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THE CHAIR INDUSTRY 1/

by

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I. Introduction

In the furniture field it is certainly possible to include, but equally, single out those companies that make chairs.
Usually, statistical data groups together this type of production under the heading "sitting furniture". There exists, however, a very great difference among furniture manufacturers in the true sense of the word, in the sense that the technology of materials used, transformation techniques, the plant, and in consequence the labour are different.
This report will set out, I hope, sufficiently clearly what I have said above. It will be enough for now to mention one fact, that is the complete utilization in this sector of solid wood, different from that used for furniture in general.
In Italy chair production is important in the wider field of furniture in general, above all in export markets but also for the entire economy of certain regions.
These companies are in the main secondary suppliers to furniture manufacturers with some expections, and despite this factor, they have only minimally felt the cricis which is still affecting the furniture industry in Italy and abroad.
This can be explained by sales policies, aimed mainly at countries abroad, together with elasticity in production and with a mean cost of the product which is certainly not high.
To speak however of an Italian chair industry is to speak, and other companies should not feel offended other areas, of a particular

area in the north east of Italy defined as the well-known "chair triangle" that has at its corners the towns of Manzano, San Giovanni al Natisone and Corno di Rosazzo, in the province of Udine up to the Jugoslavian border.

It is well noted that in this area about 80% of Italian chairs are produced and a good part of West European ones too.

Companies are particularly numerous, over 400 of then, even if they are not very big, with a mean daily production which can be taken at around 20, 000 chairs.

This concentration has brought with it certain positive consequences such as a notable imprenditorial capacity, an effect of the continuous stimulus of getting together, the formation of secondary industries mainly in the field of tools and machines and consortia for production and sales abroad and yet other initiatives but this isn't the time and place to examine them.

On the other hand there are certain negative consequences that run from the excessive disappearance of companies to the difficulty of finding labour which is really specialized and lastly, the frenetic competition, to the customer's advantage only.

After this brief but necessary to examine the product in this market sector : the chair itself, then materials and constructional techniques together with specific transformation equipment. There is also to be mentioned control techniques for quality and for the finished product and the materials necessary for its production, and, furthermore, initiatives for the instruction of personnel.

2. The product

The chair, is an object destined to fill more or less two functions : the first is aesthetic, while the second concerns mechanical resistance.

The aesthetic requirement has satisfied the whims of designers when conceiving new forms, often, however, to the detriment of that which, perhaps, is the requirement this object must first and foremost meet : mechanical resistance.

To this end many studies of chairs, carried out above all by prof. C.A. Eckelman of Purdue University in Lafayette, Indiana in the U.S.A., show that the difficulty of arriving at a mathematical model which can give scientific dimension to the individual elements and joints which make up a chair.

To arrive at this point the designer should wherever possible :

A - determine the loads which act on the structure

B - analyse the magnitude and the distribution of the forces which occur in the structure under exactly these forces

C - estimate the quantity and the distribution of materials required in the structure itself so that no element or part of it is over-loaded.

It is possible to object that it would be better to subject the chair to destructive tests to abtain the required resistance but in this way a high number of tests would be necessary with the heavy expense of energy and costly methods.

The theory, however, allows one to evalue, in a much less expensive way and, using a computor, gives a quick reply to

certain questions that the designer must ask, the angle, for example, between legs and back-rest, the dimensions between all the elements, the effect of using different materials and different types of wood.

It is possible to study, that is, the best solution in the choice of joint most suitable for use, even in relation to form and, in any case, it is possible to know beforehand what the quality of the product will be on beginning production.

In the case of a wooden chair, this is still not sufficient in that there a very negative factor arises, that is the shrinkage of the wood, depending on variations in humidity to which the material is subjected during the life of the chair itself.

Unfortunately this useful instrument is hardly ever used by the designer and this, many times, brings about serious economic damage above all with chairs intended for heavy use such as those designed for use in public buildings.

3. Joints

The connecting up of the various elements comprising a chair are different. Among these, the most used are mortise and tenon joints), dowel joints and finger joints. These parts are glued togetner and are often, when possible reinforced with so-called gusset plates or glued and fixed mechanically.

In Italy, mortise and tenon joints are nearly always used (round-end tenon - round end mortise) while dowel joints are used, with or without finger joints, only where this type of connettion is indispensable. This is made for a certain time saving in the con-

struction of these joints by machine specially made by Italian industry and moreover for greater mechanical resistance of the mortise and tenon joint compared with the dowel joint. Certain research carried out in Great Britain has demonstrated that in a T joint (side piece to rear leg), the mortise and tenon joint is about 40% more resistant that one with two dowels and having identical dimensions, with centres between the dowels comparable with the width of the tenon. Mortise-tenon joints are, in any case, more resistant by about 15% than an equivalent joint using three dowels.

