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Bearing device for a heart support system, and method for rinsing a space in a bearing device for a heart support system

Abstract

The invention relates to a bearing device (**100**) for a cardiac support system. The bearing device (**100**) comprises a stand unit (**105**) and an impeller (**110**). The stand unit (**105**) is designed to support the impeller (**110**) such that it can rotate. The impeller (**110**) is designed to rotate during an operation of the cardiac support system in order to convey a pump fluid flow (**115**). The impeller (**110**) is designed to enclose at least one subsection (**120**) of the stand unit (**105**) in the assembled state of the bearing device (**100**), wherein an intermediate space (**125**) for guiding a flushing fluid flow (**130**) is provided between the subsection (**120**) and the impeller (**110**). At least one flushing outlet (**135**) is formed in the impeller (**110**). The flushing outlet (**135**) is designed to discharge the flushing fluid flow (**130**) from the intermediate space (**125**) by means of centrifugal force when the cardiac support system is in operation.

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11167124	12/2020	Pfeffer et al.	N/A	N/A
11173297	12/2020	Muller	N/A	N/A
11179557	12/2020	Georges et al.	N/A	N/A
11185678	12/2020	Smith et al.	N/A	N/A
11185680	12/2020	Tuval et al.	N/A	N/A
11191944	12/2020	Tuval et al.	N/A	N/A
11197989	12/2020	Arslan et al.	N/A	N/A
11202901	12/2020	Barry	N/A	N/A
11219756	12/2021	Tanner et al.	N/A	N/A
11229786	12/2021	Zeng et al.	N/A	N/A
11235138	12/2021	Gross-Hardt et al.	N/A	N/A
11235140	12/2021	Siess et al.	N/A	N/A
11241568	12/2021	Keenan et al.	N/A	N/A
11241569	12/2021	Delgado, III	N/A	N/A
11253693	12/2021	Pfeffer et al.	N/A	N/A
11260212	12/2021	Tuval et al.	N/A	N/A
11260213	12/2021	Zeng et al.	N/A	N/A
11260215	12/2021	Scheckel et al.	N/A	N/A
11273300	12/2021	Schafir	N/A	N/A
11273301	12/2021	Pfeffer et al.	N/A	N/A
11278711	12/2021	Liebing	N/A	N/A
11280345	12/2021	Bredenbreuker et al.	N/A	N/A
11285309	12/2021	Tuval et al.	N/A	N/A
11291824	12/2021	Schwammenthal et al.	N/A	N/A
11291825	12/2021	Tuval et al.	N/A	N/A
11291826	12/2021	Tuval et al.	N/A	N/A
11298519	12/2021	Josephy et al.	N/A	N/A
11298520	12/2021	Schwammenthal et al.	N/A	N/A
11298521	12/2021	Schwammenthal et al.	N/A	N/A
11298523	12/2021	Tuval et al.	N/A	N/A
11298524	12/2021	El Katerji et al.	N/A	N/A
11298525	12/2021	Jahangir	N/A	N/A
11305103	12/2021	Larose et al.	N/A	N/A
11305105	12/2021	Corbett et al.	N/A	N/A

11311711	12/2021	Casas et al.	N/A	N/A
11311712	12/2021	Zeng et al.	N/A	N/A
11313228	12/2021	Schumacher et al.	N/A	N/A
D951435	12/2021	Motomura et al.	N/A	N/A
11318295	12/2021	Reyes et al.	N/A	N/A
11324940	12/2021	Earles et al.	N/A	N/A
11324941	12/2021	Xu et al.	N/A	N/A
11331465	12/2021	Epple	N/A	N/A
11331466	12/2021	Keen et al.	N/A	N/A
11331467	12/2021	King et al.	N/A	N/A
11331470	12/2021	Muller et al.	N/A	N/A
11338124	12/2021	Pfeffer et al.	N/A	N/A
11338125	12/2021	Liu et al.	N/A	N/A
11344716	12/2021	Taskin	N/A	N/A
11344717	12/2021	Kallenbach et al.	N/A	N/A
11351356	12/2021	Mohl	N/A	N/A
11351357	12/2021	Mohl	N/A	N/A
11351359	12/2021	Clifton et al.	N/A	N/A
11357967	12/2021	Zeng et al.	N/A	N/A
11364373	12/2021	Corbett et al.	N/A	N/A
11368081	12/2021	Vogt et al.	N/A	N/A
11369785	12/2021	Callaway et al.	N/A	N/A
11369786	12/2021	Menon et al.	N/A	N/A
11376415	12/2021	Mohl	N/A	N/A
11389639	12/2021	Casas	N/A	N/A
11389641	12/2021	Nguyen et al.	N/A	N/A
11413443	12/2021	Hodges et al.	N/A	N/A
11413446	12/2021	Siess et al.	N/A	N/A
11415150	12/2021	Richert et al.	N/A	N/A
11421701	12/2021	Schumacher et al.	N/A	N/A
11428236	12/2021	McBride et al.	N/A	N/A
11433168	12/2021	Wu et al.	N/A	N/A
11434921	12/2021	McBride et al.	N/A	N/A
11434922	12/2021	Roehn	N/A	N/A
11446481	12/2021	Wolman et al.	N/A	N/A
11446482	12/2021	Kirchhoff et al.	N/A	N/A
11452859	12/2021	Earles et al.	N/A	N/A
11460030	12/2021	Shambaugh et al.	N/A	N/A
11471662	12/2021	Akkerman et al.	N/A	N/A
11471663	12/2021	Tuval et al.	N/A	N/A
11471665	12/2021	Clifton et al.	N/A	N/A
11478627	12/2021	Siess et al.	N/A	N/A
11478628	12/2021	Muller et al.	N/A	N/A
11478629	12/2021	Harjes et al.	N/A	N/A
11484698	12/2021	Radman	N/A	N/A
11484699	12/2021	Tuval et al.	N/A	N/A
11486400	12/2021	Schumacher	N/A	N/A
11491320	12/2021	Siess	N/A	N/A
11491322	12/2021	Muller et al.	N/A	N/A
11497896	12/2021	Tanner et al.	N/A	N/A
11497906	12/2021	Grace et al.	N/A	N/A
11511101	12/2021	Hastie et al.	N/A	N/A
11511103	12/2021	Salahieh et al.	N/A	N/A
11511104	12/2021	Dur et al.	N/A	N/A

11517726	12/2021	Siess et al.	N/A	N/A
11517736	12/2021	Earles et al.	N/A	N/A
11517737	12/2021	Struthers et al.	N/A	N/A
11517738	12/2021	Wisniewski	N/A	N/A
11517739	12/2021	Toellner	N/A	N/A
11517740	12/2021	Agarwa et al.	N/A	N/A
11524137	12/2021	Jahangir	N/A	N/A
11524165	12/2021	Tan et al.	N/A	N/A
11529062	12/2021	Moyer et al.	N/A	N/A
11534596	12/2021	Schafir et al.	N/A	N/A
11565103	12/2022	Farago et al.	N/A	N/A
11569015	12/2022	Mourran et al.	N/A	N/A
11572879	12/2022	Mohl	N/A	N/A
11577067	12/2022	Breidall et al.	N/A	N/A
11577068	12/2022	Spence et al.	N/A	N/A
11583659	12/2022	Pfeffer et al.	N/A	N/A
11583670	12/2022	Pfeifer et al.	N/A	N/A
11583671	12/2022	Nguyen et al.	N/A	N/A
11583672	12/2022	Weber et al.	N/A	N/A
11590336	12/2022	Harjes et al.	N/A	N/A
11590337	12/2022	Granegger et al.	N/A	N/A
11590338	12/2022	Barry	N/A	N/A
11592028	12/2022	Schumacher et al.	N/A	N/A
11596727	12/2022	Siess et al.	N/A	N/A
11602627	12/2022	Leonhardt	N/A	N/A
11617876	12/2022	Scheckel et al.	N/A	N/A
11628293	12/2022	Gandhi et al.	N/A	N/A
11632015	12/2022	Sconzert et al.	N/A	N/A
11633586	12/2022	Tanner et al.	N/A	N/A
11638813	12/2022	West	N/A	N/A
11639722	12/2022	Medvedev et al.	N/A	N/A
11642511	12/2022	Delgado, III	N/A	N/A
11648387	12/2022	Schwammenthal et al.	N/A	N/A
11648388	12/2022	Siess et al.	N/A	N/A
11648389	12/2022	Wang et al.	N/A	N/A
11648390	12/2022	Spanier et al.	N/A	N/A
11648391	12/2022	Schwammenthal et al.	N/A	N/A
11648392	12/2022	Tuval et al.	N/A	N/A
11648393	12/2022	Taskin et al.	N/A	N/A
11654273	12/2022	Granegger et al.	N/A	N/A
11654275	12/2022	Brandt	N/A	N/A
11654276	12/2022	Fitzgerald et al.	N/A	N/A
11660441	12/2022	Fitzgerald et al.	N/A	N/A
11666747	12/2022	Tuval et al.	N/A	N/A
11666748	12/2022	Kronstedt et al.	N/A	N/A
11668321	12/2022	Richert et al.	N/A	N/A
11674517	12/2022	Mohl	N/A	N/A
11679234	12/2022	King et al.	N/A	N/A
11679249	12/2022	Scheckel et al.	N/A	N/A
11684275	12/2022	Tuval et al.	N/A	N/A
11684769	12/2022	Harjes et al.	N/A	N/A
11690521	12/2022	Tuval et al.	N/A	N/A
11690996	12/2022	Siess et al.	N/A	N/A
11697016	12/2022	Epple	N/A	N/A

