Low Weight Composite Dry Couplings

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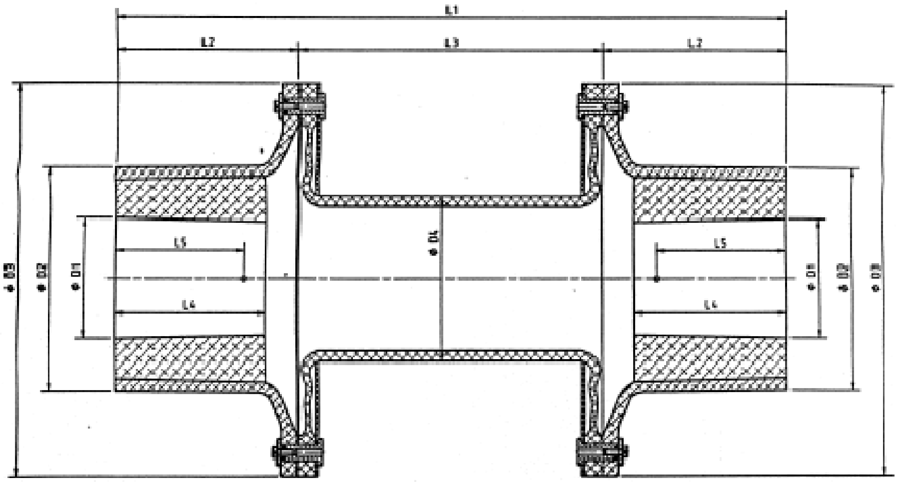
1. Design with Composite Materials

All high capacity dry couplings are today designed in steel or metal based materials. Consequently, the weight of these couplings is relatively high and a negative influence on lateral critical speeds of coupled machines, such as gears or compressors, will result.

MAAG Gear AG (now Renk-Maag GmbH) had developed a composite membrane coupling together with Geislinger, a well-known coupling manufacturer from Austria. The sleeve and the hubs of this coupling are made from carbon fiber composite material, and only the coupling bolts still consist of steel. Various patents were applied.

Figure 1 gives some technical data and main dimensions of a typical coupling out of the composite range. All the cross-hatched parts are made entirely from carbon fiber/epoxy composite. In addition, the self securing fitting bolts are designed with a new low weight design in order to reduce the centrifugal forces on the diaphragm and the overall coupling weight. The coupling has been designed to fulfill API 671 requirements and to replace conventional dry or toothed couplings. The hubs have a tapered bore and will be fitted on the shaft ends by hydraulic pressure, just as with conventional couplings. The total axial length can be adjusted in the plant by means of shims between one hub and the sleeve.

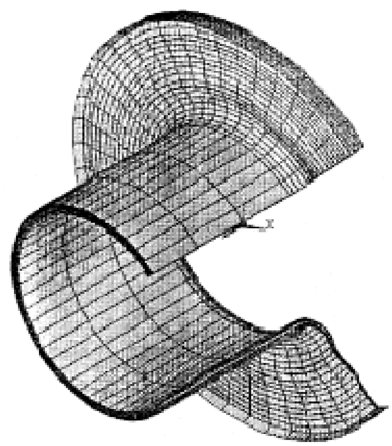
Figure 1: Composite Coupling, Technical Data



Coupling Material	Carbon Fibre / Epoxi
Nominal Torque	17'200 Nm
Maximum Speed	15'500 rpm
Total Weight	26,3 kg
Diameter D3	365 mm
Length L1	619 mm
Continuous Angular Misalignment	+/- 3 m rad
Continuous Axial Misalignment	+/- 2,5 mm

Special attention had been given to the design of the contoured diaphragms. Highest flexibility had to be combined with low space and high torque capability. The method of finite element calculation had been used to find out the best size and form of this patented diaphragm (*see figure 2*). The allowable continuous angular and axial misalignment values are well above conventional steel couplings because of the high strength and flexibility of the composite material.