3.1 The mortise-tenon joint

The resistance of a joint of this kind principally depends on the dimensions of the elements also because these condition the surface to be glued. However, other factors come into it such as the play between the parts and the type of glue used. In a chair of conventional structure, the tenon used in the connection between one side element and the rear leg can be, in height, almost equal to that of the element itself. This is not the case for the front legs so as not to give rise to splitting in the legs across the upper cross-section.

The thickness of the tenon does not have great importance in the holding power of the joint in that it has little affects in increasing the glued surface.

The depth of the tenon, however, greatly affects the whole joint hold : an increase of about 28%, by depth for an element of certain dimensions, gives an increase in hold of about 30%.

Differently from the dowel joint, the dimensional tolerance between a tenon and a mortise across their three different dimensions, thickness, width and depth, takes on notable importance for its holding power.

What most, perhaps, influences things are the dimensional variations caused by the change in the humidity of the wood from the moment of machining to that of assembly. In fact the width of the tenon undergoes dimensional variations that occur in a transversal direction, while those of the mortise occur longitudinally.

The difference is therefore evident : with the mortise there is almost nil dimensional variation caused by humidity while with the tenon this is much higher. As far as thickness is concerned things are less evident in that the directions to take into consideration are both transversal. However in this case the holding power of the glue influences matters because it is greater the less is its thickness for any type.

As it is this surface which in the main supports the resistance of all the joint, the importance of carefully checking of the dimensional tolerance across the thickness will be understood.

From what has been said it will also appear here that it is necessary to have sufficiently dried wood in a working environment that does not give excessive changes in humidity : in other words the factory environment must have air humidity related to that of the wood.

Even the change in humidity of the assembled joint wood causes a diminuation in its holding power. Tests have shown that the mortise and tenon joint, assembled in beech with a humidity of

15% and subsequently dried to 12%, can lose up to 15% of its initial holding power.

3.2 Dowel joints

The diameter of the dowel and its length have an abvious importanne in the holding power of the joint itself, in that this geometric characteristic depends on the gluing surface.
It has been demonstrated, however, that the holding power increases only up to a certain limit depending on the increase in length of the dowel, to be then kept constant.
These results could suggest the use of dowels to the widest possible dimension even if this can weaken the resistance of the joint elements. For this reason it is usual to use a diemeter normally equal to a third of the thickness of the elements or the legs with the insertion of the dowel only at 25 mm, and more instead in the side member. Greater penetration of the dowel would also make continuous application of the glue difficult over all the surface to be glued.
The wood used for dowels is in all cases beech ; it has been shown that the best woods are those with a density around 700 kg/cu. mt.
Despite the use of compression knurled dowels, which give adequate distribution of glue which is normally applied in the hole making it less sensitive to variations in humidity and therefore to the dimensional variations absorbed by the knurling, it has been demonstrated that, in optimum conditions, dowels which are completely smooth have the greatest holding power.

The centres between the dowels must be the widest possible in relation to the dimensions of the side piece as well the number of dowels themsleves even if not in a very great way.
The finger joint method of joining glued surfaces, where possible, and it is not always possible, brings a further increase in the resistance of the joint which even in this case has dowels for greater holding power, above all sideways.

4. Materials used

4.1 Wood

The woods used in the construction of chairs are beech, ash and oak. All three species are imported and their origin is in the main Eastern Europe.
Besides these types of wood which have really excellent mechanical characteristics, above all beech, for it lends itself so well to working and finishing, there are also used Swedish pine, walnut, cherry, certain types of African mahogany and some years ago also teak, afromosia, and (mansonia) abondoned several years ago because of its prcoven noxious nature. There have been, it is true, several attempts at promoting new species of african and south american woods butwithout any positive results above all for the lack of competitivity in prices and the lack of guarantees of continuity of supply.
There has also been an interesting attempt, made by the State professional school at San Giovanni al Natisone to use ramin in

this field, with satisfactory results above all as far as certain properties of this wood are concerned, for its workability and its ease of finish. Its minor mechanical resistance can be overcome by careful sizing of the elements making up the chair. Anyway, the making of several prototypes designed at the beginning of the century by Mackintosh demonstrated a certain validity in this wood.

To conclude this argument it must be said that particular attention must be paid to those woods which tend to split in that although resistant under other streasses, they give way easily at the joint particularly in "L" joints" (front leg and side piece).

