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DIAGNOSTICS OF ELECTRIC MOTOR OF LOCOMOTIVE SERIES 757

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Summary

The current very rapid technological development of means of transport with the accompanying high economic demands gives rise to their modernization, which is technically and financially particularly advantageous. One of the dominant processes in this reality is modernization of diesel locomotives that seeks, in particular, to improve their operating characteristics, energy, environmental and also maintenance parameters. This paper deals with diagnostics and troubleshooting on a modernized diesel-electric locomotive series 757 ZSSK, a.s. We present details on this traction vehicle diagnostics and specific diagnostic files that originated in real operating conditions, with the subsequent solving of diagnostic problems and tasks.

Key words: Diagnostics, error code, locomotive, traction motor.

DIAGNOSTYKA SILNIKÓW ELEKTRYCZNYCH LOKOMOTYWY SERII 757

Streszczenie

Obecnie bardzo szybki rozwój technologiczny środków transportu wraz z wysokimi wymaganiami ekonomicznymi wymusza ich ciągłą modernizację. Jest to szczególnie istotne pod względem technicznym oraz korzystne finansowo. Modernizacja spalinowych lokomotyw poprawia nie tylko ich właściwości użytkowe i obsługowe, ale także zmniejsza zużycie energii oraz negatywne ich oddziaływanie na środowisko w rzeczywistych warunkach eksploatacji. W niniejszym artykule przedstawiono metodykę diagnostyki stanu technicznego zmodernizowanych spalinowo - elektrycznych lokomotyw serii 757. Zaprezentowano szczegóły diagnostyki tego typu pojazdów trakcyjnych wraz z konkretnymi plikami diagnostycznymi, które zostały opracowane w rzeczywistych warunkach eksploatacyjnych. Opisano także sposoby rozwiązywania występujących problemów diagnostycznych i zadań.

Słowa kluczowe: diagnostyka, kod błędu, lokomotywa, silnik trakcyjny.

INTRODUCTION

Design of new structural elements for rail vehicles (e.g. car body and bogie frame) usually seeks a useful life of 30 years [1]. However, due to the different conditions that arise in normal operation, it is common to require corrective maintenance procedures on structural elements in order to safely guarantee the established design life [2, 3, 4]. All modern or modernised locomotives have a relatively large number of different electronic systems. Proper function and also the maintenance of such systems based on appropriate technical diagnostics. At the moment it is practically impossible to properly and reliably provide the functioning and maintenance of electronic systems, since corresponding diagnostics is not built-in and suitably adapted. At the same time the relevant electronic system itself gives a real basis for the application of modern diagnostics. It is important to note that a fault that occurs in electronic systems, localisation of the fault occurrence site and determination of its significance for the technical condition of the vehicle always constitutes a sequence of many levels of the whole used electronic system [5, 6, 7].

1. INTRODUCTION TO DIAGNOSTICS OF LOCOMOTIVE SERIES 757

Locomotive series 757 represent the latest project of the locomotive modernised by factory ZOS Zvolen. It is the 4-axle diesel-electric locomotive with alternate-direct current power transmission with total weight of 75 400 kg and maximum operating speed 100km/h, depending on customer´s request. The modernization is realized from original locomotives, model type 750 (T 478.0) or 754 (T 478.4) which had been produced since the end of the 60´s to the end of the 70´s in the last century by ČKD Praha. The locomotive 757 was designed for medium heavy- duty rail track service for regional and state railway tracks with gauge of 1 435 mm.

Despite the modernization, the locomotives series 757 generate a relatively large number of fault codes and messages. This leads to the fact that the vehicle is quite often under repair or maintenance for a longer time, during which it cannot fulfil the tasks for which the vehicle was designed and manufactured. Therefore it is necessary to well understand the processes of diagnostics and be able to utilize it as a tool for quick and precise identification of an impending or already occurred malfunction [6, 7, 8].

Faults and malfunctions are indicated by either a fault code, or the malfunction is detected by the operator and manifested by altered characteristics of the locomotive. The fault code is displayed on the display unit labelled A7 that is located at the locomotive dashboard. The operator has several options to solve the fault while driving the locomotive. However, these options are very limited. The main use of diagnostics is based on the repair and maintenance staff [9, 10].

