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CRAFT PROJECT CR-1043-91

Contract N°. BRE2 CT92 0406

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**SYNTHETIC DIAMOND WIRE FOR STONE  
CUTTING**

**SYNTHESIS FINAL REPORT**

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## L-INTRODUCTION

This Technical Work corresponds to the **last** Summary Progress Report to be delivered by the **RTD** performers and it reflects the investigations carried out **along** the duration of **the** CRAFT Project 1043: “SYNTHETIC DIAMOND WIRE FOR STONE CUTTING (Contract No. **BRE 2 CT92.0406**).

Due to the complementary characteristics of the **RTD** performers -Hedisa **S.A.** and Universidad de **Valladolid**- it was agreed that a joined effort and a close work collaboration during the **21** months of the Project was necessary; this implied altering the rigorous separation of tasks specified in the original Project.

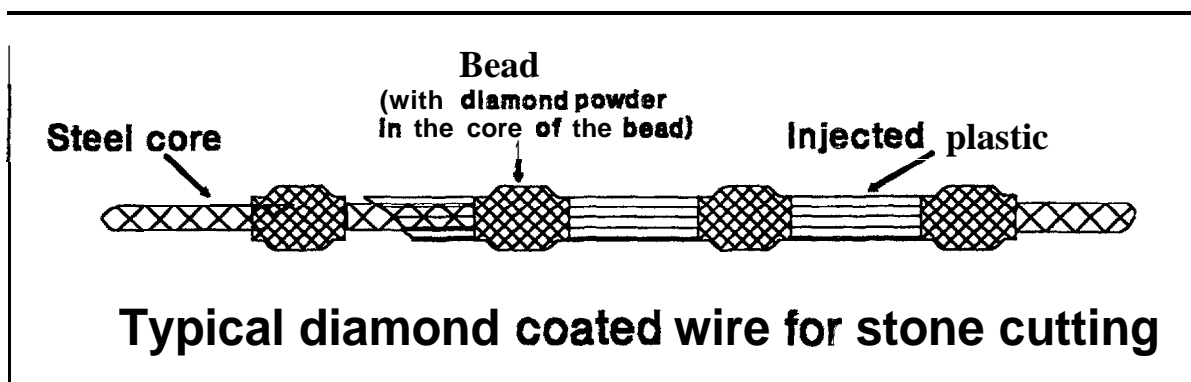
The **results** which are shown next, correspond to the technical contents of the original project (designated as tasks 1.1,1.2, 1.3,2 and 3).

## 2.-STATE OF THE ART

The main objective of the programmed research was the optimization as **well** as the development of the design and the manufacturing process of **a** cutting device for ornamental stones and concrete.

### **2.1.- TOOL DESCRIPTION**

The practical tool, known as “Diamond Coated Wire” or “Synthetic Diamond Wire”, consists on a series of periodically placed beads along a **closed loop** cable, partially covered by an elastomeric plastic. The plastic protects the wire and keeps a constant separation between the beads. Such is shown in **Figure 2.1**.



**Figure 2.1:** Synthetic Diamond Wire for Stone Cutting

It is the hardness of the diamond contained in those “beads” what allows to cut through the rocks or concrete. The diamond may be electroplated over a metallic ring or embedded in such a ring through a **pulvimetallurgical** process. This is achieved by **pressing** and posterior sintering of the diamonds together **with** the metallic powder (normally cobalt and tungsten carbide).

## **2.2.- RANGE OF APPLICATIONS**

Nowadays, we find three main **fields** on which the *Synthetic* Diamond Wire can be used. We will now briefly go through each of them.

- A. The first of this **fields** are the quarries of ornamental stones (slate, granite, marble and sandstone mainly). The Diamond Coated Wire is used here for the extraction of big stone blocks which are afterwards distributed to the customers for its further processing,
- B. The second field of application of this technique is the transformation of the big **blocks** obtained in the quarry into **smaller** pieces. Though such pieces are usually plaques of constant thickness, more complicated shapes may be obtained if the movement of the **bedplate** at the machine is controlled by means of **a** numeric control program,
- C. The last possible application of the Diamond Coated Wire is in the field of civil engineering. Some examples of the use of the tool for this purpose are: partial building demolishing, cut of underwater columns holding a pier at a **harbour**, or the elimination of the extra reinforced concrete columns used to hold highway bridges or railway lines before they harden, Such columns are neatly cut and may **be** used somewhere **else**.

