

Section d'insertion

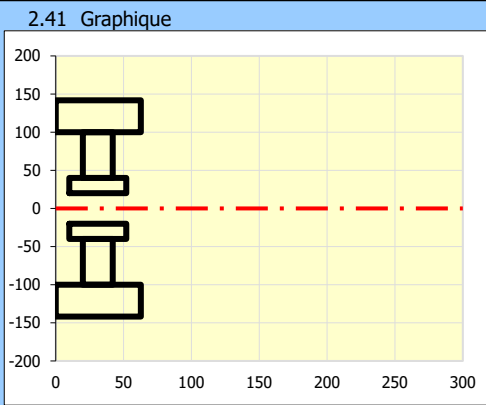
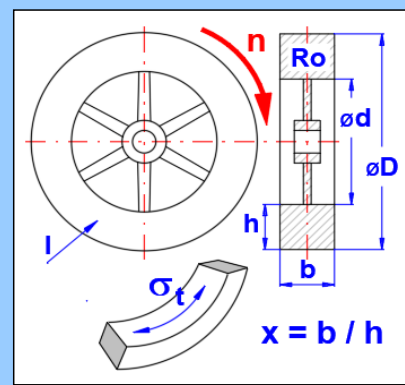
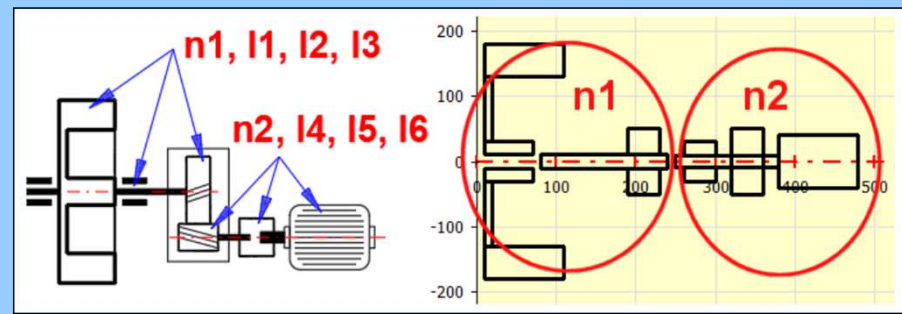
1.0 Unités de calcul, conversion d'unités

| | | | | | | | |
|----------------------|-------------------------|--|--------------|---|------------------|-------------|-------------------|
| 1.1 Unités de calcul | SI Units (N, mm, kW...) | | Vitesse | 1 | m/s | 3.280839895 | ft/s |
| | | | Accélération | 1 | m/s ² | 3.280839895 | ft/s ² |
| | | | Revolutions | 1 | /s | 6.283185307 | rad/sec |
| | | | Force | 1 | N | 0.224809 | lbf |
| | | | Moment | 1 | Nm | 0.737561 | lbf-ft |
| | | | Puissance | 1 | kW | 1.34102209 | HP |
| | | | Énergie | 1 | J | 0.737562149 | ft-lbf |
| | | | Pression | 1 | MPa | 0.145037 | kpsi |

| | | | | | | | |
|--------------------------------|---|-------------------|-------------|--------------------|--|--|--|
| 1.2 Conversion d'unités | | | | | | | |
| Longueur | 1 | m | 39.37007874 | inch | | | |
| Aire | 1 | m ² | 1550.0031 | inch ² | | | |
| Densité | 1 | kg/m ³ | 0.062427961 | lb/ft ³ | | | |
| Masse | 1 | kg | 2.204624 | lb | | | |
| Inertie | 1 | kg·m ² | 23.73037 | lb·ft ² | | | |

2.0 Conception et calcul du moment d'inertie et des dimensions du volant d'inertie

| | | | |
|--|--|-------------|----------------------|
| 2.1 Calcul approximatif du moment d'inertie du volant d'inertie | | | |
| 2.2 Type de machine | 01. Moteur diesel 4 cycles, 1 cylindre: [C = 63] | | |
| 2.3 Constante "C" pour la conception "I" | C | 63.00 | [~] |
| 2.4 Puissance nominale de la machine | Pw | 11 | [kW] |
| 2.5 Vitesse du volant d'inertie | n | 4000.00 | [/min] |
| 2.6 Degré d'irrégularité de fonctionnement | δ | 0.0100 | [~] |
| 2.7 Moment d'inertie | I | 0.2338875 | [kg·m ²] |
| 2.8 Conception préliminaire des dimensions du volant d'inertie | | | |
| 2.9 Moment d'inertie requis | I | 0.2338875 | [kg·m ²] |
| 2.10 Densité du matériau du volant d'inertie | Ro | 7800 | [kg/m ³] |
| 2.11 Rapport largeur/hauteur de la couronne du vol | x | 1.5 | [~] |
| 2.12 Diamètre intérieur | d | 200.000 | [mm] |
| 2.13 Diamètre extérieur | D | 283.617 | [mm] |
| 2.14 Largeur | b | 62.712 | [mm] |
| 2.15 Hauteur | h | 41.808 | [mm] |
| 2.16 Masse | m | 15.536 | [kg] |
| 2.17 Moment d'inertie | I | 0.233887497 | [kg·m ²] |
| 2.18 Vitesse maximale, contrainte maximale | | | |
| 2.19 Tension maximale admissible | σtmax | 100.000 | [MPa] |
| 2.20 Coeficiente de Poisson | v | 0.300 | [~] |
| 2.21 Vitesse du volant d'inertie | n | 4000 | < 7984 [~/min] |
| 2.22 Vitesse angulaire | ω | 418.879 | [rad/s] |
| 2.23 Contrainte tangentielle sur le diamètre intérieur | σt | 25.100 | [MPa] |
| 2.24 Déplacement des valeurs dans la ligne de tableau dont le | 1 | | de : |



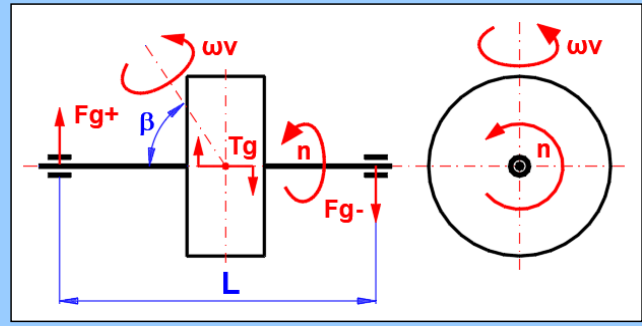
| | | | | | | | | | | | | | | | | | |
|---|-----------|------|----------|------|----------|----------------------|-----|--------|---------|----------|----------|----------------------|----------------------|----------|---------|----------|--|
| 2.25 Dimensions et calcul du volant d'inertie (masses d'inertie) | | | | | | | | | | | | | | | | | |
| | Nombre de | a | D | d | b | Ro | v | n | ω | rg | m | I | Ired | Ek | r | σt | |
| | [-] | [mm] | [mm] | [mm] | [mm] | [kg/m ³] | [~] | [/min] | [rad/s] | [mm] | [kg] | [kg·m ²] | [kg·m ²] | [J] | dx [mm] | [MPa] | |
| 1 | 1 | 0 | 283.6166 | 200 | 62.71246 | 7800 | 0.3 | 4000 | 418.879 | 122.698 | 15.53574 | 0.233887 | 0.233887 | 20518.91 | 200 | 25.10042 | |
| 2 | 1 | 20 | 200 | 80 | 22 | 7800 | 0.3 | 4000 | 418.879 | 76.15773 | 4.528417 | 0.026265 | 0.026265 | 2304.208 | 80 | 11.67403 | |
| 3 | 1 | 10 | 80 | 40 | 42 | 7800 | 0.3 | 4000 | 418.879 | 31.62278 | 1.235023 | 0.001235 | 0.001235 | 108.3483 | 40 | 1.902333 | |

