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DIAMOND AS CUTTING MATERIAL FOR WOOD AND WOOD-BASED MATERIAL

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with the kind recommendations of

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1 Lach, H. 1973 : Quicker rotating, boring and milling with synthetic diamonds. MM-Machine Market 79 (73):1610-1611

1. The Development

When in 1957, an American electro-concern offer so-called man-made diamonds in grain form to the diamond-processing industry as subsitute material for rare natural diamonds for processing artificial resin-bound diamond sliding panes, no one guessed as yet that exactly 16 years later, at the beginning of 1973, such synthetic diamonds, homogeneously joined with a metallic catalyst as so-called polycrystalline synthetic diamonds in the form of a compact diamond mix, in varying sizes for use as cutting material, would be available (picture 1). A new era in the milling process of aluminium, copper, brass and plastics of the most varying types began for the automobile and automobile accessory industry and for the electro industry.

Already in 1973, the author wrote "...these tools (with polycrystalline diamonds) represent the ideal tools as desired for several years by the modern automobile, aeronautics and plastics industry" (Lach, 1973)[1]

Without the synthetic diamond cutters - in whole further development and introduction to the industry the author has taken a leading part - the multiple utilization of electronically steered processing machines in the metal processing industry would be impossible.

In 1981, eight years therefore after the first exhibition of synthetic polycrystalline diamonds at the Hannover Fair 1973, these so-called synthetic diamonds have become established for rotating, boring, and milling, in small and large processing units, yes, even in automatic production lines of the automobile industry (picture 2), and have succeeded against hard metal, ceramics and other coated and uncoated cutting materials, because of their higher economy as long-life tools for mass-production. Why could wood and chipboard not be milled as economically? The thought was basically not new, as publications show (Saljé, Abdel Rahman 1975)[2]. The author and his colleagues first made a step forward in this direction in 1977, which, in November 1977 because of the Productronic in Munich, led to a display of a usable diamond saw for the processing of ladder-boards for electronics. The origination costs of this diamond saw were however so high that deliberations about introducing them into the furniture industry at this point in time must be deferred.

Following the development of a new type of cutting technique and new diamond cutting plates, the situation changed in 1978. First usage of diamond milling tools for postforming plastic boards and melamine-resin-coated chipboard in the kitchen furniture industry showed that the chosen way was right.

2. Processing Wood and Plastics with Diamond Tools

At the beginning of 1979 this led to the foundation of the first diamond tool factory exclusively for the manufacture of wood and plastic processing tools. At first diamong cutting plates (dreboquick) (picture 3 were developed which, because of a peculiarity of construction, could be used in all known knife-head systems. The production of a special knife-head is not necessary. The diamond milling tools and profile milling tools (dreboform) followed (pictures 4-6) for postforming edge processing and for use on routing machines. These tools were constructed for long-life utilization in the NC and CNC controlled machines developed by the machine industry for economic machine utilization. Then the diamond circular saw blades and milling tools (dreboflash) (picture 7) for the milling of wood, plastics and chipboard for use in one and multi-blade circular saw machines were developed. Here an endurance time superiority showed itself over hard metal by many hundred-fold. Several designs concerning cutting forms, cutting widths, diameter etc., were offered for the most varying applications. At Ligna '79 they could be shown as the stage of technology today.

3. Development after 1979

Within a year, the use of diamond tools could be made known in the wood processing industry in West Germany and on the European continent through practical usage and through exchange of experiences with friendly companies. Much new ground was opened up during this time. Processing set-backs were overcome through improved processing techniques.

Arguments which were produced in favour of natural expensive diamond tools were refuted; e.g. the fear of cutting-break risks. Here, the manufacturer offered a cutting-break risk insurance which up to now has only been claimed in a very few cases.

One was reminded of the time when hard metal cutters took over more and more from HSS-cutting material. Something similar now awaited the hard metal cutters in many areas. Diamond will take over from hard metal wherever the capability of performance of hard metal cutters can no longer be classed as satisfactory.

Characteristics such as longer tool endurance time, more performance through higher feeding speeds and higher processing, all form criteria which favour the diamond cutter. The wood and plastics processing industry have firstly long-life tools at their disposal, which make possible the economic use of electronically controlled machines (pictures 8-11), and at the same time, the processing of more delicate materials is also possible. For this development, experiences in diamond processing which have been collected practically since 1922 could be used. For practical interest the following possibilities for a successful application - as at December 1980 - are given by examples of various diamond tools.

