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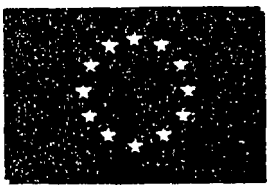

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NEW ELECTRIC MOTORS TO REDUCE THE COPPER CONTENT IN SCRAP IRON COMING FROM CAR RECYCLING - EMRECOI,

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ABSTRACT

Two different studies have been carried out to reduce the copper content (derived from electric motors) in steels obtained from the crushing of vehicles that have reached their life's end.

- One is aimed at replacing the copper windings by aluminium wire.

The other one is. aimed at replacing the steel metal magnetic circuit by a soft friable magnetic circuit in order to ensure systematically the separation of steel and windings.

Two major difficulties have been overcome :

The quality and reliability of the aluminium wire and copper commutator bond;

The mastery of the magnetic and mechanical characteristics of the soft friable material..

At the same time, a modelling tool coupling up the thermal and electromagnetic aspects has been developed and validated on the products of the study.

1. INTRODUCTION

In automobile construction, the purpose of recycling steels obtained from vehicles that have reached their life's end comes up against the problem of the insufficient quality of the products obtained. The objective is to reach a copper rate below one per thousand in mass, limit beyond which steels are unsuitable for stamping.

The excessive copper content, essentially derived from the windings of the numerous electrical slaving motors fitted to the vehicles, means that they are unsuitable for use in flat products (sheet metal for stamping).

Because of the increasing number of cars to be recycled and the considerable increase of the equipment factor, and therefore the number of electric slaving motors, in particular on top-line models, the future situation is worrying since the weight of copper could triple in recycled steels, compared to the current situation, which is already 3 to 4 times above the maximal tolerance.

Without any reconsideration of the vehicle crushing installations, the main purpose of the research project was to design, for application to automobile, electric motors whose armatures (supporting the windings) will not pollute the recycled steels. Furthermore, it is obvious that these "new" motors will have to fit the current requirements, including with regard to their weight, cost, performances and adaptation to the mass production . . . .

These new motors have been classified in two different categories :

Long or permanent operating motors (cooling, heating, wipers, ABS, etc...).

Intermittent operating actuator motors (power windows, seats, centralized locks, washer pumps, etc...).

Whatever the category, motors are of the "continuous low voltage permanent magnet" type with commutation either classical (brush/commutator system) or electronic (brushless).

2 . LONG OPERATING MOTOR

Because of their use, these motors need high efficiency, close to 70%. In general, the power is high and falls between 250 and 600 W. The solution used for this type of motor is that of developing for the armature a soft ferrite material and its implementation technology with magnetic characteristics (permeability, saturation induction) close to those of cut sheet mild steel used today, whose fragility and impulse breakage mode are controlled.

The motor made up in this way is tough enough to meet basic utilisation conditions and fragile enough to break under the effect of the violent impact of the crusher, making it easy to separate copper from iron.

2.1 FRIABLE SOFT MAGNETIC MATERIAL

Several" approaches have been contemplated. Yet, the basic points of the works have been focused on the elaboration of a compressed powder and binder-based material.

Because of the research delays, the idea of developing a specific basic material of the ferrite or ceramic type has been swiftly given up for the benefit of the pulverulent products from the stores of which an non-exhaustive list is given below-

PROPERTIES TABLE OF THE USABLE MATERIALS FAMILIES-

	0 s (T)	μ	Hc (Am-I)	Losses (W.kg -1)	f use (Hz)	Mechanical properties
Reference	2	3940 fr 1Hz 1000 fr 100Hz	315 fr 1 Hz 1000 fr 100 Hz	< = 50 to 1.5T. 100Hz	0 to 100	Bound during implementation
Iron and little alloyed iron	1.6 to 2.5	μmax 8000	6 to 50		BF	
Silicon iron oriented or no	2102.15	eq. Fe good	6 to 10 fr orient. 20 to 100	3.1 to6 :o1.5T, 50 Hz	BF	f > 4.5% weaken drop ageing
Al 16% maxi	"	"	"	"	BF	
Nickel-iron Ni36 or Ni50	0.8 to 1.6	2000 to 12000	1 to 55		"	Rm 700 to 2000 Mpa
Iron-cobalt	1.9 to 2.4	5000 to 12000	35 to 150	3 to 9.5 fr 50 Hz	BF	
Magnetic stainless steels	about 1.8	5000	80			
Powder carbonyle iron	1.56		1200		High	
Microcristallins Fe-Si 3%	2 to 2.15		20 to 100			
Amorphous MT-Fe 81-Co/Ni	0.8 to 1.6	> 1000	1 to14	0.2		Quench gives fragile bands
Amorphous FeSi 3.5 to 13)	1.2 to 1.6		6 to 16			Quench gives fragile bands

