DISTURBANCES CAUSED BY ELECTRICAL DOMESTIC EQUIPMENTS WITH UNIVERSAL FRACTIONAL HORSEPOWER MOTORS

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1. INTRODUCTION

Many electrical domestic equipments use universal fractional-horsepower commutator motors (coffee mills, vacuum cleaners, hair dryers, mixers etc.). As a consequence, it is suitable to analyze their electromagnetic compatibility, mainly owing to the great number of them [3], [4], [5] etc.

Universal fractional-horsepower motors (UFHM) utilization has got many advantages:
- very high speed can be obtained with their help (up to 20000 r.p.m or even 40000 r.p.m);
- they operates on both direct current and single-phase alternating current supply;
- the speed can be easily adjusted by varying the supply voltage or by introducing some supplementary resistances in one of the two windings circuit.

From constructive point of view, the universal fractional-horsepower commutator motors are very alike with the series-wound direct current motors.

The constructive differences occurring in comparison with series-wound direct current motors consist in:
- both the stator magnetic circuit and the rotor magnetic circuit are made of electrotechnical steel laminations;
- the number of turns supplied on d.c. is bigger than that of the turns supplied on a.c. (fig. 1).

![Fig. 1. Connection circuit of a universal fractional-horsepower commutator motor.](image-url)

The first of the previous features is given by the necessity to decrease the iron losses that might occur because both the stator and the rotor operate in variable fields.
The second constructive feature comes from the aim to draw near the mechanical characteristics obtained on d.c. supply and the ones obtained on a.c. supply, by modifying the number of turns.

Moreover, the excitation winding is usually divided up in two half-windings, from one side and another of the armature, aiming at decreasing the radio interferences caused by the motor.

2. A.C. OPERATION FEATURES

When connected to a d.c. supply, the universal fractional-horsepower commutator motors operates in the same way as series-wound d.c. commutator motors.

However, their a.c. operation involves some features detailed below.

1) The electromagnetic torque is positive, in the most part of the time. There are intervals when it becomes negative and the rotor slows down. However, the motor operation is not affected by the instability of the motor torque, owing to the important inertia moment of the rotating parts and to the high oscillation frequency of the torque.

2) Another functional feature of the universal fractional-horsepower commutator motors regards the armature reaction phenomenon in alternating current. In this case, because of $U_{eq}$, the power factor decreases $(\cos \varphi < \cos \varphi')$.

In order to remove this drawback, a compensation winding might be added in series with the other two windings. This winding will produce a magnetic field that will induce an e.m.f. in the rotor winding; this e.m.f. is equal and opposite to $U_{eq}$.

3) The third feature of the c.a. operation regards the commutation, that is worse than in d.c., because there is a supplementary non-balanced static e.m.f., dependent on the current frequency. This way, some radio interferences occur and it is imposed to use some supplementary filters.

4) The last feature of the a.c. operation is given by the mechanical characteristics shape (fig. 2).

Thus, the characteristics obtained in this case are placed under the characteristics obtained when the motor is connected to a d.c. supply. This distortion is caused by the influences of the two windings inductivities.

As a consequence, if the same rated speed is wanted in a.c. as in d.c., the excitation winding number of turns is decreased by means of some intermediary coil taps (fig. 1). This decrease causes a decrease of the inductor flux and, this way, the speed increases.

3. UNIVERSAL FRACTIONAL-HORSEPOWER COMMUTATOR MOTORS AS DISTURBANCES SOURCES

This paper refers to the commutation phenomenon (fig. 3) that transforms the universal fractional-horsepower motors in possible disturbances sources.

Thus, during the commutation, some fast current variations occur in the windings and in the connection conductors.

If the current is not null at the separation between the brushes and the commutator segments, it will be kept by an electric arc, similar to all the contacts opening on load.

A fast current variation $di(t)/dt$ occurs when the electric arc is interrupted. This induces some self-induction voltages in the inductivities L placed on the current path and mutual induction voltages $M_i/dt$ in the adjacent current paths.

The local limitation of the disturbances is possible by connecting some concentrated inductivities (in series with the supply conductors) and a by-pass capacitor (in parallel with the brushes).

In case of the universal fractional-horsepower commutator motors rated at higher powers, auxiliary poles and compensation winding are necessary; they induce some e.m.f. in the commutating windings and
these e.m.f. are opposite to the existing ones; this way, they improve the commutation.

Other methods are also available for improving the commutation [1]:
- brushshifting from the transversal axes;
- decreasing the number of turns per section;
- choosing some adequate brushes.