This paper presents examples of procedures to eliminate faults displayed as fault codes at a locomotive repair facility.

2. FAULT – "ARMATURE CURRENTS ASYMMETRY"

The "Armature Currents Asymmetry" fault is classified as an "ELECTRICAL" fault. This fault is indicated by a fault code displayed on the A7 display unit. A high value of asymmetry can have a major impact on the connected traction motors. A significant asymmetry in the currents can result in excessive loss in the motor stators and rotors, and can lead to their total destruction or shutdown of the thermally overloaded motor. Although motors are designed to manage a certain asymmetry, when the predefined threshold is exceeded it is necessary to reduce the load on the motor, or disconnect it from the power supply network. Service life of motors is radically shortened at high voltage asymmetry.

2.1. DIAGNOSTIC PROCEDURES WHEN FAULT OCCURS

When a fault occurs it is detected by the AR07 control system and displayed on the A7 display unit using a fault message in the form of a code. The fault code displayed after the occurrence of the described fault is as follows:

„068,NMS ,NR1-JG03 ,---, Armature Currents Asymmetry", what means:

- 068 – fault sequence number,
- NMS – fault code,
- NR1 – source of report (NR1 – Locomotive control system and electronic regulation),
- JG06 - source of report (JG06 – Specific card of the control system).

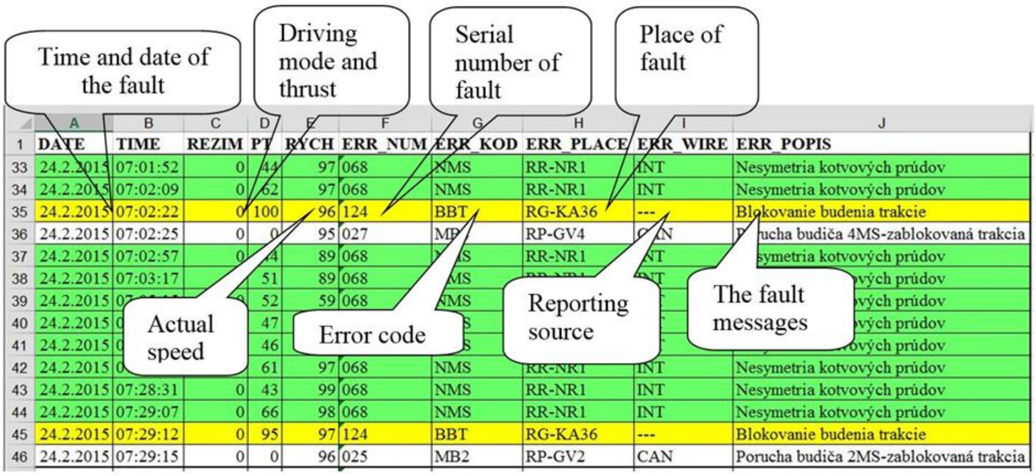
The fault removal process, if possible directly on the track, initially solves the locomotive operator. When the fault occurs and the fault message is displayed, the operator has the option to view the details of that fault. These details include further description of the fault occurred and possibly also the instructions how to remove the fault or measures to be taken to continue safe driving. These instructions are intended solely for the locomotive operator.

Example instructions displayed on the A7 panel at the "Armature Currents Asymmetry" fault look like this: "The relative difference in armature currents between the motor groups exceeded the value of 2/3. This state may occur for example in slippage or even at a fault of the armature circuit of one traction motor. As long as the fault persists and slippage is not suspected (not signalled), it is possible to use the extended display menu ZJ A7 (A7*) on the "Regulation/Traction" panel to trace and identify which armature current reaches a large difference compared to the others. Then, it is necessary to shut down that motor group."

If the operator/driver fails to completely remove the fault that occurred, he selects "Fault accepted" on the A7 display unit and continues driving, if it is possible. After the fault occurs the operator/driver records it in the fault log that is located in each locomotive driver's cab. After the end of the daily driving the engineer browses through the fault log and writes a fault report on the fault occurred or a complaint to the manufacturer, if the locomotive is still within the warranty period. The fault report is further handed to the responsible maintenance (repair) staff who takes steps (carries out operations), based on the information contained in the report, to determine the exact cause of the fault [11, 12, 13].

