The article deals with the Volvo FH 12 4x2 T 380 road-train trailer gearbox failure and technical expert's procedure to determine the cause of this failure. When operating the vehicle, the gearbox started to show signs in loss of functionality and then the vehicle was parked to service station. The gearbox failure led to a dispute between the owner of the vehicle and service station, that just sold the vehicle to the owner shortly before the failure, cause of the failure, what led to the agreement to determine the cause based on the damage analysis by technical expert, which had to assess whether the damage resulted from improper operating of vehicle by shifting a lower gear by the driver when driving downhill with a fully loaded road-train or by wear of the gear material. To determine the cause, the vehicle was serviced in the presence of a technical expert, and dismantling work was carried out according to his instructions. The result of investigation was to determine the course of failure's origin of the gearbox in question.

**Keywords:** road-train trailer, service station, gearbox failure, diagnostics, finding of damage cause

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### I INTRODUCTION

In practice, there are often cases, when service station and vehicle owner have a different opinion on the cause of vehicle failure. It is then the task of technical expert to assess and decide what caused vehicle to fail. The article deals with one of these cases, when Volvo FH 12 road-train trailer has repeatedly experienced a gear failure. The service station insisted that the gearbox failure resulted from the incorrect way of driver's operation by shifting a lower gear while driving downhill with the fully loaded road-train. The owner of vehicle was of the opinion that despite the fact that technical lifetime of the gearbox was not run out, it was damaged due to the wear of its parts. Since there was a high repair cost in this case, owner and service station agreed to invite a technical expert to evaluate technical condition of gearbox and determine the cause of failure. For this reason, the technical expert proceeded as follow: the gearbox was inspected, dismantled, disassembled, the state of the oil filling was evaluated and, based on the results of these operations and their evaluation it has come to analyse an occurrence of the failure. All operations were documented by recording with the camcorder. The described technical expert's procedure and his analysis of the identified damages is a valuable source for the work of other technical experts assessing similar cases, as it enables them to compare the nature of damages and the course of resulting analysis.

### II VEHICLE DATA

vehicle type: tractor, T-N3-TN  
make and type: VOLVO FH 12 4x2 T 380  
engine type: Volvo D 12 A  
full power in kW at rpm: 279/1800  
engine cylinder capacity (ccm): 12,130  
color: white  
size and type of tires - 315/80 R 22.5  
size and type of rims: 22.5 x 8.25  
trailer weight: 31,980 kg  
road-train weight: 40,000 kg  
Mileage: 531,653 km

The owner said that:

Named said, that he took the mentioned vehicle on Friday at the service station where he bought it, that he had driven about 50 km without load and then after loading about 200 km with a load in weight of about 13 tons. Subsequently, he drove about 200 km without load, after which, when reversing needed to park the trailer,

he noticed unusual sounds from the gearbox and vehicle was immediately parked. On Monday, a ride of about 3 km was made to a meeting with a service technician, followed by a test drive by service technician, and then the vehicle was transported to the service station by its own wheels, where damage was detected after the gearbox was removed and dismantled.

### III INITIAL OPERATIONS

<i>place:</i>	service station
<i>findings on vehicle:</i>	mileage 631,653 km, vehicle without apparent damage to other groups
<i>gearbox status at the time of the inspection:</i>	Removed from the vehicle and disassembled - without housing, the gear system is fixed in the jig
<i>Gearbox inspection findings:</i>	damaged two teeth of gear wheel of the 3rd gear shift of the spindle shaft and three teeth of gear wheel of the 3rd gear shift of the spline shaft
<i>Photo documentation:</i>	video recording of inspection

#### Visual inspection:

The vehicle and its engine were inspected in detail, as a result of which it was found that no incompleteness was observed – Fig. 1



Side view of Volvo FH 12 trailer



Front view of Volvo FH 12 trailer



View on the vehicle's tachometer

**Fig. 1: Vehicle state in sight of visual inspection**

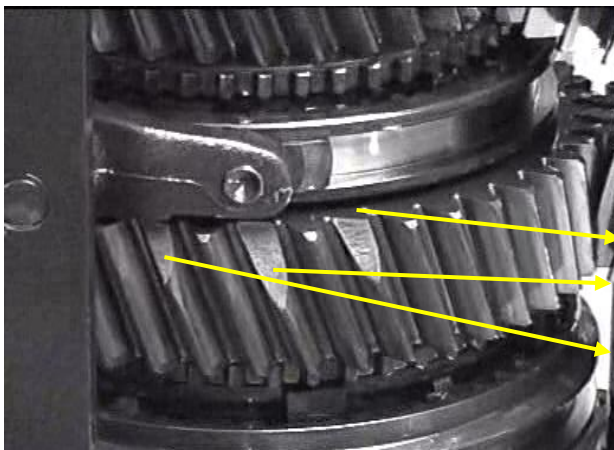
The photo documentation from the gearbox inspection is in Fig. 2



view of the spindle gear shaft after removal from the gearbox housing



a closer look at the gear shafts with gear wheels



View of spline shaft gearing and marking of damages:

D1

D2

D3



View of spindle shaft gearing and marking of damages:

P1

P2



View of fragments found in the gearbox



View of tooth fragments found



View of tooth fragments found



View of tooth fragments found

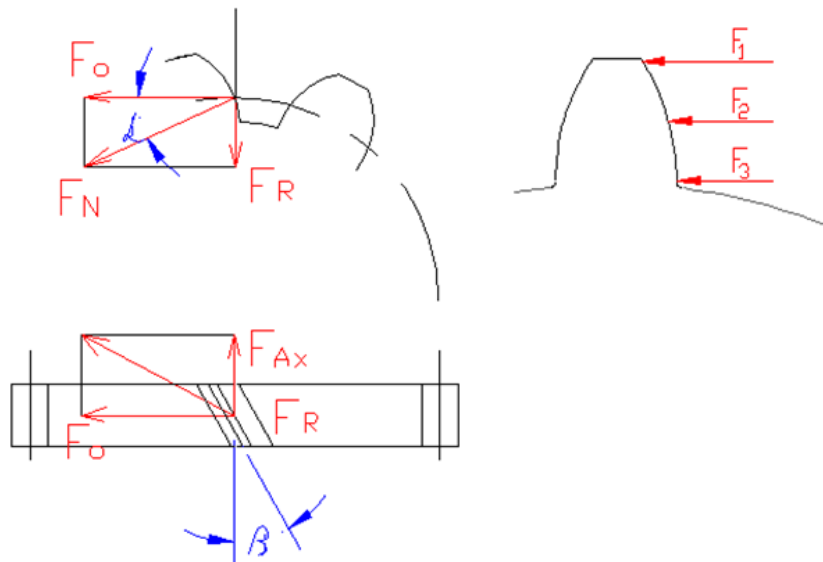


View of tooth fragments found

**Fig.2 Photo documentation of the gearbox damage found**

#### IV ANALYSIS OF THE FORCES ACTING IN GEARBOX GEARING

Fig.3 shows forces acting in gearbox gearing



**Fig.3 showing forces acting in gearbox gearing**

When transferring forces with gear wheels act:

- forces from the moment of rotation  $M_t = P / \Omega$
- additional forces caused by engine run irregularities (external dynamic forces)
- additional forces caused by inaccuracy of the gear production and the change in stiffness of tooth during the engagement (internal dynamic forces)

Gear forces:

- peripheral force  $F_o = 2 \cdot M_k / d$
- radial force  $F_R = F_o \cdot \text{tg } \alpha$
- axial force  $F_{AX} = F_o \cdot \text{tg } \beta$
- normal force  $F_N = F_o / (\cos \alpha \cdot \cos \beta)$

Fatigue effects:

- contact fatigue - when calculating teeth, it is based on the baseline number of load cycles  $N_{Hlim}$  50 to  $10 \cdot 10^6$ , which guarantees its lifetime as a whole
- bending fatigue.

Note: The position of load changes during engagement. At the beginning of engagement, the load acts on head ring ( $F_1$ ) and ends up on foot ( $F_3$ ) see fig.3.

## **V CHARACTERISTICS OF D1, D2, D3 FRACTURE AREA AND P1, P2 FRACTURE AREA**

Fig. 4, 5 shows views of the fracture areas



**Fig.4 View of characteristics of D1, D2, D3 fracture areas**

In that case, it is possible to draw from the characteristic features (grain size, coarse and broken surface with a clear microstructure of the material, without any marks and deformations) in the area of fracture, that it is a brittle fracture caused by a mechanical load whose size exceeded the mechanical properties of material in the profile where fracture occurred. This corresponds to the plane of rupture corresponding to the plane of greatest force stress (in direction of circumferential force in common normal plane, which is at the same time line of engagement)