## **2.3.- THE NATURAL STONE SECTOR IN SPAIN AND CASTILLA Y LEÓN REGION**

Cutting with a diamond coated tool is a modern technique widely employed in some European and Middle-Eastern countries. Its use is potentially important in **CASTILLA Y LEÓN** (Spain), **a** region where great reserves of quality granites, slate, **marble** and sandstone can be found. Consideration should also be given to the fact that the field of the ornamental stone could become an alternative to the currently depressed agriculture and coal mining sectors. As an example, it is enough to say that, such a region concentrates **40%** of the **slate** extraction in Europe.

In order to highlight the importance that the natural stone sector is achieving in Spain, tables of production and consumption are included below :

## GRANITES

Year	Production	Imports	Exports	National consumption
1986	30.311	2.211	7.541	24.991
1987	34.148	2.917	8.871	28.194
1988	49.000	3.345	9.049	43.296
1989	56.511	4.624	11.482	49.648
1990	71.578	6.053	11.268	66.353
1991	62.623	6.676	11.891	57.408
1992*	54.136	6.543	11.031	49.648

## MARBLE

Year	Production	Imports	Exports	national consumption
1986	30.690	2.795	4.141	29.344
1987	34.400	3.838	4.548	33.744
1988	68.661	6.030	7.650	62.037
1989	93.732	8.622	10.503	91.851
1990	134.746	10.513	10.711	134.548
1991	111.750	12.244	10.429	113.565
1992*	104.778	7.117	16.606	95.289

Year	Production	Imports	Exports	consumption
1986	11.004		3.588	2.716
1987	13.394		10.892	2.502
1988	17.441		14.571	2,870
1989	20.525		17.510	3,015
1990	22.180		18,997	3,183
1991	20.950		18.880	2.070
1992*	23.440		20.369	3.071

Value: in millions of pesetas  
 \*Provisional data  
 Source: Customs General Direction

In summary, exports in the natural stone sector during the last year reached a total value of 48,006 million pesetas, mostly to EU members (about 70% of the exports). There is tendency to a continuous growth in the sector despite the recession suffered in the national economy in recent years.

#### 2.4.-ECONOMIC AND INDUSTRIAL BENEFITS

There are many advantages in using a diamond coated tool for cutting in quarries or in construction. The technique, even with a wire not fully optimized, is extensively applied for cutting calcarean as well as magmatic materials or materials of metamorphic origin, Now, we will review some of them:

- A. If a comparison is made with other more complicated and destructive methods, such as cutting by means of a "hot dart" or explosives, the wire produces low noise, dust and vibrations, Therefore, it allows the exploitation of quarries next to residential areas and improves the working conditions,
- B. Further more, the rock immediately close to the one being cut suffers no damage and all sides of the block extracted are flat, This eases their transportation and, consequently, productivity and efficiency are maximized.
- C. Concerning the labour force, and comparing with other methods such as the pneumatic discontinuous drilling or splitting using low speed explosives, the Diamond Coated Wire method is simpler; it is relatively easy to train workers coming from other depressed economic sectors, Even more, this technique is not labour intensive, which means that the workers may start the machine and leave it alone doing its work, while they do something else, The risk of accidents and implicitly the labour compensation costs are also be reduced,

- D. The cutting speed achieved with this technique is much higher than that offered by other systems, **allowing** higher output and profits. Studies **about the** economic benefits derived from the increasing use this method have been reported. They are based on the cost by square meter for cutting different materials and the evaluation of the cost of extracting a cubic meter using **traditional** methods'. **The results** obtained are best when using the diamond coated wire, specially when cutting marble and other soft natural stones (slate and sandstone), but also when cutting granite. ..-
- E. Finally, it must be mentioned the lower impact in the environment derived from cutting with this tool compared with that derived from using other methods. The extraction of large volumes of rocks in quarries has led to an argument between industrial needs and the prejudice caused to the environment. It is sad to visit **an** old quarry in which an old fashion cutting technique has been in use. **Undoubtly, the** diamond coated wire **will** greatly reduce the mentioned harm on nature,

The mentioned advantages, make this technique more and more popular among the quarriers. However, in our opinion, it is not used in optimal conditions.

### **3. OBJECTIVES AND EXPECTED RESULTS OF THE PROPOSED RESEARCH**

The purpose of this project is to develop a wire with indented parts of synthetic diamond that will permit the cutting of several kinds of stones, This kind of tool has been successfully applied with marble but the performance with other stones, which are the target of this research, is not high enough. These stones are harder or more abrasive than marble.