Figure 2: Patented Carbon Fiber Contoured Diaphragm

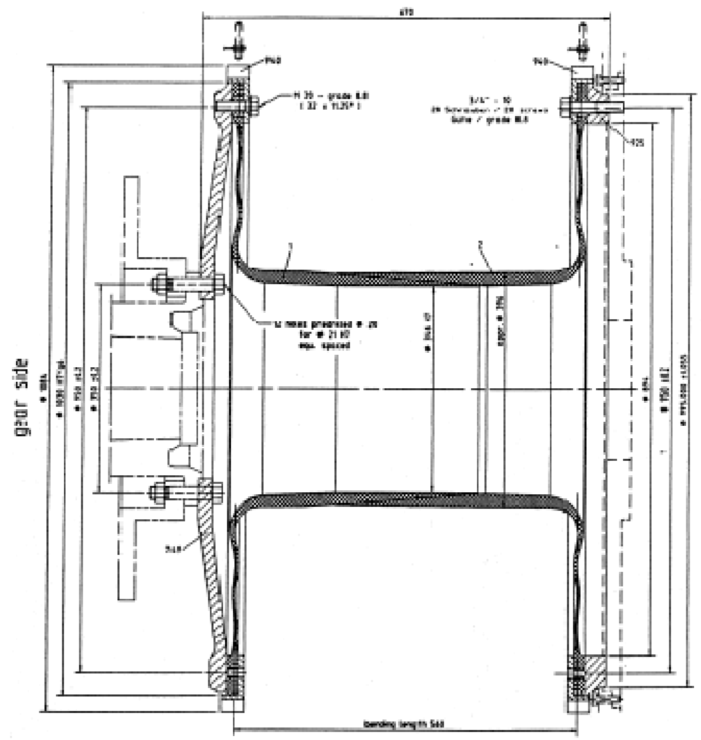


Since the composite parts of the coupling are manufactured with a special layering technique of the carbon fibers, the coupling has a preferred sense of rotation for which the nominal torque transmission has been designed. This sense of rotation and torque transmission will be clearly marked on the coupling. Of course, the composite strength in reverse torque transmission direction will be designed accordingly to meet the required (short-term) reverse operating conditions. Furthermore, an over torque capacity of at least 220% will be provided.

The use of composite glass or carbon materials is increasing rapidly in many applications, mainly in the aircraft industry and low weight high-speed ship design. For example, on modern low weight catamaran ships, whole propeller shaft lines are made from carbon fiber composite materials, offering low weight high flexibility and strength.

On a mono-hull fast ferry, there are already operating some couplings of the new composite type, made by Geislinger (*see figure 3*). They have proven to be fully reliable and extremely flexible: The high misalignments between Diesel engine and gearbox can reach up to 10 mm in lateral direction and up to 8 mm in axial direction!

Figure 3: Fast Ferry Coupling



We have given great attention to design a composite coupling for long term operation in industrial environment, such as power plants or refineries.

Following are the main features:

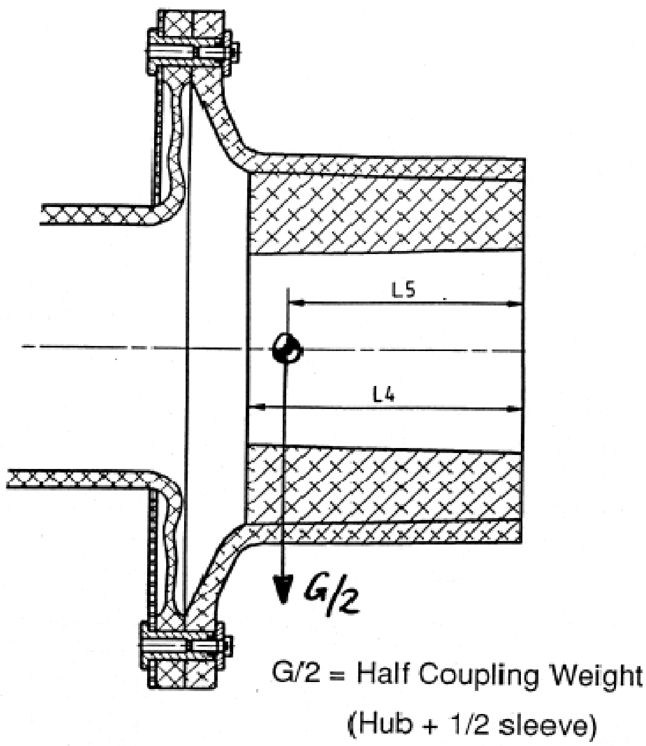
- API 671 is fulfilled
- Continuous operation for minimum ten years.
- Oil resistant.
- No corrosion.
- Electrical insulation can be provided.
- Heat resistant up to 100ºC.

2. Customer Benefits

A. Due to an advanced layering technique, the coupling diaphragms, which form together with the sleeve an integral part, can be manufactured most economical. Furthermore, the machining on the coupling is reduced to a minimum, i.e. only the hub inner contours and the bolt connections have to be machined.

B. The most important technical benefit is the low weight. Figure 4 gives key figures such as weight and center of gravity of the new composite coupling compared with conventional steel toothed and dry couplings.

