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Example of an existing system in the motor industry: the Unisurf system

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The shape of a car body is first of all defined by means of a full-scale clay-model, very carefully hand-built. Drawings, master model and stamping tools must be in perfect accordance with the model; the process is costly and time-consuming.

Accuracy and lag-time have been improved with help of numerical control which plays an important part in recording coordinates on models or drawings, marking off points on drawings, lofting, fairing curves and also defining and milling surfaces.

On the top of this, Renault now uses it to help stylists define, through figures, any shapes they have devised.

So, numerical control is used in their conception process instead of taking part into their translation only.

1. INTRODUCTION

In the motor-car industry it has become commonplace to use computers to solve problems related with materials stress, dynamics, aerodynamics, thermodynamics, etc. Taking advantage of the experience gathered in the aircraft industry, the motor-car makers have endeavoured, in the last few years, to make numerical control enter into the process of designing car bodies and manufacturing stamping tools.

Several systems have been devised and this paper will deal with the one Renault have developed.

2. LECTURE

2(a). Recollection of conventional methods

The very first image of a new car is shown to the head management by means of sketches and small-size models. Those retained are built full size, lacquered and equipped with all implements: wheels, head lights, glass, chromes, etc. to look exactly as a real car (figure 1). The models are again displayed for examination, and corrected several times before one of them is definitely selected.

Then the shape of each outside panel has to be defined, as well as the other parts of the car body: inside panels, floor, underframe, brackets, stringers, etc.

A drawing can only give an approximate, and sometimes questionable definition, and we must refer ourselves to a master built in a stable material (figure 2). For many years mahogany was used but we notice a trend to use blocks of artificial resins combined with fibre glass set on a metal frame. In spite of the great care taken, the master is liable to warp; besides, while copy milling or setting the tool, we do not use the real master but a plaster replica. This, of course, is an open gate to additional errors.



FIGURE 1. Clay model of the '4 L' Renault.

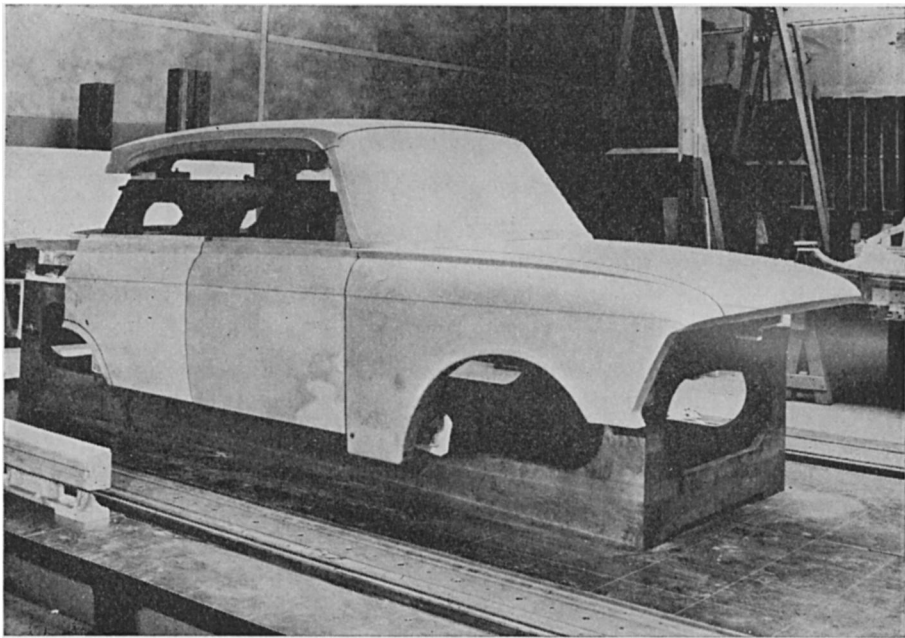


FIGURE 2. Master.

This indefiniteness is a great disadvantage of traditional methods, and the reason for making use of the potentialities of n.c. is evident: it will exclude indetermination.

2(b). *Numerical methods outlook*

Most numerical methods tend to use n.c. to translate into figures the shape of a previously hand-made model, or its graphic definition by means of curves lofted with templates or splines.

There are some well-known devices to perform these operations: measuring machines (figure 3), curve followers, photogrammetric scanners, or mathematical methods to fair curves and surfaces.