| | | | | | | | | | | | | | | | | |
|----|---|---|---|---|---|------|-----|------|----------|-----|---|---|---|---|---|-----|
| 4 | 1 | 0 | 0 | 0 | 0 | 7800 | 0.3 | 1000 | 104.7198 | --- | 0 | 0 | 0 | 0 | 0 | --- |
| 5 | 1 | 0 | 0 | 0 | 0 | 7800 | 0.3 | 1000 | 104.7198 | --- | 0 | 0 | 0 | 0 | 0 | --- |
| 6 | 1 | 0 | 0 | 0 | 0 | 7800 | 0.3 | 1000 | 104.7198 | --- | 0 | 0 | 0 | 0 | 0 | --- |
| 7 | 1 | 0 | 0 | 0 | 0 | 7800 | 0.3 | 1000 | 104.7198 | --- | 0 | 0 | 0 | 0 | 0 | --- |
| 8 | 1 | 0 | 0 | 0 | 0 | 7800 | 0.3 | 1000 | 104.7198 | --- | 0 | 0 | 0 | 0 | 0 | --- |
| 9 | 1 | 0 | 0 | 0 | 0 | 7800 | 0.3 | 1000 | 104.7198 | --- | 0 | 0 | 0 | 0 | 0 | --- |
| 10 | 1 | 0 | 0 | 0 | 0 | 7800 | 0.3 | 1000 | 104.7198 | --- | 0 | 0 | 0 | 0 | 0 | --- |
| 11 | 1 | 0 | 0 | 0 | 0 | 7800 | 0.3 | 1000 | 104.7198 | --- | 0 | 0 | 0 | 0 | 0 | --- |
| 12 | 1 | 0 | 0 | 0 | 0 | 7800 | 0.3 | 1000 | 104.7198 | --- | 0 | 0 | 0 | 0 | 0 | --- |

Σ 21.2992 0.26139 0.26139 22931.5

2.26 Faire tourner le volant d'inertie

| | | | | |
|------------------------------|----|-------------|---------|-------------------------------------|
| 2.27 Moment d'inertie | I | 0.26138734 | [kg*m²] | <input checked="" type="checkbox"/> |
| 2.28 Vitesse initiale | n1 | 0 | [/min] | |
| 2.29 Vitesse finale | n2 | 4000 | [/min] | |
| 2.30 Torque | T | 20 | [Nm] | |
| 2.31 Énergie | E | 22930.98859 | [J] | |
| 2.32 Temps pour atteindre n2 | t | 5.474483559 | [s] | |



2.33 Moment gyroscopique

| | | | | |
|--|----|-------------|---------|-------------------------------------|
| 2.34 Moment d'inertie | I | 0.26138734 | [kg*m²] | <input checked="" type="checkbox"/> |
| 2.35 Vitesse du volant d'inertie | n | 4000 | [/min] | |
| 2.36 Angle de l'axe de rotation du volant d'inertie | β | 90 | [°] | |
| 2.37 Vitesse angulaire de rotation du volant d'inertie | ωv | 0.5 | [rad/s] | |
| 2.38 Moment gyroscopique | Tg | 54.74483654 | [Nm] | |
| 2.39 Distance de roulement | L | 200 | [mm] | |
| 2.40 Force due au moment gyroscopique | Fg | 273.7241827 | [N] | |

3.0 Analyse (calcul) du volant d'inertie

3.1 Paramètres requis pour le volant d'inertie

| | | | | |
|---|------|-------------|---------|-------------------------------------|
| 3.2 Moment d'inertie | I | 0.196962176 | [kg*m²] | <input checked="" type="checkbox"/> |
| 3.3 Degré d'irrégularité de fonctionnement | δ | 0.01 | [~] | <input type="checkbox"/> |
| 3.4 Vitesse moyenne requise du volant d'inertie | nreq | 4000 | [/min] | |
| 3.5 Vitesse angulaire moyenne requise | ωm | 418.879020 | [rad/s] | |

3.6 Réglage et lancement de l'analyse

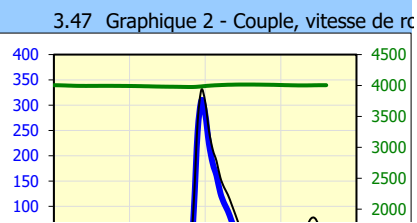
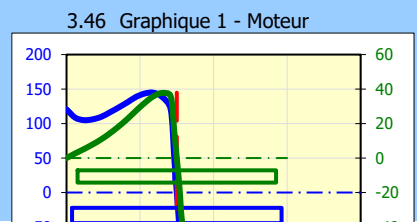
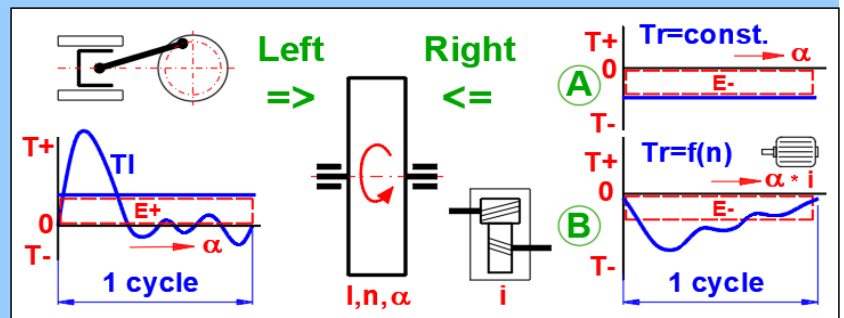
3.7 A. Analyse - moment constant (côté droit)

| | | | | |
|-----------------------------------|---|--------------|------|--|
| 3.8 Puissance (puissance fournie) | P | -10.92119521 | [kW] | |
| 3.9 Lancement de l'analyse | | | | |

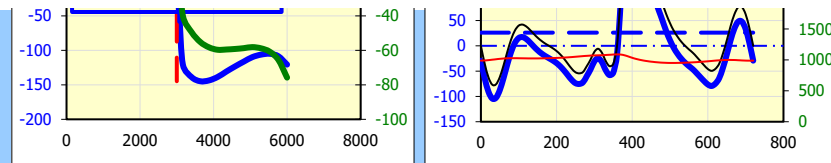
3.10 B. Analyse - moteur électrique/générateur (côté droit)

3.11 Sélection du moteur / générateur

| | | | | | |
|---|---------|-------------------------------|-------|--------|-------------------------------------|
| 3.12 Type de moteur/générateur | | 3000 / 2p ... 50Hz | | | |
| 3.13 Puissance nominale recommandée de/de à | P | -13.1 | -53.9 | [kW] | |
| 3.14 Puissance nominale | P | -15 | | [kW] | |
| 3.15 Mode de travail | | En tant que moteur-générateur | | | |
| 3.16 Vitesse synchrone | ns | 3000 | | [/min] | |
| 3.17 Vitesse nominale | nr | 2933 | 2933 | [/min] | <input checked="" type="checkbox"/> |
| 3.18 Couple nominal | Tr | 48.84077736 | | [Nm] | |
| 3.19 Coefficient de couple de démarrage | Tzcoeff | 2.47 | 2.47 | [~] | |