4. IMPROVING THE ELECTROMAGNETIC COMPATIBILITY

Some specialized circuits, called filters, might be used for improving the electromagnetic compatibility.

As known [7], the filters damp the disturbances, without influencing the useful signal.

This requirement might be fulfil by:
- adequately choosing the cutting frequencies;
- adequately choosing the transfer functions slopes.

The filters operate by the following principle: their passive components together with the sources and receivers impedances form voltage dividers; the division ratio, dependent on frequency, is the real attenuation of the filter. This ratio might be increased though in case of high frequency, the internal impedance of the disturbances source does not enable an efficient voltage division by connecting some series inductivities.

The basic components of the filters are the longitudinal impedances - for the work current and the transversal impedances - for the operation voltage, both of them having a preponderent reactiv character.

The following notations have been used in the previous figure:

- $U_p$ - disturbing voltage;
- $U_{util}$ - source voltage (useful signal);
- $Z_i$ - source internal impedance;
- $Z_R$ - receiver impedance;
- $U_{pR}$ - disturbances voltage (level) at receiver;
- $Z_t$ - transversal impedance;
- $Z_l$ - longitudinal impedance.

If the source useful signal attenuation is neglected the disturbances attenuations are obtained for three situations [7]:

$$\alpha_F = 20 \log \left( \frac{U_p(\omega)}{U_{pR}(\omega)} \right) = 20 \log \left( \frac{Z_i + Z_t + \frac{Z_R Z_l}{Z_R + Z_l}}{Z_R + Z_l} \right)$$  \hspace{1cm} (1)

$$\alpha_F = 20 \log \left( \frac{U_p(\omega)}{U_{pR}(\omega)} \right) = 20 \log \left( \frac{Z_i + \frac{Z_R Z_l}{Z_R + Z_l}}{Z_R Z_l / (Z_R + Z_l)} \right)$$  \hspace{1cm} (2)

$$\alpha_F = 20 \log \left( \frac{U_p(\omega)}{U_{pR}(\omega)} \right) = 20 \log \left( \frac{Z_i + Z_l + Z_R}{Z_R} \right)$$  \hspace{1cm} (3)

As noticed, the attenuation of the filter (of the disturbances) depends on frequency.

5. CIRCUITS

The following circuits have been used to study the disturbances caused by universal fractional-horsepower motors, with and without filters.
The following notations have been used in the previous figures:

F – filter;
MU – universal fractional-horsepower commutator motor.

As noticed, two types of filters have been used - “Π” type and “T” type.

The capacitor \( C_r \) provides a path of low impedance for the disturbances coming from the supply network. This way, the current test probe of the measuring device is only crossed by the distorted current caused by the universal fractional-horsepower commutator motor [2], [6].

The measurements have been performed by a harmonics analyzer, Fluke 41B [8].

In order to follow the system operation there has been used a specialized program; its interface is depicted in the following figure [9].

The main options of this menu carry out the functions filled in the following table.

<table>
<thead>
<tr>
<th>No.</th>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>File</td>
<td>Open, save and print files.</td>
</tr>
<tr>
<td>2.</td>
<td>Edit</td>
<td>Copy data in clipboard.</td>
</tr>
<tr>
<td>3.</td>
<td>Display</td>
<td>Display data, catch characteristics.</td>
</tr>
<tr>
<td>4.</td>
<td>Control</td>
<td>Form and test communication, fix tester.</td>
</tr>
<tr>
<td>5.</td>
<td>Options</td>
<td>Change type, labelling and scaling options.</td>
</tr>
<tr>
<td>6.</td>
<td>View</td>
<td>View data in Volt, Ampere or Watt.</td>
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<tr>
<td>7.</td>
<td>Phase</td>
<td>Select way for reading data at multimeter.</td>
</tr>
<tr>
<td>8.</td>
<td>Logging</td>
<td>Log data for multimeter Fluke 41B.</td>
</tr>
</tbody>
</table>

6. EXPERIMENTAL RESULTS

The following experimental results have been obtained by performing experimental tests with a motor for a coffee mill (figs. 9, 10 and 11).
CONCLUSIONS

1. As noticed in figure 9, the disturbances caused by commutation are important. When the motor is directly supplied, the content of the superior harmonics reaches 27%.

2. As noticed in figures 10 and 11, the filters lead to a decrease of the superior harmonics in the current curve.

3. The most favourable operation is obtained for the case when a "Π" filter is used. In this case, the distorting residuum has got a value of 11%.

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