Three technologies of implementation have been tested :

- Compression molding
- Traditional sintering
- Metal injection molding (MIM)

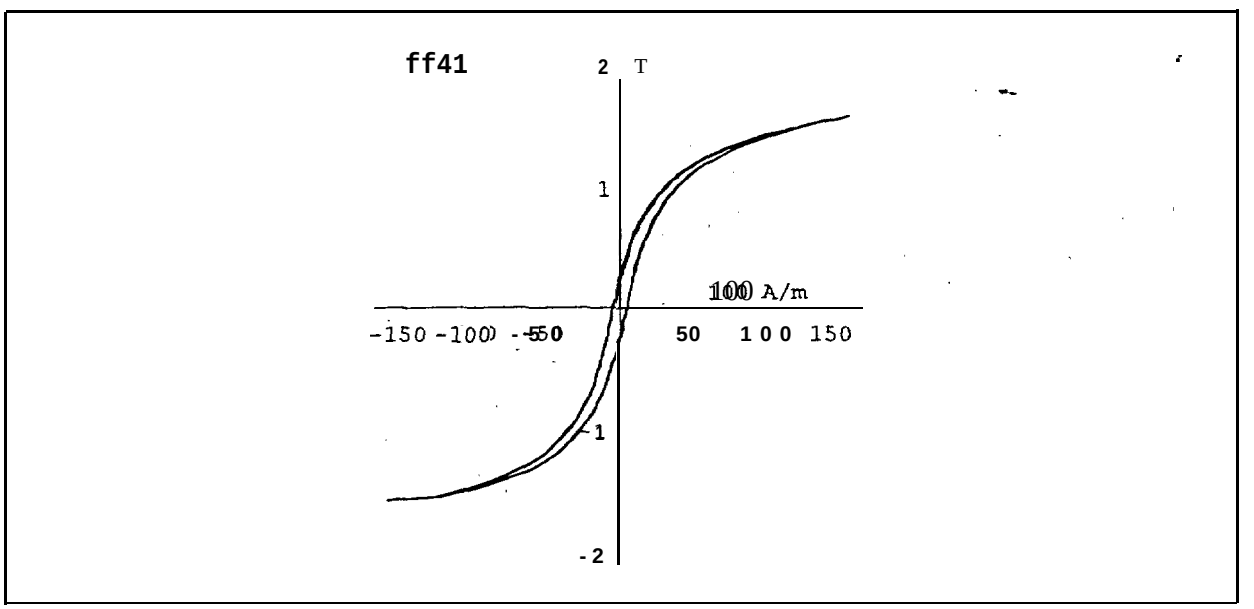
according to the following combinations :

	MATERIALS					
M.O PROCESS	CHARGES			BINDERS / INSULATORS		
	'metallic	ceramic.	without	superficial oxidation	organics	minerals
Compression	x	x	x		x	x
Sintering	x	x	x	x		
MIM	x	x		X	X	

Composite materials gave the best results because sintering does not allow a sufficient mastery of electromagnetic parameters and Injection Molding of metallic powder is so far only adapted to small parts (a few cm3).

As far as magnetic field is concerned, the highest-performance: composites are made of a mixture of iron powder which granulometry is below 500 microns and polymeric resin which rate does not exceed 390.