Figure 4: Weight Overhang Comparison



Coupling Type	L5 (mm)	G/2 (kg)
Composite Coupling	120	13.1
Steel Coupling	104	37.1

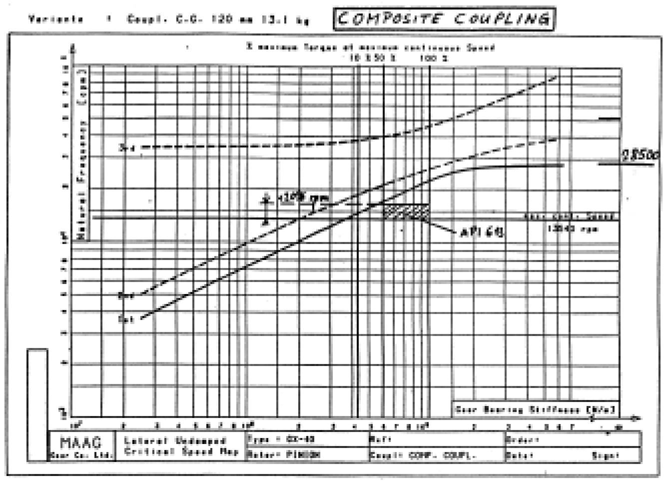
The low weight feature offers two important advantages:

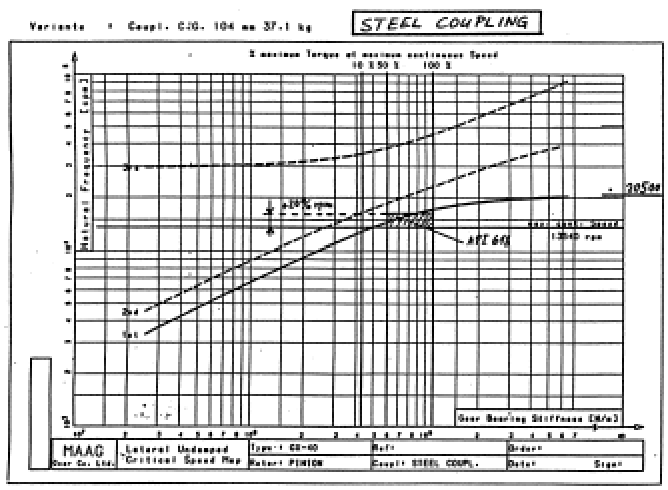
a) Handling of the coupling is very easy. In most cases, for the composite coupling a crane or other special tools are not needed for assembly or disassembly. The composite coupling shown previously in figure 1 has a total weight of 26 Kilograms; this is less than 50% of a steel coupling of the same size. This weight can be easily handled by a single man without any crane.

b) The lateral critical speeds of coupled machines, such as gears, compressors and turbines are higher due to the low overhang weight of the composite coupling. The whole machinery train will run in an improved condition with regard to lateral vibrations and the requirements of API can be fulfilled even in cases where a steel coupling would need a special "inverse hub" design. Figure 5 shows the critical lateral speed calculations for a slender high speed gear pinion as critical speeds versus bearing stiffness are shown. API 613 standard for gears requires that the three lateral critical speeds of any gear rotor shall not be less than 20% above the maximum continuous speed of the rotor. It can be clearly recognized from our example in Figure 5 that with a steel coupling the API requirements cannot be fulfilled whereas with our new composite coupling it will be possible. The same advantage will be offered of course to high-speed compressors and gas turbines, as well as any other high speed machine.

Figure 5: Pinion Lateral Critical Speed Comparison

Pinion Lateral Critical Speed Comparison





Of course, a steel coupling manufacturer could argue that with a special inverse coupling hub design and a coupling arrangement as close as possible to the radial bearings of the coupled machines API could be fulfilled as well! But this is only half of the truth, because the lateral critical speed problems are in such a case shifted from the coupling to the gear and compressor maker. Such a special coupling will require special seals on the shaft ends and the drain oil space available on the coupling side will be reduced. Oil leakage problems are often caused by "special" coupling arrangements, but oil leakage must be avoided 100% with dry couplings! We are convinced that the proposed low weight composite coupling with "standard" dimensions and interfaces is technically the best solution to increase the critical speeds of coupled machinery.