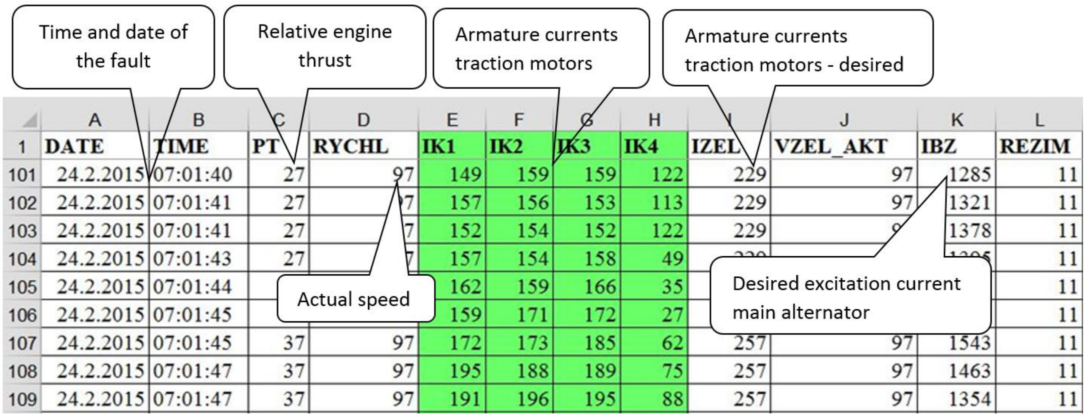
Fig. 1. USB (or DIN) slots for downloading of operational data

In step 1, it is necessary to carry out the locomotive diagnostics, which contains "downloading" all operational parameters, variables and values from sensors, and commands issued by the operator/driver for the period in question, which is two weeks in this case (Figure 1). This database is gradually renewed with new days´ data and the oldest days are automatically deleted. Locomotive series 757 diagnostics is carried out directly at the first position of the locomotive driver.



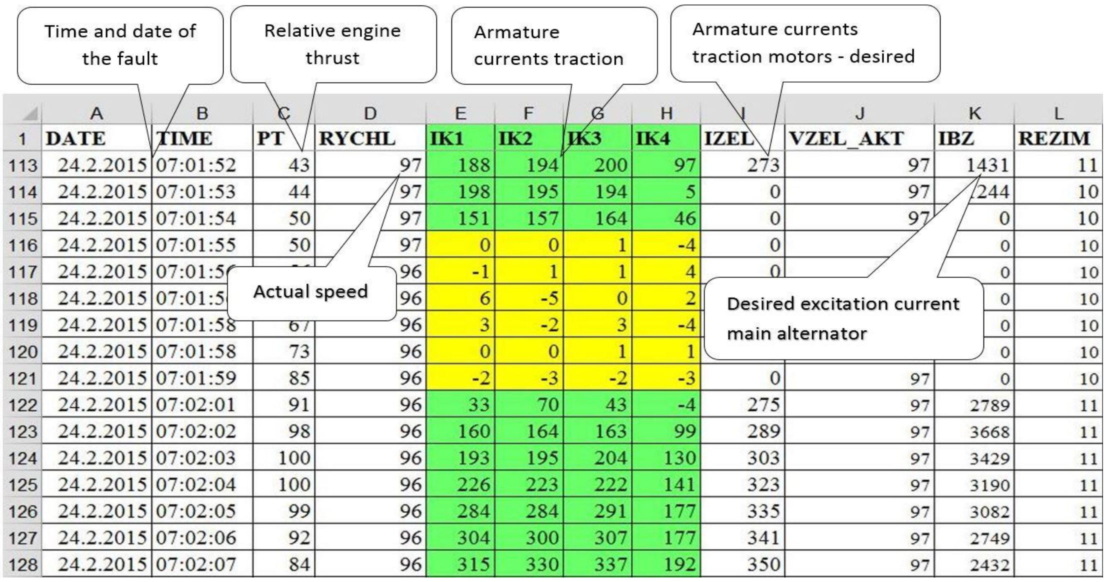
1	DATE	TIME	REZIM	PT	RYCH	ERR_NUM	ERR_KOD	ERR_PLACE	ERR_WIRE	ERR_POPIS
33	24.2.2015	07:01:52	0	44	97	068	NMS	RR-NR1	INT	Nesymetria kotvových prúdov
34	24.2.2015	07:02:09	0	62	97	068	NMS	RR-NR1	INT	Nesymetria kotvových prúdov
35	24.2.2015	07:02:22	0	100	96	124	BBT	RG-KA36	---	Blokovanie budenia trakcie
36	24.2.2015	07:02:25	0	0	95	027	[illegible]	RP-GV4	[illegible]	[illegible]ucha budiča 4MS-zablokovaná trakcia
37	24.2.2015	07:02:57	0	[illegible]	89	068	[illegible]	RR-NR1	[illegible]	[illegible]symetria kotvových prúdov
38	24.2.2015	07:03:17	[illegible]	51	89	068	[illegible]	[illegible]	[illegible]	[illegible]vých prúdov
39	24.2.2015	[illegible]	[illegible]	52	59	068	[illegible]	[illegible]	[illegible]	[illegible]vých prúdov
40	24.2.2015	[illegible]	[illegible]	47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]vých prúdov
41	24.2.2015	[illegible]	[illegible]	46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]vých prúdov
42	24.2.2015	[illegible]	[illegible]	61	97	068	NMS	[illegible]	INT	Nesymetria kotvových prúdov
43	24.2.2015	07:28:31	0	43	99	068	NMS	RR-NR1	INT	Nesymetria kotvových prúdov
44	24.2.2015	07:29:07	0	66	98	068	NMS	RR-NR1	INT	Nesymetria kotvových prúdov
45	24.2.2015	07:29:12	0	95	97	124	BBT	RG-KA36	---	Blokovanie budenia trakcie
46	24.2.2015	07:29:15	0	0	96	025	MB2	RP-GV2	CAN	Porucha budiča 2MS-zablokovaná trakcia