4. Diamond Tools

Its hardness makes the diamond superior to all other cutting material. On Knoop's hardness scale the diamond achieves 7000, in comparison to which the hard metal type K20 around 1500. In general it is said that although the diamond is very hard it is very sensitive to knocks and shocks. This is true for the natural diamond. However, polycrystalline synthetic diamonds are processed for making tools which show no growth and are therefore not cleavable. Polycrystalline synthetic diamonds have been used in the automobile and automobile accessories industry for the rotating, boring and milling of, for example, aluminium (in the piston and brake-housing areas), and plastics (abrasion-proof brake linings; fibre-glass reinforced material in aeroplanes and boat building). Synthetic diamond is not more expensive than natural diamond since synthetic diamond can be produced industrially and economically as a result of a widely developed high-pressure sinter technology.

Through the manufacturer and an authorized sharpening service equipped with the necessary basic knowledge and know-how, the tools can be re-sharpened several times without problems, i.e. depending on tool and cutting make as well as abrasion as much as eight to twelve times. However the user should not try to do this himself nor should it be attempted by inexperienced sharpening services.

The use of tools with polycrystalline cutters is justified everywhere where there is mass production and where the previously used hard metal tools have hindered the production run because of frequent necessary changing of tools and added equipping time. An endurance time of maximum 2-3h by edge processing of covered plywood or maximum 1500 lfm milled door-surrounds would be valued as insufficient for company economy.

As a rule polycrystalline cutters show an endurance time which amounts to several hundred-fold that of comparable hard metal cutters. At use in routing machines in some cases even over one thousand times longer endurance time is achieved in comparison with comparable hard metal milling tools.

This was demonstrated in a test in which the abrasion proofness of hard metal as opposed to polycrystalline synthetic diamonds was measured. Hard metal achieved the factor 2, the polycrystalline diamonds the factor 250, i.e. it was 125 times more abrasion proof than hard metal.

The use of diamond cutters however does not only show a higher endurance time, but also has the following advantages:

1. Production output efficiency through the large cessation of equipping time, which up to now was caused by changing tools. This means that expensive processing machines can be better utilized.

2. The output efficiency per time-unit made possible through an increase in feeding time speed per time unit or output efficiency per tooth. This applies particularly to automatic mass production.

3. The processing finish is not required in many cases, since the work pieces are already satisfactory through the diamond cutters. Certain processing stages can be saved.

5. Cost Savings and Cost Comparisons

With a special routing machine, according to calculations after the first re-sharpening, a cost saving of up to 94% can be achieved, which can also be seen from the following usage examples. As a rule, cost savings are between 18 and 64% after the first endurance time.

By origination of the cost comparison calculations the following were taken into consideration: a) endurance time, (b) the necessary equipping time of hard metal tools or saving during life-span of diamond tools, (c) the saved hard metal sharpening costs, (d) the hard metal tool costs saved during this time and (e) the costs for sharpening diamond tools.

Not taken into account were: possible increase in production through cessation of equipping time and the saving through corresponding better utilization of personnel. Also no included in the cost calculations were the lowering of general production and company incidental expenses as they occur e.g. from the opportunity of freeing personnel for other duties who were otherwise necessary for the control of tool conditions and the constant re-start-up of tools, or for the activity with sharpening companies, or through the opportunity of reducing the size of available tool storage.

The following cost comparisons were collected from data obtained from practical use. They are to show that diamond tools, above all in comparison with hard metal tools, can be used under thoroughly economic conditions. Regarding the very different high wages' costs with the calculation of equipping time costs, it is to be noted that the values originate from details supplied by industrial practice where they are obviously shown as very different.

Example 1

Tool:	diamond cutter, dreboflash type diameter 200 mm, cutting width 25mm saw blade Z = 24 cutter Z = 6
Machine:	folding unit, Lehbrink n = 3000 rpm s = 40 m/min
Processing:	finishing of door surrounds after the Folding System
Performance:	416000 lfm (corresponding to 20 days usage time). The relevant endurance time of an HM tool amounts to 1600 lfm; 2 layer drives; 13 equippings or sharpenings.