This translation work always raises heavy difficulties because no infallible algorithm exists that will choose automatically the conditions that must be complied with by the solution looked for.

An algorithmic method should also be able to account for the smallest detail that expresses an intention or a want, sometimes implicit, yet eliminate the details caused by fate or fault.

Such a method would be very expensive and perhaps impossible to create. This is why the methods of translation will still give a large importance to the operator's initiative and skill; therefore, inevitably, a doubt remains as to the fidelity of interpretation.

2(c). *Renault's system—Unisurf*

(i) *Principle*

Renault have wanted to do without any translation work and have created a numerical definition method for the use of draughtsmen as well as designers.

To be acceptable, this method must comply with several requirements:

(1) The time spent from the moment the operator has chosen the relevant data until the moment he sees the result of his initiative must be very short. A few seconds must be enough time to materialize a line, and a few minutes for a surface about 1 m^2 (11 ft^2).

(2) It must allow the use of a large variety of curves. Straight lines, circles, conics or cubics are not enough to solve easily all problems met in our industry.

(3) The method must not compel eventual users to add extra mathematical knowledge to what is normally required, that is geometry and descriptive geometry.

(4) Its accuracy must be about 5×10^{-5} .

(5) It must be reliable, easy to maintain or repair and moderately cheap.

(ii) *Means*

Mathematically speaking, instead of looking for an equation system defining a curve or a surface in the two-dimensional set of reference of the drawing machine or three-dimensional set of the milling machine, we have preferred to find the set in which a curve or a given surface is represented by a relation the shape of which is defined once and for all.

It would take too long to expose here the mathematical features of the functions

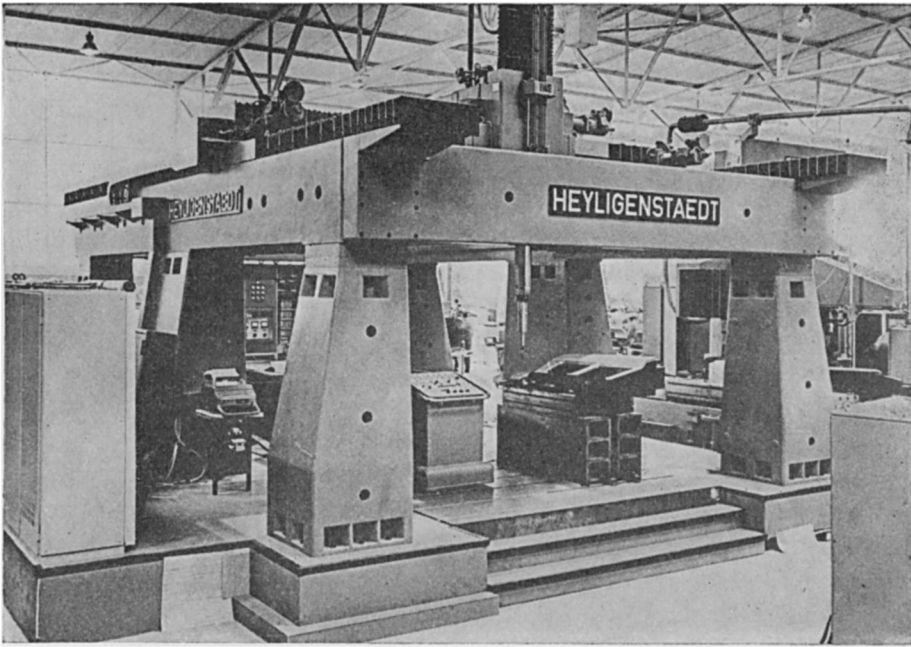


FIGURE 3. Scanner (Heyligenstaedt).