11701510	12/2022	Demou	N/A	N/A
11702938	12/2022	Schumacher et al.	N/A	N/A
11703064	12/2022	Bredenbreuker et al.	N/A	N/A
11708833	12/2022	McBride et al.	N/A	N/A
11744987	12/2022	Siess et al.	N/A	N/A
11745005	12/2022	Delgado, III	N/A	N/A
11746906	12/2022	Balta et al.	N/A	N/A
11752322	12/2022	Aboulhosn et al.	N/A	N/A
11752323	12/2022	Edwards et al.	N/A	N/A
11754075	12/2022	Schuelke et al.	N/A	N/A
11754077	12/2022	Mohl	N/A	N/A
11759612	12/2022	Tanner et al.	N/A	N/A
11759622	12/2022	Siess et al.	N/A	N/A
11766555	12/2022	Matthes et al.	N/A	N/A
11771884	12/2022	Siess et al.	N/A	N/A
11771885	12/2022	Liu et al.	N/A	N/A
11779234	12/2022	Harjes et al.	N/A	N/A
11779751	12/2022	Earles et al.	N/A	N/A
11781551	12/2022	Yanai et al.	N/A	N/A
11786386	12/2022	Brady et al.	N/A	N/A
11786700	12/2022	Pfeffer et al.	N/A	N/A
11786720	12/2022	Muller	N/A	N/A
11793994	12/2022	Josephy et al.	N/A	N/A
11804767	12/2022	Vogt et al.	N/A	N/A
11806116	12/2022	Tuval et al.	N/A	N/A
11806117	12/2022	Tuval et al.	N/A	N/A
11806517	12/2022	Petersen	N/A	N/A
11806518	12/2022	Michelena et al.	N/A	N/A
11813443	12/2022	Hanson et al.	N/A	N/A
11813444	12/2022	Siess et al.	N/A	N/A
11819678	12/2022	Siess et al.	N/A	N/A
11826127	12/2022	Casas	N/A	N/A
11833278	12/2022	Siess et al.	N/A	N/A
11833342	12/2022	Tanner et al.	N/A	N/A
11839754	12/2022	Tuval et al.	N/A	N/A
11844592	12/2022	Tuval et al.	N/A	N/A
11844940	12/2022	D'Ambrosio et al.	N/A	N/A
11850412	12/2022	Grauwinkel et al.	N/A	N/A
11850413	12/2022	Zeng et al.	N/A	N/A
11850414	12/2022	Schenck et al.	N/A	N/A
11850415	12/2022	Schwammenthal et al.	N/A	N/A
11857743	12/2023	Fantuzzi et al.	N/A	N/A
11857777	12/2023	Earles et al.	N/A	N/A
11865238	12/2023	Siess et al.	N/A	N/A
11872384	12/2023	Cotter	N/A	N/A
11883005	12/2023	Golden et al.	N/A	N/A
11883207	12/2023	El Katerji et al.	N/A	N/A
11883310	12/2023	Nolan et al.	N/A	N/A
11883641	12/2023	Dur et al.	N/A	N/A
11890212	12/2023	Gilmartin et al.	N/A	N/A
11896482	12/2023	Delaloye et al.	N/A	N/A
11898642	12/2023	Stanton et al.	N/A	N/A
11904104	12/2023	Jahangir	N/A	N/A
11911579	12/2023	Tanner et al.	N/A	N/A

11918470	12/2023	Jarral et al.	N/A	N/A
11918496	12/2023	Folan	N/A	N/A
11918726	12/2023	Siess et al.	N/A	N/A
11918800	12/2023	Muller et al.	N/A	N/A
11925356	12/2023	Anderson et al.	N/A	N/A
11925570	12/2023	Lydecker et al.	N/A	N/A
11925794	12/2023	Malkin et al.	N/A	N/A
11925795	12/2023	Muller et al.	N/A	N/A
11925796	12/2023	Tanner et al.	N/A	N/A
11925797	12/2023	Tanner et al.	N/A	N/A
11938311	12/2023	Corbett et al.	N/A	N/A
11944805	12/2023	Stotz	N/A	N/A
11980385	12/2023	Haselman	N/A	N/A
11986604	12/2023	Siess	N/A	N/A
12005248	12/2023	Vogt et al.	N/A	N/A
12011583	12/2023	Wang	N/A	N/A
12017058	12/2023	Kerkhoffs et al.	N/A	N/A
12023476	12/2023	Tuval et al.	N/A	N/A
12023477	12/2023	Siess	N/A	N/A
12059559	12/2023	Muller et al.	N/A	N/A
12064120	12/2023	Hajjar et al.	N/A	N/A
12064611	12/2023	D'Ambrosio et al.	N/A	N/A
12064614	12/2023	Agah et al.	N/A	N/A
12064615	12/2023	Stotz et al.	N/A	N/A
12064616	12/2023	Spanier et al.	N/A	N/A
12076544	12/2023	Siess et al.	N/A	N/A
12076549	12/2023	Stotz et al.	N/A	N/A
12090314	12/2023	Tuval et al.	N/A	N/A
12092114	12/2023	Siess	N/A	N/A
12097016	12/2023	Goldvasser	N/A	N/A
12107474	12/2023	Vollmer	N/A	N/A
2001/0009645	12/2000	Noda	N/A	N/A
2001/0041934	12/2000	Yamazaki et al.	N/A	N/A
2002/0076322	12/2001	Maeda et al.	N/A	N/A
2002/0147495	12/2001	Petroff	N/A	N/A
2002/0153664	12/2001	Schroeder	N/A	N/A
2003/0060685	12/2002	Houser	N/A	N/A
2003/0091450	12/2002	Davis et al.	N/A	N/A
2003/0100816	12/2002	Siess	N/A	N/A
2003/0111800	12/2002	Kreutzer	N/A	N/A
2003/0139643	12/2002	Smith et al.	N/A	N/A
2003/0191357	12/2002	Frazier	N/A	N/A
2004/0044266	12/2003	Siess et al.	N/A	N/A
2004/0066107	12/2003	Gery	N/A	N/A
2004/0102674	12/2003	Zadini et al.	N/A	N/A
2004/0115038	12/2003	Nuesser et al.	N/A	N/A
2004/0167376	12/2003	Peters et al.	N/A	N/A
2004/0234391	12/2003	Izraelev	N/A	N/A
2004/0241019	12/2003	Goldowsky	N/A	N/A
2004/0260346	12/2003	Overall et al.	N/A	N/A
2005/0006083	12/2004	Chen et al.	N/A	N/A
2005/0008509	12/2004	Chang	N/A	N/A
2005/0019167	12/2004	Nusser et al.	N/A	N/A
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2005/0220636	12/2004	Henein et al.	N/A	N/A
2005/0254976	12/2004	Carrier et al.	N/A	N/A
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2006/0062672	12/2005	McBride et al.	N/A	N/A
2006/0155158	12/2005	Aboul-Hosn	N/A	N/A
2006/0224110	12/2005	Scott et al.	N/A	N/A
2006/0276682	12/2005	Bolling et al.	N/A	N/A
2007/0004959	12/2006	Carrier et al.	N/A	N/A
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2007/0156006	12/2006	Smith et al.	N/A	N/A
2008/0015517	12/2007	Geistert et al.	N/A	N/A
2008/0058925	12/2007	Cohen	N/A	N/A
2008/0086027	12/2007	Siess et al.	N/A	N/A
2008/0114339	12/2007	McBride et al.	N/A	N/A
2008/0262289	12/2007	Goldowsky	N/A	N/A
2008/0292478	12/2007	Baykut et al.	N/A	N/A
2008/0306328	12/2007	Ercolani	N/A	N/A
2009/0004037	12/2008	Ito	N/A	N/A
2009/0112312	12/2008	Larose et al.	N/A	N/A
2009/0138080	12/2008	Siess et al.	N/A	N/A
2009/0203957	12/2008	LaRose et al.	N/A	N/A
2009/0204205	12/2008	Larose et al.	N/A	N/A
2010/0041939	12/2009	Siess	N/A	N/A
2010/0082099	12/2009	Vodermayer et al.	N/A	N/A
2010/0191035	12/2009	Kang et al.	N/A	N/A
2010/0268017	12/2009	Siess	N/A	N/A
2010/0298625	12/2009	Reichenbach et al.	N/A	N/A
2011/0184224	12/2010	Garrigue	N/A	N/A
2011/0230821	12/2010	Babic	N/A	N/A
2011/0237863	12/2010	Ricci et al.	N/A	N/A
2011/0238172	12/2010	Akdis	N/A	N/A
2012/0029265	12/2011	LaRose	N/A	N/A
2012/0035645	12/2011	Gross	N/A	N/A
2012/0088954	12/2011	Foster	N/A	N/A
2012/0093628	12/2011	Liebing	N/A	N/A
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2013/0053623	12/2012	Evans	N/A	N/A
2013/0085318	12/2012	Toellner	N/A	N/A
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2013/0289376	12/2012	Lang	N/A	N/A
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2013/0303831	12/2012	Evans	N/A	N/A
2013/0303832	12/2012	Wampler	N/A	N/A
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2014/0051908	12/2013	Khanal et al.	N/A	N/A
2014/0079557	12/2013	LaRose et al.	N/A	N/A
2014/0107399	12/2013	Spence	N/A	N/A

