(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 July 2024 (25.07.2024)

WIPO | PCT

(10) International Publication Number
WO 2024/154151 A1

(51) International Patent Classification:
B02C 1/04 (2006.01)

(21) International Application Number:
PCT/IN2024/050043

(22) International Filing Date:
17 January 2024 (17.01.2024)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
202341003454 17 January 2023 (17.01.2023) IN

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

(54) **Title:** FRUGALLY DESIGNED JAW CRUSHER

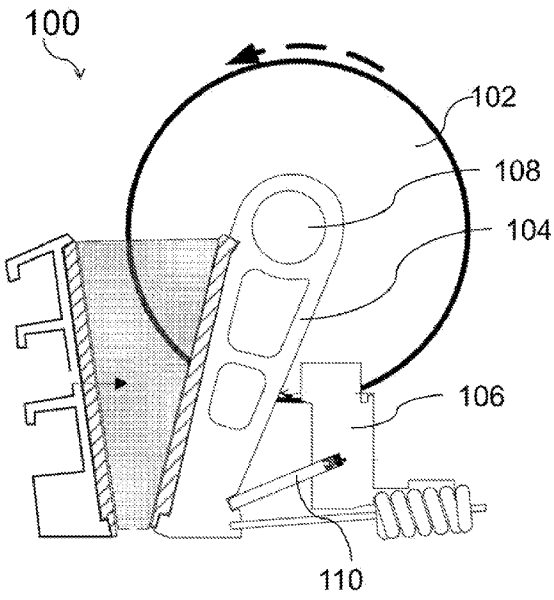

FIG. 1

(57) **Abstract:** A frugally designed jaw crusher (100) for extracting minerals is disclosed. The jaw crusher includes an optimized flywheel (102), an optimized pitman frame (104) and an optimized rear wall(106). The flywheel has a peripheral flywheel portion (202) and a petalled web (206) with five petal-shaped openings connecting to a hub of the flywheel. 5 The petalled web includes spokes (204) of rounded rectangular cross section of width to height 2:1. The optimized pitman frame houses a bearing for an eccentric shaft (108) and extends in length down to a toggle seat (308). The toggle seat has a twin wall structure (306) formed by a triangular 4-ribbed construction of uniform wall thickness. The jaw crusher is frugally designed for reduced weight and improved strength, load bearing 10 capacity, better damping and reduced peak stress with more savings on material cost.

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Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

FRUGALLY DESIGNED JAW CRUSHER

CROSS-REFERENCES TO RELATED APPLICATION

[0001] This application takes priority to Indian Provisional Patent Application No. 202341003454 titled "A FRUGALLY ENGINEERED JAW CRUSHER FOR EXTRACTION OF MINERALS" filed on January 17, 2023.

FIELD OF INVENTION

[0002] The present disclosure relates to jaw crusher, more particularly it relates to an improved jaw crusher with improved strength, load bearing capacity, better damping, reduced peak stress and frugal design for material saving.

DESCRIPTION OF THE RELATED ART

[0003] Jaw crushers are used in extraction of minerals and ores from and under Earth's surface. Typical to the mining industry, the components of a jaw crusher are bulky in design in order to be robust. Therefore, the components have good potential to be frugally redesigned. Jaw crushers are used extensively as popular primary crushing equipment for minerals and aggregates. Hence, cost plays a very significant role due to high volumes, especially in aggregates production. The requirements of robustness, value and cost-saving makes the components of a jaw crusher prime candidates for a redesign using frugality principles to facilitate weight reduction of the overall equipment.

[0004] The jaw crusher works by breaking rocks under compression and impact between a fixed and a moving jaw. Jaw crushers are classified based on the pivot position of the moving jaw and the toggle type. Based on the pivot position, a jaw crusher can be classified as Blake type (pivot at the top), Universal type (pivot at the center) or Dodge type (pivot at the bottom). Based on the toggle type, a jaw crusher can be classified either as a single toggle jaw crusher or a double toggle jaw crusher.

[0005] Various publications have tried to address the problems encountered for reducing weights for the various components of the jaw crusher while enhancing its functionality. PCT publication 2018113959A1 discloses a jaw crusher having a movable jaw support frame configured to facilitate interchange between shim and wedge settings, the support frame is configured to minimize stress concentrations. US application 8757530B2

discloses a pitman of jaw crusher has an upper part, which includes an upper supporting point for supporting the pitman in the body of the jaw crusher, and a lower part having a lower supporting point for supporting the pitman in the body of the jaw crusher through a toggle plate. Chinese application 217747204U discloses a novel jaw crusher flywheel which comprises a rim, and a hub, a web plate, a spoke and a balancing weight which are arranged in the rim. Chinese application 218422965U discloses a novel jaw crusher with an adjustable jaw plate, which comprises a jaw crusher frame, a static jaw plate and a movable jaw body are arranged in the jaw crusher frame, and an adjusting device is arranged between the static jaw plate and the jaw crusher frame or/and between the movable jaw body and the jaw crusher frame.

[0006] Presently, there is a requirement for a frugal design for jaw crushers for weight reduction as well as streamlining the major components of the jaw crusher to facilitate the reduction of the total weight of the jaw crusher.

SUMMARY OF THE INVENTION

[0007] The present subject matter relates to a jaw crusher for extraction of minerals.

