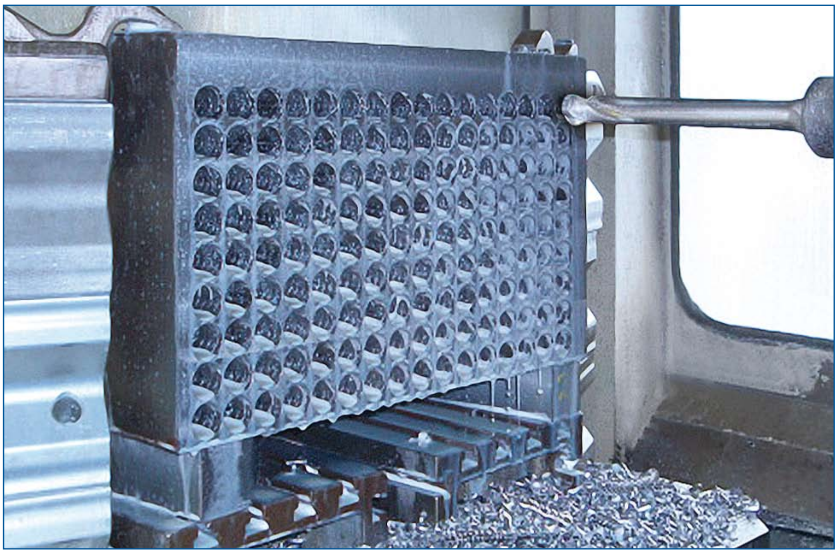
Ralf Gorski, Friedemann Dörfer

Double effect through faster drilling with lesser tool wear – more finished parts per machine and shift

1 Introduction



In 2011, the key problems faced by many companies revolve around longer delivery times due to running up against capacity limits with simultaneous cost increases for raw materials and energy. On the other hand, new orders which exceed current capacity create new opportunities. Accordingly, companies are intensely focused on optimisation of machines, tools and the materials to be machined, and are gaining advantages over their competitors in this manner. As shown in **Fig. 1**, the optimum combination of tools and machine costs depends on the material in question and the resulting cutting speed.

As a foundry steeped in tradition, Gontermann-Peipers have a long-standing commitment to high-quality cast iron. For many years now, the company has carried on with this tradition in the continuous casting sector, and claims to be the only European manufacturer to offer, for example, EN-GJS-400-15U and related grades exclusively with ferritizing heat treatment [1]. The resulting outstanding machinability is especially appreciated by manufacturers of a wide range of hydraulic blocks. This nodular cast iron, which is at least 98% ferritic, set benchmarks for potential cutting performance when drilling or milling. Users/customers have long appreciated the fact that, with this material, it is possible to obtain tensile strength and elongation values simultaneously, that substantially exceed the requirements of the EN 1563 standard.

Nevertheless, these property values are no longer sufficient to meet the increased requirements of the modern hydraulics industry, which requires nominal pressures of up to 460 bar. Out of necessity, steel grades with higher mechanical properties are used for such applications. [2,3]. In this connection, the reduced cutting parameters and higher tool wear should be taken for granted [3]. Specific developed steels with short breaking chips can reduce these problems in some cases. Nevertheless, the cutting performance of ferritic nodular cast irons and the concomitant tool life are unattainable with these steel grades.

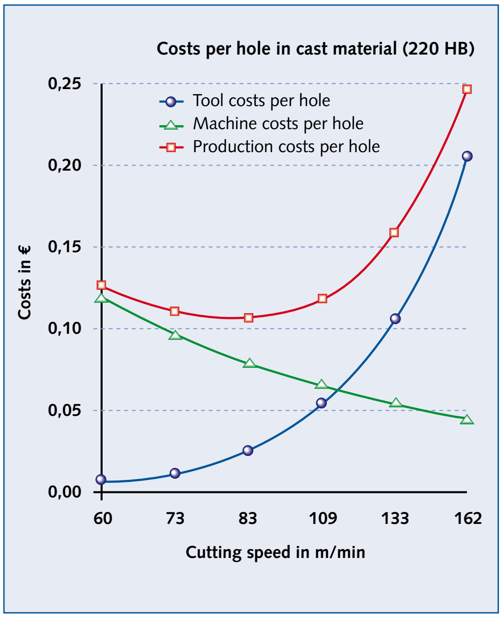


Fig 1

Tech. Business Economist Ralf Gorski, General Manager of Gontermann-Peipers GmbH, Siegen
Dipl. Ing. Friedemann Dörfer, Sales Manager at Gontermann-Peipers GmbH, Siegen