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2014/0194717	12/2013	Wildhirt et al.	N/A	N/A
2014/0200389	12/2013	Yanai et al.	N/A	N/A
2014/0207232	12/2013	Garrigue	N/A	N/A
2014/0275721	12/2013	Yanai et al.	N/A	N/A
2014/0330069	12/2013	Hastings et al.	N/A	N/A
2014/0341726	12/2013	Wu et al.	N/A	N/A
2015/0031936	12/2014	LaRose et al.	N/A	N/A
2015/0051435	12/2014	Siess et al.	N/A	N/A
2015/0051438	12/2014	Taskin	N/A	N/A
2015/0099923	12/2014	Magovern et al.	N/A	N/A
2015/0141842	12/2014	Spanier et al.	N/A	N/A
2015/0171694	12/2014	Dallas	N/A	N/A
2015/0190092	12/2014	Mori	N/A	N/A
2015/0273184	12/2014	Scott et al.	N/A	N/A
2015/0290372	12/2014	Muller et al.	N/A	N/A
2015/0290373	12/2014	Rudser et al.	N/A	N/A
2015/0306291	12/2014	Bonde et al.	N/A	N/A
2015/0343179	12/2014	Schumacher et al.	N/A	N/A
2015/0365738	12/2014	Purvis et al.	N/A	N/A
2016/0008531	12/2015	Wang et al.	N/A	N/A
2016/0030649	12/2015	Zeng	N/A	N/A
2016/0038663	12/2015	Taskin et al.	N/A	N/A
2016/0045654	12/2015	Connor	N/A	N/A
2016/0144089	12/2015	Woo et al.	N/A	N/A
2016/0144166	12/2015	Decréet al.	N/A	N/A
2016/0166747	12/2015	Frazier et al.	N/A	N/A
2016/0213828	12/2015	Sievers	N/A	N/A
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Background/Summary

BACKGROUND

Field

(1) The invention relates to a bearing device for a cardiac support system comprising a stand unit, an impeller and an intermediate space formed between the impeller and the stand unit for guiding a flushing fluid flow of a fluid, wherein the stand unit comprises a subsection which projects into the impeller and is configured to support the impeller such that it can rotate about an axis of rotation, wherein the impeller is configured to rotate about a longitudinal axis aligned with the axis of rotation when the cardiac support system is in operation to convey a pump fluid flow of the fluid in a flow direction, and wherein the impeller comprises at least one flushing inlet for introducing the flushing fluid flow into the intermediate space and at least one flushing outlet for discharging the flushing fluid flow from the intermediate space.

(2) The invention further relates to a cardiac support system having a bearing device and a method for flushing an intermediate space for guiding a flushing fluid flow with a fluid in a bearing device for a cardiac support system and a method for producing a bearing device for a cardiac support system.

Description of the Related Art

(3) To provide cardiovascular support for patients having heart failure, systems are used in particular that take over part or all of the heart's pumping function. These systems, which are also referred to as cardiac support systems or VADs (ventricular assist devices) for short, can be subdivided into temporary systems for short-term cardiac support and permanent systems for long-term use on or in the patient. One component of such a system is usually a blood pump, typically a centrifugal pump (turbo pump), which is driven by an integrated electric motor and produces the required blood flow by means of a rotor. The pump can be implanted in different locations. The pump can be sutured to the heart from the outside by means of an invasive sternotomy, for example, or it can be placed into the aorta or into a ventricle in a minimally invasive manner by means of a catheter. In the latter case, the maximum permissible outer diameter of the pump is generally limited to 10 mm, which is why the use of an axial pump having a rotor which receives flow axially is desirable. In the process, the blood to be conveyed is expelled through the discharge openings disposed on the circumference of a cylindrical pump housing in order to be returned to the aorta.

(4) EP 3 127 562 A1 discloses a blood pump for a cardiac support system, which comprises a pump housing with an impeller that is rotatably mounted in the pump housing in a sliding bearing having stationary support surfaces, against which support surfaces configured on the blades of the impeller abut. The complex structure of the blades of the impeller on which the support surfaces are formed has the effect that the sliding bearing is flushed and heat is removed from it when blood is pumped in the blood pump.

SUMMARY

(5) The object of the invention is to provide a bearing device for a cardiac support system that does not require complex blade structures and/or hoses with additional flushing pumps for flushing with a fluid, and to specify a method for flushing a bearing device for a cardiac support system that ensures that sufficient heat can be dissipated from the bearing device during operation of the cardiac support system.

(6) This object is achieved by the bearing device specified herein and the method specified herein. Advantageous embodiments of the invention are described herein.

(7) A bearing device according to the invention for a cardiac support system includes a stand unit and an impeller and comprises an intermediate space formed between the impeller and the stand unit for guiding a flushing fluid flow of a fluid. The stand unit comprises a subsection which projects into the impeller and is configured to support the impeller such that it can rotate about an axis of rotation. The impeller is configured to rotate about a longitudinal axis aligned with the axis of rotation when the cardiac support

system is in operation to convey a pump fluid flow of the fluid in a flow direction, wherein the impeller comprises at least one flushing outlet for discharging the flushing fluid flow from the intermediate space. The at least one flushing outlet in the impeller is configured such that, due to a centrifugal force acting upon the fluid in the at least one flushing outlet, a rotation of the impeller about the axis of rotation during operation of the cardiac support system causes the fluid to be expelled from the intermediate space through the flushing outlet to at least one discharge opening, whereby the flushing fluid flow is discharged from the intermediate space. For this purpose, the at least one flushing outlet in the impeller can comprise a discharge opening for discharging the flushing fluid flow, which has an opening cross-section, in which, at at least one location, an opening cross-section normal vector has a directional component which faces away from the axis of rotation and is radial to the axis of rotation. The at least one flushing outlet in the impeller is configured such that, due to a centrifugal force acting upon the fluid in the at least one flushing outlet, a rotation of the impeller about the axis of rotation during operation of the cardiac support system causes the fluid to be expelled from the intermediate space through the flushing outlet to at least one discharge opening, whereby the flushing fluid flow is discharged from the intermediate space.

(8) A plurality of flushing outlets can be formed in the impeller. The at least one flushing outlet preferably extends along an axis which intersects the longitudinal axis of the impeller or is disposed at an angle to said longitudinal axis. The at least one flushing outlet can in particular be configured as a tube. The at least one discharge opening of the flushing outlet can, for example, be disposed in a jacket section of the impeller enclosing the subsection of the stand unit projecting into the impeller. The at least one discharge opening of the flushing outlet can in particular be disposed in a transition section between a region of a propeller of the impeller and a jacket section of the impeller enclosing the subsection of the stand unit projecting into the impeller.

(9) It is also possible for the impeller to comprise a plurality of flushing outlets, wherein the at least one discharge openings of the flushing outlet are disposed at least partially in a transition section between a region of a propeller of the impeller and a jacket section of the impeller enclosing the subsection of the stand unit projecting into the impeller.

(10) It should be noted that a number of flushing outlets in the impeller can correspond to a multiple of the number of blades of the impeller. It should also be noted that the bearing device can have a flushing inlet which, in the assembled state of the sliding bearing device, opens into the intermediate space. The flushing inlet can be configured as a gap between a base of the stand unit and a jacket section of the impeller enclosing the subsection of the stand unit projecting into the impeller, for example.

(11) It should be noted that the flushing inlet can also be configured as at least one inlet channel extending in a direction which intersects the longitudinal axis of the impeller or extends at an angle to said longitudinal axis. The bearing device can also comprise a flushing inlet having a plurality of inlet channels.

(12) The flushing inlet can in particular be disposed downstream with respect to the flushing outlet in the flow direction of the pump fluid flow.