4.2 Glues

The use of glues in the furniture industry in general started many centuries ago. The advantages of the use of glues compared with mechanical joints are very diverse and go from a better aesthetic result to one of more even distribution of loads through time.

The choice of the type of glue is not simple : one has passed in recent times from the use of animal glues to those with synthetic resin bases which have better characteristics of resistance and practicality in use.

Glues must have a certain affinity with the material to be glued and must be able to wet it and must have a sufficiently low viscosity to be able to penetrate all the irregular surfaces of the piece to be glued but not so much as allow it to seep out of the joint and they must have a high enough pot life and a quick holding power, and lastly, good filling properties.

In the case of chairs assembly, besides these properties, the glue must be adequately elastic in order to withstand the repeated loads to which it is subjected.

As has been said animal glues have been abandoned because of their inferiority from different points of view compared with those with synthetic resin bases which have come into common use, such as glues with a polyvinylacetate (PVA) base : a dispersion of polyvinyl acetate or its copolymers in water.

These are glues with a dry residue around 40/45 % with a viscosity of about 15, 000 cps with holding power, according to ASTM tests, of about 180 kg/sq. cm. on beech test pieces, with a humidity of 12%. With DIN tests, using the same wood at the same humidity, the holding power is about 80/85 kg/sq. cm.

They give, however, some important inconveniences : they are very sensible to temperature; at low temperatures (lower than 8-10^{o}c) filmation does not occur while with the humidity of the wood the holding power becomes only 10% of that given above with test pieces kept at 18% humidity; they do not stand up well to constant loads but this is hardly ever the case met with in chairs.

Tests carried out by us have shown that a certain resistance even through time with humidity variation stresses repeated on the test pieces for up to two years.

The use of other types of glues is very limited to particular uses such as : the glueing of padding, upholstery etc, using contact or hot melt, glues, seats and backreats in polywood using urea formaldehyde glue. These products shall be dealt with in other conversations.

4 ~~3~~.3 Dyes

Colouring wood, when necessary, must better the aesthetic aspect of the surface bringing out the best features but also hiding possible defects such as marks or differences in colouring.

The characteristics that these colorants must have are absolute transparency so as not to screen the wood, high performance on successive treatments, the stability of the colour and lastly a certain facility in application and good penetration.

For the coloration of chairs basically two types of colorant are used : those soluable in water and those soluable in organic solvents. The former are certainly the best from the aesthetic point of view for their complete transparency and ease of application even if they require a rather long drying time. This latter factor has determined in certain cases the application of quicker organic solvents even if they are less resistant in general to light and bring the wood grain much less into relief.

To this end it should be said that in the wood sector, only for the chair industry, acrylic or vinylic water dispersions have been used for years now as vehicles in which these pigments are dispersed, being water soluable, with a result that far from diminishes that damaging phenomenon of "skin heightening", even gaining a stage in the finishing of the article. From then on experiments with several of these products which also give an effect of marked grain, interesting above all for oak and ash veneers and besides which moreover give the possibility of sanding down.

4 3.4 Paints

Both in undercoats and in finishing coats there has been a movement away from nitrocellulose paints towards those with a polyurethane base.

These paints have shown themselves to be very versatile and fully responding to the requirements of chair painting.

Compared with the former type of paint, they have a dry much higher dry residue and are more resistant mechanically and chemically.

They are easily applied, especially by spray, with a quite long pot life, cover well and are particularly suitable for electrostatic situations.

These paints are obtained through the polymerization between polyalcohol and a polyisocyanate, the latter being rather toxic and irritant in nature so that even in small quantities it can be dangerous for operators.

The olfactory threshold value for man is certainly greater than the maximum admissable value, 0.02 ppm (0.14 mg/mc). Respecting this figure the danger of intoxication does not exist. This danger threshold can be respected only if breathing apparatus and adequate application techniques are used.

Only for the finishing coat are catalysed acid paints used. These are products with a urea formaldehyde base which hardens on the addition of a suitable catalyst, usually an acid.

They have optimum mechanical resistance characteristics and are in general cheaper that polyurethane types.

4 B. 5 Other materials

In the construction of chairs other materials are used together with wood ranging from covering materials : fabrics, string for rustic chairs, made of paper of grass, and plastics, particularly for seats and backreats etc.

5 A. Equipment

It is suitable to discuss here, even if quickly, appartus specifically used in the wood transformation field.
However, we limit ourselves to those that are only rarely used in other fields .