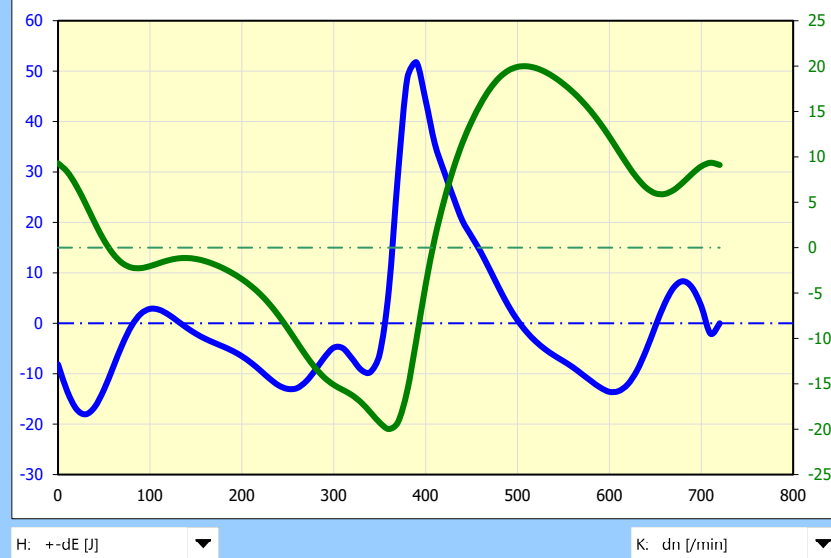
| | | | | | |
|------|---|----|-------------|----------|----------------------|
| 3.20 | Couple de démarrage | Tz | 120.6367201 | [Nm] | |
| 3.21 | Moment d'inertie du moteur / $I_e * i$ | Ie | 0.068 | 0.039504 | [kg*m ²] |
| 3.22 | Rapport de transmission volant d'inertie/moteur | i | 0.762 | 0.762 | |
| 3.23 | Puissance utilisée mini/maxi | P | -14.22 | -7.034 | [kW] |
| 3.24 | Définition des paramètres d'itération | | | | |
| 3.25 | Nombre d'étapes d'itération/sensibilité | | 10 | 5 | |
| 3.26 | Lancement de l'analyse | | | | |



3.27 Résultats d'analyse - B (moteur électrique/générateur)

| | | | | | |
|------|--|--------------------|----------------|---------------|----------------------|
| 3.28 | Valeurs du côté gauche et du côté droit | | Gauche | Droit | |
| 3.29 | Moment de rotation moyen | Tm | 26.07243 | -26.18154 | [Nm] |
| 3.30 | Énergie fournie au volant d'inertie | E+ | 528.8606 | 0 | [J] |
| 3.31 | Énergie retirée du volant d'inertie | E- | -201.2247 | -329.0069 | [J] |
| 3.32 | Somme de l'énergie+/-écart en pourcentage | E | -1.6366 | -0.50% | [J] |
| 3.33 | Volant d'inertie | | | | |
| 3.34 | Vitesse moyenne du volant d'inertie | n | 3995.874 | 3995.836 | [/min] |
| 3.35 | Vitesse angulaire moyenne | ω_m | 418.446958 | | [rad/s] |
| 3.36 | Vitesse au début et à la fin du cycle | n1,n73 | 4005.171 | 4004.981 | [/min] |
| 3.37 | Vitesse minimale / maximale | nmin/max | 3975.895 | 4015.854 | [/min] |
| 3.38 | Vitesse moyenne du volant d'inertie | nm | 3995.874133 | | [/min] |
| 3.39 | Vitesse angulaire minimale/maximale | $\omega_{min/max}$ | 416.3547 | 420.5392 | [rad/s] |
| 3.40 | Vitesse angulaire moyenne | ω_m | 418.4469607 | | [rad/s] |
| 3.41 | Degré d'irrégularité de fonctionnement | δ | 0.01 | | [~] |
| 3.42 | Moment d'inertie | I | 0.196962176 | | [kg*m ²] |

3.48 Graphique 3 - Valeurs sélectionnées



3.43 Définition du tableau des moments (côté gauche)

| | | | | | |
|------|--|----|----|----|-------------------------------------|
| 3.44 | Nombre de lignes valides dans le tableau | nr | 73 | 73 | <input checked="" type="checkbox"/> |
|------|--|----|----|----|-------------------------------------|

3.45 Tableau des charges et des résultats

| ID | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q |
|----|----------|-----------|-----------|-----------|----------|-----------|-----------|------------------|----------|----------|-----------|----------|------------|-----------|----------------------------------|-----------|-----------|
| | Angle | Gauche | Entrée | Droit | Moteur | | | Volant d'inertie | | | | | | | 3.49 C. Analyse de l'utilisateur | | |
| | α | Tl | Ti=Ti+Tr | Tr=Te*i | ne | Te | Pwe | +dE | E | n | dn | ω | d ω | Pw | 30 | 30 | 1 |
| | [°] | [Nm] | [Nm] | [Nm] | [/min] | [Nm] | [kW] | [J] | [J] | [/min] | [/min] | [rad/s] | [rad/s] | [kW] | | | |
| 1 | 0 | 0 | -29.33033 | -29.29332 | 3052.722 | -38.43283 | -12.28531 | -8.130158 | 17324.16 | 4005.171 | 9.296446 | 419.4205 | 0.973522 | 12.30084 | 0.000134 | -62.3291 | -95.14428 |
| 2 | 10 | -34.90361 | -63.83442 | -28.89528 | 3052.006 | -37.9106 | -12.11554 | -13.4755 | 17316.03 | 4004.231 | 8.35653 | 419.3221 | 0.875094 | 26.76521 | 0.000134 | -62.23829 | -95.15765 |
| 3 | 20 | -62.3149 | -90.58347 | -28.23533 | 3050.818 | -37.04474 | -11.83422 | -16.99524 | 17302.55 | 4002.672 | 6.798161 | 419.1589 | 0.711902 | 37.96607 | 0.000134 | -62.08774 | -95.17981 |
| 4 | 30 | -76.73453 | -104.1676 | -27.40264 | 3049.319 | -35.95225 | -11.47957 | -18.04077 | 17285.56 | 4000.706 | 4.831888 | 418.953 | 0.505994 | 43.63811 | | | |
| 5 | 40 | -76.01871 | -102.5644 | -26.51827 | 3047.728 | -34.79197 | -11.10329 | -16.58076 | 17267.52 | 3998.618 | 2.743594 | 418.7343 | 0.287308 | 42.94407 | | | |
| 6 | 50 | -61.70739 | -87.43713 | -25.70507 | 3046.264 | -33.72504 | -10.75763 | -13.15952 | 17250.93 | 3996.697 | 0.823339 | 418.5332 | 0.08622 | 36.59264 | | | |
| 7 | 60 | -38.27803 | -63.35984 | -25.05938 | 3045.102 | -32.8779 | -10.48341 | -8.696835 | 17237.77 | 3995.173 | -0.701351 | 418.3735 | -0.073445 | 26.50613 | | | |
| 8 | 70 | -11.64514 | -36.29854 | -24.63253 | 3044.334 | -32.31787 | -10.30224 | -4.205623 | 17229.08 | 3994.165 | -1.709304 | 418.268 | -0.178998 | 15.1814 | | | |
| 9 | 80 | 12.55172 | -11.89435 | -24.42607 | 3043.962 | -32.047 | -10.21464 | -0.523348 | 17224.87 | 3993.677 | -2.196822 | 418.2169 | -0.230051 | 4.97405 | | | |
| 10 | 90 | 30.31728 | 5.897216 | -24.40038 | 3043.916 | -32.01329 | -10.20374 | 1.862702 | 17224.35 | 3993.617 | -2.257493 | 418.2106 | -0.236404 | -2.466096 | | | |
| 11 | 100 | 39.95935 | 15.44778 | -24.49182 | 3044.081 | -32.13326 | -10.24254 | 2.858682 | 17226.21 | 3993.833 | -2.041557 | 418.2332 | -0.213791 | -6.460298 | | | |
| 12 | 110 | 41.96243 | 17.3103 | -24.63216 | 3044.333 | -32.31738 | -10.30208 | 2.688162 | 17229.07 | 3994.164 | -1.710183 | 418.2679 | -0.17909 | -7.23981 | | | |
| 13 | 120 | 38.27803 | 13.49377 | -24.76411 | 3044.571 | -32.4905 | -10.35808 | 1.746537 | 17231.76 | 3994.476 | -1.398601 | 418.3005 | -0.146461 | -5.644034 | | | |
| 14 | 130 | 31.39011 | 6.520066 | -24.84983 | 3044.725 | -32.60297 | -10.39446 | 0.448184 | 17233.51 | 3994.678 | -1.196175 | 418.3217 | -0.125263 | -2.727284 | | | |
| 15 | 140 | 23.50764 | -1.384253 | -24.87183 | 3044.764 | -32.63183 | -10.40379 | -0.884221 | 17233.95 | 3994.73 | -1.144231 | 418.3271 | -0.119824 | 0.579028 | | | |