(13) The impeller can be located in a housing comprising a housing section to which an inlet hose for supplying the fluid is connected.

(14) The housing section of the bearing device preferably has at least one discharge opening for discharging the pump fluid flow. The housing section can comprise webs for connecting to a connection section for connecting an inlet hose, wherein the webs delimit at least one discharge opening of the housing section.

(15) A bearing device according to the invention can be configured as a sliding bearing device which comprises a sliding bearing for supporting a rotating component, or as a magnetic bearing device, in which a rotating component is magnetically supported.

(16) A sliding bearing device according to the invention comprises a stand unit and an impeller. The stand unit is designed to support the impeller such that it can rotate. The impeller is designed to rotate during an operation of the cardiac support system in order to convey a pump fluid flow. The impeller is configured to enclose at least one subsection of the stand unit in the assembled state of the sliding bearing device. An intermediate space for guiding a flushing fluid flow is provided between said subsection and the impeller. At least one flushing outlet is configured in the impeller to discharge the flushing fluid flow from the intermediate space by means of centrifugal force when the cardiac support system is in operation.

(17) A sliding bearing device according to the invention for a cardiac support system in particular enables the sliding bearing device to be flushed by utilizing centrifugal force. For this purpose, an impeller of the sliding bearing device can comprise a flushing outlet that rotates with the impeller in order to use the

centrifugal force at the rotating flushing outlet as the driving force for flushing the sliding bearing device. Flushing the sliding bearing device is beneficial during operation of the cardiac support system to dissipate heat and prevent the formation of thromboses.
(18) Flushing that utilizes centrifugal force, as a result of which the flushing rate substantially depends only on the rotational speed of the cardiac support system and not on the static pressure difference between the flushing inlet and the flushing outlet, advantageously reduces the risk of thrombosis formation, because the flushing rate is significantly less affected by loss of pressure in the blood stream and can thus be set more robustly. It is also not necessary for an external pressure difference to be imposed via the flushing system.
(19) The utilization of the centrifugal force via the flushing outlet in the impeller furthermore enables a compact design of the sliding bearing device, which is advantageous in particular for the use of the sliding bearing device in conjunction with the cardiac support system.
(20) The cardiac support system can be a heart pump, for example, such as a left ventricular support system, a right ventricular support system, or a biventricular support system. The stand unit can be understood to be a non-rotating component of the sliding bearing device. The impeller can be a rotating component, such as a rotor. In the assembled state of the sliding bearing device, the impeller can enclose at least one subsection of the stand unit, whereby the sliding bearing device can be configured as a cylindrical sliding bearing, for example. In the implanted state of the cardiac support system, the impeller can be positioned in the blood. The pump fluid flow to be conveyed can, for example, be a blood flow pumped by the cardiac support system and produced by means of the cardiac support system. In the assembled state, an intermediate space in the form of a gap can emerge between the impeller and the subsection of the stand unit. The flushing outlet can be realized as a bore or another type of through-opening in the impeller. The flushing outlet can be configured to conduct the flushing fluid flow from the intermediate space through a portion of the impeller to discharge the flushing fluid flow from the intermediate space. It is also possible to configure two or more flushing outlets in the impeller.
(21) According to one embodiment, the flushing outlet can be inclined relative to a longitudinal axis of the impeller, which in particular corresponds to an axis of rotation of the impeller. This is advantageous for utilizing the centrifugal force to effect a flushing of the sliding bearing device. The flushing outlet can have a longitudinal extension axis which is inclined relative to the longitudinal axis of the impeller. The longitudinal extension axis of the flushing outlet can also be inclined at a right angle with respect to the longitudinal axis of the impeller.
(22) According to one embodiment, the flushing outlet can be configured as a tube having a discharge opening. The flushing outlet can thus advantageously be realized in a cost-saving manner, for example as a bore in the impeller, which also enables a compact design of the sliding bearing device.
(23) According to one embodiment, the discharge opening can be disposed in a jacket section of the impeller enclosing the subsection of the stand unit or in a transition section between a region of a propeller of the impeller and said subsection. The transition section can be configured as a narrowing of the jacket section in the direction of the propeller, for example.
(24) The discharge opening can alternatively also be disposed in the region of the propeller. The potential of the centrifugal force, by means of which the flushing effect for flushing the sliding bearing device can advantageously be set, can be set via the positioning of the discharge opening.
(25) According to one embodiment, the impeller can also comprise a plurality of flushing outlets. The discharge openings of the flushing outlets can be disposed at least partially in the transition section. In the assembled state of the sliding bearing device, the flushing outlets can extend radially outward with respect to the stand unit, for example. The discharge openings can be disposed evenly spaced around the periphery of the transition section. This positioning of the flushing outlets and the discharge openings is advantageous in terms of uniform flushing of the intermediate space and in terms of presenting the largest possible cross-section of the flushing outlets.
(26) According to one embodiment, at least one pair of flushing outlets can be configured in the impeller. The flushing outlets of the at least one pair can be disposed opposite one another with respect to a longitudinal axis of the impeller. The configuration of the oppositely disposed pair of flushing outlets is advantageous to prevent an imbalance of the rotating propeller.
(27) A number of flushing outlets in the impeller can correspond to a multiple of the number of blades of the impeller. The flushing outlets in the form of flushing bores are disposed just as periodically as the blading of the impeller, for example. This makes it possible to prevent an imbalance. In this case, for example, two

blades result in a multiple of two as the number of flushing outlets.
(28) According to one embodiment, the sliding bearing device can also comprise a flushing inlet for introducing the flushing fluid flow. In the assembled state of the sliding bearing device, the flushing inlet can open into the intermediate space. Using the acting centrifugal force, the flushing fluid flow can flush the intermediate space and thus also the bearing of the sliding bearing device, even without the provision of a static pressure difference between the flushing inlet and the flushing outlet.
(29) According to one embodiment, the flushing inlet can also be configured as a gap between a base of the stand unit and a jacket section of the impeller enclosing the subsection of the stand unit. Additionally or alternatively, the flushing inlet can be configured as an inlet channel in the impeller. The inlet channel can be inclined relative to an axis of rotation of the impeller. The flushing outlet can furthermore be formed in the impeller by a plurality of inlet channels with at least one inclined inlet channel. At least one side of the flushing inlet can thus be configured to be stationary and one side such that it can rotate. The flushing fluid flow can be drawn in on the stationary side of the flushing inlet, e.g., on a wall of the stand unit. If the flushing inlet is configured as an inlet channel in the impeller, the flushing inlet can be configured at least partially in the rotating body of the impeller. A portion of the flushing fluid flow that is partially enclosed in the intermediate space can be introduced through the flushing inlet and discharged again through the flushing outlet, for example to absorb and dissipate heat from the stand unit. The centrifugal pressure is advantageously increased if the flushing inlet is not or only partially located in the rotating body, the impeller.
(30) The flushing inlet can furthermore be disposed downstream with respect to the flushing outlet in the flow direction of the pump fluid flow. By introducing the flushing fluid flow along the stand unit and along the impeller, a constant flushing of the sliding device can advantageously be set thanks to the rotation of the flushing fluid flow at the flushing outlet, even when the pressure levels at the flushing inlet and flushing outlet are the same.
(31) The invention further presents a cardiac support system having an embodiment of the aforementioned sliding bearing device. The cardiac support system can be a left ventricular cardiac support pump, for example. For minimally invasive transfemoral or transaortic insertion, for example, the cardiac support system can furthermore have an elongated, cylindrical shape.
(32) A method for producing a bearing device for a cardiac support system configured as a sliding bearing device or as a magnetic bearing device is presented as well. The method comprises the following steps: providing a stand unit, which is designed to support an impeller such that it can rotate, and the impeller, which is configured to rotate during operation of the cardiac support system to convey a pump fluid flow; forming at least one flushing outlet in the impeller, wherein the flushing outlet is designed to discharge a flushing fluid flow from the bearing device by means of centrifugal force when the cardiac support system is in operation; and assembling the impeller and the stand unit to produce the bearing device, wherein at least one subsection of the stand unit is enclosed by the impeller, and wherein an intermediate space for guiding the flushing fluid flow is disposed between the subsection and the impeller.
(33) An embodiment of the aforementioned bearing device can advantageously be produced by carrying out the method.
(34) The condition for the flushing to function by the action of centrifugal force is set out in the following:
(35) The flushing is independent of the static pressure difference. Centrifugal force is used to flush the sliding bearing device; no external pump or additional geometries or structures to produce a static pressure difference are needed. This requires the mechanical energy balance due to the kinetic rotational energy at the exit, at the discharge opening of the flushing outlet, to be positive; i.e., the mechanical energy of the flow at the exit has to be greater than at the entry, at the flushing inlet. This is illustrated in the following using formulas according to Bernoulli's principle:
(36) $\frac{p_{\text{exit}}}{\text{density}} - \frac{v_{\text{exit}}^2}{2} < \frac{p_{\text{entry}}}{\text{density}} - \frac{v_{\text{entry}}^2}{2}$
(37) If v is the rotational speed and the flushing inlet is not subject to rotation, then:
(38) $\frac{p_{\text{exit}}}{\text{density}} - \frac{v_{\text{exit}}^2}{2} < \frac{p_{\text{entry}}}{\text{density}}$
rearranged:
(39) $\frac{(p_{\text{exit}} - p_{\text{entry}})}{\text{density}} < \frac{v_{\text{exit}}^2}{2}$
with the rotation speed $v=2\pi Rn$ and with n being the speed in revolutions/second