The objectives of the original project can be summarized as follows:

- A. Improvement of efficiency: 30-40 % with granite and 40-50 % with slate.
- B. Increment of cutting speed: 20540
- C. Reduction of current manufacturing costs by 25 %, by reducing raw materials costs and increasing production yields.
- D. Reduction of the number of failures and repairs needed before the wire ceases to be useful.
- E. Recycling of residual diamond particles.
- F. In conclusion: a reduction superior to the 50 % in the global cost for the user.

The **final** aim of this project would be to obtain a new tool in a pre-competitive stage, ready to be manufactured and used by industrial companies.

## 4.- BACKGROUND AND STATUS AT THE BEGINNING OF THE RESEARCH

In this epigraph, we will approach the study of some technical characteristics of the Synthetic Diamond Wire. More specifically, we will focus on the deficiencies identified on the tool at the start of this research, as well as on its initial yields.

### 4.1.- IDENTIFIED DEFICIENCIES FOR SYNTHETIC DIAMOND WIRE

The problems described below, appear during service, both all together and isolated. The appearance of one or more of this drawbacks would reduce the efficiency of the tool:

- A. Non optimized manufacturing processes.
- B. Difficulties when having to decide which composition of the beads was appropriate for the type of stone to be cut.
- C. Radial and axial shifts of the beads along the steel cable.
- D. Separation of the sintered powders from the carrier which holds them.
- E. Uneven and non concentric wear of the beads in zones or all along the wire,
- F. Failures at the junction of the two ends of the wires,
- G. Difficulties when starting the cut with a new wire.
- H. Cable breaking.

### 4.2.-INITIAL PERFORMANCE DATA

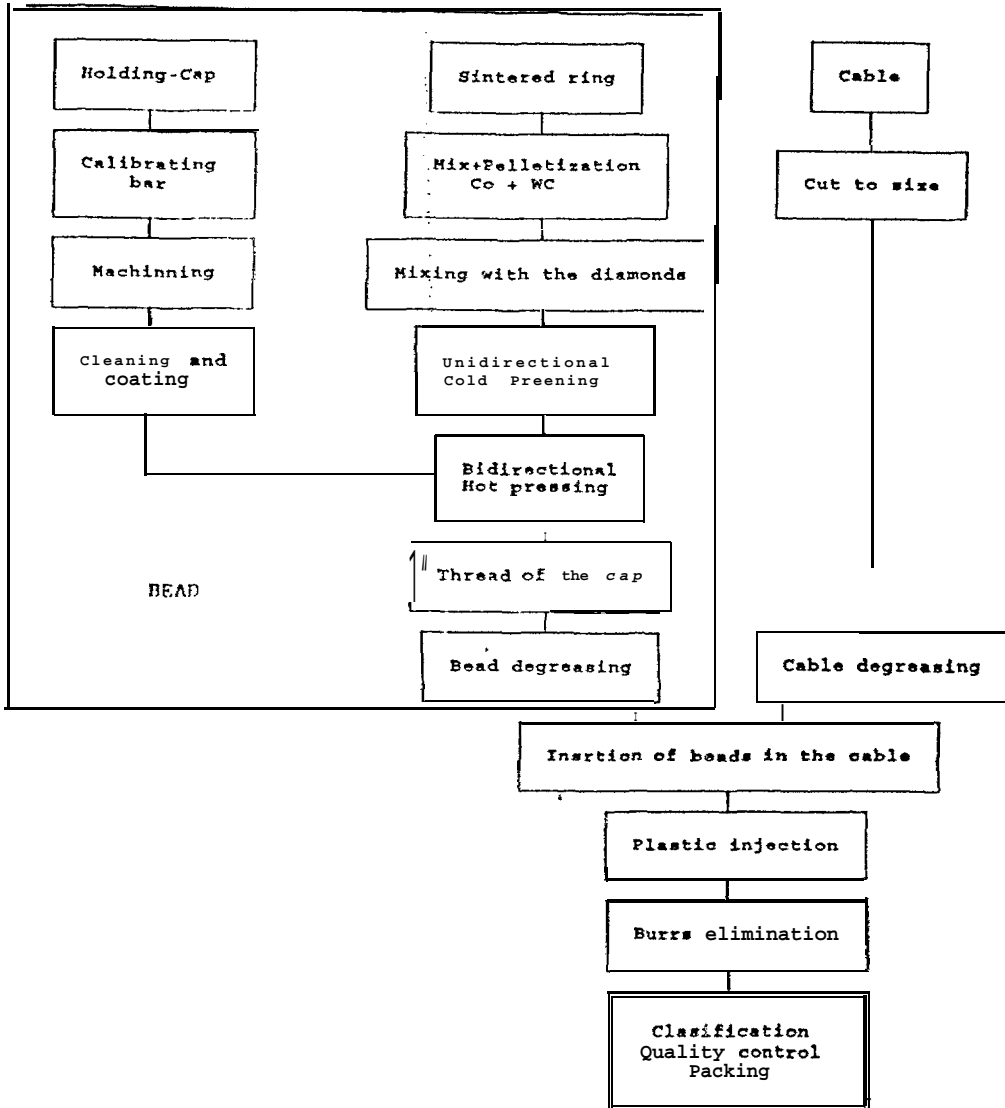
Some initial performance data for different types of materials is gathered in the following table:

MATERIAL	CUTTING RATE (m <sup>2</sup> /h)	WIRE LIFE (m <sup>2</sup> /m)
Granite	2	6
Slate	6	13
Marble <sup>1</sup>	8-16	20-35
Marble <sup>2</sup>	6-8	30-50

- 1. Electroplated bead
- 2. Impregnated bead

## 5.- DESCRIPTION OF COMPONENTS AND MANUFACTURING PROCESS OF THE SYNTHETIC DIAMOND WIRE.

The general procedure when manufacturing the Diamond coated wire is summarized in the following Mock diagram :



According to the description of a Diamond Coated wire provided in section 2.1 of this research, and to the manufacturing process described on the previous block diagram, our study will be divided in the following chapters: **Bead, Steel cable and Plastic.**

## **6.- STUDY OF THE BEAD**

In this section, we describe the initial **problems** found, **relative** to 'the manufacturing process of the bead and **to** the bead in service, as well as the means adopted to solve such a problems. A typical manufacturing process **for** these **tools** may involve the following steps:

1. Selection and preparation of the appropriate **powder** forming the basic matrix (metallic).
2. Mixing of metallic dust with diamond.
3. Cold packing.
4. Unidirectional hot packing (hot pressing).
5. Mechanization **of** the carrier (thread, **turriculation**).

Each one the steps **listed** above will be tackled during the project. It seems appropriate here to advance some general comments on the subject.

### **6.1.- MANUFACTURING PROCESS**

### **6.2.- DIMENSIONAL ANALYSIS**

### **6.3.- INITIAL DEFICIENCIES AND PROPOSED IMPROVEMENTS OF THE MANUFACTURING PROCESS**

#### **6.3.1.- Difficulties found in the mixing of the powders with the diamond**

#### **6.3.2.- Problems** encountered when filling the Cold-Press **mould**

#### **6.3.3.- High consumption of Cold-Press matrices**

#### **6.3.4.- Premature ware and failure of the graphite Hot-Press moulds**

#### **6.3.5.- Macrohardness** heterogeneity

#### **6.3.6.- Deficient union** between the sintered **ring** and **the** carrier

#### **6.3.7.- Waste of raw materials**

#### **6.3.8.- Low productivity**

#### **6.3.9.- Difficulties when starting a new cut: Sharpening**

### **6.4.- COMPARATIVE STUDIES OF THE BEADS MANUFACTURED BY HEDISA S.A. WITH OTHER PRODUCTS PRESENT IN THE MARKET**

#### **6.4.1.- Morphological and X-Ray analysis of the sintered ring**

#### **6.4.2.- Metallographical and Chemical Analysis of the carrier**

### **6.5.- OTHER INVESTIGATIONS RELATIVE TO THE DEVELOPMENT AND OPTIMIZATION OF THE BEAD**

#### **6.5.1.- Development of alternative matrix phases**

#### **6.5.2.- Optimization of mixing**

#### **6.5.3.- Die pressing of green compacts**

#### **6.5.4.- Alternative processing to Hot-Press**

## 6.6.- CONCLUSIONS

By **going** through **all** the previously **stated** problems relative **to** the manufacturing process of the beads, and through the solutions adopted for each of those **problems**, we can conclude with:

- A. When the mixing of the metallic powders **and** the diamond is appropriately done, **an** adequate homogeneity of the material is obtained. At the same time, the formation of dust -very harmful to the process- is avoided. — .
- B. A correct dosage of the powders during the green compacts manufacturing, avoids the premature ware of the compaction matrices and the failures of the graphite sintering **moulds**. Even more, more homogeneous beads are obtained in what regards to hardness and by this, a better union between the sintered ring and the carrier is obtained.
- C. As a consequence of the facts stated on conclusion A and B, an **increase** in the productivity of around 25 to 30 % has been achieved.

