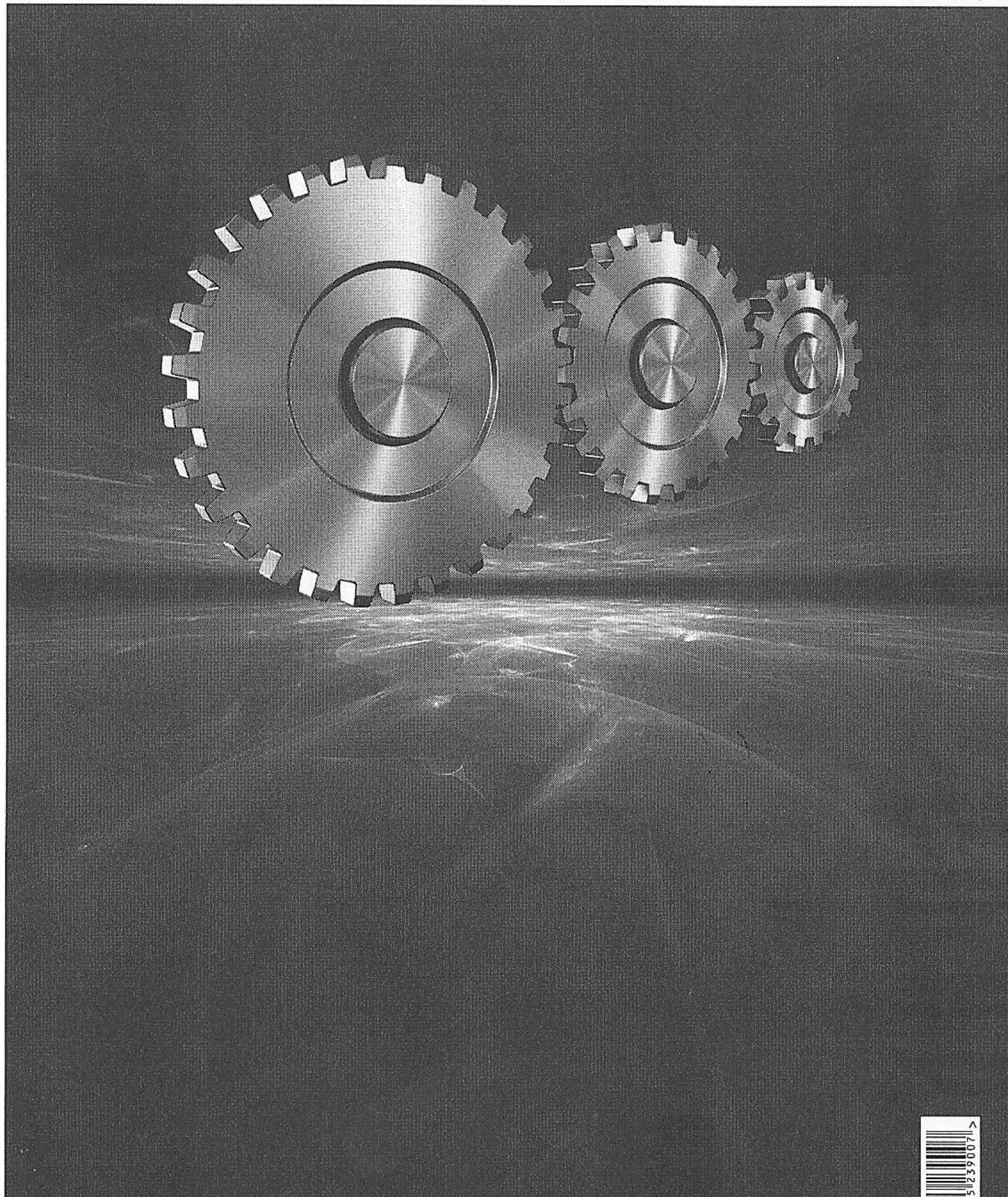

www.actamechanica.sk

ISSN 1335-2393

1/2017
Acta Mechanica Slovaca

Acta Mechanica Slovaca

VOLUME 21
No 1/2017
[15 March 2017]

Journal published by Faculty of Mechanical Engineering | The Technical University of Košice

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Influence of Rotational Moulding Process Parameters on Accuracy *of* ***Polymer Casts***

