Fatigue destruction of automobile construction materials

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Abstract. Fatigue test methods are presented in the article by example of 08sg and 20sg sheet steel with the use of hardware-software small-size desktop complex allowing to estimate fatigue destruction resistance of automobile construction materials. The obtained test results allow to timely at the maintenance stage prevent the destruction of the vehicle construction elements and parts while in operation affected by cyclic loads.

1. Introduction

As soon as the majority of all kinds of steel constructions destruction are of fatigue character [1,2], issues of ensuring the required vehicle parts performance capacity are acute. Performance indices of construction materials, designed for manufacturing automobile hardware items are formed at all stages of metal conversion: from the selection of charge materials for metal smelting to obtaining the fabricated parts [3].

Car body and other automobile construction elements while in operation are among other factors subject to fatigue destruction which can lead to the item performance degradation as well as irreparable consequences and even loss of life.

Nowadays in automotive manufacturing metal items of different construction materials are used [4,5]. In automobile and machine-building industries stamped sheet constructional low-carbon steel is widely used which makes it necessary to find optimal design solutions in the choice of material and technological processes ensuring parts and constructions high performance.

2. Literature data analysis and setting of a problem

In order to estimate metal items performance capacity at different loading conditions except static strength and ductility parameters it is necessary to know fatigue destruction resistance characteristics. To study fatigue properties of construction materials samples, different kinds of test machines are used [6]. Requirements for selecting fatigue testing-machines parameters and their dynamic design are determined by test methods, metrology, reliability and efficiency. Basic schemes and principles of creating and calculating fatigue testing-machines are detailed in professional literature [7,8].

3. Purpose and objectives of the research

The purpose of the research work is to develop fatigue test methods of automobile construction materials plane samples with the use of hardware-software small-size desktop complex EMU-5-PK [9], comprising desktop hardware-software automated installation EMU-5 and a PC with a DAC-ADC embedded board and software. The complex is designed for carrying out conventional, short-time and special fatigue tests of plane samples and construction elements as well as for fatigue cracks growth.
4. Fatigue test methods of automobile construction materials plane samples

When reduction in metal consumption of machines and technological devices is strictly required it is difficult to avoid fatigue cracking in essential parts. However, in some materials fatigue cracks might appear at a relatively early stage and for most part of their “lives” the parts have to operate with the cracks. Thus, for their performance capacity overall estimate it is desirable to know not only fatigue crack life and fatigue strength parameters but also maximum information about the damage accumulation process at all stages of construction materials fatigue destruction: at the stage of crack birth, further development up to complete (catastrophic) destruction of the sample.

Therefore a critical characteristic feature of materials behaviour at cyclic load is cyclic strengthening (softening) curves reflected on the current sample bending change curves during the fatigue tests [10]. Cyclic strengthening (softening) curves reflect structural processes changes in the metal under fatigue.

For example by them it is possible to determine fatigue cracking, resulting in the bending increase and to estimate the crack propagation rate as well.

This information becomes especially important at materials cyclic load during the tests, when the sample surface direct observation is difficult. Therefore, a decision to upgrade EMU-5 installation has been made in the work. Upgrading meant mounting a dial test sensor to correctly determine the sample load amplitude.

Research and refinement of fatigue test methods of automobile construction materials plane samples were carried out on the basis of GAZ 3302 car frames. 20sg and 08sg steel is used to manufacture car frames constructions.

The samples fatigue fractures surface research was carried out on optical comparator having a tenfold magnification and also on photos with up to seven-fold magnification.

5. Research results and discussion

Figure 1 shows fatigue curve for 08sg steel. Fatigue endurance was determined by Lokati method ($\sigma_{-1} = 176 \text{ MPa}$).

![Fatigue curve for 08sg steel](image)

**Figure 1.** Fatigue curve for 08sg steel in coordinates $\sigma - N$.

Correlation coefficient $R = -0.829$. 
As an example a bending change curve of a 08sg steel sample under fatigue is used (Figure 2).

![Bending change curve](image)

**Figure 2.** Current bending change curve of a 08sg steel sample at cyclic load at $\sigma = 265$ MPa; plane bending of frequency 27 Hz; $N_p = 262000$ cycles

Plateau on the current bending curve shows that the sample has not been affected by fatigue destruction and preserves its strength properties. The bending point shows the fatigue macrocrack birth which grows and on the last curve line of sharp amplitude increase shows the destruction of the sample.

Figure 3 presents a photo of the fatigue sample surface made of 08sg steel.

![Fatigue crack](image)

**Figure 3.** Fatigue crack on the sample surface made of 08sg steel at $\sigma = 265$ MPa ($N_p = 262000$ load cycles)

Mathematical treatment results of parameters ratio of the sample current bending curves under cyclic load and the fatigue crack birth observation and its further development are shown in table 1. Analysis of the results obtained shows that 20sg steel has fatigue endurance, obtained by Lokati method, higher than 08sg steel. However, the fatigue macrocracking takes place earlier and grows at a considerably lower rate in 08sg steel. Consequently it can be preferable for essential parts as a greater possibility to discover and identify fatigue damage during the vehicle maintenance appears which lowers car accidents probability.
Table 1. Fatigue destruction parameters of automobile 08sg and 20sg steel

| Material      | \(N_p\), cycle | \(n_{и,тр.}\), cycle | \(n_{роста \, тр.}\), cycle | \(l_{тр.}\), mm | \(V_{ср. \, тр.}\), mm/cycle | \(n_{и,тр.}\), \% by \(N_p\) | \(n_{роста \, тр.}\), \% by \(N_p\) | \(\sigma_{1}\), MPs |
|---------------|----------------|----------------------|--------------------------|----------------|---------------------------|------------------|------------------|----------------|
| 08sg steel    | 262000         | 82000                | 180000                   | 9,8            | 5,38 \times 10^{-5}       | 31,3             | 68,7             | 176             |
| 20sg steel    | 174000         | 68000                | 106000                   | 9,4            | 8,86 \times 10^{-5}       | 39,8             | 60,2             | 190             |

\(N_p\) – total number of cycles before the sample destruction;
\(n_{и,тр.}\) – number of cycles before the fatigue crack birth;
\(n_{роста \, тр.}\) – number of fatigue crack growth cycles;
\(l_{тр.}\) – fatigue crack full length;
\(V_{ср. \, тр.}\) – average fatigue crack growth rate;
\(n_{и,тр.}\) – proportion of fatigue life before the fatigue crack birth, from the fatigue life up to the complete sample destruction;
\(n_{роста \, тр.}\) – proportion of fatigue life of fatigue crack growth from the fatigue life up to the complete sample destruction;
\(\sigma_{1}\) – fatigue endurance by Lokati method.

6. Conclusion

Fatigue destruction of plane samples of 08sg and 20sg steel has been researched in the work; fatigue endurance, fatigue cracks birth period and their further growth rate have been determined.

Data of plane samples current bending change of automobile 08sg and 20sg steel have been obtained, basing on which it is possible to judge microcracks birth rate and macrocracks development in the samples up to fatigue destruction which increases the vehicle operation safety, its maintenance and lowers repair costs.

Thus, the methods realized for plane samples fatigue tests of automobile construction materials let us make a conclusion about plane samples fatigue destruction resistance of automobile construction materials of 08sg and 20sg steel. With the help of the data obtained at maintenance stage it is possible to prevent the destruction of construction elements and parts while in operation affected by cyclic loads.

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