P1, P2

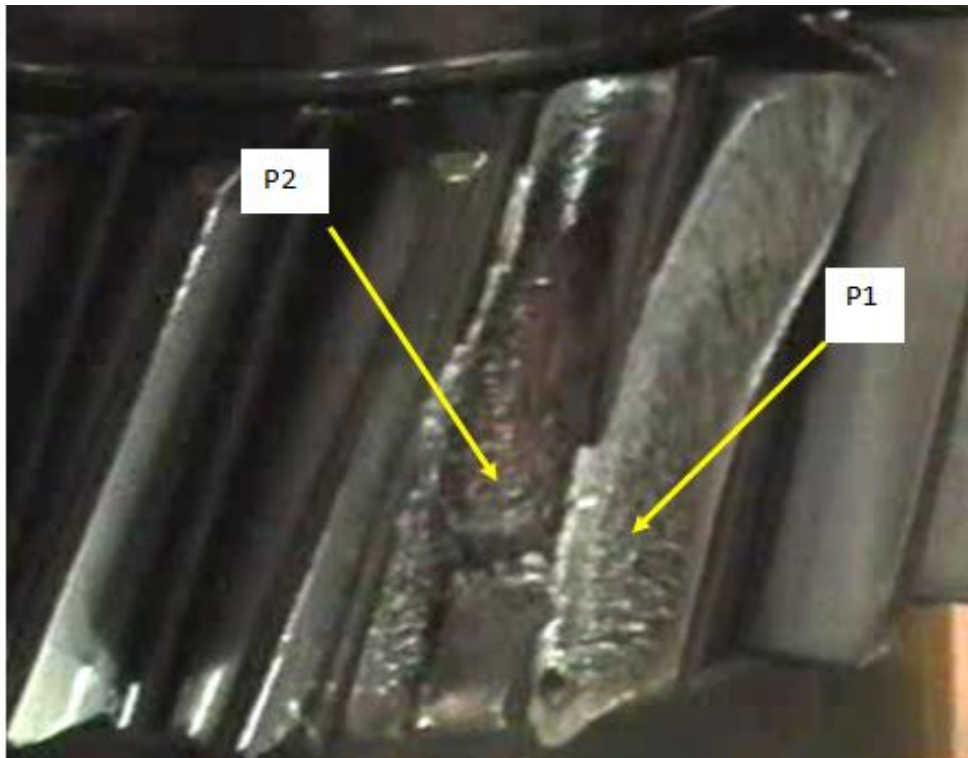


Fig.4 View of characteristics of P1, P2 fracture areas

#### VI CHARACTERISTICS OF FRACTURE AREAS OF BROKEN TEETH

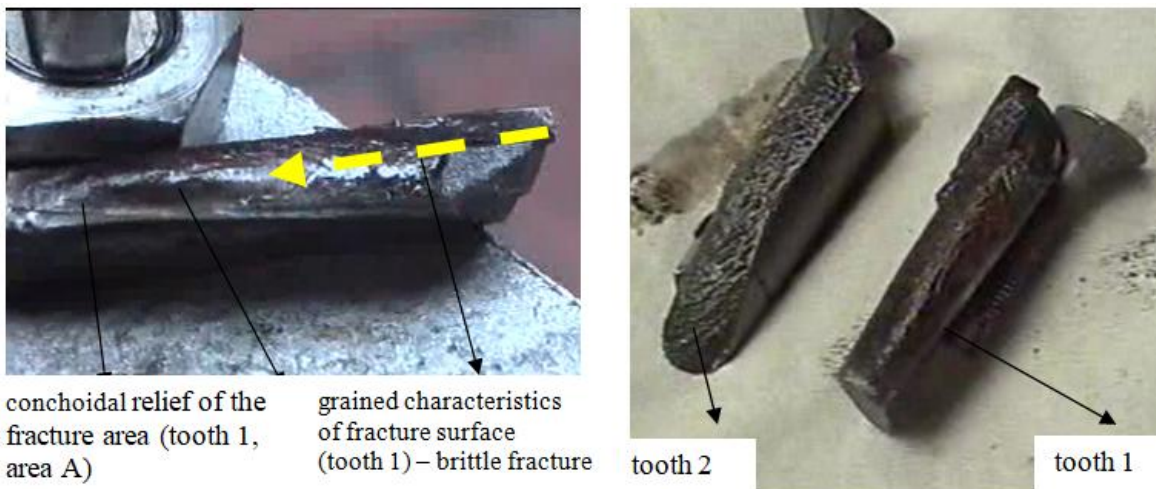


Fig. 5 View of characteristics of teeth fractures areas 1,2 with an indication of fracture spreading - yellow arrow