(40) $\frac{(p_{\text{exit}} - p_{\text{entry}})}{\text{density}} < 2(\quad R\ n)^2$
from which then follows:
static pressure difference<<2(π*Rn*).sup.2*density
(41) For water, the “centrifugal pressure” corresponds to a pressure difference of approx. 5 bar at a radius of 1 cm and a speed of 30,000 revolutions/minute. The described approach is therefore effective for this numerical example if the static pressure difference is only approx. 500 mbar (interpreted as “much greater” than a factor of ten).
(42) Flushing of the sliding bearing device by means of centrifugal force requires a rotating system with system limits, the “entry” and “exit”, which point outward in the direction normal to the axis of rotation. The flushing path of the flushing fluid flow extends between the rotating body, the jacket section of the impeller, and the body which is stationary relative to it, the stand unit. According to the design example shown here, the flushing fluid flow moves along the path, i.e., along the intermediate space to the flushing outlet. At the exit of the flushing outlet, the flushing fluid flow flows out of the flushing path. In order to impose the centrifugal force across the entire cross-section, the exit boundary of the flushing outlet is located inside the rotating body, inside the jacket section. The cross-section normal vector should have a component in radial direction, which is not the case on the end face of a cylindrical sliding bearing device, for example, but in radial direction, i.e., when the jacket section is drilled into.
(43) The invention also extends to a cardiac support system in which there is a bearing device as described above.
(44) In a method according to the invention for flushing an intermediate space for guiding a flushing fluid flow with a fluid in a bearing device for a cardiac support system, wherein the intermediate space comprises at least one flushing inlet for introducing the flushing fluid flow and at least one flushing outlet for discharging the flushing fluid flow and wherein the intermediate space is configured between an impeller which can rotate about an axis of rotation for conveying a pump fluid flow and a stand unit for rotatably supporting the impeller, in which the fluid is introduced into the intermediate space through the at least one flushing inlet, the fluid is expelled from the intermediate space through the flushing outlet to at least one discharge opening by means of a centrifugal force acting upon said fluid in the at least one flushing outlet relative to the axis of rotation.
(45) Advantageous design examples of the invention are described in more detail in the following with reference to schematic drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The figures show:
(2) FIG. **1** a first sliding bearing device for a cardiac support system comprising an impeller and comprising a stand unit as a section;
(3) FIG. **2** a portion of a cardiac support system comprising the first sliding bearing device;
(4) FIG. **3** a side view of the first sliding bearing device;
(5) FIG. **4** a rear view of the impeller in the direction of the arrow IV of FIG. **3**;
(6) FIG. **5** other possible designs of an impeller in a sliding bearing device for a cardiac support system;
(7) FIG. **6** an intermediate space having various flushing fluid volumes in different sliding bearing devices for a cardiac support system with different configurations of flushing outlets;
(8) FIG. **7** a further sliding bearing device comprising an impeller and comprising a stand unit;
(9) FIG. **8** the further sliding bearing device comprising an impeller and comprising a stand unit as a section;
(10) FIG. **9** a detail of a further sliding bearing device for a cardiac support system in a sectional view;
(11) FIG. **10** the detail of the further sliding bearing device for a cardiac support system of FIG. **9** in a plan view;
(12) FIG. **11** a detail of a further sliding bearing device for a cardiac support system in a sectional view; and
(13) FIG. **12** a flow diagram of a method for producing a sliding bearing device.
DETAILED DESCRIPTION
(14) In the following description of favorable design examples of the present invention, the same reference

signs are used for the elements shown in the various figures, which are the same or have a similar effect, whereby a repeated description of these elements is omitted.

(15) FIG. **1** shows a schematic illustration of a bearing device **100** for a cardiac support system which is configured as a sliding bearing device according to one design example. The bearing device **100** comprises a stand unit **105** and an impeller **110**. The stand unit **105** is configured to support the impeller **110** such that it can rotate about an axis of rotation **112** which is coaxial with the longitudinal axis **114** of the impeller **110**. The impeller **110** is designed to rotate about the axis of rotation **112** when the cardiac support system is in operation in order to convey a pump fluid flow **115**. In the assembled state of the sliding bearing device shown here, the impeller **110** encloses at least one subsection **120** of the stand unit **105**. An intermediate space **125** for guiding a flushing fluid flow **130** is provided between the subsection **120** and the impeller **110**. At least one flushing outlet **135** is formed in the impeller **110**. The flushing outlet **135** is designed to discharge the flushing fluid flow **130** from the intermediate space **125** by means of centrifugal force when the cardiac support system is in operation.

(16) The flushing outlet **135** comprises a discharge opening **140** for discharging the flushing fluid flow **130**, which has an opening cross-section **132**, in which, at at least one location, an opening cross-section normal vector **134** has a directional component **136** which faces away from the axis of rotation **112** and is radial to the axis of rotation **112**.

(17) According to the design example shown here, the flushing outlet **135** is inclined relative to the longitudinal axis **114** of the impeller **110** which is coaxial with the axis of rotation **112**. The flushing outlet **135** comprises an axis **137** along which said flushing outlet **135** extends and which is thus a longitudinal extension axis of the flushing outlet **135**, which is inclined relative to the longitudinal axis **114** of the impeller **110** and forms an acute angle α with it. It should be noted that this axis **137** can also be inclined relative to the longitudinal axis **114** of the impeller **110**.

(18) Furthermore, according to the design example shown here, the flushing outlet **135** is configured as a tube with a discharge opening **140**. The discharge opening **140** is disposed at an end of the tube facing away from the intermediate space **125**.

(19) According to the design example shown here, the sliding bearing device **100** also comprises a flushing inlet **145** for introducing the flushing fluid flow **130**. In the assembled state of the bearing device **100** shown here, the flushing inlet **145** opens into the intermediate space **125**.

(20) According to the design example shown here, the flushing inlet **145** is configured as a gap between a base **107** of the stand unit **105** and a jacket section **150** of the impeller **110** enclosing the subsection **120** of the stand unit **105**. It should be noted that the flushing inlet can in principle also be configured as an inlet channel in the impeller **110**.

(21) In the sliding bearing device shown in FIG. **1**, the flushing inlet **145** is disposed downstream with respect to the flushing outlet **135** in the flow direction of the pump fluid flow **115** as in the design example shown here. FIG. **1** shows a flushing fluid flow **130** with a flushing path for flushing the bearing device **100** which extends from the flushing inlet **145** through the intermediate space **125** to the flushing outlet **135** with the discharge opening **140**.

(22) FIG. **2** shows a perspective view of a portion of a cardiac support system **200** with the sliding bearing device **100** in the form of a left ventricular cardiac support pump (LVAD heart pump). FIG. **3** is a side view of the bearing device **100**.

(23) The bearing device **100** and its function in a cardiac support system are described in more detail in the following:

(24) The impeller **110** is a rotor that forms a rotating component in the bearing device **100** of the cardiac support system **200**, which is supported magnetically or by means of sliding bearings, wherein the rotating component is positioned over a fluid to dissipate heat or reduce friction. When the impeller **110** is positioned directly in the blood during operation of the cardiac support system, as is the case, for example, with the left ventricular cardiac support pump (LVAD heart pump) shown in FIG. **2** in the implanted state of the cardiac support system, it is beneficial to flush the bearing device **100** to dissipate heat and prevent the formation of thromboses (“blood clotting”). To enable robust flushing of the sliding bearing device **100**, a constant flow is necessary. Flushing the sliding bearing device **100** prevents the formation of thromboses. A pump design (such as baffles) that converts mechanical energy into hydrodynamic energy can be used for this purpose. With the sliding bearing device **100** shown in FIG. **1** and FIG. **2**, it is possible to utilize the centrifugal force on the flushing outlet **135** rotating with the impeller **110** using only a bore in the form of

the flushing outlet **135**. The centrifugal force represents the driving force for the flushing. Such a structure is inexpensive to produce.

(25) A plurality of flushing outlets **135** can alternatively also be provided at different locations on the impeller **110** to utilize the centrifugal force, as shown in the following figures.