[0008] In one embodiment of the present subject matter, a jaw crusher for extraction of minerals. The jaw crusher includes a flywheel of optimized construction having a peripheral flywheel portion and a petalled web connecting to a hub of the flywheel. The petalled web includes five petal-shaped openings bounded by spokes of rounded rectangular cross section, the spokes having a width and a height and a width to height ratio of 2:1, wherein the flywheel has a peak torque of 75 Nm/kg or more. The jaw crusher further includes a pitman frame for providing mounting surfaces for crusher plates, an eccentric shaft and a toggle mechanism including the pitman frame housing a bearing for the shaft and extending in length down to a toggle seat, the frame having a height to width ratio of 2:1, and having a twin wall structure with side walls extending from the bearing location to the toggle seat and the toggle seat is formed by a triangular 4-ribbed construction. The jaw crusher also includes an optimized rear frame.

[0009] In various embodiments, the optimized rear frame is filleted with ribs and having uniform wall thickness.

[0010] In various embodiments, the spokes of the flywheel (102) have a section of width to height ratio of 2:1.

[0011] This and other aspects are described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The invention has other advantages and features, which will be more readily apparent from the following detailed description of the invention and the appended claims, when taken in conjunction with the accompanying drawings, in which:

[0013] FIG. 1 illustrates a frugally designed jaw crusher, according to an embodiment of the present subject matter.

[0014] FIG. 2 illustrates the frugally designed flywheel of the jaw crusher, according to an embodiment of the present subject matter.

[0015] FIG. 3 illustrates the frugally designed pitman frame of the jaw crusher, according to an embodiment of the present subject matter.

[0016] FIGS. 4A and 4B illustrate the frugally designed rear wall/frame of the jaw crusher, according to an embodiment of the present subject matter.

[0017] FIGS. 5A, 5B and 5C illustrate the three design versions of the flywheel, according to an embodiment of the present subject matter.

[0018] FIGS. 6A, 6B and 6C illustrate the three design versions of the pitman frame, according to an embodiment of the present subject matter.

[0019] FIGS. 7A, 7B and 7C illustrate the different sections of the optimized flywheel.

[0020] FIGS. 8A-8E illustrate the different sections of the optimized pitman frame

[0021] FIGS. 9A, 9B and 9C illustrate the different sections of optimized flywheel.

[0022] Referring to the figures, like numbers indicate like parts throughout the various views.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0023] While the invention has been disclosed with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the invention. In

addition, many modifications may be made to adapt to a particular situation or material to the teachings of the invention without departing from its scope.

[0024] Throughout the specification and claims, the following terms take the meanings explicitly associated herein unless the context clearly dictates otherwise. The meaning of "a", "an", and "the" include plural references. The meaning of "in" includes "in" and "on." Referring to the drawings, like numbers indicate like parts throughout the views. Additionally, a reference to the singular includes a reference to the plural unless otherwise stated or inconsistent with the disclosure herein.

[0025] The present subject matter describes a frugally designed jaw crusher with reduced weight and improved strength, load bearing capacity, better damping and reduced peak stress with more flexibility and savings on material cost. The jaw crusher in various embodiments may be a Blake-type single toggle with the flywheel, pitman frame and rear wall/frame of the jaw crusher being redesigned to reduce weight.

[0026] A jaw crusher for crushing mineral ores or rocks as illustrated in FIG. 1, in various embodiments of the subject matter. The jaw crusher **100** includes a flywheel **102** of optimized construction, an optimized pitman frame **104** for providing mounting surfaces for crusher plates, an eccentric shaft **108**, a toggle mechanism **110** and an optimized rear wall **106**. The flywheel **102** uses moment of inertia to store energy while rotating which is for providing extra energy required to crush rocks during the crushing stroke in a jaw crusher **100**. Further, the flywheel also compensates for the drop in the speed of the shaft during crushing, hence optimized flywheel **102** has reduced weight while maintaining the moment of inertia.

[0027] In various embodiments, the optimized flywheel **102** illustrated in FIG. 2 includes a peripheral flywheel portion and a petalled web **206** that is connecting to a hub **208** of the flywheel **102**. The petalled web **206** comprises five petal-shaped openings bounded by spokes **204** of rounded rectangular cross section and the spokes **204** have a width and a height and a width to height ratio of 2:1. In the optimized flywheel **102**, the height of the rounded rectangle is 30mm, the cross section of the rounded rectangle increases near the hub. The petalled web **206** creates a branching effect that facilitates in improving the damping and load bearing capacity of the flywheel **102** while reducing peak stress on the component. Further, the odd number of spokes **204** present in the petalled web **206** and reduced section thickness facilitates a significant increase in the value of endurance

strength, reduction in overall stress as well as a more uniform distribution of stress throughout the component. The optimized flywheel uses biomimetics for redesigning the component leading to more material savings ΣMS of 0.05+0.03 = 0.08. In one embodiment, the optimized flywheel **102** has a peak torque of 75 Nm/kg or more. The optimized flywheel is casted with ASTM A48 (grey cast iron) material which has good shock absorption properties.

[0028] In various embodiments, the pitman frame is one of the heaviest components of the jaw crusher **100** and is configured to be of robust design. The optimized pitman frame **104** illustrated in FIG. 3 provides mounting surface for crusher plates, an eccentric shaft **108** and a toggle mechanism **110**. The optimized pitman frame **104** includes a bearing for the shaft **108** at one end and extends in length to a toggle seat **308** with a height to width ratio of 2:1. In various embodiments, the height h of the pitman frame is defined as the length of the frame measured from a center of the shaft opening to the bottom of the frame, and width is defined as. The optimized pitman frame **104** has a twin wall structure **304** with a wall thickness and side walls **306** extending from the bearing location to the toggle seat **308**. Further, the toggle seat **308** formed by a triangular 4-ribbed construction **310**. The pitman frame **104** incorporates a beaded rib design and rounded off corners to reduce stress on the component. The twin wall structure **304** is designed to be similar to the shape of lower jaw bone of many animals, including canines. In some embodiments, the material ASTM A352 (cast alloy steel) is utilized for casting the optimized pitman frame **104**. As biomimetics is used for optimizing the pitman frame design there is savings of material ΣMS of 0.06+0.02 = 0.08.