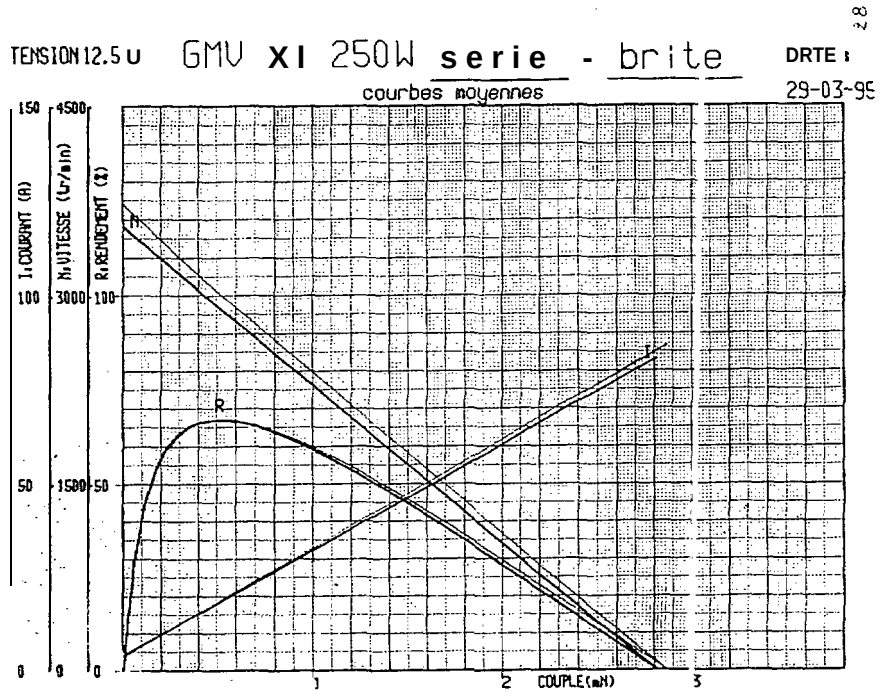
On the other hand, it has been more difficult to adjust the mechanical characteristics without altering the composite electromagnetic properties. Optimum has been reached only after implementing a large experiment plan taking more particularly into account the size and geometry of powder grains, resin types' and rates, compaction pressures, as well as cooking time and temperatures. The best products we currently have at our disposal is characterized by the curve below and perfectly suits the aimed applications.



2.2 RESULTS

Every prototype made with the dimensions of the current standard product has successfully been subject to the different tests of the requirements :

- Electromechanical tests (See curves below)



- Ageing tests

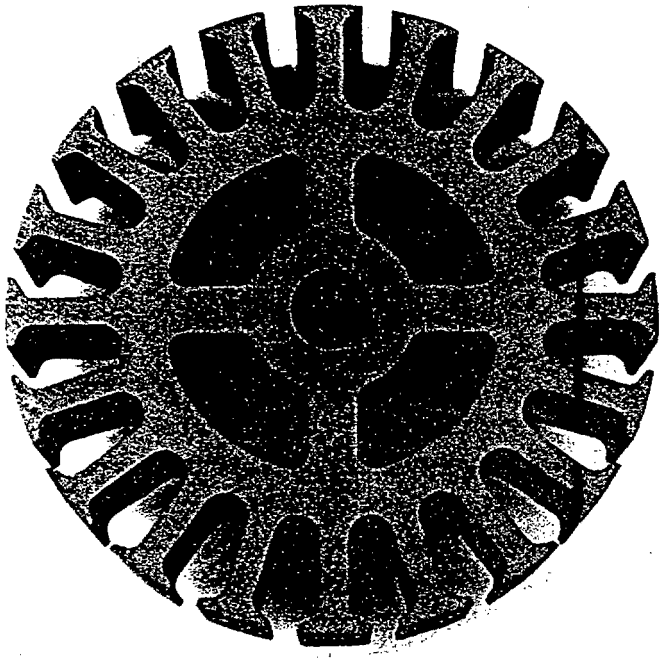
- Endurance tests (automobile requirements)

- Crushi ng tests (see pictures)

2.3 CONCLUSION

The objectives of the research program have been reached and checked on dozens of motors and part of them have been tested in a factory on mass production equipment.

The friability of powerful electric permanent operating motors with high efficiency (for this type of motor) has been proved. Nevertheless, it would be regrettable to confine ourselves, like the study does, to purely and simply substituting the armature magnetic circuit. This molding offers possibilities that widen the field of improvements as the scooped out armature testifies (below picture) ; It is not an overstatement to say that this new concept of magnetic circuit opens the way to new generations of electric motors.



3. *INTERMITTENT* OPERATING MOTORS

This type of motor is satisfied with a lower efficiency which is about 50%. Because it generally turns quicker than the M 1 motor, it is very often combined with a speed reducer. The power is of the order of 100 W.

For this type of motor, the project consisted in replacing the copper wire of the winding by a non-polluting conductive metal. Aluminium has been chosen because its fusion point is very far from that of steel and also because steel makers do not dread the presence of this metal in recycling steels.

3.1 Aluminium wire / copper commutator soldering technologies

It was the major problem to resolve in this research' program, less because of the soldering technique than more specifically because of the quality and durability of the winding / commutator wire bond-

Three different technologies have been examined

Traditional electric soldering with resistance

- Soldering with laser beam

Soldering with ultrasonic sounds

As for soldering with laser beam, the research did not go further than the feasibility. The very big difficulties inherent to the coefficient of reflection for materials to be soldered involve the implementation of means totally out of proportion with regard to stakes. Moreover, the fusion temperatures differential between wire and commutator leads to a near impossibility with the technique currently known (see the BRITE Program, JOCAL N° 0164 on this matter).