Fig. 2. Daily record disorders



1	DATE	TIME	PT	RYCHL	IK1	IK2	IK3	IK4	IZEL	VZEL_AKT	IBZ	REZIM
101	24.2.2015	07:01:40	27	97	149	159	159	122	229	97	1285	11
102	24.2.2015	07:01:41	27	[illegible]	157	156	153	113	229	97	1321	11
103	24.2.2015	07:01:41	27	[illegible]	152	154	152	122	229	[illegible]	1378	11
104	24.2.2015	07:01:43	27	[illegible]	157	154	158	49	[illegible]	[illegible]	[illegible]	11
105	24.2.2015	07:01:44	[illegible]	[illegible]	162	159	166	35	[illegible]	[illegible]	[illegible]	11
106	24.2.2015	07:01:45	[illegible]	[illegible]	159	171	172	27	[illegible]	[illegible]	[illegible]	11
107	24.2.2015	07:01:45	37	97	172	173	185	62	257	97	1543	11
108	24.2.2015	07:01:47	37	97	195	188	189	75	257	97	1463	11
109	24.2.2015	07:01:47	37	97	191	196	195	88	257	97	1354	11

Fig. 3. Values of the document "GRA"



1	DATE	TIME	PT	RYCHL	IK1	IK2	IK3	IK4	IZEL	VZEL_AKT	IBZ	REZIM
113	24.2.2015	07:01:52	43	97	188	194	200	97	273	97	1431	11
114	24.2.2015	07:01:53	44	97	198	195	194	5	0	97	[illegible]	10
115	24.2.2015	07:01:54	50	97	151	157	164	46	0	97	0	10
116	24.2.2015	07:01:55	50	97	0	0	1	-4	0	[illegible]	0	10
117	24.2.2015	[illegible]	[illegible]	96	-1	1	1	4	[illegible]	[illegible]	0	10
118	24.2.2015	[illegible]	[illegible]	96	6	-5	0	2	[illegible]	[illegible]	0	10
119	24.2.2015	07:01:58	[illegible]	96	3	-2	3	-4	[illegible]	[illegible]	0	10
120	24.2.2015	07:01:58	73	96	0	0	1	1	[illegible]	[illegible]	0	10
121	24.2.2015	07:01:59	85	96	-2	-3	-2	-3	0	97	0	10
122	24.2.2015	07:02:01	91	96	33	70	43	-4	275	97	2789	11
123	24.2.2015	07:02:02	98	96	160	164	163	99	289	97	3668	11
124	24.2.2015	07:02:03	100	96	193	195	204	130	303	97	3429	11
125	24.2.2015	07:02:04	100	96	226	223	222	141	323	97	3190	11
126	24.2.2015	07:02:05	99	96	284	284	291	177	335	97	3082	11
127	24.2.2015	07:02:06	92	96	304	300	307	177	341	97	2749	11
128	24.2.2015	07:02:07	84	96	315	330	337	192	350	97	2432	11