[0029] In various embodiments, the optimized rear wall of the jaw crusher **100** holds up one of the ends of the jaw crusher and provides an assembling point for side plates. The other end is held up by a front wall. The rear wall also provides a mounting point for the toggle mechanism **110** as well as motor frame (not shown in picture) in the jaw crusher **100**. The rear wall performs the function of conducting the crushing forces through the pitman frame **104**, through the toggle **110** and into the side walls where foundation pads are assembled. The rear wall is also subjected to high levels of loading and requires strong material for casting. The optimized rear wall **106** as illustrated in FIGS. 4A and 4B is filleted **404** with ribs **402** to ensure less stress on the overall structure and having uniform

wall (**406**) thickness of 25mm. The material ASTM A352 (alloy steel) is utilized for casting the optimized rear wall **106** and there is savings of material ΣMS of 0.03.

[0030] The jaw crusher optimization follows a frugal design approach which has several advantages over the present prior art. The frugal design is based on the factor of frugality that has yielded material savings of 8%, 7% and 30% while increasing the factor of safety by 35%, 71% and 18% in the flywheel, the Pitman and the rear frame/wall respectively over their base designs. Optimized designs for the flywheel, the pitman frame and the rear frame/wall contributed to weight savings of 49 Kg, 212 Kg, 368 Kg respectively with total weight reduction for the jaw crusher amounting to 678 Kg, which is 14.2% of the weight of the three components (the flywheels, the pitman frame and the rear wall) considered for redesign. For a 110 kW jaw crusher weighing approximately 22 metric tons, the weight saving equals about 3% of total weight. Reduction in total weight of the jaw crusher also leads to reduction in the running cost of the equipment. The factor of frugality of $1.87^{1.79}$, $1.76^{1.68}$ and $1.63^{1.33}$ is obtained for each of the components respectively based on the frugal design optimization.

[0031] Although the detailed description contains many specifics, these should not be construed as limiting the scope of the invention but merely as illustrating different examples and aspects of the invention. It should be appreciated that the scope of the invention includes other embodiments not discussed herein. Various other modifications, changes and variations which will be apparent to those skilled in the art may be made in the arrangement, operation and details of the system and method of the present invention disclosed herein without departing from the spirit and scope of the invention as described here, and as delineated in the claims appended hereto.

EXAMPLES

[0032] EXAMPLE 1: Frugality Analysis for different designs versions of Flywheel

[0033] In a first design version of the flywheel, a simple design commonly available in the market is used featuring a flat profile for easy manufacturing. The flywheel has a periphery portion that is connected to the hub by 5 spokes, each spoke has a width of 158mm and the thickness of 60mm. In a second version of the flywheel, a spoke web connects the hub of the flywheel with the periphery. The spoke web has 4 openings bound by rounded rectangular cross section, the height of the rounded rectangle is 60mm. The

third version is the optimized flywheel is described perviously. The three design versions of the flywheel are illustrated in FIG. 5.

[0034] The following table provides a comparison of the flywheel's three versions of design.

TABLE 1: Frugality analysis for flywheel design

Version	V1	V2	V3
Mass (Kg)	627	597	578
Endurance Strength (MPa)	49.05	50.3	54.71
Peak Stress (MPa)	37.1	30.2	30.6
N	1.32	1.67	1.79
ΣMS	0	0.05	0.08
F	1.32	1.72	1.87
F^N	$1.32^{1.32}$	$1.72^{1.67}$	$1.87^{1.79}$

[0035] Wherein, N is fatigue based factor of safety that is dependent on endurance strength and which is provided as a ratio of maximum material stress to actual working stress, MS is the material saving, F is defined as factor of frugality and F^N is given by factor of frugality and factor of safety.

[0036] As can be observed from TABLE 1, there are distinct differences in each design version with respect to stress, endurance, mass and other factors. For first design version the stress concentration at the base of each spoke and the torque applied at the periphery is transferred to the hub via the spokes. This version of the flywheel design displays the highest peak stress value and the lowest endurance strength value of the three designs. For second design version the concentration of stress is still at the base of each spoke similar to previous version but to a reduced extent. The peak von Mises stress values have gone down from 37.1 MPa in first version to 30.2 MPa in second version. The stress is also less due to reduction of material Since second version uses a simple design scheme to reduce mass, MS1 = 0.05 and ΣMS = 0.05. The third design version as disclosed with reference to

FIG. 2 presents the best performance with reduced mass, higher endurance and more savings on material.

[0037] EXAMPLE 2: Frugality Analysis for different designs versions of Pitman frame

[0038] In a first design version of the pitman frame, a simple design commonly available is used to satisfy assembly and packaging constraints, the general wall thickness for this version is maintained at 43mm, which includes the ribs. In a second version of the pitman frame, the design for the pitman frame was changed to allow weight reduction but the general wall thickness was increased to 50mm. Further, the geometry at the bottom portion of the pitman frame was also modified to accommodate a webbed rib design to facilitate easier core removal and to give better strength for casting. The third version is the optimized pitman frame is described previously. The three design versions of the pitman frame are illustrated in FIG. 6.