In late 2009, with GOPAG® C 500 F (EN-GJS-500-14U), Gontermann-Peipers marketed a new material that combines the familiar advantages of ferritic EN-GJS-400-15U with the mechanical properties of hydraulic steel. Thus a material with outstanding machinability and which permits hydraulics applications for pressures up to 460 bar is now available to the hydraulics industry. Simultaneously, this offers opportunities for new potential applications throughout the manufacturing industry, where now various steel grades can be replaced by a modern nodular cast iron grade (high cutting performance with low tool wear, extremely high elongation with outstanding strength values, low specific weight) [4].

During the realisation of drilling tests with several customers, it became apparent that tool manufacturers' data sheets contain little or no specific information about the maximum possible feed rates and cutting speeds for different cast materials. Because these have improved considerably during the past few years (in the continuous casting sector, last but not least by Gontermann-Peipers), and the differentiation between heat treated and as-cast materials was not taken into consideration until now, considerable performance potential when machining nodular cast iron continues to be wasted. Fortunately, tool manufacturer Kennametal agreed to determine optimum cutting parameters and service life of tools for various materials with professional equipment and methods at its Fuerth development centre.

2 Drilling benchmarking of steel and cast materials

Besides the investigation of cast materials – in this case, GJS 400-15U and GOPAG ® C 500 F (EN-GJS 500-14U) – another objective was to carry out comparative tests of grades of steel frequently used in hydraulics. For this, the forged steels C45 E and Hyt 60 were selected. These are frequently used in the European hydraulics industry and fluid engineering in the nominal pressure range of 320 - 460 bar.

The blocks used in each case measured approx. 300 x 330 x 450 mm. Because only one block was available in each case, a maximum total drilling path of 43.20 m resulted for ∅ 25 mm KenTip boreholes and a maximum total drilling path of 61.20 m resulted for ∅ 4 mm solid carbide deep-hole drill bits. That is why higher tool lives were projected on the basis of the ascertained wear.

All materials were tested beforehand in Gontermann-Peipers GmbH's accredited laboratory. The following material properties were measured:

	Position of sample in the block	Tensile strength Rm	Yield strength Rpo,2	Breaking elongation A 5	Hardness
		(Mpa)	(Mpa)	(%)	HB
GOPAG® C 500 F	Outside	494	381	23	172 - 177
	Middle	482	371	22,5	171 - 176
GJS-400-15U (kg)	Outside	458	294	12	154 - 157
	Middle	433	282	20	153 - 156
C 45 E	Outside	650	322	16,5	180 - 200
	Middle	640	304	20	165 - 185
Hyt 60	Outside	677	408	8,5	185 - 205
	Middle	681	409	11,5	170 - 185

Table 1

		Basic structure			Graphite (according to EN ISO 945)		
		Ferrite	Perlite	Zementite	Form	Size	Degeneration
GOPAG® C 500 F	Outside	100%	0	0	IV V' VI	(5) 6 7 8	None
	Middle	100%	0	0	IV V' VI	(5) 6 7 8	None
GJS-400-15U (kg)	Outside	97%	1%	2%	IV V VI	5 6 7 8	None
	Middle	89%	11%	0	IV V VI	6 6 7 (8)	None
C 45 E	Outside	55%	45%	0	-	-	-
	Middle	55%	45%	0	-	-	-
Hyt 60	Outside	95%	5%	0	-	-	-
	Middle	40%	60%	0	-	-	-

Table 2

3 Test set-up and tools

The tests were carried out at KMT's Fuerth T&D Centre (Kennametall) on a DC55 Deckel machine with IC 40 bar. For each material, ∅ 25 mm (modular) and ∅ 4 mm (deep hole) holes were made **(Fig. 2)**. Pilot holes were made prior to deep hole drilling. At time intervals, the drill bits were removed and measured optically several times.

