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Experimental research of electromagnetic minilifter working body gripping force determination

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Abstract
The method of carbody leveling when interacting of the tool working body and the leveling surface by means of electromagnetic interaction is considered in the paper. The system for electromagnetic force determination under different parameters such as working nozzle size of leveling metal thickness and lacquer coating thickness is presented. The empirical dependence of car leveling technological parameters impact on the leveling device working body gripping force was obtained.
Key words: LEVELING, CARS, CARBODY, MAGNET, FORCE

The number of cars is growing steadily around the world. The downward trend in private and commercial vehicles demand is not observed, and traffic infrastructure does not manage to react promptly to the increasing of traffic congestion growth rates. These factors lead to stepping up of the requirements for the drivers skill and, as a consequence, to the accident rate increase. [1]

The accidents, which do not threaten life of a person, are the largest share, more than eighty percent, i.e. they affect only the integrity of the vehicle [2]. As a result of such accidents, the car body is damaged, and in most cases, these damages are of small and medium nature [3].

In recent years, we can observe the growing of popularity of car body paintless dent repair methods. One of such methods is the dents repair using a set of minilifter and adhesive system [4]. After heating, the hot-melt adhesive, which has a property of liquid form taking at higher temperatures, is applied in the special hot air gun into a plastic adapter, which is fixed to the car body. After hot-melt adhesive final solidification, the minilifter, with which the damaged area is repaired, is attached to the adapter. The disadvantages of this method are mainly connected with the use of hot-melt adhesive in its composition. It requires the time expenditures for its heating and subsequent solidification. The remover, which is able to affect the lacquer coating, that is already unstable after the initial damage, is used for hot-melt adhesive removing from the carbody surface [5].

Thus, the repair services market is not flexible enough for meeting of the increasing demands of the modern automotive world. Consequently, fast and high quality carbody repairing without the need for subsequent painting is still a significant problem.

One of the most promising directions of paintless dent repair technology development is the use of an electromagnet as a working body; it carries out clamping to the carbody surface. The use of an electromagnet allows avoiding of lacquer coating damages, as the magnet affects the metal directly, leaving the of lacquer coating almost untouched. The magnetic minilifter significantly increases the reasonability of electromagnetic means and leveling methods commercial use, allowing eliminating of the need for aggressive solvents as well as accelerating of the repair process as a result of instantaneous clamping to the work surface [6, 7].

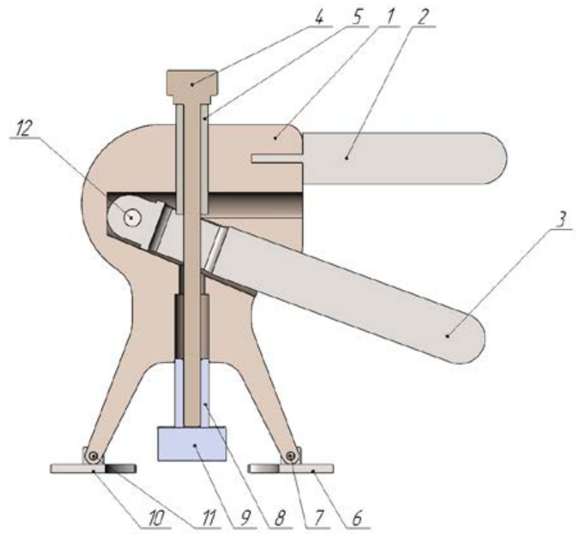

Figure 1. Minilifter internal design: 1 – body; 2 - fixed handle; 3 - movable handle; 4 -control bar; 5 – control clutch; 6, 10 - support points; 7, 11 - fixing screws; 8 - hold-down mechanism; 9 – magnet; 12 - grub screw

The tool is installed by support points 6, 10 on the processed body part surface. The magnet 9 is supplied to the working area and is fixed to the part surface by control bar 4. Then, the predetermined metal portion is straightened by the movable handle 3.

A series of experiments were conducted in order to detect empirical dependences for the working body nature and pressing force determination. In particular, the optimal parameters of adapters used for electromagnetic force transmission from the source to the part under repair were determined. Adapters are used in order to improve portability and convenience of the device as well as to adapt the device to the requirements of each specific body part.

Figure 2. Experimental facility and a set of adapters

The experiments were performed at the facility consisting of the milling machine, the strain sensor, the force indicator and the grip. The joist type strain sensor attached to indicating unit is secured by collet mandrel in the work spindle. The electromagnet is installed on the strain sensor body, and the tested sample is installed in the grip attached to the machine table. This unit is able to detect the table movement with an accuracy of 1 micrometer and determine the strain sensor force change with an accuracy of up to 1 gram which corresponds to the necessity of high-accuracy measurements.

The tested adapters had a length in the range of 5 ... 40 mm. As follows from the experiment, the data, which allowed describing of the dependence of the adapters length and its imparted force, were obtained.