[0039] The following table provides a comparison of the pitman frame's three design version.

TABLE 2: Frugality analysis for pitman design

Version	V1	V2	V3
Mass (Kg)	2932	2764	2720
Yield strength (MPa)	276	276	276
Peak Stress (MPa)	281.4	186.2	164.1
Max displacement (mm)	2.081	1.876	1.63
N	0.98	1.48	1.68
ΣMS	0	0.06	0.08
F	0.98	1.54	1.76
F^N	$0.98^{0.98}$	$1.54^{1.48}$	$1.76^{1.68}$

[0040] As can be observed from TABLE 2, there are distinct differences in each design version with respect to stress, endurance, mass and other factors. For first design version the stress concentrations near the base of the frame. For second design version, due to changes in the design and rounding of edges shows reduction in stress for the overall

frame and ΣMS is 0.06. The third design version presents the best performance with reduced mass, higher endurance and more savings on material.

[0041] EXAMPLE 3: Frugality Analysis for different designs versions of Rear wall /frame

[0042] In a first design version of the rear frame/wall, a simple design based on available geometrical constraints with high wall thickness. In a second version of the rear frame/wall, the design for the rear frame/wall was changed to reduce unwanted material and bring complexity in shape. This version is described previously.

[0043] The following table provides a comparison of the rear frame's two design version.

TABLE 3: Frugality analysis for rear frame/wall design

Version	V1	V2
Mass (Kg)	1209	841
Peak Stress (MPa)	243.4	207.4
N	1.13	1.33
ΣMS	0	0.3
F	1.13	1.63
F^N	$1.13^{1.13}$	$1.63^{1.33}$

[0044] As can be observed from TABLE 3, there are distinct differences in each design version with respect to stress, endurance, mass and other factors. For first design version the stress concentrations near bosses where the rear frame/wall is assembled with the side walls. For second design version, is better filleted with ribbed design with the stress mostly concentrated around the center of the rear wall/frame and ΣMS is 0.03 with higher F value.

[0045] FIGS. 7A, 7B and 7C illustrate the different sections of the optimized flywheel. FIGS. 8A-8E show the different sections of the optimized pitman frame. FIGS. 9A, 9B and 9C show the different sections of optimized rear wall.

WE CLAIM:

1. A frugally designed jaw crusher (100) for extraction of minerals, comprising:

i. a flywheel (102) of optimized construction comprising a peripheral flywheel portion (202) and a petalled web (206) connecting to a hub (208) of the flywheel (102), wherein the petalled web (206) comprises five petal-shaped openings bounded by spokes (204) of rounded rectangular cross section, the spokes (204) having a width and a height and a width to height ratio of 2:1, wherein the flywheel (102) has a peak torque of 75 Nm/kg or more;

ii. a pitman frame (104) for providing mounting surfaces for crusher plates, an eccentric shaft (108) and a toggle mechanism (110) including:

a. the pitman frame (104) housing a bearing (302) for the shaft and extending in length down to a toggle seat (308), the frame (104) having a height to width ratio of 2:1, and having a twin wall structure (304) with side walls (306) extending from the bearing location to the toggle seat (308); and

b. the toggle seat (308) formed by a triangular 4-ribbed construction (310); and

iii. an optimized rear frame (106).

2. The jaw crusher (100) as claimed in claim 1, wherein the optimized rear frame (106) is filleted (404) with ribs (402) and having uniform wall (406) thickness.

3. The jaw crusher (100) as claimed in claim 1, wherein the spokes of the flywheel (102) have a section having width to height ratio of 2:1.