Fig. 4. Values of the document "GRA" – blocking the traction motors excitation

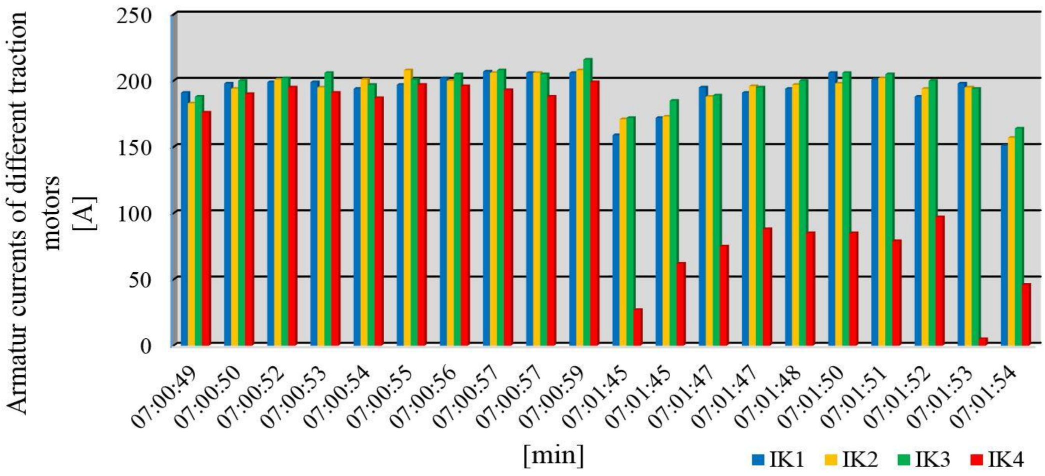


Fig. 5. Streams anchors traction motors – the emergence of disturbances

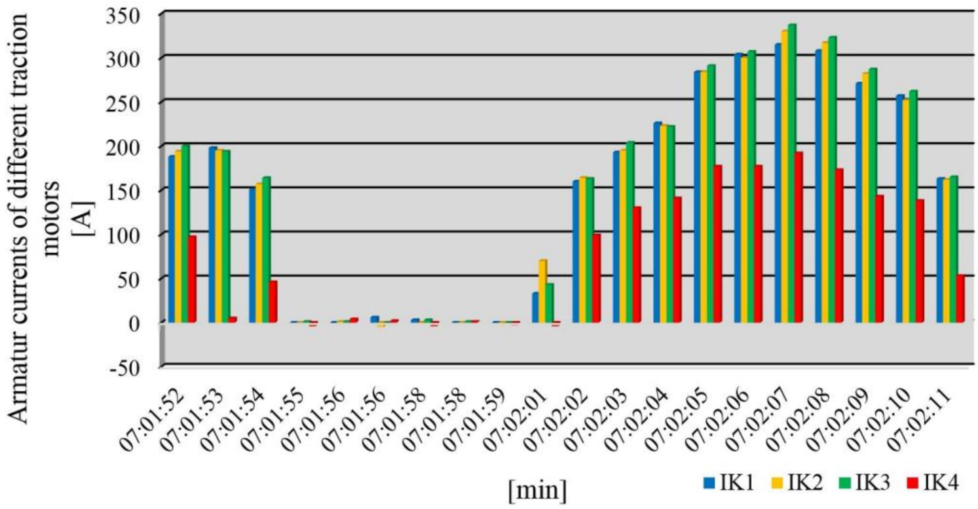


Fig. 6. Streams anchors traction motors - failure and unblock the excitation traction

Example file name:
GRA_240215_07, where is:

- > GRA – voltage and current data,
- > 240215 – date of the file: 24/02/2015,
- > 07 – hour of entering the record in the document (07:00 – 07:59).

In step 2 it is necessary to open the file named “ERR – Fault Data” (Tab 1). This file records all indicated faults that occurred while driving the locomotive on that day.