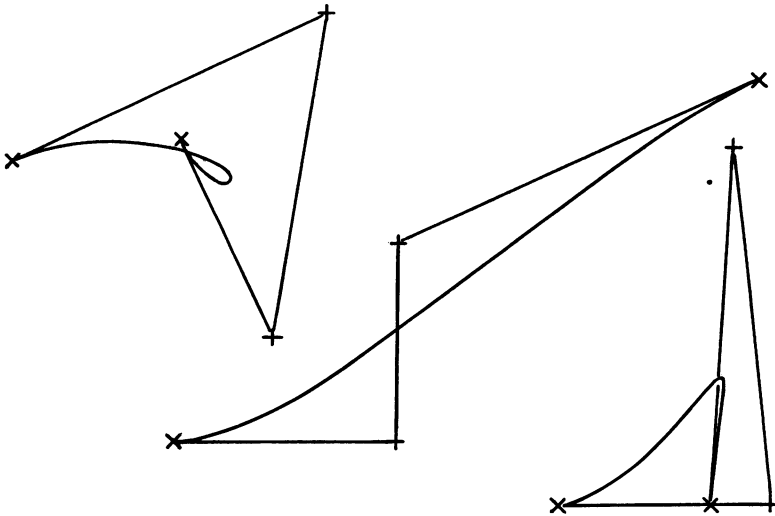


FIGURE 4. Samples of Unisurf curves.

chosen. Let us say that vectors representing each curve segment's own set of reference depend on their geometric features: end points, intermediate points, tangents, curvature, etc. (figure 4). The parametric solution so reached has the advantage of making the shape of curves and surfaces independent from their position with regard to the coordinates of the machine, and make easy all computation dealing with descriptive geometry operations such as translations, rotations, and perspective views.

We have used to a great extent the characteristics governing the blending of bi-parametric surfaces. Mathematical operations are practically restricted to linear transformations.

We use a small computer ($8K \times 16$ bits) to control the motions of a drawing machine (figure 5) ($1.5 \text{ m} \times 7 \text{ m}$) and a milling machine (figure 6) ($1.60 \text{ m} \times 1.1 \text{ m} \times 0.9 \text{ m}$).

We did not seek great accuracy. One tenth of a millimetre (0.004 in) is ample for our purpose. The drawing machine operates at a 100 mm/s (4 in/s) speed and the milling machine at a 17 mm/s feed ($\frac{3}{4}$ in/s), but it will very soon be increased up to 100 mm/s (4 in/s).

At the moment, coordinates are supplied to the computer through decade switches, a typewriter keyboard, and a tape reader. We will add the possibility of supplying the computer with the coordinates read on the encoders related with the motion of the pencil and optical viewer carrier.

A magnetic disk will record the data pertaining to all operations in process, which are normally related with several different vehicles.

(iii) *Use*

Style. Our stylists show their new project by means of one-fifth scale models, which are handed to the Design Office that is to define the feature lines that characterize the stylist's conception (figure 7).

Project. Once the coordinates of a few points are picked up on each feature line, the designer transfers them on his drawing machine and chooses the vectors defining each curve segment that will help to calculate the path of the tracer. Two attempts are usually sufficient to obtain the curve desired, but sometimes we have to divide a line into several segments (figure 8) because the use of a three-vector system limits the variety of shapes available. We are thinking of using a five-vector system as we believe it would, in most cases, avoid this breaking down which increases the number of patches to be juxtaposed to compose the surface.

When the designer has chosen the boundaries of one patch, he completes its definition by means of the coordinates of other vertices completing the definition of the feature 'network'.

A block of polystyrene foam can now be immediately machined and it materializes with the shape of the patch.

We notice that if several attempts are usually necessary to obtain a satisfying curve, we often get a surface out of one trial only.



FIGURE 5. Drawing machine (Renault).