Published Since **1996**

ISSN 1335-2393

Acta Mechanica Slovaca 21 (1): 48 - 52, 2016

Acta Mechanica Slovaca
ISSN 1335-2393
www.actamechanica.sk

The Study of Fatigue Failure Performance of Vehicle Metal Structures Used in Transportation of Corrosive Materials

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Abstract: The processes of corrosion-fatigue failure of materials in contact with mineral fertilizers are insufficiently studied. As a result of joint influence of atmospheric corrosion and mechanical loads, about 70 to 80% of machine parts get out of order, 20 to 25% of which are failures caused by operating overload due to the strength loss because of atmospheric corrosion. A large part of metal structures of agricultural vehicles used to transport mineral fertilizers is under the direct influence of aggressive environments and dynamic loads that occur during the motion by field roads. Saturated solutions of the most aggressive working environments used in agricultural production, in particular ammonium sulphate and nitrophosphate are investigated to reduce fatigue resistance of ordinary steels groups – St3 and St5 (GOST 2651:2005; DIN 17100) and quality steels – 10 Steel, 15 Steel, 20 Steel, 25 Steel (GOST 1050-88; DIN 17200) when loaded at all levels. The fatigue endurance limit decreases in comparison with air up to 2.02 times in a solution of ammonium sulphate, and to 2.32 times in a solution of nitrophosphate. In organic fertilizer environments, compared to distilled water, the conditional fatigue endurance limit increased to 9%. The properties of the given materials as an inhibitor of corrosion-fatigue failure were discovered and proved.

Keywords: Tractor-trailer, metal structure, carbon steels, agricultural working environment, fatigue fracture, fatigue limit.

1. Introduction

The key factors of fatigue and corrosion-fatigue failure of vehicle metal structures used in agricultural production determine the state of working surfaces, load parameters, environments aggressiveness degrees in consideration of the different kinds of fertilizer, weather conditions, etc. [3, 7, 8]. On examining the technical state of agricultural machinery after 3 years of operation, it is observed that corrosion contributes to approximately 80% of all mechanical failures of assembly units [8, 9], Fig. 1, Fig. 2. The corrosion fatigue failure is the result of additive effects of service loads, environments, and thermodynamic lability of metal structures materials. Corrosion damages and light-gage sheet metal failures change a state of workpiece surface and intensify the wear processes. They significantly degrade tribotechnical

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properties and corrosion processes, causing a simultaneous decrease in fatigue strength. As a result, the reliability and durability of vehicles are significantly reduced.

The processes of corrosion-fatigue failure of materials in contact with organic and mineral fertilizers are insufficiently studied. The absence of reliable data makes it difficult to develop new effective methods of corrosion protection of agricultural fertilizing machines. In particular, in [2, 3, 5], two steels are studies without taking into account the fact that for manufacturing metal structures of this class machinery, the whole range of standard and quality steels are applied. There is a need for experimental research of the whole range of metal materials of tractor-trailers, fertilizing machines, etc. under the influence of corrosive agricultural environments. The results of such research could be used as input data for the objective and quantitative assessment of operability parameters of the given type vehicles.

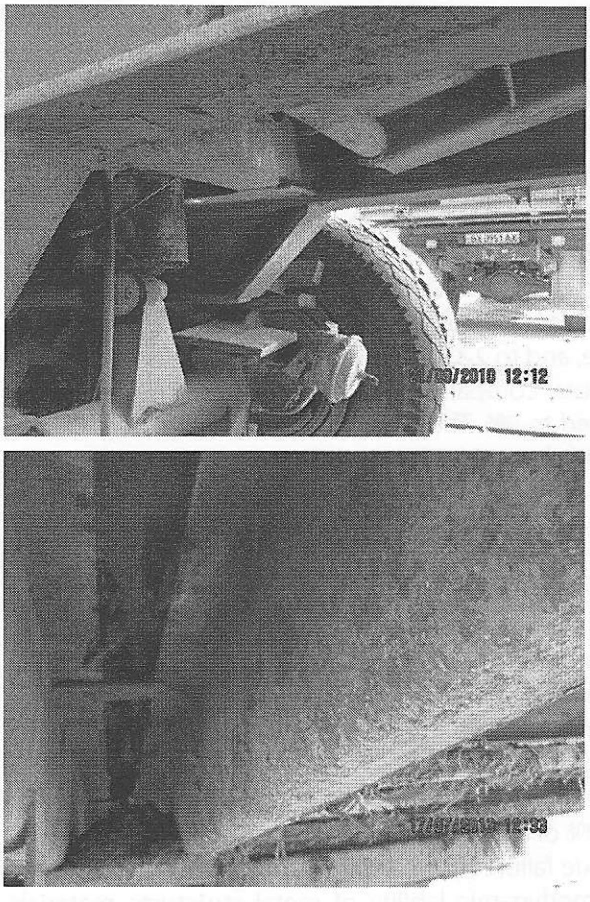


Fig. 1: *Corrosion-fatigue failures of machine units used in agricultural production.*