Figure 2 shows a part of the table of the daily “ERR” faults records dated 24/02/2015. On that day, a fault occurred that will serve us to show the fault diagnostic and solving procedures. This table clearly shows the time the fault occurred, the fault sequence number and other information needed for further action. As can be seen in Figure 2 the “Armature Currents Asymmetry” fault occurred at 7:01:52. This fault is repeatedly featured in the fault log with short time intervals. At 7:02:22 the control system recorded “Traction Excitation Blocking”. The “ERR” table features “Traction Excitation Blocking” repeatedly as well.

In next step will be selected the proper .xlsx file from which is able to read the data necessary to determine the specific cause of the locomotive fault. In this case, it is a document entitled “GRA” that is a recording of the currents and voltages in the locomotive electric system. Figure 3 shows a part of the “GRA” table. It is already known from the “ERR” file that the fault recorded by the locomotive control system occurred at 7:01:52. It may seem that the permissible difference in armature currents TM (2/3) was exceeded even earlier, for example at 7:01:43, but the control system has not yet evaluated it as armature currents asymmetry. This is due to a certain time delay being set. And also slippage is not evaluated as a fault.

At 7:01:55 there is another change in the “IK1 – IK4” values in the “GRA” table, as seen in Figure 4. The “IK1 – IK4” values at the above-mentioned time dropped to zero, which was caused by blocking the traction motors excitation. Excitation blocking can be seen in the “GRA” file also in the “IBZ” column – “Desired excitation current of the main alternator” that has a value of “0” at the de-excitation time (7:01:55 – 7:01:59). De-excitation can occur due to slippage and traction motors protection (overvoltage, asymmetry). In this case, de-excitation was caused by traction motors´ armature currents asymmetry. Subsequently, at 7:02:02 the control system unblocks the traction excitation again. As can be clearly seen in Figure 4, armature currents asymmetry persists and exceeds the permissible extent of 2/3.

Tab 1. File names of diagnosis

File name – abbreviation	Meaning
DO	Digital inputs
DI	Digital outputs
TPT	Analogue inputs
MEN	Converter data
BUD	Excitation data
KUR	Heating data
TRK	Traction data
CAT	Combustion engine data
ERR	Fault data
DAT	Train driver and train data
VYK	Performance data
ODP	Water resistance test data
GRA	Voltage and current data
GRB	Voltage and current data

In the case above, asymmetry and the subsequent traction excitation occurred repeatedly several dozen times throughout the locomotive ride. Each occurrence of this phenomenon was recorded by the control system as a repeated fault.

The cause of the recurring asymmetry was discovered after carrying out diagnosing and the follow-up inspection of the traction motors. The cause was the short carbon brushes on the fourth traction motor. These short carbon brushes could not to transmit currents large enough into the traction motor armature [14].

The values of currents on traction motors armatures in the “GRA” file may seem confusing. Therefore, these data can be displayed in a chart. Figure 5 clearly shows that in its first part the armature currents are approximately the same and the control system does not indicate a fault. After 7:01:45 there is a clear difference between the IK1 – IK3 currents compared to the IK4 current, resulting in indication of the “Armature Currents Asymmetry” fault. Figure 6 shows the course of excitation blocking on the traction motors armatures and their subsequent re-excitation.

Like in the “GRA” file values shown in Figure 4, also Figure 6 clearly shows that the currents on the fourth traction motor armature do not reach the desired values, and the fault manifests even after the control system intervention.

2.2. FAULT REPAIR PROCEDURE

When the “Armature Currents Asymmetry” fault occurs it is necessary to make the inside and outside inspection of the damaged traction motor. It requires dismantling of the service aperture covers – two are located at the traction motor bottom and another two at the traction motor top, performing a cooling function thermally stressed parts of the traction motor. The collection system is visually checked through the service apertures (Figure 7).

Fig. 7. Traction motor service aperture

This operation involves checking the carbon brushes (Figure 8), in particular their length and correct position, then checking the insulators whose surface needs to be inspected on any signs of destruction by stator current flashover, which is manifested as a ceramic material burn-off or destruction (Figure 9). It is also necessary to check the main and auxiliary stator poles (Figure 10), their loosening and connection burn-off [15]. Next inspection of mechanical damage is made on the armature together with the rotor and the traction motor insulation condition is also measured.