Soldering with ultrasonic sounds presents many potentialities, but after several months of works, this track could' not be brought to completion.

Nevertheless, the results that have been achieved are interesting.

With a Ø 0.6 mm 180°C isolation class wire soldered on a copper plaque with the same characteristics as" the commutator, soldering supported a traction superior to 25N... and the resistance of contact was excellent.

3.2 Conventional electric soldering bond

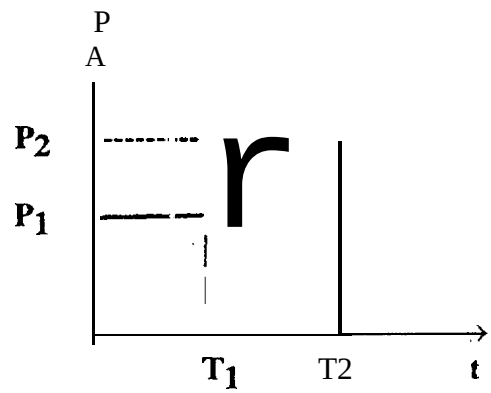
The study has been carried out through an experiment plan focused on more than 10 " parameters. It swiftly turned out essential to perfectly master the soldering energies which are the major entry parameters (see below graph).

T1 = Duration of the 1st soldering

P1 = Power of the 1st soldering

T2 = Duration of the 2nd soldering

P2 = Power of the 2nd soldering



Therefore, the implementation of the soldering has been carried out by means of a special machine with rectified current and piloted in closed loop. These soldering specific works have been completed systematically by a search for suiting the aluminium wire, for mechanical, dielectric as well as thermic characteristics. It was not possible to maintain the same bending coefficient of wires under the hooks as for coppe . Yet, as below pictures show it, the results are satisfying.

Photo 7
Copper wire

Photo 8,
Aluminium wire

Save the aluminium fragility, the soldering perpetuity quality is jeopardized by two phenomena well known at the chemical (battery effect) as well as at the mechanical level (differential of the expansion coefficients of both materials).

Mastering these phenomena was the subject of a careful attention through tests specifically created for the need. It appears that with products from the stores and a good master of the soldering, we achieve decent results. Supply metals like pewter and (or) the use of appropriate protection resins are sufficient to master the degrading phenomena.

3.3 Dimensionality and tests

Considering the aluminium inferior properties compared with copper, prototypes motors had to be extended to provide the same exit characteristics.

Several dozens of prototypes have been achieved with standard means and subject to the usual tests of the automobile requirements. The rate of success is more than decent since 85% of the products are successfully subject to endurance tests of the automobile requirements.

All the other tests, electromechanical characterization, starting, vibration, corrosion..., have been Achieved successfully by every motors.

3.4 Conclusion

We could be disappointed to see that only 85% of the prototypes *have* successfully achieved endurance tests. It is yet outstanding to notice that 97% of them are quite close to the purpose. Furthermore, no deterioration has been noticed " 'under the hooks", contacts . have kept their original quality.

4 ELECTROMAGNETO-THERMIC MODELLING

Simultaneously and complementarily to works on Ml and M2, a calculation model has been developed so that electric motor makers have at their disposal a new conception tool that would take into account new materials used and coupling up both electromechanical and thermic aspects. This developed tool is an innovation in this branch of activity.

Every definition electromagnetic and mechanical calculations of the program have been achieved with the developed model. The results enabled the validation of the tool which is currently operational. In relation to other existing models on the market it has the advantage of being particularly easy to use and suited to the research department needs of which it uses the usual approach language. The thermic model has not been totally validated during the study-period. Yet its implementation is carried on until complete satisfaction.

5. GENERAL APPRECIATION

The two examined approaches for electric motor recyclability enable to have solutions that can be applied in the industrial field at a rather short term. Although the friable armature motor is developed within the automobile sphere of application, it can represent interesting appropriateness in other spheres of activity, like domestic appliances. It can also, thanks to the flexibility of the material implementation, open the way to new concepts of motors.

At last, the' calculation model gathering both electromechanical and thermic aspects will be, after it is validated, a strategic tool allowing cost and delay decreases in relation to traditional solutions, while improving the quality of the definition of new products.

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We also wish to thank Mr. Alain ADJEMIAN, our project officer for his advises and help which allowed a efficient work in a total clarity and trust climate.

These great European programs also have to their credit other aspects, less immediate, such as acquiring efficient and rigorous methods of working, bringing together the partners and a wider opening to European realities.

Every partner wishes he could 'take part soon in a new. '' European adventure".

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