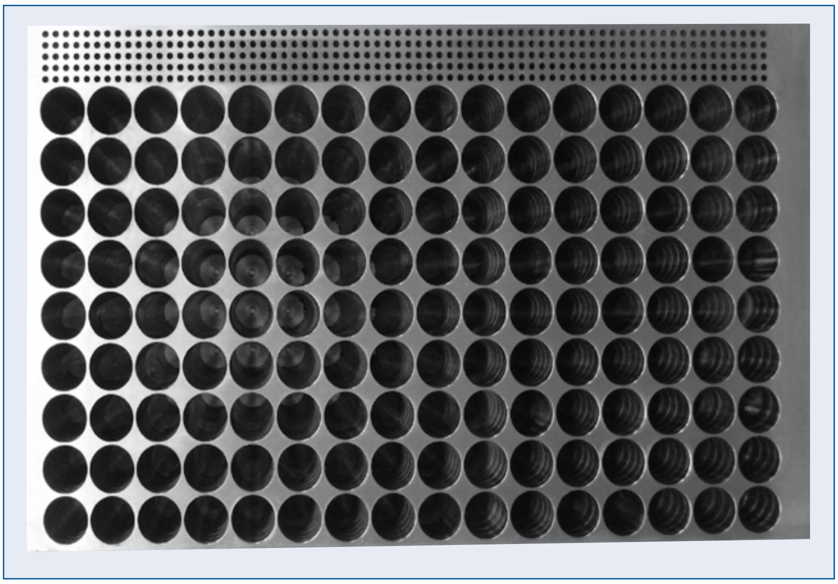


Fig 2

The following tools were used in the tests:

Solid carbide drilling (∅ 4 mm) **Fig. 3**:
B274Z04000HPG KC7425
Pilot drill 3xD: B976A04000 KC7315

Mod drilling (∅ 25mm) **Fig. 4**:
KTIP2500HPM KC7315
KenTIP bodies:
KTIP250R8SCF25M

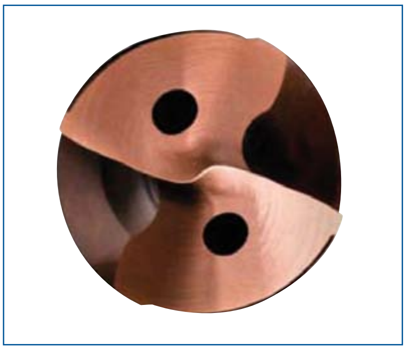


Fig 3

Fig 4

4 Kennametall results [5]

4.1 Cutting performance

During the tests, the cutting parameters shown in **Table 3** proved to be optimal:

Material	Deep hole drilling *) 4 mm				Modular drilling 25 mm			
	Vc **)	equals N:	f	equals Vf	Vc	equals N:	f	equals Vf
	(m/min)	(U/min)	mm/U	mm/min	(m/min)	(U/min)	mm/U	mm/min
GJS 400-15U (kg)***	70	5573	0,20	1115	150	1910	0,45	860
GOPAG® C 500 F	70	5573	0,20	1115	150	1910	0,45	860
C45 E	70	5573	0,16	892	90	1146	0,35	401
Hyt 60	70	5573	0,16	892	90	1146	0,35	401

*) Pilot hole 3xD with Unidrill B976A04000 in KC7315
**) higher Vc impossible because of speed limitation of the spindle
***) kg = short-cycle heat treatment under 800 degrees C

Table 3

4.2 Tool wear [5]

The wear of the tools used was determined optically and recorded photographically **(Fig. 5)**

Fig 5

In the final result, the following service life figures resulted for the various materials with the cutting parameters mentioned above:

C45 E

(Forged steel, stress-relieved, homogeneous structure, isolated non-metallic inclusions with carbide precipitation. Pea rlite banding in places) [6]

Wear: Solid carbide – flank wear of 0.05 mm
KenTIP – slight markings at the guide chamfers

Tool life: Solid carbide deep hole drilling 61.2 m – end of service life anticipated at approx. 80m
KenTIP 43.2 m – end of service life anticipated at approx. 80 m

C45 forged steel showed a consistently good chip formation, which is a prerequisite for high tool performance. The level of wear with both deep hole drilling and modular drilling was consistently low. The end of service life was not yet reached with both tools, so the anticipated performance was interpolated on the basis of the ascertained wear.