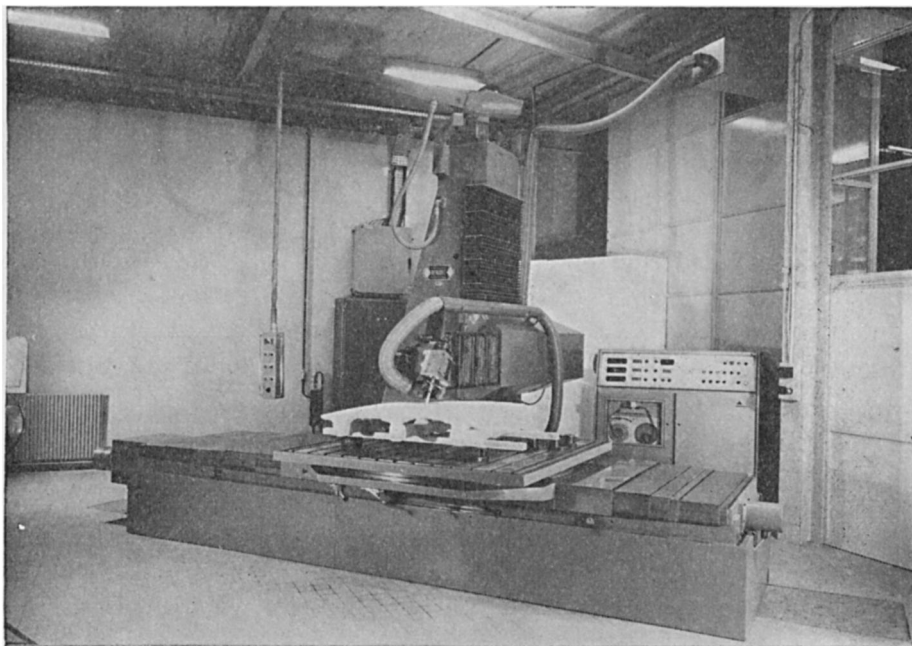


FIGURE 6. Three-dimensional machine (Renault).

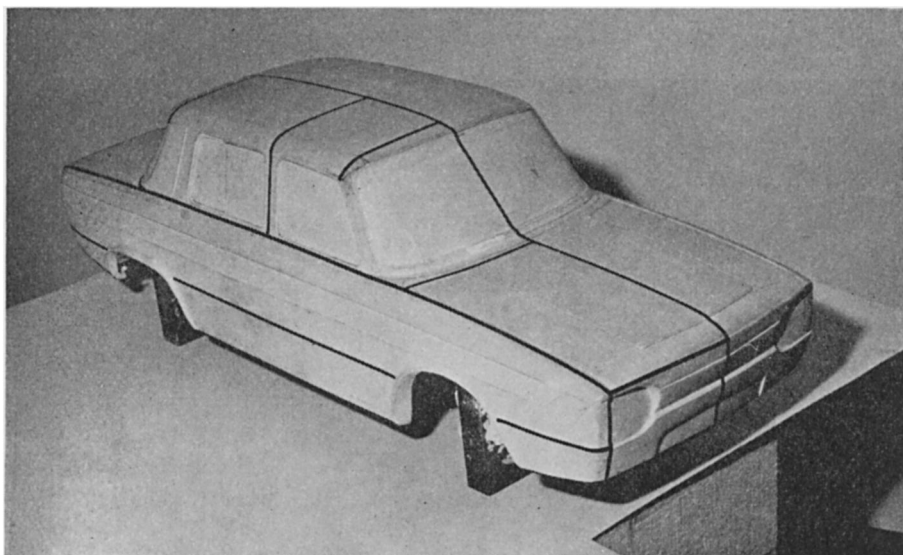


FIGURE 7. Small scale model with character lines.

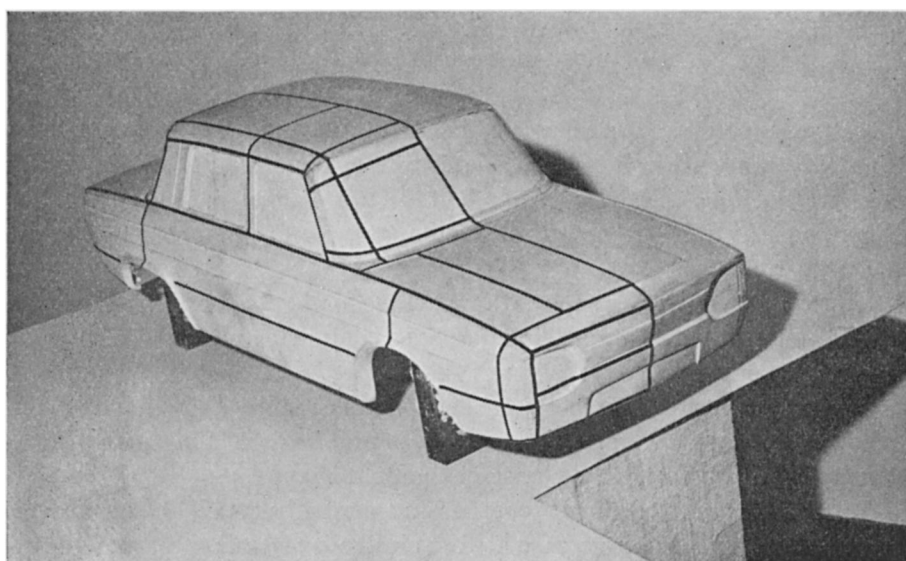


FIGURE 8. Small scale model with sub patches.