(26) Using a design example of the bearing device **100** shown here, introduction can be realized by suctioning out the flushing fluid flow **130** with the aid of the centrifugal force at the flushing outlet **135**. Structurally, this is achieved by configuring the flushing outlet **135** such that the flushing outlet **135** is enclosed by the rotating component, the impeller **110**, e.g., by having a bore as the flushing outlet **135**, while the inlet side in the form of flushing inlet **145** is not or only partially, e.g., only on one side, subject to the rotation. This is achieved by configuring the flushing inlet **145** with at least one section of the stand unit **105** as a wall section. In this case, the statistical pressure difference has practically no effect on the flushing flow of the flushing fluid flow **130**, which is why the flushing effect of the bearing device **100** is substantially determined by the centrifugal force and the rotational speed of the pump of the cardiac support system. The flushing effect of the bearing device **100** is thus largely independent of other potential influencing variables, such as the magnitude of the mass flow or the level of the pressure build-up through or over the cardiac support system. Consequently, there is no need for a static pressure difference to flush the bearing device **100**. The positioning of the flushing outlet **135** in the impeller **110**, which is trumpet-shaped here as an example, with widely varying diameters relative to a longitudinal extension axis **114** of said impeller **110**, can therefore be realized in different ways, whereby a positioning of the flushing outlet **135** far upstream of the longitudinal extension of the impeller **110** can be omitted. Complex structures, such as a pump wheel, or the application of a pressure difference in or around the sliding bearing device **100** are not necessary to effect the flushing of the sliding bearing device **100** either. Because of the independence from the pump flow, the pump flow of the pump fluid flow **115** shown here, the flushing of the bearing device **100** is possible without an absence of flushing as long as the impeller **110** is rotating.

(27) In the design example discussed here, the bearing device **100** comprises the impeller **110** as a rotating part which, together with the stand unit **105** as a stationary part, forms a cylindrical sliding bearing. The flushing effect of the bearing device **100** is based on the centrifugal force that results from a rotation at the flushing outlet **135**. The prerequisite for this is that, as shown here, at least one side at the flushing inlet **145** is stationary; in this case the inner side in the form of the stand unit **105**. As a result, even if the pressure levels at the flushing inlet **145** and the flushing outlet **135** are comparable or the same, a constant flushing of the sliding bearing device **100** can be set due to the rotation of both sides of the flushing outlet **135** formed in the rotating impeller **110** or the fluid volume of the flushing outlet **135**. The design example of the bearing device **100** shown here also makes it possible to flush a partially enclosed volume, which is shown here in block **155** which, as an example, is disposed around the fixed bearing of the stand unit **105**, by combining a rotating and a stationary side. The reason for this is that the flushing fluid flow **130** is accelerated on the rotating side of the impeller as a result of the molecular adhesion conditions. The flushing fluid flow **130** is accelerated along the wall of the intermediate space **125** toward a larger diameter due to the centrifugal force, as a result of which the flushing fluid flow **130** is drawn in on the stationary side of the intermediate space **125** in the form of a wall of the stand unit **105**. This causes the partially enclosed fluid of the flushing fluid flow **130** to be flushed, which allows heat at the fixed bearing of the stand unit **105**, for example, to be absorbed and dissipated.

(28) The cardiac support system **200** shown in FIG. **2** comprises a housing section **205**. The impeller **110** of the bearing device **100** is located in the housing section **205** of the cardiac support system **200**. In the cardiac support system **200**, the impeller **110** is disposed in a housing section **205** on which an inlet hose **210** for supplying the fluid is provided. In the housing section **205** of the housing of the cardiac support system, there are discharge openings **215** for discharging the pump fluid flow **115**. For connecting the inlet hose **210**, the cardiac support system **200** comprises a connection section **220** which is connected to webs **225** of the housing section **205** that delimit two discharge openings **215** for discharging fluid conveyed by a rotation of the impeller **110** in the cardiac support system **200** from the housing section **205**.

(29) The housing section **205** of the cardiac support system **200** has a cylindrical, elongated structure with a substantially constant outer diameter for easy placement in a blood vessel, such as the aorta, by means of a catheter. The elongated axial design shown here allows transfemoral implantation of the cardiac support system **200**. The sliding bearing device **100** is accordingly disposed in a window opening in the housing section **205** such that, in the implanted state of the cardiac support system **200**, the rotating rotor

component, the impeller **110**, is positioned in the blood. Due to the axial design of the cardiac support system **200**, the flow received by the impeller **110** is axial relative to the longitudinal axis **114** of the impeller **110**, which corresponds to a longitudinal axis of the cardiac support system **200**. The flushing outlet **135** in the impeller **110** is disposed in the region **111** of a propeller of the impeller **110**, whereby the flushing outlet **135** is realized by a drilled hole or a through-bore or another type of through-hole in the impeller **110**.

(30) FIG. **3** shows the sliding bearing device **100** with the stand unit **105** and the impeller **110** in the assembled state, whereby the stand unit **105** forms the non-rotating counterpart to the rotating impeller **110**. The stand unit **105** has a section which narrows in the direction of the impeller **110**. The narrowed section of the stand unit **105** is mostly enclosed by the impeller **110**. The stand unit **105** is connected to the impeller **110** and supports the impeller **110** such that it can rotate. The flushing outlet **135** having a discharge opening **140** is configured in the impeller **105**. As an example, the discharge opening **140** of the flushing outlet here is disposed in the region of the propeller of the impeller **110**.

(31) FIG. **4** shows a perspective rear view of the impeller in the direction of the arrow IV of FIG. **3**. The side of the impeller **110** facing away from the propeller of the impeller **110**, which can be coupled to the stand unit **105** of the bearing device, is shown as the rear side of the impeller **110**. To connect the impeller **110** to the stand unit **105**, the impeller **110** here comprises a ball bearing **405** for supporting the impeller **110**. The flushing outlets **135** of the impeller **110**, which, as an example, are configured here as discharge bores and which communicate with the intermediate space **125** shown in FIG. **1**, can be seen as well.

(32) According to the design example shown here, at least one pair of flushing outlets **135** is configured in the impeller **110**. The flushing outlets **135** of the at least one pair are disposed opposite one another with respect to a longitudinal axis **114** of the impeller **110**. As an example, the flushing outlets **135** of the pair are evenly spaced with respect to the axis of rotation **112** of the impeller **110**, i.e., they extend symmetrically relative to a longitudinal axis **114** of the impeller **110** coaxial with the axis of rotation **112**.

(33) FIG. **5** shows further possible designs of an impeller **110** in a bearing device for a cardiac support system, which can be configured as a sliding bearing device or as a magnetic bearing device. The figure shows a perspective view of the impeller **110**, wherein different example positionings of a discharge opening **140** of the flushing outlet **135** in the impeller **110** as well as a respective opening cross-section normal vector **134** and the longitudinal axis **114** of the impeller **110** are identified.

(34) According to one design example, the discharge opening **140** of the flushing outlet **135** is disposed in a jacket section **150** of the impeller **110** enclosing the subsection of the stand unit. Alternatively, the discharge opening of the flushing outlet is disposed in a transition section **510** between a region of a propeller **515** of the impeller **110** and the jacket section **505**.

(35) This figure shows a potential estimate for the design example, where the strongest suction force occurs, and thus where a suitable location for positioning the flushing outlet and the discharge opening of the flushing outlet is. Three regions **520**, **525** and **530** for disposing the discharge opening of the flushing outlet in the impeller **110** are shown as examples. The region **520** is located in the region of the propeller **515**. The region **525**, for example, identifies a position of the discharge opening of the flushing outlet **135** in the transition section **510**. The region **530**, for example, identifies a positioning of the discharge opening of the flushing outlet in the jacket section **150**. According to the potential estimate shown here, when the flushing outlet **135** and the discharge opening **140** are positioned in the region **530**, a beneficial flushing effect is achieved in a bearing device having such an impeller **110** and a stand unit **105** because the centrifugal force between the flushing inlet and the flushing outlet is sufficient to drive the flushing.

(36) FIG. **6** shows the intermediate space **125** with different flushing fluid volumes in different bearing devices for a cardiac support system designed as a sliding bearing device or as a magnetic bearing device having different configurations of flushing outlets, wherein the flushing outlets **135** are configured differently. The flushing outlet **135**, through which the flushing fluid flow passes, has different configurations **605**, **610**, **615**, **620**, **625** here. At least one pair of flushing outlets **135** is configured in the impeller of these sliding bearing devices, whereby the flushing outlets **135** of the at least one pair in a bearing device are disposed opposite one another with respect to the longitudinal axis **114** of the impeller **110** aligned with the axis of rotation **112**. The respective configurations **605**, **610**, **615**, **620**, **625** of the flushing outlets shown here show examples of the pair of flushing outlets. In a first configuration **605**, the flushing outlets of the pair extend radially from the longitudinal axis **114** of the impeller inclined at an obtuse angle α with respect to said longitudinal axis **114** of the impeller, whereby a starting point of the

flushing outlets **135** is formed in close proximity to the longitudinal axis **114**. In a second configuration **610**, the flushing outlets **135** of the pair extend inclined at an acute angle α with respect to the longitudinal axis **114** of the impeller; the flushing outlets **135** of the pair are accordingly angled toward one another. A third configuration **615** corresponds to the first configuration **605** with the exception of the starting point of the flushing outlets **135**, which are disposed further apart than the starting points of the flushing outlets of the first configuration **605**. In a fourth configuration **620**, the flushing outlets **135** of the pair extend at a right angle β to the longitudinal axis **114** of the impeller. A fifth configuration **625** shows an example of two pairs of flushing outlets **135**, which are disposed opposite one another with respect to the longitudinal axis **114** of the impeller and are disposed evenly spaced apart from one another. Like the pair shown in the fourth configuration **620**, the two pairs of flushing outlets **135** extend at a right angle β to the longitudinal axis **114** of the impeller.