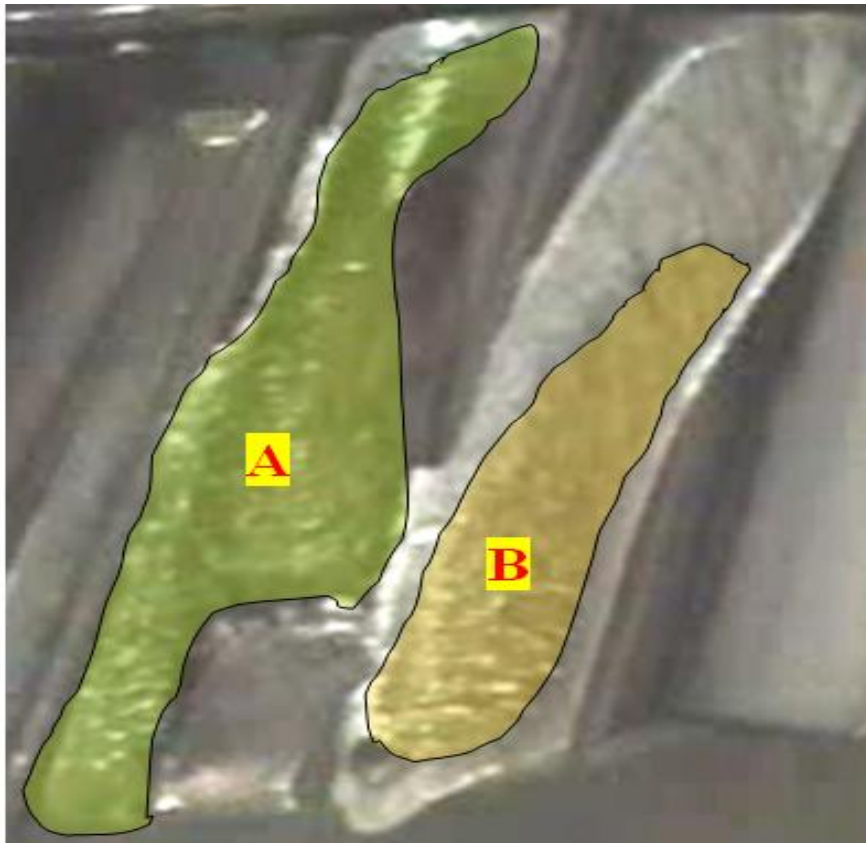
#### VII COMPARISON OF FRACTURE AREAS CHARACTERISTICS

Fracture areas of the tooth 1 in area of Fragment A show a conchoidal relief with signs of gradual spread of the fatigue fracture from surface of the active tooth in the tooth engagement (in direction of the force acting) in area of the foot ring and then also down towards to the axis of the wheel. This characteristic of the fracture area is identical to

a characteristic of the fracture area in the area B of the tooth 2

Other parts of fracture of tooth 1 and tooth 2 correspond to the brittle fracture characteristics (grain, rough and rugged surface with clear microstructure of the material, with no marks and deformations)

Area of fracture is located outside the lines of image – fig.6



Obr.6 View of characteristics of teeth fracture areas P2 (A), P1 (B)

### VIII ANALYSIS OF THE COURSE OF FRACTURES OCCURENCE

- 1<sup>st</sup> stage: occurrence of fatigue fracture on tooth no.1 at fracture area A (P1)  
Mentioned fatigue fracture with its characteristic of the fracture surface gives with the number of fatigue and relaxation lines assumption that its formation took place over a longer period of time, that it originated with plastic deformations in the fracture area and from the direction of line it is possible to derive its propagation direction (as shown) and the fracture area does not cross the engagement line.
- 2<sup>nd</sup> stage: formation of brittle fracture on the tooth No. 1 outside of area A (P1)  
After a time when the fatigue fracture propagation process in area A reached the limit of strength of the remaining tooth material, a brittle fracture of this material occurred (fracture of tooth out of the engagement line)
- 3<sup>rd</sup> stage: : formation of brittle fracture on the tooth No. 2 in area B (P2)  
Listed fatigue fracture with its characteristic of the fracture surface gives with the number of fatigue and relaxation lines assumption that its formation took place over a shorter period of time than the fatigue fracture on tooth No. 1 in the region A that its propagation direction is the same as the propagation direction of fracture in region A, the area of the fracture does not cross the engagement line.
- 4<sup>th</sup> stage: formation of brittle fracture on the tooth No. 2 outside of area B (P2)  
After a time when the fatigue fracture propagation process in area B reached the limit of strength of the remaining tooth material, a brittle fracture of this material occurred (fracture of tooth out of the engagement line)
- 5<sup>th</sup> stage: formation of brittle fractures D1, D2, D3  
These occurred as a consequence of tooth abruption due to subsequent impacts in the transmission of driving force in the plane of engagement line which was not smooth at any given time

### IX CONCLUSION

On the basis of the known facts and the findings made, technical expert has concluded that the detected failure of Volvo FH 12 4x2 T 380 TN trailer gearbox was caused by fatigue fracture (P1 - area A) on the tooth (1) of the countershaft, resulting in the teeth 1 (P1 – outside of area A) being broken off with brittle fracture, during which the fatigue (P2-area B) on the second tooth of the shaft (tooth 2), due to which the tooth 2 (P2 - outside area B) was broken off with brittle fracture, and it is most likely that in time after the tooth 1 breaks there have been D1, D2, D3 fractures on the teeth of engagement gear wheel on the spline shaft.



Estimated start of fatigue fracture of the tooth 1 (P1) has been established for a longer period of vehicle operation until a fracture D1, D2, D3.

It follows that the failure of gearbox has not occurred due to improper handling of the vehicle by driver.

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