Clay model. Styrofoam is excellent for rapidly obtaining and checking the shape of a patch, but that material is too soft for building a complete model. Besides, it would not stand lacquering.

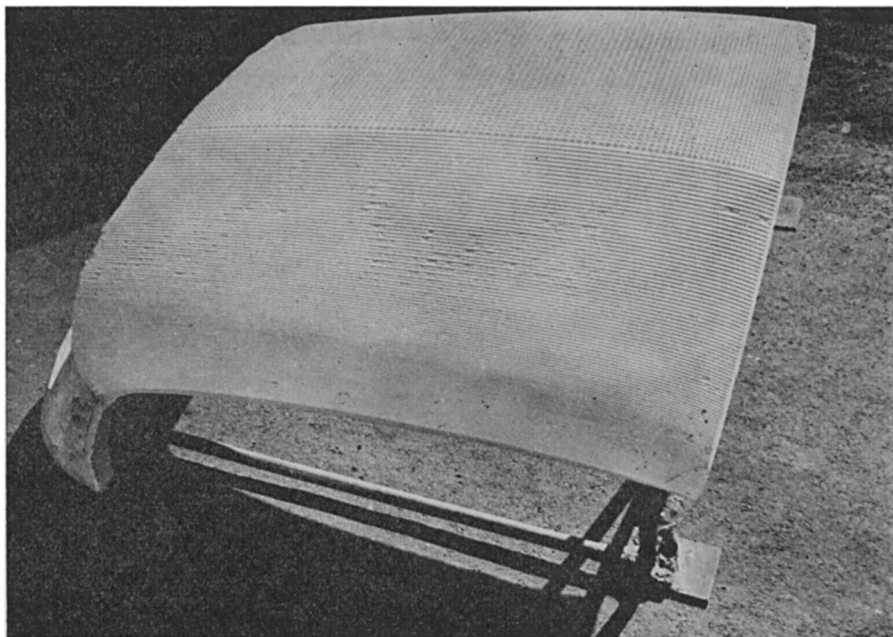


FIGURE 9. Clay model component (top).

When the shape of a patch is accepted, it is sculptured, by means of the same tape, out of a plaster block set on a metal frame (figure 9). It is fitted with pads bearing locating holes. All blocks are bolted on a central parallelepiped bearing corresponding dowel holes, thus giving full guarantee for setting precision of each block (figure 10).

To sculpture soft materials such as polystyrene foam, plaster, impregnated wood, or plastic, we use a pointed tool. This simplifies computing because there is no need for cutter compensation.

The excess of matter left between each cut is removed by hand. With the distance between two cuts ranging from 5 to 10 mm (0.2 to 0.4 in), manual smoothing cannot bring any detectable error in the final shape.

When all blocks are assembled together and perfectly fitted, they are lacquered and supplied with all accessories, so as to look like a real car.

While building the model, stylists may request some additional alterations. These will be translated into figures, tried on the drawing machine, and new blocks will be sculptured and compared with old ones kept for this purpose.

Final drawing. When the model is definitely accepted, it has to be completed by definition of all complementary surfaces. In the first step, we have in fact only