## 7.- STUDY OF THE STEEL CABLE

The aims of the cable on **a** diamond wire saw are:

To give a closed loop configuration which will allow the continuous cutting.

To provide physical support of the beads and the **plastic** in between them.

To support the stresses suffered by the wire when in service, such as traction, fatigue, torsion, and impacts (hooks)

**To** induce a twisting torque to the wire which provokes, along with the axial movement, an spiral movement that aids to achieve an homogeneous ware on the whole surface of the beads.

**7.1.- IDENTIFIED DEFICIENCIES**

**7.2.- DESIGN AND CONSTRUCTION OF CABLE TESTING EQUIPMENT**

**7.3.- COMPARATIVE STUDIES OF **THE** CABLE LIFETIME WHEN IN SERVICE**

**7.3.1.- Testing types of union caps**

**7.3.2.- Testing types of cables**

**7.3.3.- Wire twist testing**

**7.3.4.- Brazed union testing**

**7.3.5.- Improvement tests**

## 7.4.- CONCLUSIONS

- Best cable: Hedisa S.A.  
Best sleeve (program obtests): Cu 8\*5\*30  
The number of turns per meter of wire does not influence the fatigue of the cable,  
The brazed junction leads to a longer lifetime of the wire compared to the sleeve junction.  
The proposed bead for enhanced performance, which is shorter and slightly opened on both ends, indicates that it is possible to obtain a good performance of the sleeve junction, comparable to that of the brazed junction, provided there are not coincidences and after further confirmation.

## 8.- STUDY AND DEVELOPMENT OF THE PLASTIFICATION PROCESS

In the frame of our project, one of the aspects to be optimized was the plastic coating of the wire,

As we had stated in the chapter "State of the Art", one of the main problems with the wire in service was that the beads rotated and shifted, causing fractures and grips in the wire. This represented one of the serious problems posed by the Sumiroc clients, and so it was a priority. To overcome it, we have combined first tests in factory (Hedisa S.A.), in order to improve the conditions in the plastification and coating process : increase of the injection pressure by improving the closing conditions of the mould, adequate dosing in the elastomer-curing agent relation, a new design for the mould, a turruculation in the cap, etc.. And secondly, research in the University of Valladolid attempting to set a better adhesion between the plastic and the cable by means of both improving the contact surfaces, and using selected special adhesives.

In close collaboration with the Technical School of Engineering Studies of the University of Barcelona (Plastic Materials Department), an optimization study of the plastic injection mould has been carried out by means of a finite elements discretization package.

### 8.1.- CHARACTERISTICS AND FUNCTIONS OF THE PLASTIC COATING

### 8.2.- FACTORY PLASTIFICATION TESTS

### 8.3.- LABORATORY ADHESION TESTS

### 8.4.- TESTS RESULTS

### 8.5.- CONCLUSIONS

- 1- The improvement in the mould closing and the consequent increase in the injection pressure has been essential in the filling of the mould, the plastic penetration in the cable and the bead fixing obtained.
- 2- The "turruculation" seems interesting even though it complicates the industrial process.

- 3- Hardness measurements carried out on the plastic showed deficiencies in the former system. An optimal choice in the relation elastomer-curing agent gave best flexibility and resistance of the whole.
- 4- After testing products and processes, a sensible improvement is observed in the adhesion when using two primers with polyurethane as basic component. This can be confirmed in the adjoint results (samples N, Nbis and O).
- 5- During the manufacturing process, it is very important to have every surface perfectly degreased in order to achieve an efficient adhesion. In order to speed up the reticulation it is probable that the plastified wire had to be heated according to information to be given by the adhesive manufacturer.
- 6- To be sure of the adhesion efficiency, it is convenient to test in use two wires. One manufactured according to how it is being currently done, and the other one using adhesives. The same cutting conditions (type of rock, machine, working parameters, etc.) must be set for both tests .
- 7- It has been observed that the adhesive dosage, the evaporation time of the solvents and the reticulation time are essential in order to obtain an efficient adhesion.

## 8.6.- GEOMETRY OPTIMIZATION OF THE PLASTIC INJECTION MOULD

### **Introduction**

The following inputs are necessary in order to start a CAE study for plastic injection: Geometry of the mould (CAD drawing), coolant data (water or oil, Temperature, mass flow), mould material, data from the injection machine , process data and convergency criterium.