5 A.1 . Drying chambers

There are p.esent all the various industrial systems for the drying of wood. The starting point for a quality end product is the degree of drying of the wood used : the joints and the woods behave batter and the paint is improved and therefore in the last analysis even the aesthetic aspect gains.
Normally drying takes place in part naturally, in part using drying chambers.
Besides the traditional systems, hot-air conditioning ovens, other systems are used such as low temperature dehumidifiers, Italian patented, of great size, at least for the so-called "chair triangle" and vacuum ovens, also patented in Italy.

It is not the case here to evalue the good points and the defects of the various systems, an argument dealt with in another report, but it should be said however that the latter is perhaps the one that is better adapted to the needs of this sector, formed as it is of small to medium companies.

5 A.2 Machines

We limit ourselves to mentioning only those machines specific to the sector in which they are more widely used. Among these those designed for the construction of mortise and tenon joints; the transfer tenoning machine and the oscillating mortising machine. The first gives the formation of a rounded tenon in one stage which in the most sophisticated version can realize, at the same time and independently, the two tenons at the ends of a side member. This is a machine specially developed by two Italian firms and is of high precision and productivity and very resistant.
The second in its simple version gives the formation of a mortise joint through oscillation driven by a special revolving bit. Also this in its more complex versions can carry out a certain number of mortise joints at the same time and independently, even all the mortise joints necessary in a leg, even on different sides.
We limit ourselves to a brief description, however difficult it is to illustrate a machine without seeing it in operation, of these two machines which seem to us significant even if the market offers in this sector some machines able to carry out several other processes ot the same time as those illustrated byt which however, given their cost which is very high, can be written off in a relatively

short time just for work shifts which go above the normal eight hours.

The apparatus necessary for finishing chairs merits an argument on the side. This normally bears a finishing cycle that goes as follows : dyeing with or without impregnator by immersion or spray, one or two undercoats applyed by spray gun, normally of the electrostatic type, one finishing coat applied by spray gun, Between the undercoat and the finishing coat the rubbing down of the ground is carried out by hand.

The use of the manual mixed-air electrostatic gun is practically universal in this field both for the savings in application time and in quantity of paint and the quality of finish.

Only in the last few months have two machines for automatic painting for in-line insertion have been put into use.

The first, in time order, provides for the rotation and vertical translation of two automatic electrostatic spray guns while the object to be painted is situated in the centre of the electrostatic field thus created.

The other, on the other hand, is designed for the translation of just one electrostatic pistol, also manual, while the object rotates.

Both systems, after a period of running-in in production, have shown themselves to be particularly useful, giving notable savings in paint, with constant quality of application and above all they permit the removal of personnel from the area of painting cabin, which is not to be considered healthy, no matter what paint is being used.

One problem yet to be solved is, however, that of the rubbing down of the undercoat which is a job which must still be done by hand and which takes ups to 10% of the personnel of a company in this field. Attempts are being made without concrete results yet to carry out this operation automatically.
In conclusion there is still to mention a machine that permits the application of string in paper or straw to the chair frame automatically.

5.0 Controls

It should be quite obvious from what has been said above that it is necessary to carrying out a certain number of checks on both the raw materials, the wood, paint and glue, etc. and on the finished product to guarantee high quality.
Everyone well understands how the employment of a "live" material like wood is never the same, but brings about problems with the finished product, some of which have already been mentioned, problems which if totalled up and related to how many could arise from an incorrect use of or the lack of good quality in other materials, can create really great damage economically and to credibility.
This be comes a rather difficult matter given the medium dimensions of the companies operating in this field and which cannot obviously employ capital and labour to a level relevant to the sector.
It is exactly to face this problem, in the area mentioned several times above, in which there is a high concentration of companies of the same type, that there has been set up a centre which pursues just this purpose, Catas.

Besides several public bodies, industrialized and crafts companies

participate in this institute through their various organizations.
Tests usually carried out can be grouped together in to three categories :

a) tests on raw materials

b) application tests on the same

c) tests on finished products.

The first group provides for chemical and physical tests to ascertain the consistency in quality of paints, glues, dilutants and plastics etc, through analysis, which also uses adequately sophisticated equipment (gas-chromatograph, spectrophotometer I.R.) giving almost immediate answers. This analysis other than evaluing the components of the product used also determines the yield or applicability or resistance to various stresses and therefore the economic and qualitative validity of the product.

The second group of tests, application tests, take on notable significance only, however, with comparative tests, which only with difficulty can give absolute results.

The third and last group consists in practice in tests mechanical resistance tests on the chair structure.

This test is very interesting in that it evalues the correct execution as established by the design and the design itself.

The system adapted by us uses apparatus which stresses under repeated forces the chair loaded to 70 Kg and repeats what a person would normally do rocking backwards and forwards in a chair.