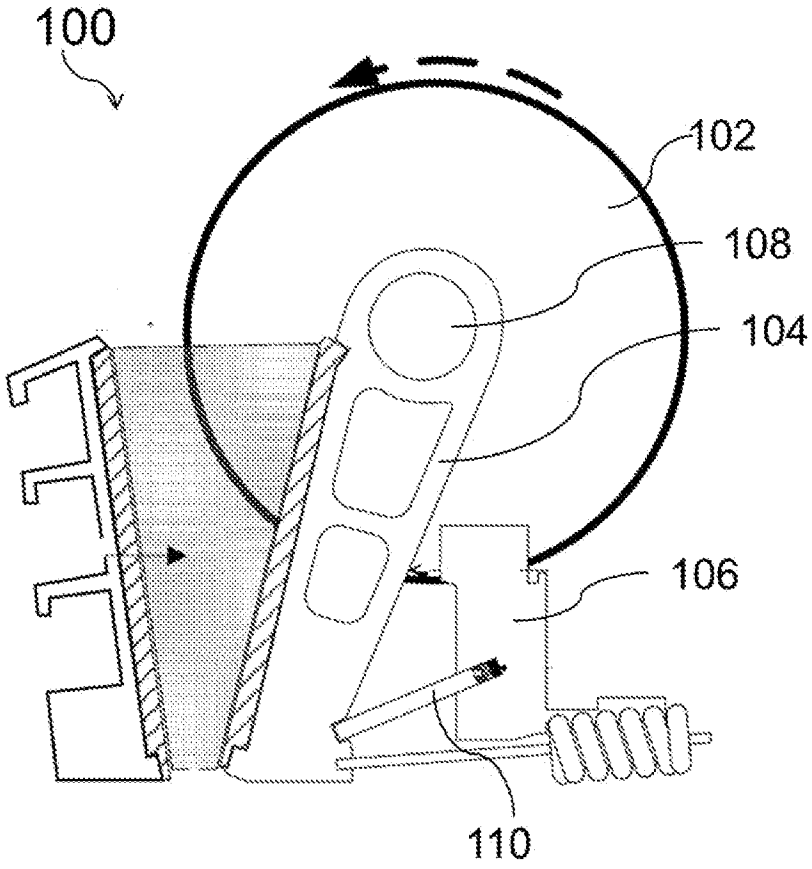

FIG. 1

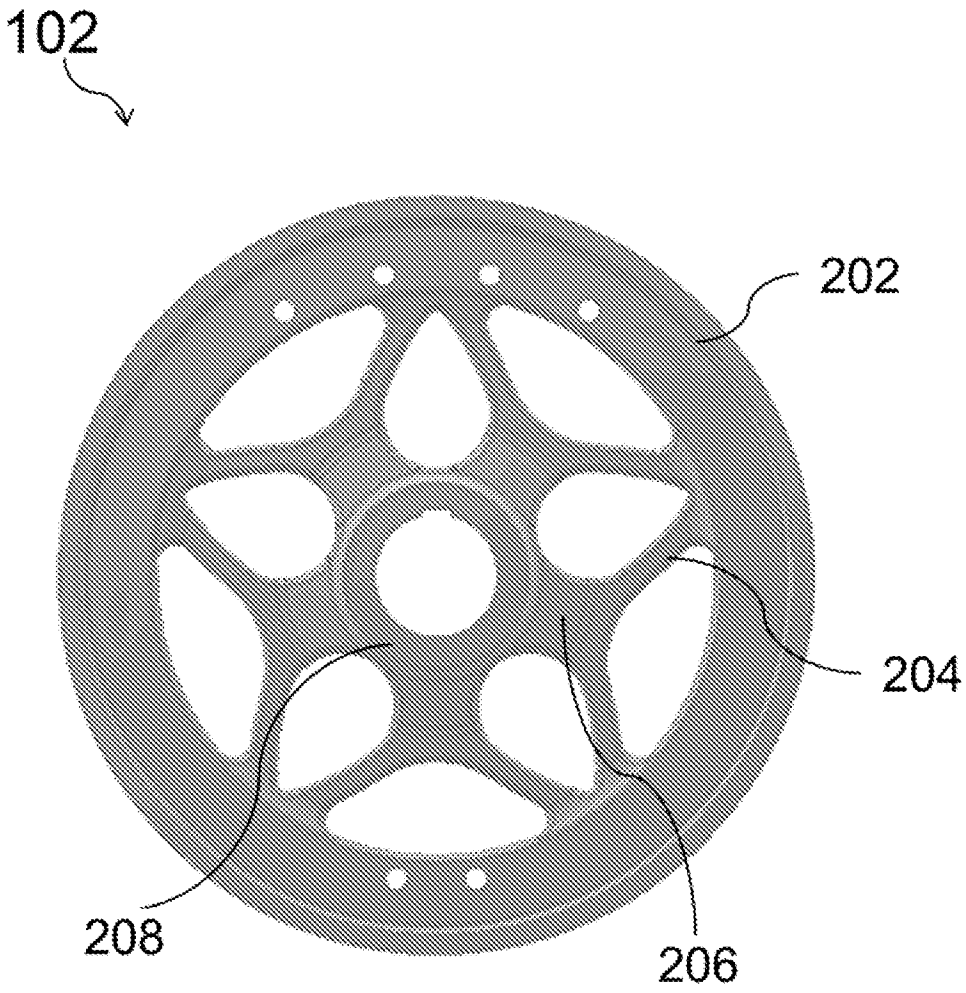

FIG. 2

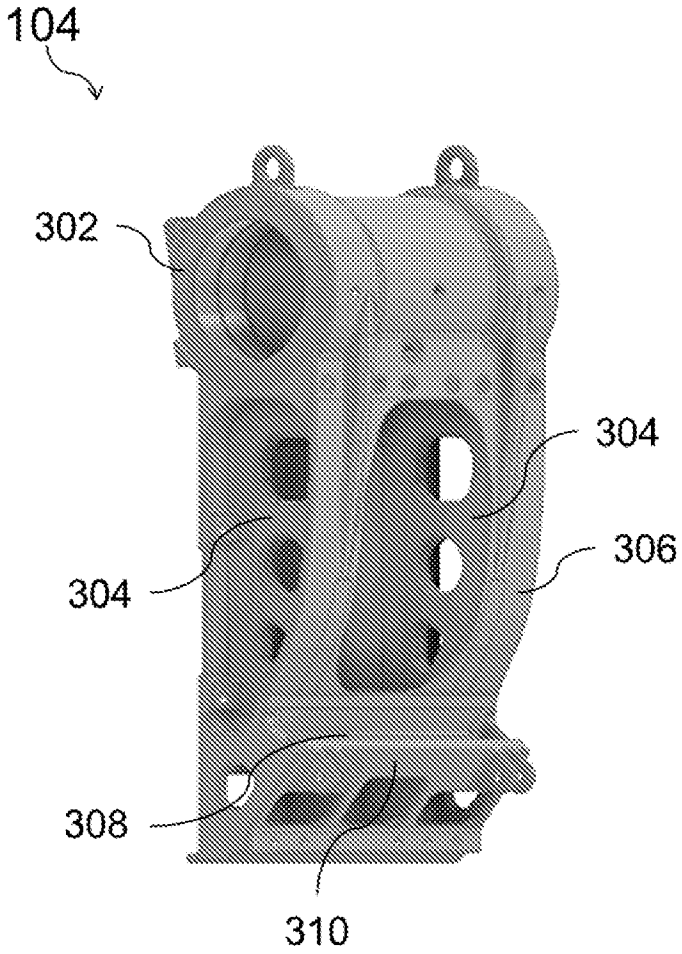

FIG. 3

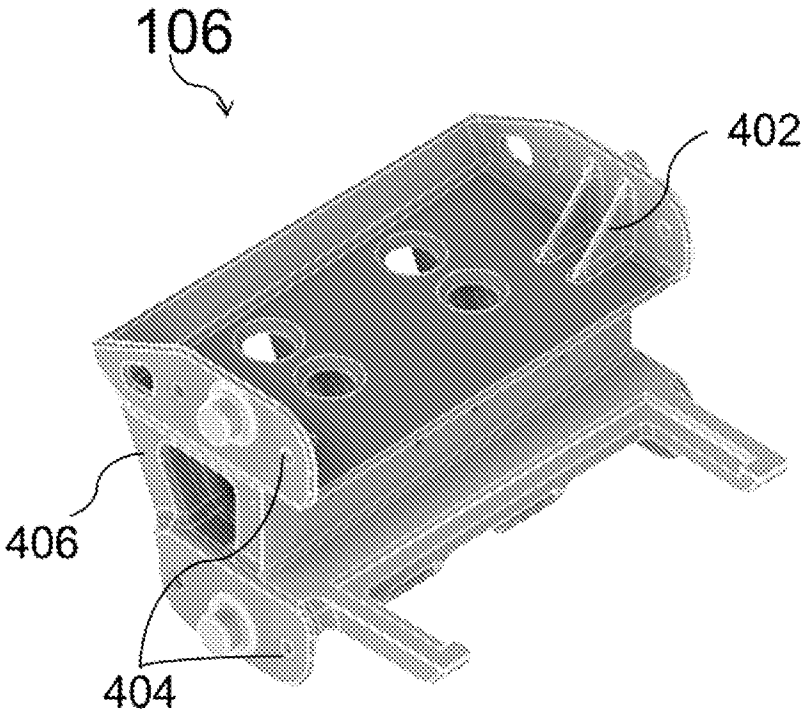

FIG. 4A

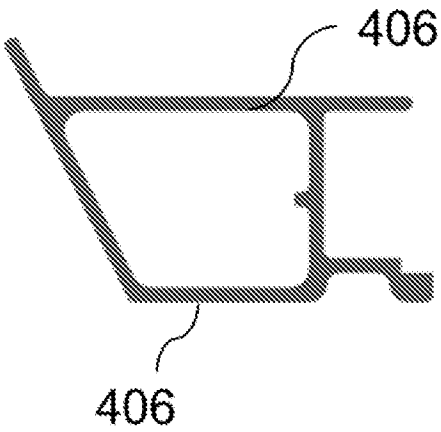

FIG. 4B

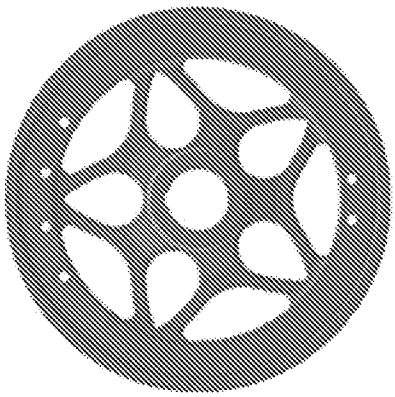

FIG. 5C

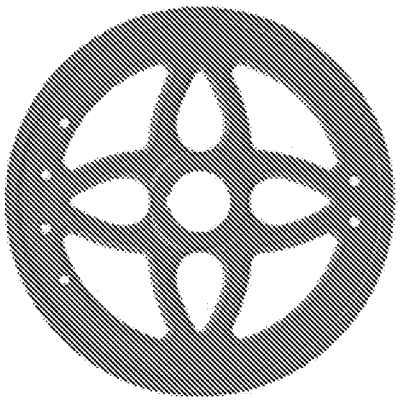

FIG. 5B

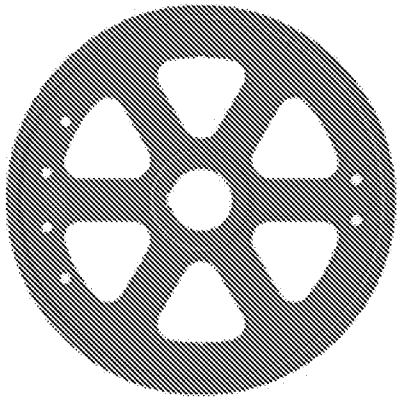

FIG. 5A

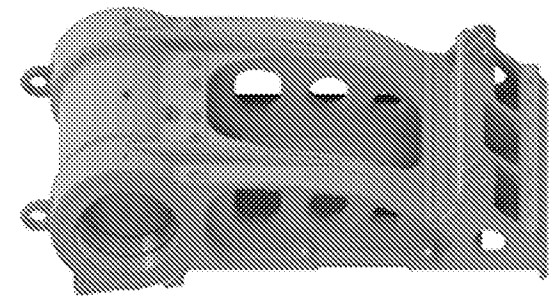

FIG. 6C

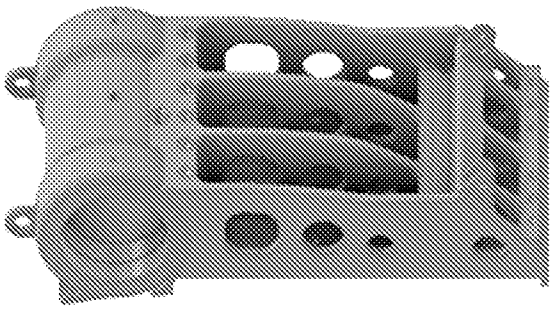

FIG. 6B

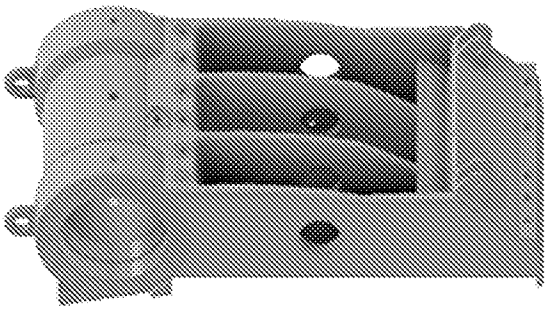