About the geometry, what it is really needed is the shape of the neutral fibre, being the thickness the assigned characteristic of every surface for the model to have the necessary topology and to assure, with the posterior discretization, the mathematical continuity that the analysis needs. The following surface thicknesses have been used, calculated as the difference between the mould cavity dimension and the piece dimension:

Cable between beads:	1.5 mm.
Cable under the bead :	0.2 mm,
Coating over the carrier:	0.2 mm.

Discretizing consists on dividing the topology in many elements bounded up to each other by common union points called nodes. The process equations are solved for everyone of those nodes. Initial conditions are assumed at the inflow nodes of every element and the induced parameters at the outflow nodes of the same element are calculated. Those will be the inflow conditions for the next element. These elements may be of triangular or rectangular in shape, depending on how well they adapt to the geometry of the piece. In this case triangular elements have been chosen.

The study is based on a 40 beads per meter wire disposition. About the **plastic material**, it is **necessary** to know some data about its **behaviour** under different conditions such as temperature, cooling velocity, pressure, etc. Since **Elastollan** distributes do not supply some of the necessary data (thermal conductivity, viscosity vs. temperature or pressure curves), data from one of the **TPU** in the program database, with similar mechanical and thermal properties, has been used. (**Tecoflex EG-72D**).

Due to the absence of **cooling** in the actual **plastification** process and in order to avoid fast toolings at the walls, water at **80 °C** has been used for **this** simulation.

In order to avoid program failures if the maximum injection pressure is exceeded, an injecting machine with greater capacity than the one which is currently being used at **HEDISA**, is assumed.

The **process parameters** which are most relevant are the injection time, the filling velocity profile and the melt injection temperature,

The **injection time** is the time needed for the polymer to completely **fill** the cavity of the **mould**. Although it is normally short and its influence is **small** compared to the cycle time, its proper determination is sometimes essential in order to control the shear stress and the shear rate that the polymer can resist, aiding to assure a uniform filling and dimensional stability. A first estimation **of** the filling time can be obtained from the time needed to completely cool down the piece, which is proportional to the thermal diffusion index of the polymer **and** to the average thickness of the piece. In our study the injection time currently used at **Hedisa S.A.** (around 1 second) has been used as a reference.

Using a fixed **mould** geometry, it is possible to obtain the optimal injection time, which would be the one to induce the smallest injection pressure. Since several geometries have been used in order to find the optimal one, **the** injection time in every case has not been the optimal, However, for a given geometry, the influence of the injection time on the filling characteristics has been studied.

Analysis using the package **CFLOW-EZ** gives the recommended filling velocity profile for each geometry. Such a profile aims to achieve a constant speed melt flow advancement, so that uniform stress distribution is obtained along the piece. **The** analysis is based **on** the **Hele-Shaw** law for Newtonian fluids under isothermal conditions and it is independent of the material properties and of the process conditions,

The most interesting data obtained from the analysis of the program is the filling report which gives the maximum, minimum and average parameters at 5% **and** 95% of the filling completed. Also the isolines distribution give a very intuitive idea of how well the process progresses, The distributions considered are:

- **Isochrones**, to predict the melt flow during the filling.
- **Isobars** or pressure distribution at different stages of the filling.

- Isotherms or temperature distribution.
- Representative shear rate.
- Wall** shear stress.
- Bulk** temperature.

### Clamping force

When the cavity is fully filled up, pressure **in the mould** increases greatly due to the **overpacking**. Values for the clamping forces during the filling are not the same to those needed to complete the whole process. This value is obtained afterwards using an special package -C-PACK-. **During** the filling stage [C-FLOW) it is possible to use **the clamping force as** an approximate value (required clamp force) and then use a security coefficient to obtain the estimated clamping force.

### Pressure

The pressure gradient between two points is the driving force that pushes the **plastic** during the filling stage. Mass always moves in the direction of the pressure gradient and from high to low pressure. This is why the highest pressure is always found at the point of entrance of the plastic, and the lowest pressure is at the melt front. A non uniform pressure gradient may derive into abrupt changes of velocity (tracks in the piece), **overpacking** (possibility of burrs) or underpacking ( possibility of excessive contractions).