Costs by using an HM tool

origination costs:	DM 680
new equipping: 219DM/day x 20 days	DM4380
sharpening costs: 24DM/sharpening x 20 x 13	DM6240
equipping costs: 14 min.x0.57DM/min x 13 x 20 x 3	DM6224.40
	DM 17524.40

Costs by using a diamond tool

origination costs:	DM 14400
savings over HM based on HM	DM 3524.40
total costs after the last endurance time	round 20%

Example 2

Tool:	diamond profile milling tool, dreboform DF 150-2-15-35, Z=2, R=8, axial and radial 5^{o} finish.
machine:	fluting machine, Weinig n = 6000 rpm s = 25 m/min
Processing:	uncoated chipboard
Performance:	7000 lfm/day corresponding to 581000 lfm (from 9.9.1980 to 5.2.1981). The tool is still in use. The corresponding endurance time of an HM milling tool is around 5000 lfm; afterwards the tool must be exchanged.

Costs by using an HM milling tool

HM milling tool, basic body :	DM 932
116 turning plates at DM 28	DM 3284
116 equipping times at per 40 min at 45 DM/h	DM 3480
	DM 7696

Costs by using a diamond tool

origination costs:	DM 4420
equipping time costs:	DM 30
	DM 4450
Savings against HM based on HM total costs:	DM 3246 around 42%

Example 3

Tool:	1 set diamond profile milling tool, dreboform DF 70-3-15-20, Z=3 R=3
Machine:	edge processing machine, EMA n = 11000 rpm s = 34 m/min
Processing:	veneer chipboard, 13...16 mm thick

Performance:	1000000 lfm. The tool is still in use. The corresponding endurance time of an HM milling tool is around 8000 lfm.	

Costs by using an HM milling tool

origination costs: 6xDM 300/milling tool	DM 1800
sharpening costs:	
21 sharpenings x DM 12 x 125	DM 1500
equipping time costs: 15 min by DM 22/h x 25	DM 687.50
	DM 3987.50

Costs by using a diamond milling tool

origination costs:	DM 2540
equipping time costs:	DM 5.50
	DM 2945.50
Savings against HM based on total HM costs	DM 1042 around 26%

Example 4

Tool :	1 set diamond profile milling tool, dreboform DF 80-2-10-20-KN 6 x 4 mm R = 5, axial and radial 5° finish
Machine:	edge processing machine, EMA n = 12000 rpm, s= 16 m/min
Processing:	veneer chipboard, 22...39 mm thick
Performance:	250000 lfm (= 83 times HM endurance time). The corresponding endurance time of an HM milling tool is around 3000 lfm.

Costs by using an HM milling tool

origination costs: 8.3 x DM300/milling tool:	DM 2490
sharpening costs:	
10 sharpenings x DM12 x 83	DM 996
equipping time costs: 60 min by DM25/h x 83	DM 2075
	DM 5561

Costs by using a diamond milling tool	
origination costs:	DM 1680
equipping time costs:	DM 25
	DM 1705
Savings against HM based on HM	DM 3856
total costs	around 69%

6. <u>Areas of usage and types of processing for diamond tools</u>

Following extensive tests in the most diverse areas of the wood and plastics industry, certain areas can be shown as advantageous for use of diamond tools (pictures 12 - 16). An example of this is the use in door finishing according to the Folding System (picture 17). For all milling duties arising here such as rabbet milling, form milling, and for work on upper and lower milling machines, diamond shaft milling tools have proved themselves at an advantage. The material to be worked on consists especially of pressed, coated or uncoated chipboard, made from hard wood or tough and/or strong fibre plastics. The further development of chipboard leads in part to ever more thicker, highly inflammable material and to a quality with special characteristics. The milling of this quality material will probably be retained by diamond tools. All areas of the wood and plastics industry will profit from this development, the manufacturers too, as in earthenware housing and wooden toys industry.

7. <u>Summary</u>

In conclusion, it has been established that the manufacture of diamond tools has overcome some laws and is not to be compared with the manufacture of hard metal tools. Also the cutting characteristics of diamond and metal milling machines can only be compared in a limited way. For diamond cutting, for example, a different cutting geometry must be applied than for hard metal cutting. The company founded by the writer is the first and only business in the world which has devoted itself exclusively to the manufacture of diamond tools for the wood and plastics industry. From the beginning, unburdened by the development of hard metal tools, it went its own way, a way which should lead, in cooperation with consumers, machine manufacturers, research institutes and professional bodies, to better tools for the economic processing of wood, wood-based materials and plastics.