Hyt 60

(Forged steel, optimised with alloying elements for short chip breakage, sharply fluctuating perlite/ferrite ratio in the block, otherwise homogeneous with increased non-metallic precipitation, decarburized at the edges) [7]

Wear: Solid carbide – flank wear of 0.2 mm
KenTIP – clear markings at the guide bevels – 0.7 mm

Tool life: Solid carbide deep hole drilling 61.2 m – end of service life already exceeded
in this case, maximum 50m service life attainable with a clean drilling pattern.
KenTIP 43.2 m – end of service life likewise anticipated at approx. 50m.

In the test, Hyt 60 forged steel proved to be less homogeneous with cutting parameters identical to those for C45. Chip formation varied widely depending on the area of the test work piece, which can lead to problems in deep hole drilling (chip jams, chip transport). Flank wear exceeded the limit in deep hole drilling (Ø 4mm) with 0.2 mm after a drilling path of 61.2m. With KTIP (Ø 25 mm) wear at the guide bevels after 43.2 m was likewise substantially higher than with C45.

The end of service life was already exceeded in deep hole drilling. With modular drilling, a slightly longer drilling path would be possible because of one-time use (no regrinding).

In addition, the following areas of the drill were examined (see underlined designations in **Fig. 6**):

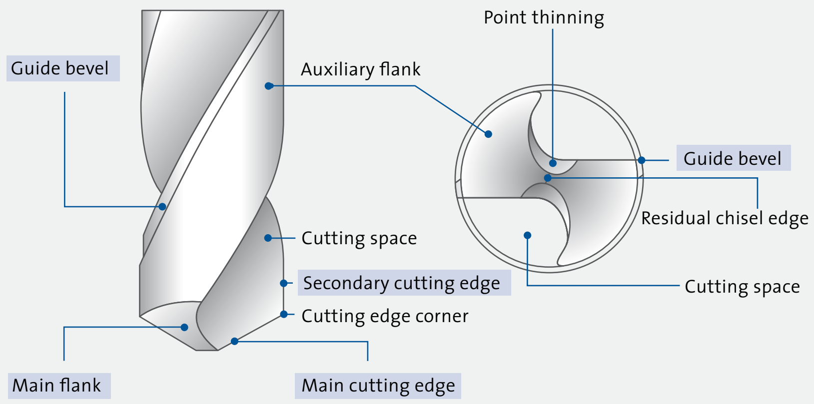


Fig 6

GOPAG® C 500 F (EN-GJS 500-14U)

(Chill casting, high-silicon spheroidal graphite cast iron, fully ferritic, less than 1 % carbides and/or pearlite) [8]

Wear: Solid carbide deep hole drilling – flank wear 0.035 mm
KenTIP – slight markings at the guide chamfers

Tool life: Solid carbide deep hole drilling 61.2 m – end of service life anticipated at approx. 120 m – 150 m
KenTIP 43.2 m – end of service life anticipated at approx. ca.120 – 150 m

GOPAG® C 500 F – Based on the ferritic structure, the same tools were used as for steel, but with substantially higher cutting parameters. In this connection, it became apparent that at more than twice the feed rate, power consumption during modular drilling merely increased from 9.3 kW to 11.5 kW. Chip formation was outstanding. The end of service life was not even nearly approached by either tool.

EN-GJS 400-15U

(short-cycle heat treated chill casting, thus substantial pearlite content in center of block and low cementite content. Basically, this material corresponds to a quality frequently encountered in the market) [9]

Wear: Solid carbide deep hole drilling – flank wear 0.1 mm
KenTIP – slight markings at the guide chamfers, slight cutting edge wear

Tool life: KenTIP 43.2 m – end of service life anticipated at approx. ca. 110 – 120 m
Solid carbide deep hole drilling 61.2 m – end of service life likewise anticipated at approx. 110m – 120m.