### Bulk temperature

The polymer temperature varies **along** the injection process with position, time and also with the thickness of the piece, To illustrate this phenomena in j ust one graph iris necessary to introduce the concept of bulk temperature. The bulk temperature is the average temperature value of all the layers in which the thickness of the piece is divided for the analysis, weighting at every layer the effect of the flux velocity. Physically it represents the transported energy through each node. Regions of continuous flux have higher bulk temperature while regions in which the flow stops have a **fastly** decreasing bulk temperature,

### Shear stress

**In** all sections considered, and for the viscous flow formulation used, **shear** stress is zero at the centre point and maximum at the points in contact with the **walls**. This magnitude, which is proportional to the pressure gradient at each point, is an indirect indication of the degree of molecular orientation of the polymer, **In** order to obtain get good quality products, it is convenient to keep the shear stress at small values.

### Shear rate

Usually, **low** shear rates **lead** to low production rates. Economic **criterium** advises to use **shear** velocities as high as possible in order to reduce the total processing time. However this was **not** the purpose of our study. Same as bulk temperature, shear rate changes with thickness. However shear rate is not an average value obtained from the values at the cross-section of the piece.

Representative shear rate is obtained from the shear stress at the walls and from the fluidity, Both magnitudes are calculated during the analysis. At the end of the filling stage an increase in the shear rate value is observed.

### ***Conclusions***

The adequate conditions for the filling of the mould are those that lead to a well balanced flow. To achieve this, the geometry of the mould must be modified in two ways: \_

1.- Use an extra entrance of melt after the last bead or otherwise eliminate it. Every bead must be fed by two polymer entrances.

2.- The diameter of the entrances of fluid must be progressively varied as the distance to the centre of the mould increases. This modification must be carefully done, parallel to an optimization study of the processing conditions (bulk temperature and injection time).

## **8.7.- REMOVAL OF THE PLASTIC FROM THE WIRE FOR BEADS RECYCLING**

### ***Introduction.***

The objectives of the plastification of the diamond coated wire are mainly:

- The establishing of the beads
- The protection of the metallic joint
- Energetic absorption of the impacts
- Homogenizing the torque at the joint

Since the diamond coated wire beads do not always wear homogeneously until the end of their lifetime, it is very frequent to plastify the wire again with used beads. Therefore, the process of eliminating the plastic and recover the half-worn beads has a certain importance, mainly if it refers to :

- Obtaining surfaces (on the recovered beads) without carbonaceous remains, pulverulents or plastics wastes,
- Low costs
- Avoiding the modification of the mechanical characteristics in the beads,
- Stiffness
- Ecology

The procedure currently used by Hedisa is to burn the wire, It presents the advantages of being fast and cheap but the disadvantage of producing carbonaceous remains and possibly changes in the mechanical characteristics of the beads due to the combustion, if it is not properly controlled, Furthermore, it pollutes the environment.

As alternative methods we have been testing **the** following techniques:

- **Criogenization (Na)** + mechanical fracture
- .. - Controlled Pyrolysis
- Plastic dissolution with organic solvents
- Melting
- Melting inside of recipients containing naphtha, terpene (oils), over **230°C**
- Melting in convection furnaces .
- Melting in melting salt furnaces

For different reasons, every process has presented several problems (technical and economic) which have prevented their definitive use.

On the search of an acceptable industrial solution to this problem, we have recently tested the process of controlled melting inside of a commercial furnace with a sand flow couch at **420°C**.

### ***Conclusions***

**The samples** tested show that this method **fulfils** the requirements for the total plastic removal of the beads.

A complete wire was sent to **Decater** with the purpose of observing **the** end level of the recovered beads, and it proved to be very satisfactory ..

It seems logical to think that this **could** be an acceptable solution to this problem, However, a logistic problem remains because the **recovery** of a wire in this process takes 48 hours for its mailing, processing and returning from Barcelona, with more additional costs,

A solution to this problem would be to purchase of a small equipment (diameter = **600mm**. and **500mm**. depth and **140 litres** of sand capacity ) and to carry out the' process in the factory **Hedisa S. A.**..

The supplier of this furnace is **DINAMEC** (Belgium)

**Finally**, we believe it would not be difficult to design an oven for this industrial process,

## **9.- QUALITY CONTROL OF MATERIALS, PROCEDURES AND FINAL PRODUCT**

The proper development of a manufacturing process, requires nowadays a strict control of the raw materials and of the different stages comprising such a process.