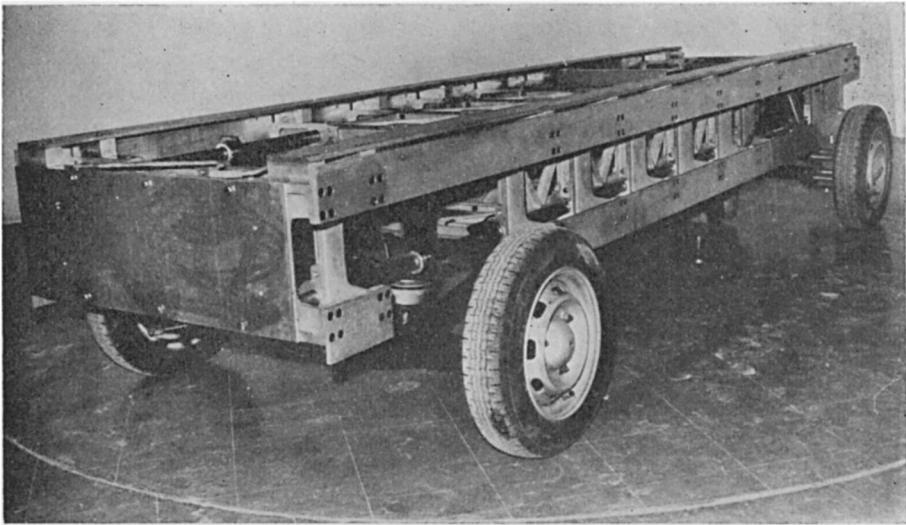


FIGURE 10. Clay model central parallelepiped.

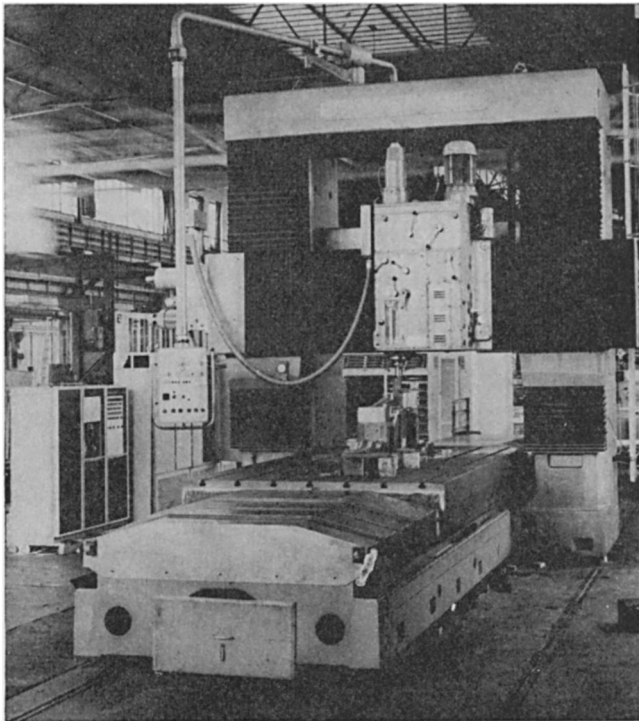


FIGURE 11. Tool milling machine (Heyligenstaedt).

defined the outside of the car. But there remain many details such as locks, hinges, welding-lines, seals, crimpings. Inside panels, linings, underframe, brackets and stringers also have to be defined. These parts are much more numerous than external ones, but their continuity and aesthetic requirements are not so stringent.

Up to now, we have only dealt with external panels, but we are working out a simple programme that will be applied to other parts.

Tool design. Once the shape of the part to be stamped is determined, it is handed to the Methods and Tooling Department which completes its preparation for stamping operations by the addition of ancillary surfaces, extension of the part surface, walls, blank-holding surfaces, etc.

The proper tipping of the part for stamping also has to be worked out. The time necessary for finding a convenient, if not the best, tipping angle through the conventional method used to reach several weeks as different attempts had to be tried. The use of n.c. has cut this time down to a few minutes.

Furthermore, the shape of the tool can take into account springback, so long as one dares to predict it.

Numerical control can also take part in the definition and manufacturing of welding electrodes.

Tool manufacturing. When numerical control entered the process of tool manufacturing, it brought two great advantages: it is completely independent from the accuracy of a master and it clears off any possibility of distortion due to error signal generated by the probe.

Our machine (figure 11) is supplied with linear interpolation control; it means that the coordinates of the points picked on the tool path have to be computed in advance.

This is done on an IBM 360/50 computer; the shape of the tool, either spherical or toroidal, is accounted for, and eventual interference between tool and surfaces is also investigated.

Because the spindle is vertical, the system simultaneously controls three motions only. It uses a fairly long punched tape; this appears to be an impediment because tape-readers are fragile. For this reason, and although the rapidity of the answer brings no additional profit in this case, we seriously consider the possibility of using a system that would directly compute the coordinates of points located on the surface and work out the orientation of the normal in each point, so as to care for cutter compensation.

We have already performed several machining operations by very close cuts; this leaves roughly 100 g of metal in excess per square metre of active surface.