| | | | | | | | | | | | | | | | | | |
|----|-----|-----------|-----------|-----------|----------|-----------|-----------|-----------|----------|----------|-----------|----------|-----------|-----------|--|--|--|
| 16 | 150 | 16.09997 | -8.748177 | -24.82843 | 3044.686 | -32.57489 | -10.38537 | -2.067386 | 17233.07 | 3994.627 | -1.246711 | 418.3164 | -0.130555 | 3.659236 | | | |
| 17 | 160 | 9.803822 | -14.94232 | -24.72696 | 3044.504 | -32.44176 | -10.34231 | -3.050115 | 17231 | 3994.388 | -1.486329 | 418.2913 | -0.155648 | 6.249783 | | | |
| 18 | 170 | 4.586322 | -20.00942 | -24.57723 | 3044.234 | -32.24532 | -10.27878 | -3.875861 | 17227.95 | 3994.034 | -1.839874 | 418.2543 | -0.192671 | 8.368411 | | | |
| 19 | 180 | 3.14E-15 | -24.40467 | -24.38696 | 3043.892 | -31.99568 | -10.19805 | -4.646978 | 17224.08 | 3993.585 | -2.289178 | 418.2072 | -0.239722 | 10.20546 | | | |
| 20 | 190 | -4.670173 | -28.84577 | -24.1588 | 3043.481 | -31.69634 | -10.10128 | -5.490196 | 17219.43 | 3993.046 | -2.82794 | 418.1508 | -0.296141 | 12.06099 | | | |
| 21 | 200 | -10.16228 | -34.06724 | -23.8892 | 3042.996 | -31.34262 | -9.986961 | -6.524887 | 17213.94 | 3992.41 | -3.464557 | 418.0842 | -0.362808 | 14.24192 | | | |
| 22 | 210 | -17.11917 | -40.70246 | -23.56874 | 3042.419 | -30.92217 | -9.851122 | -7.813146 | 17207.41 | 3991.653 | -4.221284 | 418.0049 | -0.442052 | 17.01258 | | | |
| 23 | 220 | -25.63151 | -48.82959 | -23.18492 | 3041.728 | -30.41861 | -9.688497 | -9.339953 | 17199.6 | 3990.747 | -5.127605 | 417.91 | -0.536962 | 20.40487 | | | |
| 24 | 230 | -35.46087 | -58.19839 | -22.72599 | 3040.902 | -29.81649 | -9.494139 | -10.94791 | 17190.26 | 3989.663 | -6.211306 | 417.7965 | -0.650446 | 24.31329 | | | |
| 25 | 240 | -45.05792 | -67.25547 | -22.18789 | 3039.934 | -29.1105 | -9.266386 | -12.31052 | 17179.31 | 3988.392 | -7.481952 | 417.6635 | -0.783508 | 28.08808 | | | |
| 26 | 250 | -52.22254 | -73.81273 | -21.58261 | 3038.845 | -28.31637 | -9.010371 | -13.01414 | 17167 | 3986.963 | -8.911228 | 417.5138 | -0.933182 | 30.81556 | | | |
| 27 | 260 | -54.37049 | -75.31838 | -20.94249 | 3037.692 | -27.47654 | -8.739821 | -12.86312 | 17153.99 | 3985.451 | -10.42275 | 417.3555 | -1.091468 | 31.43222 | | | |
| 28 | 270 | -51.76928 | -72.08208 | -20.30957 | 3036.553 | -26.64615 | -8.472508 | -11.51081 | 17141.13 | 3983.957 | -11.9173 | 417.199 | -1.247977 | 30.07036 | | | |
| 29 | 280 | -40.07783 | -59.82208 | -19.74299 | 3035.534 | -25.90279 | -8.233381 | -9.273467 | 17129.61 | 3982.619 | -13.2552 | 417.0589 | -1.388082 | 24.94749 | | | |
| 30 | 290 | -27.15798 | -46.44402 | -19.28639 | 3034.712 | -25.30374 | -8.04079 | -6.740035 | 17120.34 | 3981.541 | -14.33339 | 416.946 | -1.500989 | 19.36322 | | | |
| 31 | 300 | -11.83821 | -30.79109 | -18.95445 | 3034.114 | -24.86824 | -7.900846 | -4.833058 | 17113.6 | 3980.757 | -15.1172 | 416.8639 | -1.58307 | 12.83475 | | | |
| 32 | 310 | -5.877769 | -24.59167 | -18.71639 | 3033.686 | -24.5559 | -7.800513 | -4.954187 | 17108.77 | 3980.195 | -15.67935 | 416.805 | -1.641937 | 10.24918 | | | |
| 33 | 320 | -13.71023 | -32.17913 | -18.47233 | 3033.247 | -24.23569 | -7.697679 | -7.002642 | 17103.81 | 3979.618 | -16.25566 | 416.7447 | -1.702289 | 13.40949 | | | |
| 34 | 330 | -29.94264 | -48.06524 | -18.1273 | 3032.626 | -23.78301 | -7.552351 | -9.240667 | 17096.81 | 3978.804 | -17.07041 | 416.6594 | -1.787609 | 20.02536 | | | |
| 35 | 340 | -40.15942 | -57.825 | -17.67188 | 3031.806 | -23.1855 | -7.360621 | -9.661104 | 17087.57 | 3977.728 | -18.14581 | 416.5467 | -1.900225 | 24.08504 | | | |
| 36 | 350 | -35.69545 | -52.88309 | -17.19561 | 3030.949 | -22.56063 | -7.160222 | -6.088529 | 17077.91 | 3976.604 | -19.27045 | 416.429 | -2.017997 | 22.02043 | | | |
| 37 | 360 | -8.44E-14 | -16.88631 | -16.89539 | 3030.408 | -22.16674 | -7.033957 | 6.608148 | 17071.82 | 3975.895 | -19.97937 | 416.3547 | -2.092235 | 7.030178 | | | |
| 38 | 370 | 109.8232 | 92.61011 | -17.22123 | 3030.995 | -22.59424 | -7.170999 | 29.63092 | 17078.43 | 3976.664 | -19.20995 | 416.4353 | -2.011661 | -38.56328 | | | |
| 39 | 380 | 265.613 | 246.9352 | -18.68151 | 3033.623 | -24.51014 | -7.785814 | 48.56289 | 17108.06 | 3980.112 | -15.76171 | 416.7964 | -1.650562 | -102.9141 | | | |
| 40 | 390 | 330.6303 | 309.5545 | -21.07209 | 3037.926 | -27.64657 | -8.794578 | 51.73223 | 17156.62 | 3985.757 | -10.11674 | 417.3875 | -1.059423 | -129.1947 | | | |
| 41 | 400 | 306.8797 | 283.2532 | -23.61495 | 3042.502 | -30.98281 | -9.870709 | 44.22083 | 17208.35 | 3991.762 | -4.112155 | 418.0163 | -0.430624 | -118.3957 | | | |
| 42 | 410 | 249.284 | 223.4802 | -25.78557 | 3046.409 | -33.83066 | -10.79184 | 35.62458 | 17252.58 | 3996.888 | 1.01343 | 418.5531 | 0.106126 | -93.53143 | | | |
| 43 | 420 | 212.3032 | 184.7474 | -27.53221 | 3049.553 | -36.12225 | -11.53473 | 30.13481 | 17288.2 | 4001.012 | 5.137858 | 418.985 | 0.538035 | -77.40068 | | | |
| 44 | 430 | 189.6085 | 160.5722 | -29.00829 | 3052.209 | -38.05887 | -12.16373 | 25.08203 | 17318.33 | 4004.498 | 8.623393 | 419.35 | 0.90304 | -67.33097 | | | |
| 45 | 440 | 157.1145 | 126.8468 | -30.2359 | 3054.419 | -39.66949 | -12.68767 | 20.34689 | 17343.42 | 4007.396 | 11.52219 | 419.6536 | 1.206601 | -53.22779 | | | |
| 46 | 450 | 137.5773 | 106.3114 | -31.23109 | 3056.21 | -40.97518 | -13.11296 | 17.22038 | 17363.76 | 4009.746 | 13.87219 | 419.8997 | 1.452692 | -44.63682 | | | |
| 47 | 460 | 123.1299 | 91.01961 | -32.07291 | 3057.725 | -42.07965 | -13.47309 | 14.12451 | 17380.98 | 4011.734 | 15.86002 | 420.1078 | 1.660857 | -38.23523 | | | |
| 48 | 470 | 103.6379 | 70.8354 | -32.76308 | 3058.967 | -42.98514 | -13.7686 | 10.56184 | 17395.11 | 4013.364 | 17.48974 | 420.2785 | 1.831521 | -29.7684 | | | |
| 49 | 480 | 83.51433 | 50.19441 | -33.27898 | 3059.896 | -43.66201 | -13.98965 | 6.922016 | 17405.67 | 4014.582 | 18.70795 | 420.4061 | 1.959092 | -21.10048 | | | |
| 50 | 490 | 62.78496 | 29.12605 | -33.617 | 3060.504 | -44.10549 | -14.13456 | 3.498904 | 17412.59 | 4015.38 | 19.50615 | 420.4896 | 2.042679 | -12.2463 | | | |
| 51 | 500 | 44.79865 | 10.96844 | -33.78784 | 3060.812 | -44.32963 | -14.20782 | 0.605556 | 17416.09 | 4015.784 | 19.90956 | 420.5319 | 2.084924 | -4.612238 | | | |
| 52 | 510 | 29.83052 | -4.029277 | -33.81741 | 3060.865 | -44.36842 | -14.2205 | -1.735974 | 17416.7 | 4015.854 | 19.97937 | 420.5392 | 2.092235 | 1.694344 | | | |
| 53 | 520 | 17.91122 | -15.86352 | -33.73265 | 3060.712 | -44.25722 | -14.18415 | -3.61824 | 17414.96 | 4015.653 | 19.77923 | 420.5182 | 2.071276 | 6.670407 | | | |
| 54 | 530 | 7.999066 | -25.59845 | -33.55598 | 3060.394 | -44.02543 | -14.1084 | -5.143835 | 17411.34 | 4015.236 | 19.36205 | 420.4745 | 2.027589 | 10.76271 | | | |
| 55 | 540 | 1.56E-14 | -33.34555 | -33.30478 | 3059.942 | -43.69586 | -14.00071 | -6.401305 | 17406.2 | 4014.643 | 18.76889 | 420.4124 | 1.965474 | 14.01785 | | | |
| 56 | 550 | -6.976081 | -40.00801 | -32.99213 | 3059.379 | -43.28566 | -13.86673 | -7.511719 | 17399.8 | 4013.905 | 18.03061 | 420.3351 | 1.888161 | 16.81553 | | | |
| 57 | 560 | -13.40613 | -46.06996 | -32.62517 | 3058.719 | -42.80421 | -13.70953 | -8.697097 | 17392.29 | 4013.038 | 17.16409 | 420.2444 | 1.79742 | 19.35921 | | | |
| 58 | 570 | -21.35389 | -53.59144 | -32.2002 | 3057.954 | -42.24666 | -13.52757 | -10.05534 | 17383.59 | 4012.035 | 16.1606 | 420.1393 | 1.692334 | 22.51421 | | | |
| 59 | 580 | -29.88971 | -61.63426 | -31.70874 | 3057.07 | -41.60185 | -13.31725 | -11.44742 | 17373.53 | 4010.874 | 15.00007 | 420.0178 | 1.570804 | 25.88558 | | | |
| 60 | 590 | -38.36039 | -69.54353 | -31.14905 | 3056.062 | -40.86755 | -13.07788 | -12.73387 | 17362.09 | 4009.553 | 13.67847 | 419.8794 | 1.432406 | 29.19774 | | | |