The experiment showed that with the adapter length increase, its transmitted force is reduced. The clamping force sharp decrease, when exceeding of adapter length to 20 mm, allows determining of effective operating range of the length in the range from 10 to 20 millimeters [8].

After determining of the effective length range, the following series of experiments were carried out. The purpose was to find rational parameters considering generated forces and the adapter diameter. By analogy with the previous experiment, the adapter length was taken as 5 to 40 millimeters in order to facilitate calculations and obtain more accurate data. The results of the experiment allowed determining of the most efficient adapter diameter, in terms of force transmission, in the range of 10…20 mm [9].
Based on previous researches results, the adapter with a diameter of 20 millimeters and a height of 10 millimeters was selected for the further experiments, as it showed the most positive results in previous experiments.

The metal samples of various thicknesses ranging from 0.5 to 5 millimeters were selected for investigation of process material parameters impact on the electromagnet fixing force. The data obtained during this series of experiments outline a concept of correlation between the processed metal thickness and the magnet attractive force. During the experiment, it was determined that with the metal thickness increasing, the electromagnet holding force is also increased. In fact, this ratio is a linear dependence. The adapter tested in this series of experiments demonstrated holding force of more than 65 kilograms with the metal thickness of 0.5 millimeters, which is enough for performing of the required repair actions. With the subsequent increase of the metal thickness, holding force of the electromagnet is also increased. It should be noted that the thickness of the carbody metal is 0.5...1 mm in the vast majority of cars. Thus, the electromagnetic minilifter operating range coincides with the thickness of the metal used in the automotive industry.

A series of experiments, the aim of which was to determine the effect of the lacquer coating thickness on the electromagnet holding force, became the further development of experiments with the body material thickness.

The automotive enamel of popular brand was applied one layer at a time on the metal sample under investigation. After complete drying of each layer, the measurements were carried out. The paint thickness was controlled by thickness gauge. It should be noted that the lacquer coating thickness is 80-250 microns for 95% of cars.

Based on the above, the experimental matrix was made (Table 1).

No	Parameters				Test number			N_{cp}	$ln(N_1)$	$ln(N_2)$	$ln(N_3)$	$Ln(N_{cp})$
	D	H	T_m	T_p	N_1	N_2	N_3					
1	20	20	0.5	80	8.3	8.5	8.3	8.4	2.116	2.140	2.116	2.128
2	20	20	0.5	250	7.2	7.4	7.4	7.3	1.974	2.001	2.001	1.988
3	20	20	1	80	18	18.2	18.6	18.3	2.890	2.901	2.923	2.907
4	20	20	1	250	17	17.1	16.9	17	2.833	2.839	2.827	2.833
5	20	10	0.5	80	9.5	9.7	9.6	9.6	2.251	2.272	2.262	2.262
6	20	10	0.5	250	8	7.8	7.8	7.9	2.079	2.054	2.054	2.067
7	20	10	1	80	20.1	20.8	20.2	20.4	3.001	3.035	3.006	3.016
8	20	10	1	250	18.4	18.5	18.3	18.4	2.912	2.918	2.907	2.912
9	10	20	0.5	80	7.6	7.7	7.7	7.7	2.028	2.041	2.041	2.041
10	10	20	0.5	250	7	7	6.7	6.9	1.946	1.946	1.902	1.932
11	10	20	1	80	18.4	18.6	18.5	18.5	2.912	2.923	2.918	2.918
12	10	20	1	250	16.9	16.8	17	16.9	2.827	2.821	2.833	2.827
13	10	10	0.5	80	8.9	8.7	8.2	8.6	2.186	2.163	2.104	2.152
14	10	10	0.5	250	7.6	7.5	7.3	7.5	2.028	2.015	1.988	2.015
15	10	10	1	80	20.1	20.1	19.9	20	3.001	3.001	2.991	2.996
16	10	10	1	250	18.6	18.5	18.9	18.7	2.923	2.918	2.939	2.929

where D – nozzle diameter (mm); H – nozzle heigh (mm); T_m – metal thickness (mm); T_p – paint thickness (micron).

As a result of data processing, the empirical dependence of the effect of the car leveling technological parameters on gripping force of the working body leveling device.

$$y = e^{3,6548} \cdot H^{0,014} \cdot T_m^{1,2574-0,157\ln D} \cdot T_p^{0,0774\ln T_m - 0?07375}$$

Thus, the method of the carbody leveling when interacting of the tool working body and the leveling surface by means of electromagnetic interaction is considered in the article. The system for the electromagnetic force determining at different parameters is presented. The empirical dependence of car leveling technological parameters impact on the leveling device working body gripping force was obtained. This dependence allows determining of the force generated by the magnetic field if the parameters such as working nozzle size of leveling metal thickness and lacquer coating thickness are known.

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