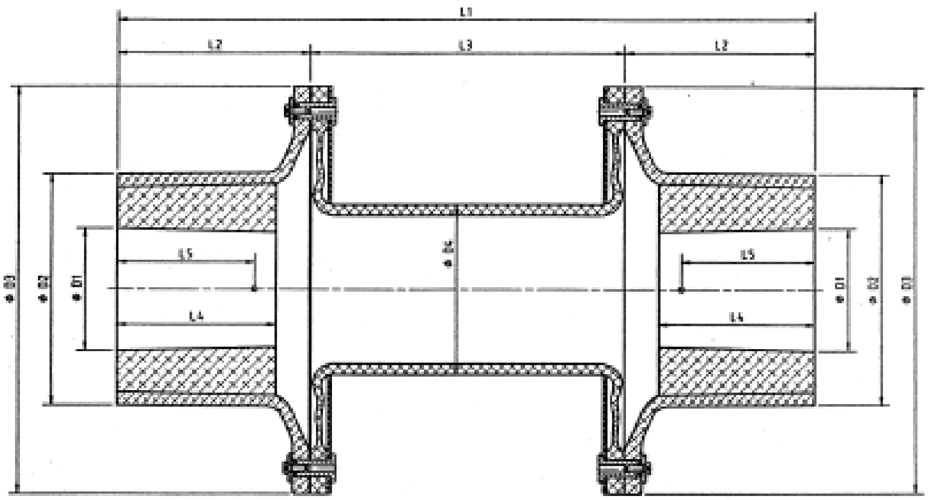
C. A further technical advantage is the following: Due to the fact that the carbon fiber composite hub is shrunk on the steel shaft end directly, we have a shrinking fit with a steel-composite material combination. This means that in case of high over torque transmission when the shrunk-on coupling hub will slip on the shaft, there will be no fretting as between conventional steel pieces. Therefore, this composite coupling can be used as a torque limiting security device! Such torque limiting devices are often required to protect for examples gas turbines suffering damages in over torque condition. With our new coupling, this feature can be covered all in one without any special design, just by applying the hub shrink fit accordingly.

3. New High Speed Composite Coupling Range

The basic idea of the Composite Coupling range is to replace our traditional, well-known ZUD high-speed gear coupling range. Technical data such as speed and torque capacity have been chosen accordingly, as well as the coupling type identification. The composite coupling will be marketed under the trade mark name HIFLEX coupling.

Figure 6 gives an overview on the whole composite high-speed coupling range, including relevant technical data and main dimensions.

<u>Figure 6: Composite Coupling Range</u>



Type	Size	Tkn [kNm]	L1 [mm]	L2 [mm]	L3 [mm]	L4 [mm]	L5 [mm]	D1 [mm]	D2 [mm]	D3 [mm]	D4 [mm]	m [kg]
GMC 13	13	1.53	276	76	125	63	54	49	92	163	68	2.3
GMC 15	15	2.15	310	85	140	70	60	55	104	183	76	3.3
GMC 16	16	2.99	345	95	156	78	67	61	116	204	85	4.6
GMC 18	18	4.20	387	106	174	88	75	69	129	228	95	6.4
GMC 21	21	6.27	442	121	199	100	86	79	148	261	109	9.6
GMC 23	23	8.92	497	137	224	113	96	88	166	293	122	13.6
GMC 26	26	12.24	553	152	249	125	107	98	185	326	136	18.7
GMC 29	29	17.20	619	170	279	140	120	110	207	365	152	26.3
GMC 32	32	23.91	691	190	311	156	134	123	231	407	170	36.6
GMC 36	36	33.59	774	213	349	175	150	138	259	456	190	51.4
GMC 41	41	47.83	870	239	392	197	169	155	291	513	214	73.1
GMC 46	46	68.47	981	269	442	222	190	174	328	578	241	104.7
GMC 52	52	97.94	1105	304	498	250	214	196	370	652	271	149.8

Tkn [kNm] = Nominal torque
L5 [mm] = c.o.g. of one coupling half
m [kg] = Total weight of coupling

Technical Data

Type	Size	Tkn [kNm]	I [kgm2]	CT [MNm/rad]	CW [kNm/rad]	CA [N/mm]	n [rpm]
GMC 13	13	1,53	0,01	0,13	2,4	893	26880
GMC 15	15	2,15	0,01	0,19	3,4	1000	24000
GMC 16	16	2,99	0,02	0,26	4,7	1116	21504
GMC 18	18	4,20	0,03	0,37	6,6	1250	19200
GMC 21	21	6,27	0,06	0,55	9,8	1429	16800
GMC 23	23	8,92	0,10	0,78	14,0	1607	14933
GMC 26	26	12,24	0,17	1,07	19,2	1786	13440
GMC 29	29	17,20	0,30	1,50	27,0	2000	12000
GMC 32	32	23,91	0,52	2,09	37,5	2232	10752
GMC 36	36	33,59	0,92	2,93	52,7	2500	9600
GMC 41	41	47,83	1,65	4,17	75,1	2813	8533
GMC 46	46	68,47	3,00	5,97	107,5	3170	7572
GMC 52	52	97,94	5,45	8,54	153,7	3571	6720
Tkn	Nominal torque						
I	Total mass moment of inertia of the coupling						
CT	Total torsional stiffness of the coupling						
CW	Bending stiffness of one membrane						
CA	Total axial stiffness of the coupling						
n	Maximum speed						