GJS400-15U – machineability was at a level comparable with the likewise highly machineable material GOPAG® C 500 U. Here, too, there was outstanding chip formation with substantially increased cutting parameters. Only wear – apparently due to the perlite content in the structure (11%) – slightly exceeded the values for GOPAG® 500. Thus anticipated tool life might be slightly lower. The end of service life was not reached by either tool.

5. Summary

5.1 Service life

Comparative statements by satisfied customers were confirmed by the investigations, with the ferritic GOPAG ® C 500 F the longest tool life were obtained in the test **(Figs. 7, 8)**.

With 11% perlite content in short-cycle heat treated 400-15U EN-GJS, 15% higher tool wear was obtained than with a purely ferritic material. Customarily in the market, as cast materials contain up to 30% perlite, which increases tool wear by 40 % or more.

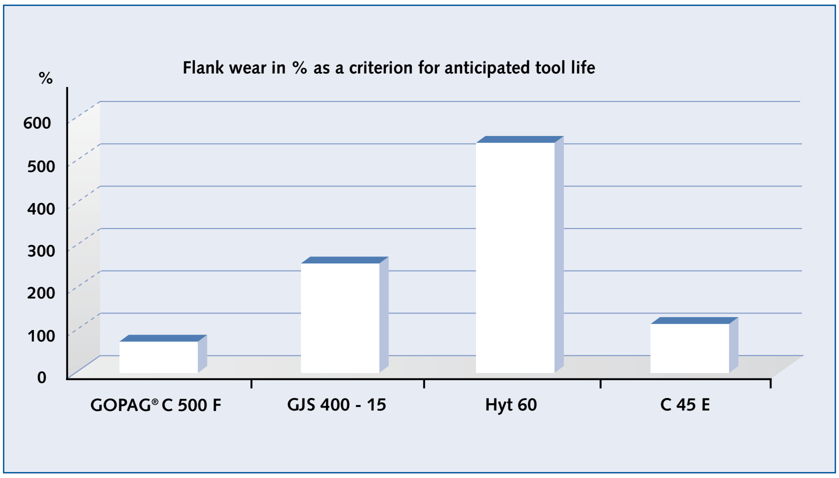


Fig 7

This consideration of tool life and tool wear is an important factor when it comes to reducing tool costs. It serves to stabilise the processes, but does not have a major effect on production costs.

Normally, a 50% increase in service life or a 30% reduction in tool costs only decreases the cost per component by approx. 1% because, on average, tool costs account for only 3 to 5% of production costs [10].

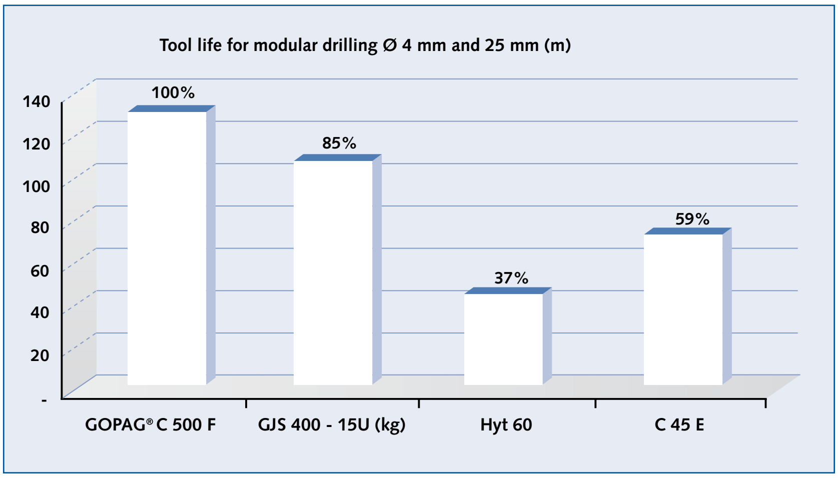


Fig 8

5.2 Cutting performance

Increased cutting performance and process improvements can lower the cost per component and thus increase the profitability of the company [10]. In the case examined in the study, cutting performance was increased by 100% for cast materials with the 25 mm drill (see **Fig. 9**) and approx. 23% with the 4 mm drill as shown in **Fig. 10**.