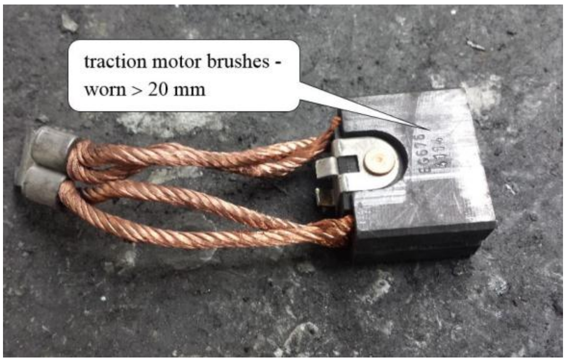


Fig. 8. Worn brushes traction motor

Checked is the traction motor inner parts cleanliness, especially moisture generated primarily during winter operation, which is caused by the intrusion of snow together with cooling air. This problem is treated during locomotive winter operating mode. Currently, the problem of preventing this disorder is being addressed in collaboration with the 757 locomotive traction motor manufacturer – ČKD Praha. New calculations are being carried out in order to reveal whether these traction motors are under-dimensioned or overloaded [7, 14].

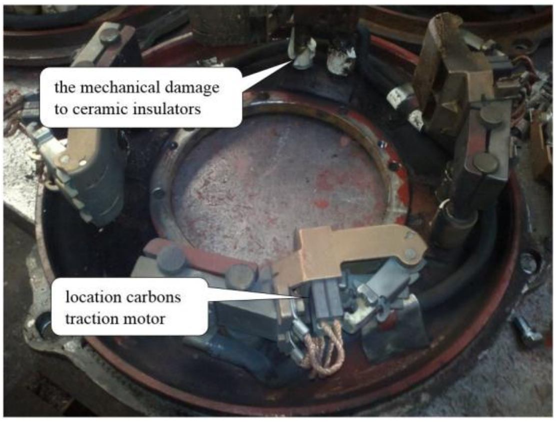


Fig. 9. Brush rigging of the traction motor (mechanical damage of ceramic insulators)

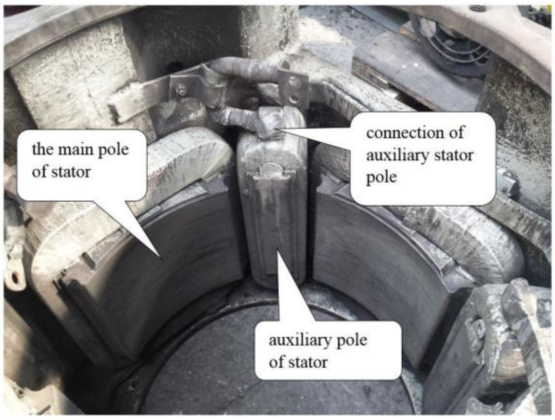


Fig. 10. Stator poles traction motors and their connection

3. SUMMARY

The 757 locomotives diagnostics defines a relatively large number of fault codes and the associated hierarchy of faults and causes. In order to better utilise diagnostics and understand the processes we have elaborated and drawn up several procedures aimed at rationalising the maintenance operations in a locomotive depot. Fault codes are divided into several groups according to the type of fault and functional unit in which the fault occurred. All divisions and tabular displays, together with the procedure to diagnose 757 series locomotives are summarised in a newly compiled handbook. In transport and traffic practice, this has created a significant paradigm shift in understanding, performing and utilising diagnostics, resulting in faster and higher quality performance of repair or maintenance of a fault or malfunction occurred on a 757 series locomotive.

Overall, a proper diagnostic approach – starting from the fault occurrence through to its elimination – requires an extensive, demanding and intensive process. When a fault message is generated and a diagnostic code is displayed, data downloading (collection) is done from the diagnostics memory. Such data are subsequently subject to analysis, which has several fixed steps. After analysing a number of files downloaded from the diagnostics memory the operator is able to determine the range of devices where the fault/disorder occurred, localise the fault itself, determine the severity of the disorder and recommend a preliminary repair plan and interventions. This leads primarily to a reduction in the locomotive downtime while under maintenance/repair, which also obviously increases the time of the locomotive on-track use and hence the effectiveness of its operation.

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