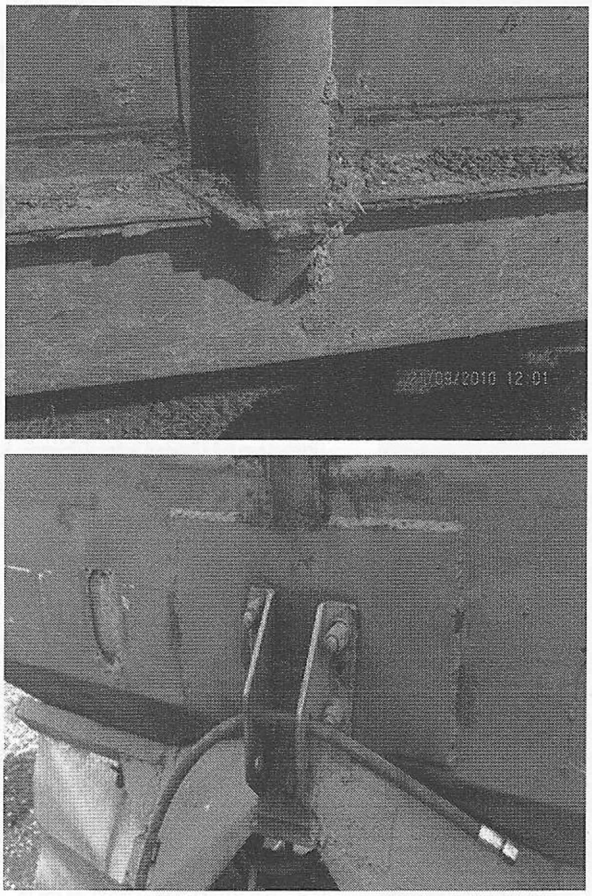


Fig. 2: *Welded fatigue failures of light-gage sheet metal structures of trailers.*

2. Materials and technique

For fatigue and corrosion fatigue tests [1], the cylindrical specimens (Fig. 3) with a diameter of 10 mm (GOST 23026-78) made of standard steels St3, St5 (ISO 2651: 2005; DIN 17100) and quality steels 10 Steel, 15 Steel, 20 Steel, 25 Steel (GOST 1050-88; DIN 17200) under supply condition were used. The working body was an aluminum oxide wheel ЭB25SMIK. After turning, the grinding allowance was 0.35 mm. Rotation velocity of a specimen was 3 m/min, linear velocity of a stone – 30 m/sec, depth of grinding during the final passage – 0.005 mm/rev, surface roughness Rz=2.5 µm.

To eliminate the traces of mechanical grinding and to provide the fine precision of obtained results, the working area of all specimens before testing was polished using a sandpaper and diamond pastes with different dispersion. The same type of manufacturing technology was applied for manufacturing the batch of specimens. Therefore, the specimen designation was carried out on both specimen holders (Fig. 3). The precision of measurements of the prepared specimens working area was 0.01 mm.