It has been shown that a positive result of 10,000 of these stresses for a chair in common use is acceptable, with 50,000 for one that must be adopted for use in public buildings.

In conclusion it should be noted that what has been said means a certain sensibilization and preparation not only on the part employers but also on the part of workers. It is clearly necessary to train skilled personnel through periodic up-dating courses and scholastic lessons.

Citing, as an example, the area to which reference has often been made, it must be said that the good initiative, for more than a decade now, of setting up a professional school for this sector, and which has turned out a high number of technicians who have found a ready place in local industry .

In the rooms of this institute Catas has found hospitality with the notable advantage, which everyone can well understand, for both the students of the college and the centre itself.

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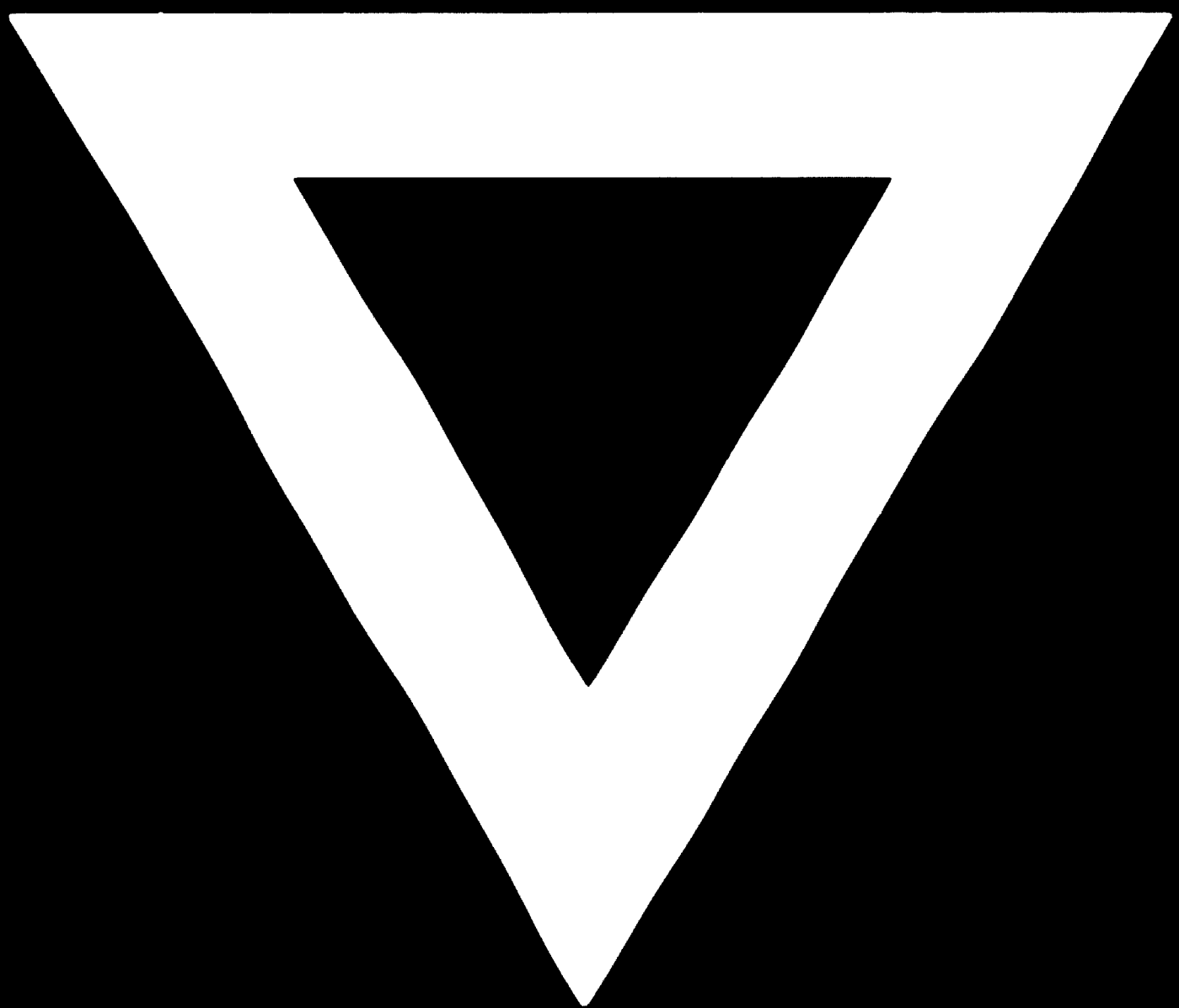

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