At the moment, we are carrying out EDM tests for finishing operations. The basic idea is to replace hand fitting of cast iron or steel stamping tools by that of graphite electrodes. Results are encouraging, but we have not got enough financial information yet to say whether this technique is profitable or not.

Master. The master is no more used to obtain replicas for copying machines, but it is still very helpful for 'spotting' the tools after fitting. To build it we use

the same technique as for the model, except that we pay more attention to distortion.

Plaster is replaced with plastic material such as araldite and the metal frame replaced by a cast part (figure 12) the pads of which bear locating and bolting holes.

The part is machined with a pointed tool, and hand finished.

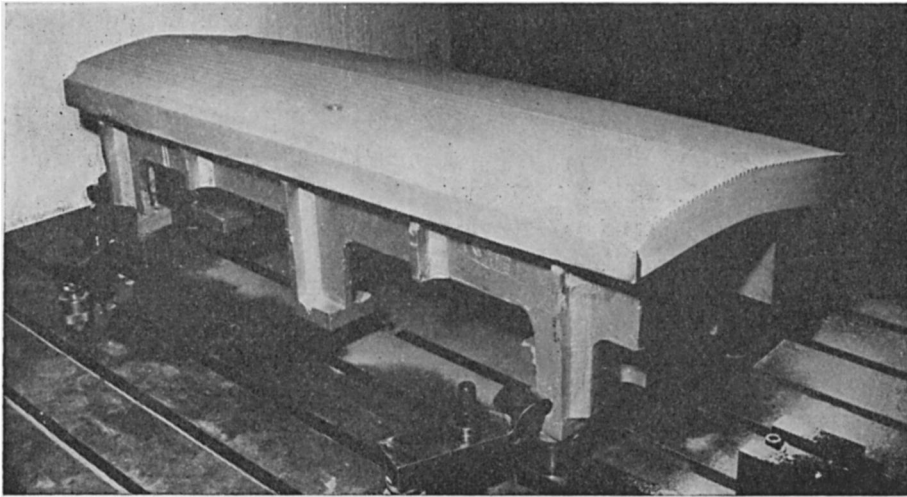


FIGURE 12. Master component.

Foundry. For tool casting, we use consumable styrofoam patterns. In the past, we had quite large allowances, the allotted time being so short that sometimes the pattern had to be finished before the part was exactly defined. Now that numerical definition is applied to the pattern we can even account for distortion occurring during the cast part cools down.

The first results have been most encouraging (figure 13). But we still have a lot of experience to acquire before we can predict safely what amount of compensation is needed to obtain a rough part very close to the finished part.

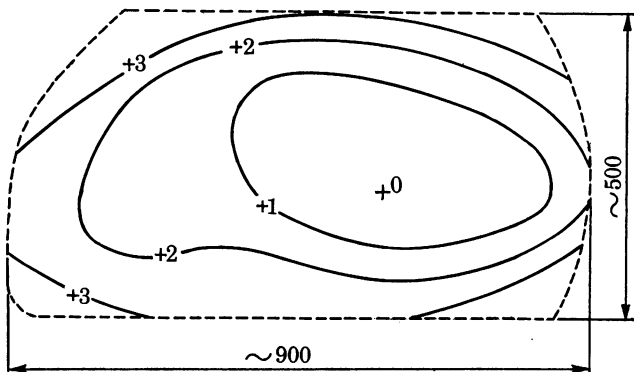


FIGURE 13. Allowance on a cast tool.

3. CONCLUSION

In the light of our experience, we believe that the Style and Design Office can use numerical control to build models and to design car bodies. Using this technique, we can obtain a precise and undisputable definition that the Methods and Tooling Office can use to design and manufacture stamping tools. No doubt this saves cost and cuts down delay, because drawing and machining operations are accelerated and the fitting time shortened because of better precision.

Our equipment and programme can still be developed and improved. It is fundamental that their conception be based on a synthesis of needs and constraints sometimes very different or opposing, and on characteristics peculiar to each department that uses n.c.

One must not overlook the consequences on the functioning of people in departments such as inspection, fitting, welding, etc., who, although they do not use this technique themselves, feel its reaction on their own working conditions. And here we see another example of the importance of the part played by a synthesis-orientated mind over human, and particularly technical, progress.