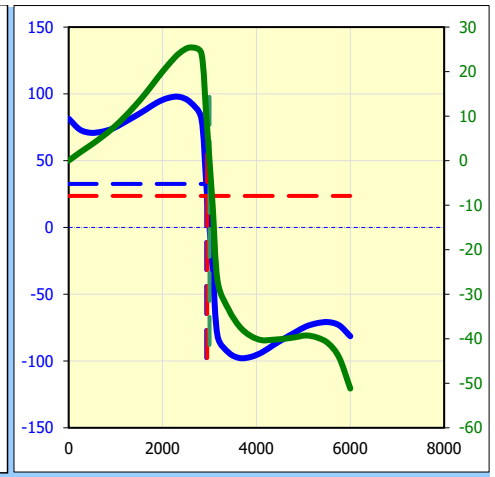
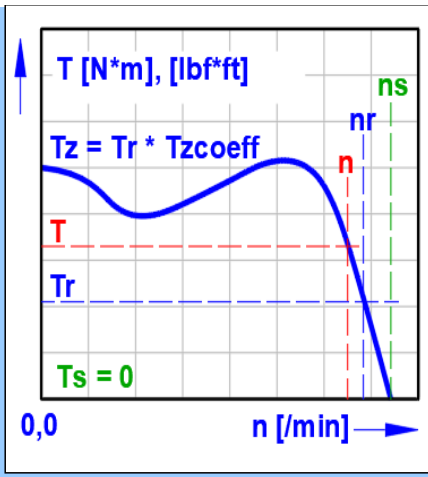
| | | | | | | | | | | | | | | | | | |
|-----|-----|-----------|-----------|-----------|----------|-----------|-----------|-----------|----------|----------|----------|----------|----------|-----------|--|--|--|
| 61 | 600 | -45.81742 | -76.37583 | -30.52626 | 3054.941 | -40.05044 | -12.8117 | -13.58649 | 17349.35 | 4008.082 | 12.20784 | 419.7254 | 1.278402 | 32.05451 | | | |
| 62 | 610 | -49.42224 | -79.31384 | -29.86151 | 3053.745 | -39.1783 | -12.5278 | -13.44209 | 17335.77 | 4006.512 | 10.63814 | 419.561 | 1.114024 | 33.27454 | | | |
| 63 | 620 | -45.48953 | -74.72114 | -29.20358 | 3052.561 | -38.31508 | -12.24703 | -12.10365 | 17322.32 | 4004.959 | 9.084525 | 419.3983 | 0.951329 | 31.33561 | | | |
| 64 | 630 | -35.33928 | -63.97642 | -28.61093 | 3051.494 | -37.53753 | -11.9943 | -9.37623 | 17310.22 | 4003.559 | 7.685086 | 419.2517 | 0.80478 | 26.82025 | | | |
| 65 | 640 | -15.29081 | -43.46727 | -28.15169 | 3050.668 | -36.93501 | -11.79858 | -5.336228 | 17300.84 | 4002.475 | 6.600658 | 419.1382 | 0.691219 | 18.21745 | | | |
| 66 | 650 | 10.23284 | -17.68139 | -27.89027 | 3050.197 | -36.59203 | -11.68721 | -0.635853 | 17295.51 | 4001.857 | 5.983354 | 419.0735 | 0.626575 | 7.409259 | | | |
| 67 | 660 | 38.27803 | 10.39505 | -27.85912 | 3050.141 | -36.55115 | -11.67394 | 3.842397 | 17294.87 | 4001.784 | 5.909791 | 419.0658 | 0.618872 | -4.355891 | | | |
| 68 | 670 | 61.70739 | 33.63558 | -28.04736 | 3050.48 | -36.79813 | -11.75413 | 7.089017 | 17298.71 | 4002.228 | 6.354304 | 419.1124 | 0.665421 | -14.09605 | | | |
| 69 | 680 | 76.01871 | 47.59857 | -28.39461 | 3051.105 | -37.25372 | -11.90209 | 8.334256 | 17305.8 | 4003.048 | 7.174277 | 419.1982 | 0.751288 | -19.95177 | | | |
| 70 | 690 | 76.73453 | 47.90497 | -28.80277 | 3051.839 | -37.78922 | -12.07609 | 7.072332 | 17314.14 | 4004.012 | 8.138069 | 419.2992 | 0.852217 | -20.08504 | | | |
| 71 | 700 | 62.3149 | 33.13798 | -29.14904 | 3052.463 | -38.24353 | -12.22376 | 3.37711 | 17321.21 | 4004.83 | 8.955748 | 419.3848 | 0.937844 | -13.89654 | | | |
| 72 | 710 | 34.90361 | 5.560849 | -29.31437 | 3052.76 | -38.46044 | -12.29429 | -2.066507 | 17324.59 | 4005.22 | 9.346139 | 419.4257 | 0.978725 | -2.332191 | | | |
| 73 | 720 | 1.02E-13 | -29.24128 | -29.2132 | 3052.578 | -38.32771 | -12.25114 | | 17322.52 | 4004.981 | 9.107257 | 419.4007 | 0.95371 | 12.26291 | | | |
| 74 | | | | | | | | | | | | | | | | | |
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| 99 | | | | | | | | | | | | | | | | | |
| 100 | | | | | | | | | | | | | | | | | |