### **9.1.- RAW MATERIALS RECEPTION**

9.1.1 .- Metallic powders

9.1.2 .- Diamond

9.1.3 .- Steel rod

9.1.4 .- Steel **cable**

9.1.5.- Plastic

**9.2.- POWDER MIXING**

**9.3.- COLD-PRESS**

**9.4.- HOT-PRESS SINTERING**

**9.5.- EVALUATION OF THE RING ADHESION TO CARRIER**

**9.6.- DIMENSIONAL MEASUREMENT OF THE BEAD**

**9.7.- HARDNESS VERIFICATION OF INJECTED PLASTIC**

**9.8.- EVALUATION OF PLASTIC ADHESION**

**9.9.- VISUAL VERIFICATION**

**9.10.- IDENTIFICATION OF THE WIRE**

## **10.- PRACTICAL CUTTING TESTS**

In order to correlate results of the Synthetic Diamond Wire under different service conditions and our research, a “test page” in which the most interesting data referred to the Diamond Wire was included was prepared,

10.1.- TESTS CARRIED OUT

10.2.- ANALYSIS OF RESULTS

10.3.- CONCLUSIONS

From all the tests carried out it can be concluded that the most influent parameters when cutting with a Synthetic Diamond Wire are:

- A. Material to be cut
- B. Number of beads per linear meter of wire
- C. Hardness of the beads
- D. Types of cables and connections

- E. Peripheral speed of the wire
- F. Type of speed: Workshop or Quarry

This makes us think that for every customer it is necessary to carry out an individual study where everyone of these parameters is taken into account.

#### 10.4." PROTOTYPE TESTING OF THE ' SYNTHETIC DIAMOND WIRE MANUFACTURED BY **HEDISA**

An necessary stage of our research was to validate our results, which were many times related to the independent behaviour of the wire components, in a study of the wire in service.

With this reasonable idea in mind, we contacted with De Beers Industrial Diamond Division, one of the companies which provides Hedisa S.A. with the synthetic diamond. We knew that they had developed a complete equipment to characterise the operation of the Diamond Wire under controlled conditions.

We visited their R+D laboratories in Charters, Berkshire (England) and together with their technical team, the conditions for the test were set.

### **11.- PRECOMPETITIVE PROCESS DESIGN**

Nowadays, the wire manufactured by Hedisa S. A., after having introduced all the changes and improvements described in the precedent chapters, is placed in a advantageous position when compared to other existing competitors in the market

Nevertheless, aiming to obtain a bigger market share, and within the framework of a continuous improvement of both products and processes, new production options are being currently studying, which will briefly describe now.

#### **11.1.- MATERIALS**

#### **11.2.- MANUFACTURING SYSTEMS**

#### **11.3.- QUALITY CONTROL**

#### **11.4.- CONCLUSION'S**

From what we have considered in this chapter, the following statements can be assumed:

- A. The means actually used for the production of the Diamond Wire by Hedisa allows it to be placed in a competitive market position.
- B. We face a changing market, therefore an open and change-oriented policy will have to be adopted by Hedisa S.A.

## 12.-FINAL CONCLUSIONS: MILESTONES

The objectives aimed by this project and the results obtained have been:

**Objective A :**      *A yield improvement of 30/40% for granite, and of 40/50% for the slate.*

**Results:**

	YIELD (m <sup>2</sup> /m)		
MATERIAL	January 1993	January 1995	% increase
Granite	6	8	33%
Slate	13	25	93%

**Objective B :**      *Achieving a cutting speed increase of 20%.*

**Results:**

	CUTTING SPEED (m <sup>2</sup> /h)		
MATERIAL	January 1993	January 1995	% increase
Granite	"2"	2.3	15%
Slate	6	10	75%

**Objective C :**      *A decrease in the current manufacturing costs of 35%,*

**Results:**

By sensibly increasing the productivity, decreasing the rejections, at the same time that the lifetime of Cold-Press matrices and graphite sintering moulds has also been increased, it can be concluded that the manufacturing costs have been reduced in an approximate **25-30%**

**Objective :**            ***Reduction in the number of failures in the wire***

**Results:**

The improvements carried out in the manufacturing of the wire -both in the bead as well as in the adequate choice of the best cable and in the optimization of the plastification process- together with a better knowledge of the using conditions of the tool; has allowed us to achieve a reduction on the number of mendings in a 50-60%.

**Objective E :**            ***Recycling of the residual diamond particles***

**Results:**

Objective 100% fulfilled

**Objective F :**            ***Reducing the global cost for the user in over 50%***

**Results:**

In January 1992, the average price for a meter of diamond wire for granite or slate was 26,000 pesetas. At the time being, the price is around 18,000 pesetas, which means a 31% price reduction for the user.

Taking into account that the yield in the tool has increased in a 33% for granite, and in a 93% for slate, we may conclude that the final cost has been reduced in a 45% for granite and 66% for slate.