FIG. 6A

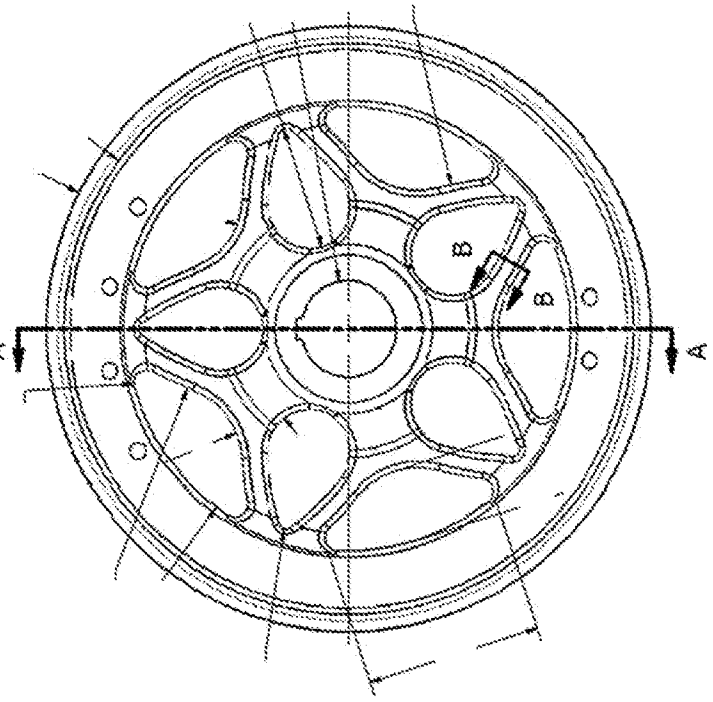

FIG. 5A

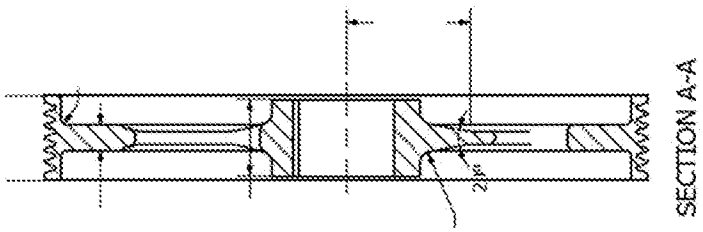

FIG. 7B

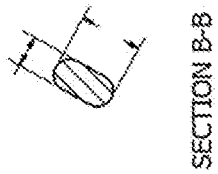

FIG. 7C

FIG. 7A

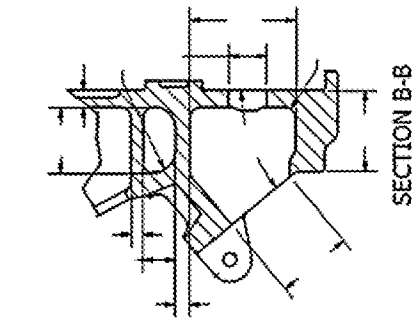

FIG. 8D

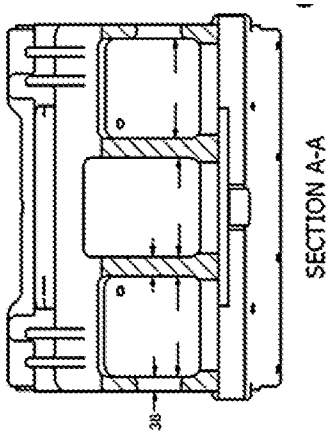

FIG. 8E

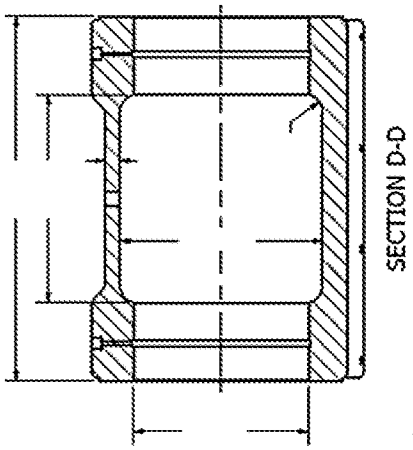

FIG. 8B

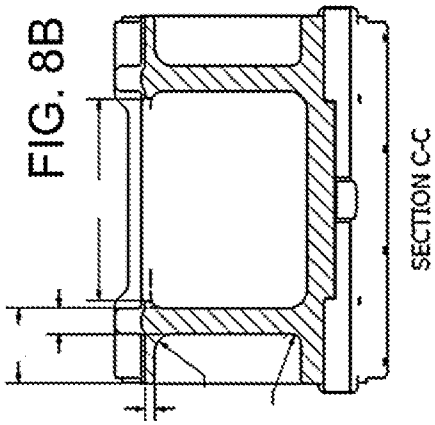

FIG. 8C

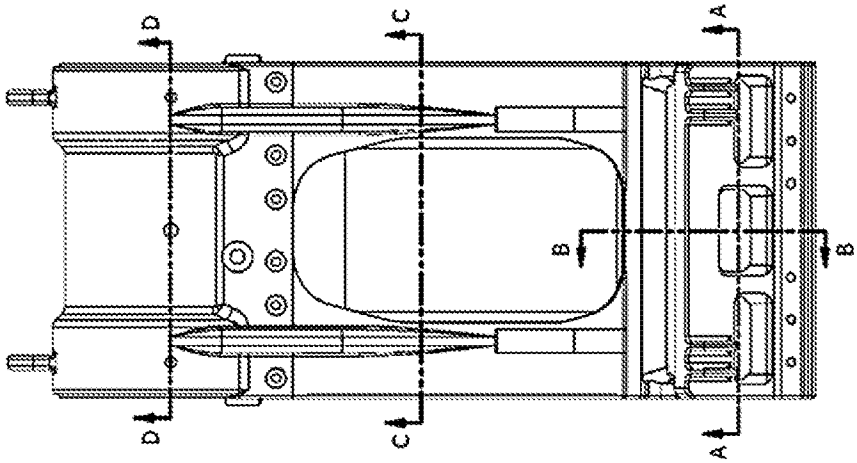

FIG. 8A

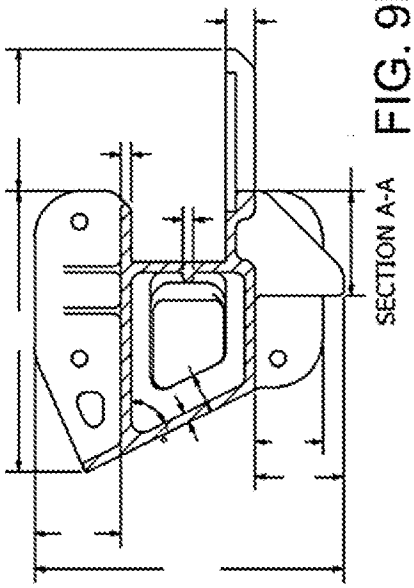

FIG. 9B

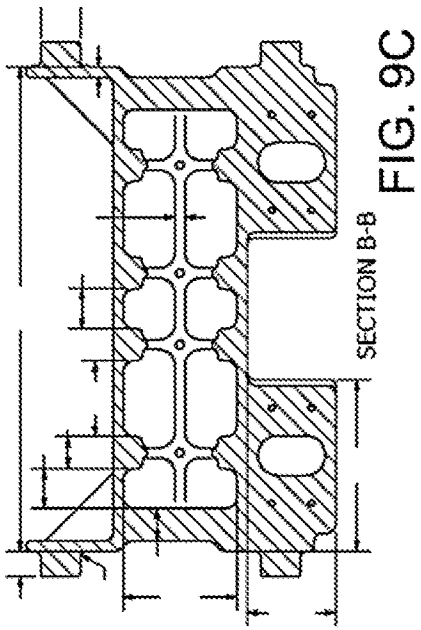