? **Section d'additions**

4.0 Courbes de couple des moteurs, puissances, moments d'inertie, poids, rendement

4.1 Paramètres du moteur électrique asynchrone (générateur) 4.18 Courbe de couple et de puissance

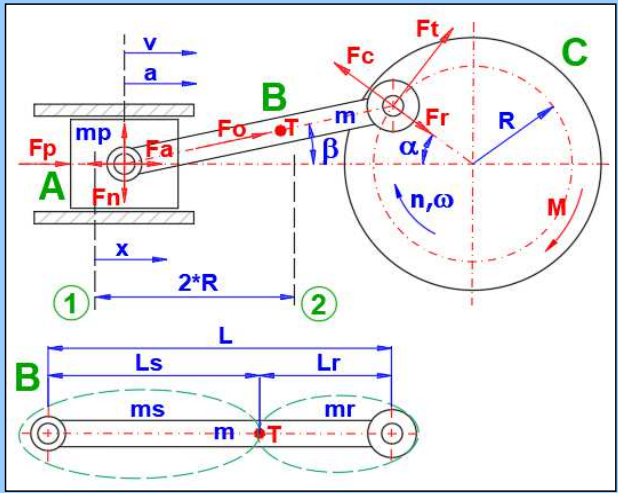
| | | |
|--|-------------------------------|------------------------------|
| 4.2 Type de moteur/générateur | 3000 / 2p ... 50Hz | |
| 4.3 Puissance nominale | Pr | 10 [kW] |
| 4.4 Mode de travail | En tant que moteur-générateur | |
| 4.5 Vitesse synchrone | ns | 3000 [/min] |
| 4.6 Vitesse nominale | nr | 2931 2931 [/min] |
| 4.7 Couple nominal | Tr | 32.58273627 [Nm] |
| 4.8 Coefficient de couple de démarrage | Tzcoeff | 2.5 2.5 [~] |
| 4.9 Couple de démarrage | Tz | 81.45684067 [Nm] |
| 4.10 Poids du moteur (environ) | m | 120 [kg] |
| 4.11 Moment d'inertie (environ) | Ie | 0.04529 [kg*m ²] |
| 4.12 Rendement nominal IE1/IE2 | ηN | 87.1 89 [%] |
| 4.13 Rendement nominal IE3/IE4 | ηN | 90.9 92.3 [%] |
| 4.14 Calcul du couple et de la puissance pour la vitesse spécifiée | | |
| 4.15 Vitesse | n | 2950 [/min] |
| 4.16 Couple | T | 23.61067845 [Nm] |
| 4.17 Puissance | Pw | 7.293350936 [kW] |



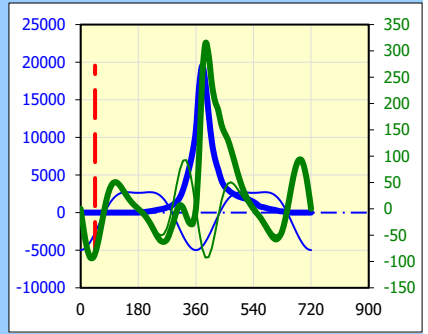
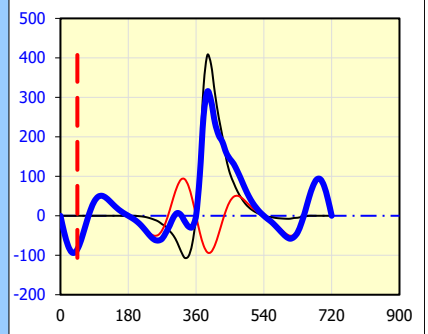
5.0 Mécanisme à manivelle