(37) FIG. **7** shows a further sliding bearing device **100** for a cardiac support system. The figure shows a perspective view of the sliding bearing device **100** in the assembled state, in which the impeller partly encloses the stand unit **105**. FIG. **8** shows this sliding bearing device **100** as a section. The sliding bearing device **100** shown here is similar to the sliding bearing device described with reference to the preceding figures. According to the design example shown here, the impeller **110** comprises a plurality of flushing outlets **135**. The discharge openings **140** of the flushing outlets are disposed at least partially in the transition section **510** between the propeller **515** and the jacket section **505**. As an example, the discharge openings **140** are disposed evenly spaced around the periphery of the transition section **510**. FIG. **7** shows a utilization of the flushing position of the plurality of flushing outlets having the suction force determined to be the strongest.

(38) FIG. **8** shows a further sliding bearing device **100** for a cardiac support system. The figure shows a sectional view of a side view of the sliding bearing device **100**. The stand unit **105** is partially enclosed by the jacket section **150** of the impeller **110**. The plurality of discharge openings **140** of flushing outlets **135** is disposed in the transition region or transition section **510** between the propeller of the impeller **110** and the jacket section **150**. The figure shows the flow direction of the pump fluid flow **115** and the flow path of the flushing fluid flow **130**. The flushing fluid flow **130** is introduced through the flushing inlet **145** which, according to the design example shown here, is configured as a gap **905** between the base **107** of the stand unit **105** and the jacket section **505** of the impeller **110** enclosing the subsection **120** of the stand unit **105**. The flushing fluid flow **130** is then conducted through the intermediate space **125** to one of the discharge openings **140** of the plurality of flushing outlets **135** by means of centrifugal force in order to flush the sliding bearing device **100**.

(39) FIG. **9** shows a schematic illustration of a detail of a sliding bearing device **100** for a cardiac support system according to one design example. The figure shows a cross-section of a part of the sliding bearing device **100** with the subsection of the stand unit **105** enclosed by the jacket section **150** of the impeller. The configuration of the flushing outlet **135** here is intended to show that the flushing outlets can also be disposed in a non-mirror-symmetrical manner.

(40) The figure shows a portion of the flushing path of the flushing fluid flow **130** that flows through the intermediate space **125** to the flushing outlet **135** and is discharged from the discharge opening of the flushing outlet **135**. The outflow of the flushing fluid flow is shown in the following FIG. **10** with the aid of a plan view from the direction identified here with the arrow **1005**.

(41) FIG. **10** shows a schematic illustration of a detail of a sliding bearing device **100** for a cardiac support system according to one design example. The figure shows a plan view onto the detail of the sliding bearing device **100** identified in the preceding FIG. **9**. The flushing outlet **135** is disposed in the jacket section **150** radially to a longitudinal extension axis **116** of the subsection of the stand unit **105** enclosed by the jacket section **505** which is aligned with the axis of rotation **112** in the bearing device. The flushing fluid flow **130** exits the jacket section **150** at the discharge opening **140** of the flushing outlet.

(42) FIG. **11** shows a schematic illustration of a detail of a sliding bearing device **100** for a cardiac support system according to one design example. According to the design example shown here, the flushing inlet **145** is realized in the intermediate space **125** by a plurality of inlet channels, namely by the channel **1105** and the channel **1107**. This is also intended to demonstrate that the inlet direction does not necessarily only have to be oriented in the direction of the longitudinal extension axis **116** of the bearing device **100** aligned with the axis of rotation **112** of the bearing device **100**, but can also be inclined relative to said longitudinal extension axis. If the flushing inlet **145** is configured such that there is no acting centrifugal force there, for

example such that the boundary of the flushing inlet **145** is not or only partially in the rotating body as in the design example of the flushing inlet **145** shown here as an inlet channel **1105** which is partially configured in the jacket section **150**, the centrifugal pressure is advantageously increased.

(43) FIG. **12** shows a flow diagram of a method **800** for producing a bearing device for a cardiac support system configured as a sliding bearing device or as a magnetic bearing device according to one design example. The method **800** comprises a step **801** of providing, a step **803** of forming, and a step **805** of assembling. In step **801** of providing, a stand unit is provided, which is configured to support an impeller such that it can rotate. Also provided in step **801** is the impeller, which is designed to rotate during an operation of the cardiac support system in order to convey a pump fluid flow. In step **803** of forming, at least one flushing outlet is formed in the impeller, which is designed to discharge a flushing fluid flow from the sliding bearing device by means of centrifugal force when the cardiac support system is in operation. In step **805** of assembling, the impeller and the stand unit are assembled to produce the sliding bearing device. At least one subsection of the stand unit is enclosed by the impeller. An intermediate space for guiding the flushing fluid flow is furthermore provided between said subsection and the impeller. During the operation of the cardiac support system, the flushing fluid flow is conducted from the intermediate space into the flushing outlet by means of centrifugal force and from there is discharged from the bearing device in order to flush the bearing device.

(44) In summary, in particular the following should be noted: The invention relates to a bearing device **100** for a cardiac support system. The bearing device **100** comprises a stand unit **105** and an impeller **110**. The stand unit **105** is designed to support the impeller **110** such that it can rotate. The impeller **110** is designed to rotate when the cardiac support system is in operation in order to convey a pump fluid flow **115**. The impeller **110** is designed to enclose at least one subsection **120** of the stand unit **105** in the assembled state of the bearing device **100**, wherein an intermediate space **125** for guiding a flushing fluid flow **130** is provided between the subsection **120** and the impeller **110**. At least one flushing outlet **135** is formed in the impeller **110**. The flushing outlet **135** is designed to discharge the flushing fluid flow **130** from the intermediate space **125** by means of centrifugal force when the cardiac support system is in operation.

(45) The invention relates, in particular, to the aspects specified in the following clauses: 1. Sliding bearing device (**100**) for a cardiac support system (**200**), wherein the sliding bearing device (**100**) has the following features: a stand unit (**105**) is designed to support an impeller (**110**) such that it can rotate; and the impeller (**110**), which is configured to rotate when the cardiac support system (**200**) is in operation to convey a pump fluid flow (**115**), wherein the impeller (**110**) is designed to enclose at least one subsection (**120**) of the stand unit (**105**) in the assembled state of the sliding bearing device (**100**), wherein an intermediate space (**125**) for guiding a flushing fluid flow (**130**) is provided between the subsection (**120**) and the impeller (**110**), wherein at least one flushing outlet (**135**) is formed in the impeller (**110**), wherein the flushing outlet (**135**) is designed to discharge the flushing fluid flow (**130**) from the intermediate space (**125**) by means of centrifugal force when the cardiac support system (**200**) is in operation. 2. Sliding bearing device (**100**) according to clause 1, wherein a plurality of flushing outlets (**135**) are formed in the impeller (**110**). 3. Sliding bearing device (**100**) according to any one of the preceding clauses, wherein the at least one flushing outlet (**135**) is inclined relative to a longitudinal axis of the impeller (**110**). 4. Sliding bearing device (**100**) according to any one of the preceding clauses, wherein the flushing outlet (**135**) is configured as a tube having a discharge opening (**140**). 5. Sliding bearing device (**100**) according to clause 4, wherein the discharge opening (**140**) is disposed in a jacket section (**505**) of the impeller (**110**) enclosing the subsection (**120**) of the stand unit (**105**) or in a transition section (**510**) between a region of a propeller (**515**) of the impeller (**110**) and the jacket section (**150**). 6. Sliding bearing device (**100**) according to clause 5, wherein the impeller (**110**) comprises a plurality of flushing outlets (**135**), wherein the discharge openings (**140**) of the flushing outlets (**135**) are at least partially disposed in the transition section (**510**). 7. Sliding bearing device (**100**) according to any one of the preceding clauses, wherein a number of the flushing outlets (**135**) in the impeller (**110**) corresponds to a multiple of the number of blades of the impeller (**110**). 8. Sliding bearing device (**100**) according to any one of the preceding clauses, comprising a flushing inlet (**145**) for introducing the flushing fluid flow (**130**), wherein, in the assembled state of the sliding bearing device (**100**), the flushing inlet (**145**) opens into the intermediate space (**125**). 9. Sliding bearing device (**100**) according to clause 8, wherein the flushing inlet (**145**) is formed as a gap (**905**) between a base of the stand unit (**105**) and a jacket section (**150**) of the impeller (**110**) enclosing the subsection (**120**) of the stand unit (**105**), and/or wherein the flushing inlet (**145**) is formed in the impeller (**110**) as an inclined inlet channel