With a 20% increase in cutting performance, the unit cost is reduced by more than 10%, depending on cost structure. This improvement directly influences machine and operator costs, as well as the overhead costs [10].

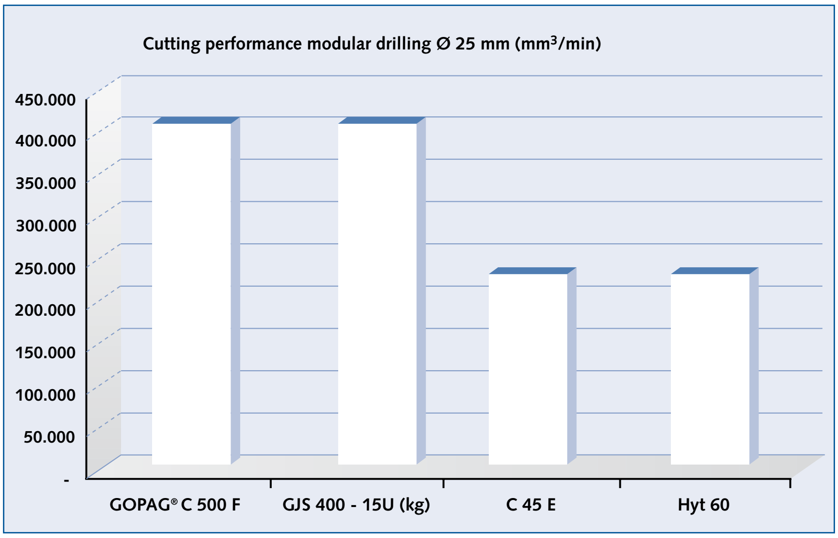


Fig 9

The investigations show more clearly how the different materials affect cutting performance and there are apparent advantages in connection with cast material.

The influence of the multiphase structure when considering the different grades of steel also reveals differences between C 45 E and Hyt 60. The high pearlite content of more than 40%, in conjunction with the relatively high tensile strength in comparison with cast iron material, leads to a substantial reduction in performance during machining. Because of the proof strength/tensile strength ratio of 0.6 to 0.8, which is typical for castings, both cast materials evidence comparable or better yield strengths and/or elongation values than the steels do.

This also proves that modern cast materials are, in many cases, a more economical alternative to the ordinary forged or drawn steel used in hydraulics.

Ferritic cast materials, in addition to the financial advantage outlined above, which results from

- extended tool service life and
- higher cutting performance

offer other advantages as well. These include:

- longer trouble-free run times – thus also fewer trouble alarms during unmanned shifts
- low scrap
- higher precision during deep hole drilling
- less cost-intensive remachining due