5.1 Paramètres du mécanisme à manivelle

| | | | |
|---|--------|-------------|---------|
| 5.2 Poids de la partie coulissante | mp | 0.4 | [kg] |
| 5.3 Poids de la bielle (total) | m | 1 | [kg] |
| 5.4 Longueur de la bielle | L | 100.00 | [mm] |
| 5.5 Position du centre de gravité de la | Ls | 70.00 < 100 | [mm] |
| 5.6 Répartition du poids de la bielle | ms, mr | 0.3 0.7 | [kg] |
| 5.7 Rayon de la manivelle | R | 31.00 | [mm] |
| 5.8 Vitesse de la manivelle | n | 4000 | [/min] |
| 5.9 Vitesse angulaire de la manivelle | ω | 418.8790205 | [rad/s] |
| 5.10 Rapport rayon manivelle/longueur | λ | 0.31 | [~] |
| 5.11 Force centrifuge pour mr | Fc | 3807.474053 | [N] |
| 5.12 Vitesse moyenne du piston | vs | 8.266666667 | [m/s] |
| 5.13 Angle de rotation | α | 45 | [°] |



5.15 Graphiques de moments



5.16 Graphiques des valeurs sélectionnées

| | | |
|-------------------------------|----|-------------|
| Courbe bleue (gauche, forte) | 1. | 05. Fp [N] |
| Courbe bleue (gauche, faible) | 2. | 06. Fa [N] |
| Courbe verte (droite, forte) | 3. | 20. ΣM [Nm] |
| Courbe verte (droite, faible) | 4. | 19. Ma [Nm] |

5.14 Tableau

| ID | A | B | C | D | E | F | G | H | I | J | K | L | M | Graphiques des valeurs sélectionnées | | | |
|----|-------|--------|--------|---------|-----------------------|-----------|--------|-----------|--------|-----------|---------|---------|--------|--------------------------------------|-----------|------------|------------|
| | α [°] | Fp [N] | x [mm] | v [m/s] | a [m/s ²] | Fa [N] | Fn [N] | Fo [N] | Ft [N] | Fr [N] | Mp [Nm] | Ma [Nm] | M [Nm] | 1. Fp [N] | 2. Fa [N] | 3. ΣM [Nm] | 4. Ma [Nm] |
| 1 | 0 | 0 | 0 | 0 | 7125.416 | -4987.791 | 0 | -4987.791 | 0 | -4987.791 | 0 | 0 | 0 | 0 | -4987.791 | 0 | 0 |

