DETERMINATION OF SERVICE LIFE OF GEARS WITH CRACKS INITIATED IN TOOTH ROOT

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The paper presents the method for determination of the direction and speed of propagation of the crack of hardened and case hardened gear with initiated crack in the tensile zone of the tooth root. The method is numerical and is based on the elastic fracture mechanic by taking into account the real load capacity characteristic.

INTRODUCTION

The direction of crack propagation is determined numerically by means of the finite element method (FEM) by using a suitable computer packed, suitable elements and required network FE. For the numerical crack propagation, in addition to the load capacity characteristic it is necessary to know also the crack propagation speed in the gear material and changing of the factor of intensity of stress during the crack propagation. The direction and speed of propagation are verified experimentally.

PROBLEM

We must determined the life of 1.st step gear of a car charge-speed gear with initialed crack in the tooth root.

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SYSTEM OF SOLUTION

Stress and service life of gears without crack

For solving the problem it is necessary the state of stresses in the tooth root without crack in order to be able to determine the probability of fracture and the service life.

The following applies for stress:

$$\sigma_{FP} = \sigma_{FPdau}\left(\frac{3.10^6}{N_L}\right)^{exp}, \quad exp = 0,288 \log\frac{\sigma_{FPstat}}{\sigma_{FPdau}} \quad \ldots\ldots\ldots\ldots\ (1)$$

and for a service life (without initiated crack):

$$N_L = 3.10^6\left[\frac{\sigma_{FPdau}}{\sigma_{FP}}\right]^{\frac{(1)^* \text{ or } (2)^*}{exp}} \quad \ldots\ldots\ldots\ldots\ (2)$$

$(1)^*$ for $\sigma_{FPstat} > \sigma_F > \sigma_{FPdau}$, $(2)^*$ for $\sigma_F < \sigma_{FPdau}$

The results for the service life with the probability of fracture are indicated in Figure 1.

Residual stresses

The residual stresses are of vital importance for the process of the crack propagation, since the majority of gears are hardened or case hardened. According to T. Tobe (1) the residual stresses on gears are a result of different specific volume of structures in the core and on surface.

The stress is determined according to the Hook's law:

$$\sigma = E\ .\left((\bar{v}\ /v_o) - 1\right)\ /\ 3 \quad \ldots\ldots\ldots\ldots\ (3)$$

The residual stresses are transformed into a form of thermal loading.

Direction and speed of crack propagation

The crack propagation speed in material 16MnCr5 is adopted from P. Uggowitzer (2). The program package for calculating the direction and speed of the crack propagation (3) is complemented by taking into account the residual stresses. Fig 2 shows the directions of the crack propagation with and without the residual stresses. For determining the service life it is necessary to know the influence of residual stresses on the changing of the factor of the stress intensity depending on the crack length. It is important that in case of an initiated crack the suitably high tensile stresses occur. Fig 3 shows the service life (expressed in terms of the mileage done) for different initialed crack length.

Experimental results

The experimental results were obtained by means of the model shown in Fig 2. Comparison of the numerical and experimental results is indicated Fig 3. In this stage of researches the accordance is adequate.

CONCLUSION

We successfully linked the conventional calculations of gear with the numerical method (FEM) and by means of the fracture mechanics we correctly anticipated the service life of the gears with initiated crack in the tooth root.

SYMBOLS USED

σ_{FP}, σ_{FPdau}, σ_{FPstat} = stresses (MPa)

$\bar{v}$ = average specific volume of martensitic structure

v_o = volume of material before heat treatment

N_L = service life (cycle)

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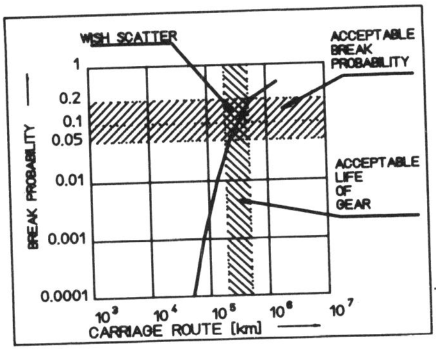

Fig.1 Service life of gear

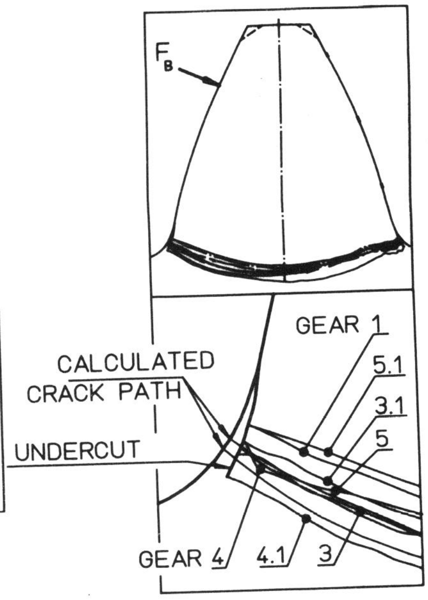

Fig.2 Practical and theoretical crack path

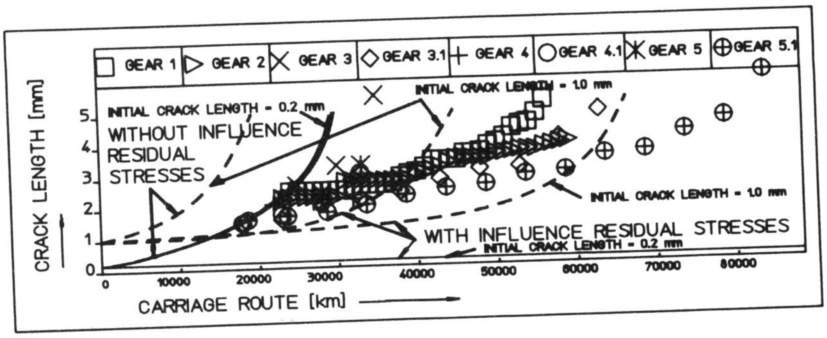

Fig.3 Practical and theoretical crack growth curve