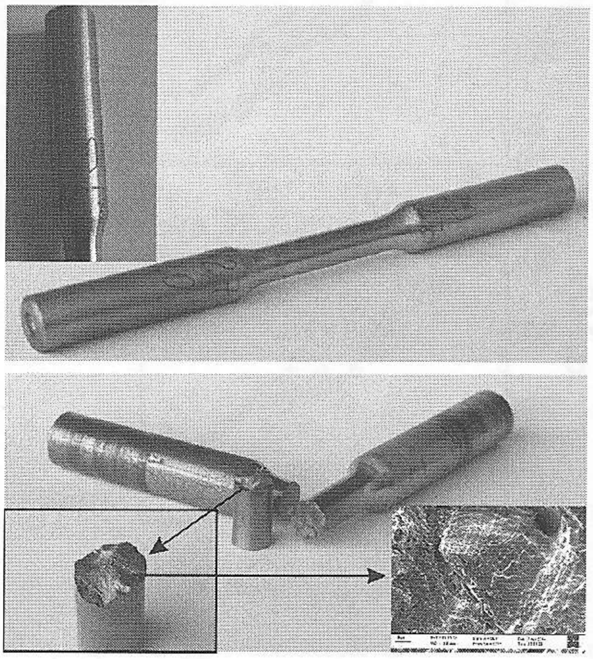


Fig. 3: *General appearance and specimen designation for fatigue tests before and after study.*

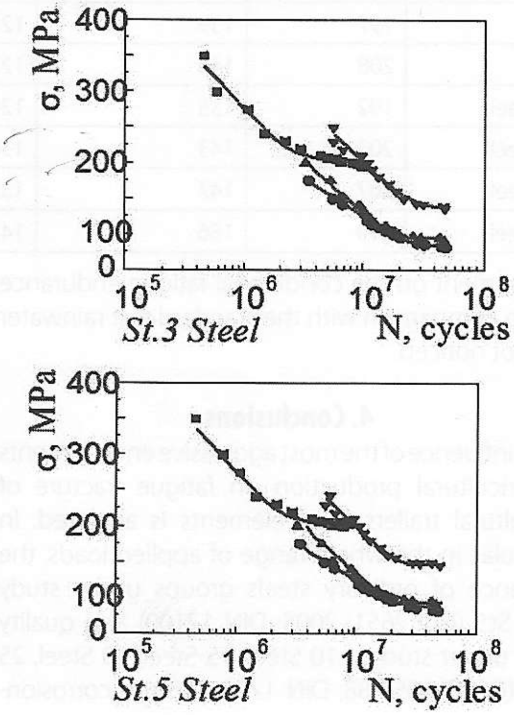
Distilled water as a standard test condensate of water or rainwater, saturated solutions of ammonium sulphate and nitrophosphate, mixed liquid manure of cattle and pigs in proportion 1/2 acted as corrosive environments [2, 3, 5, 10]. Acidity levels of environments before and after the experimental studies were measured by pH meter I-160M. Fatigue tests were carried out on the equipment IMA-5. The specimens were loaded by the scheme of rotating bend; cycle asymmetry coefficient was R=-1 [1, 2, 5, 6]. A fast-speed counting device before fracture N fixed the number of cycles. Based on obtained data, the Wohler curves were built. Tests started at 2/3 $\sigma_в$, incrementally reducing the value to the limit of endurance σ_{-1} within the framework of research (10^7 cycles – when tested in air, $5{\cdot}10^7$ cycles – in environments under study). As a research material, 5-15 specimens at a level of stress (0.95 ... 1.05)$\cdot\sigma_{-1}$ were used. Based on the research results, the fatigue limit was determined. Two specimens under study remained non-failed after reaching the specified database of testing. After examining 10-15 specimens, the fatigue curves were built [1].

3. Results and Discussion

The study of ordinary steels St3, St5 (GOST 2651:2005; DIN 17100) and quality steels – 10 Steel, 15 Steel, 20 Steel, 25 Steel (GOST 1050-88; DIN 17200) proved that in the whole range of loads, the resistance of quality steels to corrosion-fatigue failure in environments of mineral fertilizers, as compared with air and standard test environment condensate (rainwater), was significantly reduced. (Fig. 1, Tab. 1).

In a solution of ammonium sulphate, the conventional limit of quality steels corrosion fatigue, maximum for 10 Steel, decreased to 2.02 times, in a solution of nitrophosphate – to 2.31 times compared with air, accordingly, to 1.3 and 1.49 times compared with distilled water. In organic fertilizer environments, compared to distilled water, the conditional fatigue endurance limit increased to 9%. Therefore, the properties of the given material as an inhibitor of corrosion-fatigue failure were discovered and proved [2, 3]. The same tendencies in resistance to corrosion-fatigue failure in environments under study are observed in ordinary steels St3, St5 (Fig. 4, Tab. 1).