(**1105**) or by a plurality of inlet channels having at least one inclined inlet channel (**1105**). 10. Sliding bearing device (**100**) according to any one of clauses 8 to 9, wherein the flushing inlet (**145**) is disposed downstream with respect to the flushing outlet (**135**) in the flow direction of the pump fluid flow (**115**). 11. Cardiac support system (**200**) comprising a sliding bearing device (**100**) according to any one of the preceding clauses 1 to 10. 12. Method (**800**) for producing a sliding bearing device (**100**) for a cardiac support system (**200**), wherein the method (**800**) comprises the following steps: providing (**801**) a stand unit (**105**), which is designed to support an impeller (**110**) such that it can rotate, and the impeller (**110**), which is configured to rotate during operation of the cardiac support system (**200**) to convey a pump fluid flow (**115**); forming (**803**) at least one flushing outlet (**135**) in the impeller (**110**), wherein the flushing outlet (**135**) is designed to discharge a flushing fluid flow (**130**) from the sliding bearing device (**100**) by means of centrifugal force when the cardiac support system (**200**) is in operation; and assembling (**805**) the impeller (**110**) and the stand unit (**105**) to produce the sliding bearing device (**100**), wherein at least one subsection (**120**) of the stand unit (**105**) is enclosed by the impeller (**110**), and wherein an intermediate space (**125**) for guiding the flushing fluid flow (**130**) is disposed between the subsection (**120**) and the impeller (**110**).
LIST OF REFERENCE SIGNS
(46) **100** Sliding bearing device **105** Stand unit **107** Base **110** Impeller **111** Region of a propeller of the impeller **112** Axis of rotation **114** Longitudinal axis **115** Pump fluid flow **116** Longitudinal extension axis **120** Subsection of the stand unit **125** Intermediate space **130** Flushing fluid flow **132** Opening cross-section **134** Opening cross-section normal vector **135** Flushing outlet **136** Directional component **137** Axis **140** Discharge opening **145** Flushing inlet **150** Jacket section **155** Block **200** Cardiac support system **205** Housing section **210** Inlet hose **215** Discharge opening **220** Connection section **225** Web **405** Ball bearing **505** Jacket section **510** Transition section **515** Propeller **520**, **525**, **530** Region **605**, **610**, **615**, **620**, **625** Configuration **800** Method **801** Step of providing **803** Step of forming **805** Step of assembling **905** Gap **1005** Arrow **1105**, **1107** Inlet channel

Claims

1. A heart pump having a bearing device, the bearing device comprising: a stand unit; an impeller; and an intermediate space formed between the impeller and the stand unit for conducting a flushing fluid flow from a fluid; wherein the stand unit comprises a subsection enclosed by the impeller and configured to align the impeller about an axis of rotation, wherein the impeller is configured to rotate about a longitudinal axis aligned with the axis of rotation when the heart pump is in operation to convey a pump fluid flow of the fluid in a flow direction, wherein the impeller comprises at least one flushing outlet for discharging the flushing fluid flow from the intermediate space, wherein the at least one flushing outlet comprises a first discharge opening for discharging the flushing fluid flow, which has an opening cross-section in which, an opening cross-section normal vector faces away from the axis of rotation and is radial to the axis of rotation, wherein the impeller is disposed in a housing section comprising at least two second discharge openings for discharging the pump fluid flow and connected to an inlet hose for supplying the fluid, and wherein the opening cross-section normal vector intersects with one of the at least two second discharge openings of the housing section at a time and is perpendicular to the axis of rotation.
2. The heart pump according to claim 1, wherein the at least one flushing outlet comprises a plurality of flushing outlets formed in the impeller.
3. The heart pump according to claim 1, wherein the at least one flushing outlet is tubular.
4. The heart pump according to claim 1, wherein the first discharge opening of the at least one flushing outlet is disposed in a jacket section of the impeller enclosing the subsection of the stand unit.
5. The heart pump according to claim 1, wherein the first discharge opening of the at least one flushing outlet is disposed in a transition section between a region of a propeller of the impeller and a jacket section of the impeller surrounding the subsection of the stand unit.
6. The heart pump according to claim 1, wherein the at least one flushing outlet comprises a plurality of flushing outlets formed in the impeller, the first discharge openings of the plurality of flushing outlets disposed at least partially in a transition section between a region of a propeller of the impeller and a jacket section of the impeller enclosing the subsection of the stand unit.
7. The heart pump according to claim 1, wherein a number of the flushing outlets formed in the impeller correspond to a multiple of a number of blades of the impeller.

8. The heart pump according to claim 1, wherein the housing section comprises webs, wherein the webs delimit the at least two second discharge openings for discharging the pump fluid flow.
9. The heart pump according to claim 1, wherein the bearing device is configured as a sliding bearing device comprising a sliding bearing for supporting a rotating component in the form of the impeller, or as a magnetic bearing device in which a rotating component in the form of the impeller is magnetically supported.
10. The heart pump according to claim 1, wherein a flushing inlet opens into the intermediate space in an assembled state of the bearing device.
11. The heart pump according to claim 10, wherein the flushing inlet is configured as a gap between a base of the stand unit and a jacket section of the impeller enclosing the subsection of the stand unit.
12. The heart pump according to claim 10, wherein the flushing inlet is configured as at least one inlet channel extending in a direction which intersects the longitudinal axis of the impeller or extends at an angle to the longitudinal axis of the impeller.
13. The heart pump according to claim 10, wherein the flushing inlet comprises a plurality of inlet channels.
14. The heart pump according to claim 10, wherein the flushing inlet is disposed downstream with respect to the at least one flushing outlet in the flow direction of the pump fluid flow.
15. The heart pump according to claim 1, wherein the impeller comprises a jacket section, the jacket section comprising an inner surface comprising a first constant radius from a longitudinal axis; wherein a flushing inlet is positioned at a first end of the jacket section and the at least one flushing outlet is positioned at a second end of the jacket section opposite the first end, wherein the intermediate space is parallel to the longitudinal axis between the flushing inlet and the at least one flushing outlet.
16. A method for flushing an intermediate space for guiding a flushing fluid flow with a fluid in a bearing device of a heart pump, the method comprising: providing the intermediate space, the intermediate space comprising at least one flushing inlet for introducing the flushing fluid flow and at least one flushing outlet for discharging the flushing fluid flow, wherein the intermediate space is configured between an impeller which can rotate about an axis of rotation for conveying a pump fluid flow and a stand unit configured to align the impeller about the axis of rotation; introducing the fluid into the intermediate space through the at least one flushing inlet; expelling the fluid from the intermediate space through the at least one flushing outlet to at least one first discharge opening by means of a centrifugal force acting upon the fluid in the at least one flushing outlet relative to the axis of rotation, wherein the at least one flushing outlet comprises the at least one first discharge opening for an exit of the flushing fluid flow, wherein the at least one first discharge opening has an opening cross-section in which an opening cross-section normal vector faces away from the axis of rotation and is radial to the axis of rotation, wherein the impeller is disposed in a housing section connected to an inlet hose for supplying the fluid, wherein the housing section comprises at least two second discharge openings for discharging the pump fluid flow, and wherein the opening cross-section normal vector intersects with at the least two second discharge openings of the housing section and is perpendicular to the axis of rotation.
17. A heart pump configured to be delivered to the heart via catheter for pumping blood, the heart pump comprising: a conduit having a discharge opening and configured to convey blood through the discharge opening into a blood vessel; an impeller comprising a first magnet and configured to rotate about an axis to convey the blood; and a support comprising a second magnet and configured to magnetically communicate with the first magnet to rotate the impeller, wherein the impeller and support define an intermediate space therebetween, the intermediate space configured to convey from a flushing inlet to a flushing outlet a portion of the blood conveyed through the conduit, the flushing inlet disposed downstream of the flushing outlet with respect to a direction of flow of the blood conveyed in the conduit, and the flushing outlet extending perpendicular to the axis; wherein the flushing outlet extends in a direction that intersects the discharge opening of the conduit.
18. The heart pump according to claim 17, wherein the conduit comprises a tubular inlet hose connected to a tubular housing section.
19. The heart pump according to claim 17, wherein the flushing inlet defines a disc-like gap configured to receive blood from a plurality of angular locations about the axis.
20. The heart pump according to claim 17, further comprising a plurality of the flushing outlets defining elongated channels extending through the impeller.