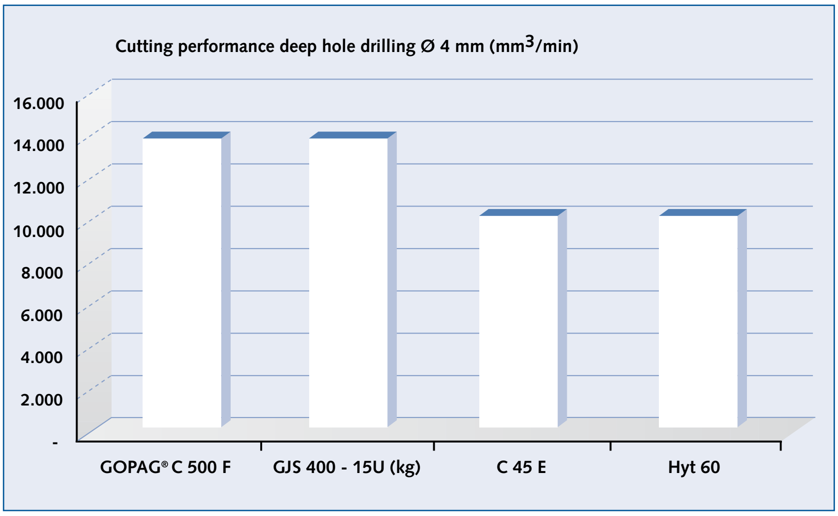


Fig 10

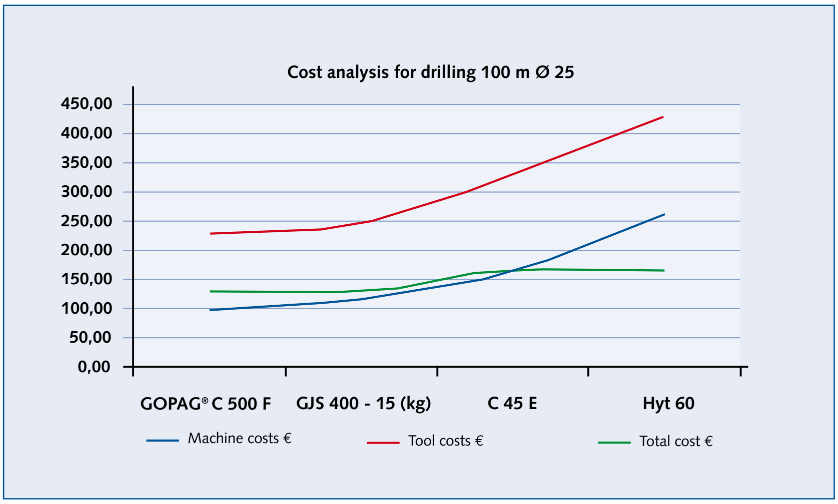


Fig 11

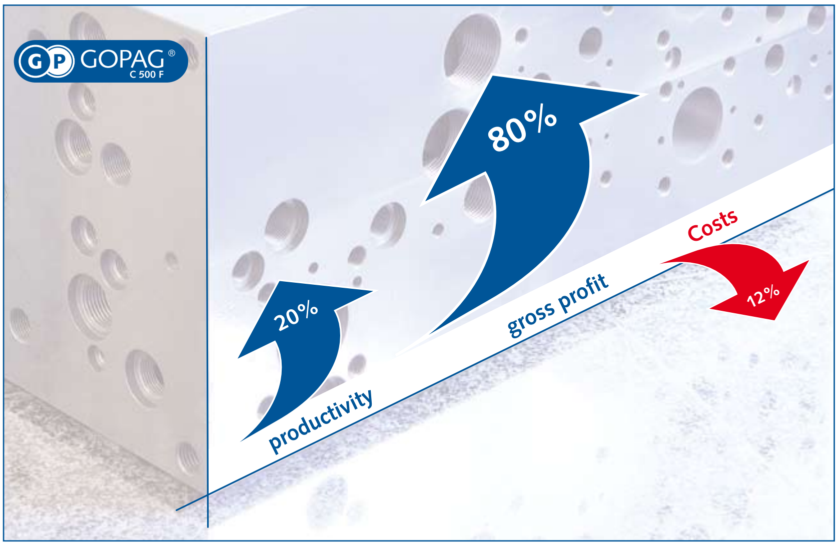


Fig. 11 shows a strictly cost-based analysis. Assuming an hourly rate of 87.00 € /h and tool costs of 130.00 € / tool (drill bit tip) under the test conditions described above, the following ratio and an overall savings of nearly 50% result with the 25 mm drill.

The investigations have shown the influences originating from material selection and how the cutting parameters can change. If a company is able to boost its productivity by 20% through the selection of a better material and produce 60 components per shift instead of 50, according to our calculations, costs will decline by 12% and gross profit will increase by 80%. Unfortunately, the economic advantages are frequently not emphasized clearly enough because of prejudices that cast material is „dirty" and the graphite will leave the operator with black hands.

In view of the fact that Gontermann-Peipers offers **GOPAG® C 500 F** in chill cast as well as continuous cast form, it represents huge potential savings for the user. In the experience of GP customers, who have reported total savings of up to 30% through the use of the new material instead of forged steel, it opens up genuine opportunities to far more than compensate for diametrically opposed cost trends, e.g., with regard to energy, wages or material, which represents a clear competitive advantage in the long term.

Today, therefore, it is not only the „Old Economy" in Germany that stands as a guarantee of success for good corporate earnings numbers in a solid national economy. The new cast materials also represent success factors for innovative companies in the area of products that require extensive machining.

GP GOPAG® C 500 F

In the machinability simply better

Literature:

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