FIG. 9C

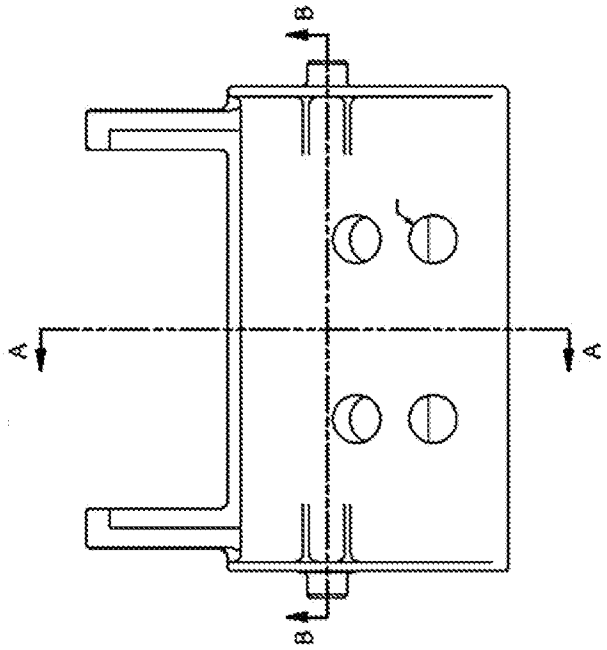

FIG. 9A

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2024/050043

A. CLASSIFICATION OF SUBJECT MATTER
B02C1/04 Version=2024.01

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

Espacenet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US20140239101A1 (Sandvik Intellectual Property AB) August 28, 2014. Abstract; Figure 1-4; Para [0021-0028]	1-3
A	CN217747204U (Chengdu Dahongli Machinery Co Ltd) November 8, 2022. Translation as per Espacenet Abstract; Figure 1-2;	1-3

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14-05-2024	14-05-2024

Name and mailing address of the ISA/	Authorized officer
Indian Patent Office Plot No.32, Sector 14,Dwarka,New Delhi-110075 Facsimile No.	Aniruddh Garg Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IN2024/050043

Citation	Pub.Date	Family	Pub.Date
US 20140239101 A1	28-08-2014	AU 2012306583 A1	27-02-2014
		BR 112014005054 A2	28-03-2017
		CA 2845484 A1	14-03-2013
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		ZA 201401030 B	29-06-2016