Less intense impact on the steels' fatigue endurance limit of two groups of mixed manure under study compared to mineral fertilizers was noticed. However, the negative impact of



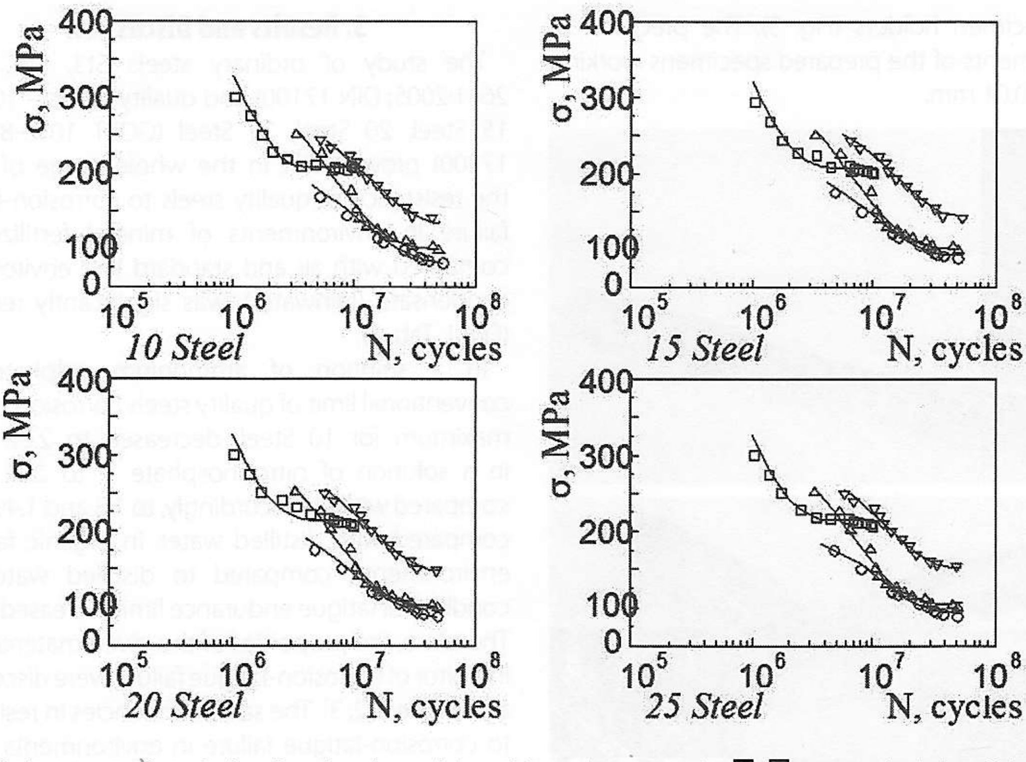


Fig. 4: *Fatigue curves of standard steels and quality steels in working environments: air – □, ■; saturated solution of nitrophosphate ○, ●; saturated solution of ammonium sulphate △, ▲; fixed manure – ▽, ▼.*

Table 1: *Fatigue endurance limits of metal structure materials in working environments, MPa.*

Steel	Air	Organic fertilizer	Distilled water	Mineral fertilizers	
				Ammonium sulphate	Nitrophosphate
St3	197	139	121	93	85
St5	208	146	127	98	89
10 Steel	192	135	124	95	83
15 Steel	202	143	136	102	90
20 Steel	207	147	135	104	90
25 Steel	219	156	143	111	96

environment on the conditional fatigue endurance limit in comparison with the standard test rainwater was not noticed.

4. Conclusions

The influence of the most aggressive environments of agricultural production on fatigue fracture of agricultural trailers steel elements is analyzed. In particular, in the whole range of applied loads, the resistance of ordinary steels groups under study - St3, St5 (ISO 2651: 2005; DIN 17100) and quality steels under study – 10 Steel, 15 Steel, 20 Steel, 25 Steel (GOST 1050-88; DIN 17200) to the corrosion-fatigue failure in mineral fertilizers environments compared with air decreased significantly. In a solution of ammonium sulphate, the conditional fatigue endurance limit of steel quality decreased to 2.02 times, in a solution of nitrophosphate - to 2.31 times as compared with air, and to 1.3 and 1.49 times compared to distilled water. In organic fertilizer environment, the conditional fatigue endurance limit increased to 9% compared to standard test rainwater. The resistance to the corrosion-fatigue failure of ordinary steels occurred to be lower than quality steels. Less intense impact of organic fertilizers on the fatigue endurance limit of both steels compared to mineral fertilizers was noticed.

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