| | | | | | | | | | | | | | | | | | |
|----|-----|-------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-------|-----------|-----------|-----------|
| 2 | 10 | 0 | 0.615848 | 2.943254 | 6941.093 | -4858.765 | -261.9317 | -4865.82 | -1358.872 | -4739.466 | 0 | -42.12504 | -42.12504 | 0 | -4858.765 | -42.12504 | -42.12504 |
| 3 | 20 | 0 | 2.431607 | 5.734964 | 6402.901 | -4482.031 | -477.9067 | -4507.437 | -2426.053 | -4048.277 | 0 | -75.20764 | -75.20764 | 0 | -4482.031 | -75.20764 | -75.20764 |
| 4 | 30 | 0 | 5.354462 | 8.235686 | 5553.611 | -3887.528 | -609.9382 | -3935.085 | -2987.44 | -3061.729 | 0 | -92.61065 | -92.61065 | 0 | -3887.528 | -92.61065 | -92.61065 |
| 5 | 40 | 0 | 9.237933 | 10.32889 | 4459.506 | -3121.654 | -634.7635 | -3185.538 | -2959.572 | -1983.308 | 0 | -91.74672 | -91.74672 | 0 | -3121.654 | -91.74672 | -91.74672 |
| 6 | 50 | 0 | 13.89327 | 11.92941 | 3203.482 | -2242.437 | -548.2019 | -2308.474 | -2402.401 | -1021.464 | 0 | -74.47444 | -74.47444 | 0 | -2242.437 | -74.47444 | -74.47444 |
| 7 | 60 | 0 | 19.10375 | 12.98862 | 1876.541 | -1313.579 | -366.0934 | -1363.64 | -1490.246 | -339.7431 | 0 | -46.19763 | -46.19763 | 0 | -1313.579 | -46.19763 | -46.19763 |
| 8 | 70 | 0 | 24.6403 | 13.49589 | 568.6537 | -398.0576 | -121.213 | -416.1039 | -453.3704 | -22.24073 | 0 | -14.05448 | -14.05448 | 0 | -398.0576 | -14.05448 | -14.05448 |
| 9 | 80 | 0 | 30.27702 | 13.47636 | -639.9631 | 447.9742 | 143.6187 | 470.433 | 488.6655 | -63.64689 | 0 | 15.14863 | 15.14863 | 0 | 447.9742 | 15.14863 | 15.14863 |
| 10 | 90 | 0 | 35.805 | 12.98525 | -1686.167 | 1180.317 | 384.8577 | 1241.476 | 1180.317 | -384.8577 | 0 | 36.58983 | 36.58983 | 0 | 1180.317 | 36.58983 | 36.58983 |
| 11 | 100 | 0 | 41.04321 | 12.09959 | -2528.994 | 1770.296 | 567.5496 | 1859.048 | 1555.703 | -866.3359 | 0 | 48.22681 | 48.22681 | 0 | 1770.296 | 48.22681 | 48.22681 |
| 12 | 110 | 0 | 45.84555 | 10.9084 | -3152.012 | 2206.408 | 671.8761 | 2306.438 | 1633.687 | -1385.993 | 0 | 50.64431 | 50.64431 | 0 | 2206.408 | 50.64431 | 50.64431 |
| 13 | 120 | 0 | 50.10375 | 9.502495 | -3562.708 | 2493.896 | 695.0469 | 2588.939 | 1490.246 | -1848.876 | 0 | 46.19763 | 46.19763 | 0 | 2493.896 | 46.19763 | 46.19763 |
| 14 | 130 | 0 | 53.74611 | 7.965142 | -3789.081 | 2652.357 | 648.4138 | 2730.465 | 1222.084 | -2201.616 | 0 | 37.88461 | 37.88461 | 0 | 2652.357 | 37.88461 | 37.88461 |
| 15 | 140 | 0 | 56.73269 | 6.364622 | -3873.906 | 2711.734 | 551.4096 | 2767.229 | 915.2028 | -2431.748 | 0 | 28.37129 | 28.37129 | 0 | 2711.734 | 28.37129 | 28.37129 |
| 16 | 150 | 0 | 59.04804 | 4.749564 | -3867.444 | 2707.211 | 424.751 | 2740.329 | 626.8063 | -2556.889 | 0 | 19.43099 | 19.43099 | 0 | 2707.211 | 19.43099 | 19.43099 |
| 17 | 160 | 0 | 60.69255 | 3.14747 | -3819.543 | 2673.68 | 285.0872 | 2688.836 | 381.6838 | -2609.943 | 0 | 11.8322 | 11.8322 | 0 | 2673.68 | 11.8322 | 11.8322 |
| 18 | 170 | 0 | 61.67393 | 1.566476 | -3772.135 | 2640.495 | 142.3467 | 2644.329 | 178.5554 | -2625.098 | 0 | 5.535216 | 5.535216 | 0 | 2640.495 | 5.535216 | 5.535216 |
| 19 | 180 | 0 | 62 | 1.1E-15 | -3753.082 | 2627.157 | 9.98E-14 | 2627.157 | 1.22E-13 | -2627.157 | 0 | 3.79E-15 | 3.79E-15 | 0 | 2627.157 | 3.79E-15 | 3.79E-15 |
| 20 | 190 | 40 | 61.67393 | -1.566476 | -3772.135 | 2640.495 | -144.5031 | 2684.387 | -181.2602 | -2664.865 | -0.083851 | -5.535216 | -5.619068 | 40 | 2640.495 | -5.619068 | -5.535216 |
| 21 | 200 | 81 | 60.69255 | -3.14747 | -3819.543 | 2673.68 | -293.724 | 2770.295 | -393.2471 | -2689.012 | -0.35846 | -11.8322 | -12.19066 | 81 | 2673.68 | -12.19066 | -11.8322 |
| 22 | 210 | 142 | 59.04804 | -4.749564 | -3867.444 | 2707.211 | -447.0303 | 2884.066 | -659.6838 | -2691.004 | -1.019204 | -19.43099 | -20.4502 | 142 | 2707.211 | -20.4502 | -19.43099 |
| 23 | 220 | 203 | 56.73269 | -6.364622 | -3873.906 | 2711.734 | -592.688 | 2974.383 | -983.7147 | -2613.789 | -2.12387 | -28.37129 | -30.49516 | 203 | 2711.734 | -30.49516 | -28.37129 |
| 24 | 230 | 285 | 53.74611 | -7.965142 | -3789.081 | 2652.357 | -718.0869 | 3023.858 | -1353.399 | -2438.183 | -4.070762 | -37.88461 | -41.95537 | 285 | 2652.357 | -41.95537 | -37.88461 |
| 25 | 240 | 366 | 50.10375 | -9.502495 | -3562.708 | 2493.896 | -797.0509 | 2968.887 | -1708.952 | -2120.214 | -6.779888 | -46.19763 | -52.97751 | 366 | 2493.896 | -52.97751 | -46.19763 |
| 26 | 250 | 447 | 45.84555 | -10.9084 | -3152.012 | 2206.408 | -807.9927 | 2773.703 | -1964.659 | -1666.784 | -10.26012 | -50.64431 | -60.90442 | 447 | 2206.408 | -60.90442 | -50.64431 |
| 27 | 260 | 529 | 41.04321 | -12.09959 | -2528.994 | 1770.296 | -737.1448 | 2414.569 | -2020.579 | -1125.215 | -14.41114 | -48.22681 | -62.63794 | 529 | 1770.296 | -62.63794 | -48.22681 |
| 28 | 270 | 692 | 35.805 | -12.98525 | -1686.167 | 1180.317 | -610.4933 | 1969.333 | -1872.317 | -610.4933 | -21.452 | -36.58983 | -58.04183 | 692 | 1180.317 | -58.04183 | -36.58983 |
| 29 | 280 | 814 | 30.27702 | -13.47636 | -639.9631 | 447.9742 | -404.5837 | 1325.242 | -1376.604 | -179.2977 | -27.52611 | -15.14863 | -42.67474 | 814 | 447.9742 | -42.67474 | -15.14863 |
| 30 | 290 | 1099 | 24.6403 | -13.49589 | 568.6537 | -398.0576 | -213.4449 | 732.7203 | -798.3431 | 39.16386 | -38.80312 | 14.05448 | -24.74864 | 1099 | -398.0576 | -24.74864 | 14.05448 |
| 31 | 300 | 1425 | 19.10375 | -12.98862 | 1876.541 | -1313.579 | -31.05308 | 115.6678 | -126.4069 | 28.81797 | -50.11624 | 46.19763 | -3.918614 | 1425 | -1313.579 | -3.918614 | 46.19763 |
| 32 | 310 | 2035 | 13.89327 | -11.92941 | 3203.482 | -2242.437 | 50.71157 | -213.546 | 222.2348 | -94.49078 | -67.58516 | 74.47444 | 6.889278 | 2035 | -2242.437 | 6.889278 | 74.47444 |
| 33 | 320 | 3053 | 9.237933 | -10.32889 | 4459.506 | -3121.654 | 13.96029 | -70.05921 | 65.08957 | -43.61869 | -89.72895 | 91.74672 | 2.017777 | 3053 | -3121.654 | 2.017777 | 91.74672 |
| 34 | 330 | 4478 | 5.354462 | -8.235686 | 5553.611 | -3887.528 | -92.64284 | 597.6957 | -453.759 | 465.0426 | -106.6772 | 92.61065 | -14.06653 | 4478 | -3887.528 | -14.06653 | 92.61065 |
| 35 | 340 | 6107 | 2.431607 | -5.734964 | 6402.901 | -4482.031 | -173.2661 | 1634.181 | -879.5705 | 1467.711 | -102.4743 | 75.20764 | -27.26668 | 6107 | -4482.031 | -27.26668 | 75.20764 |
| 36 | 350 | 8143 | 0.615848 | -2.943254 | 6941.093 | -4858.765 | -177.0501 | 3289.004 | -918.5165 | 3203.596 | -70.59905 | 42.12504 | -28.47401 | 8143 | -4858.765 | -28.47401 | 42.12504 |
| 37 | 360 | 10993 | 2.88E-31 | -4.17E-15 | 7125.416 | -4987.791 | -4.56E-13 | 6005.209 | -2.38E-12 | 6005.209 | -1.35E-13 | 6.14E-14 | -7.39E-14 | 10993 | -4987.791 | -7.39E-14 | 6.14E-14 |
| 38 | 370 | 16693 | 0.615848 | 2.943254 | 6941.093 | -4858.765 | 637.973 | 11851.42 | 3309.733 | 11543.66 | 144.7268 | -42.12504 | 102.6017 | 16693 | -4858.765 | 102.6017 | -42.12504 |
| 39 | 380 | 19543 | 2.431607 | 5.734964 | 6402.901 | -4482.031 | 1605.91 | 15146.34 | 8152.266 | 13603.43 | 327.9279 | -75.20764 | 252.7203 | 19543 | -4482.031 | 252.7203 | -75.20764 |
| 40 | 390 | 17100 | 5.354462 | 8.235686 | 5553.611 | -3887.528 | 2072.986 | 13374.11 | 10153.36 | 10405.84 | 407.3648 | -92.61065 | 314.7542 | 17100 | -3887.528 | 314.7542 | -92.61065 |
| 41 | 400 | 13028 | 9.237933 | 10.32889 | 4459.506 | -3121.654 | 2014.376 | 10109.08 | 9391.989 | 6293.885 | 382.8984 | -91.74672 | 291.1516 | 13028 | -3121.654 | 291.1516 | -91.74672 |
| 42 | 410 | 9364 | 13.89327 | 11.92941 | 3203.482 | -2242.437 | 1740.987 | 7331.282 | 7629.578 | 3243.979 | 310.9914 | -74.47444 | 236.5169 | 9364 | -2242.437 | 236.5169 | -74.47444 |
| 43 | 420 | 7125 | 19.10375 | 12.98862 | 1876.541 | -1313.579 | 1619.639 | 6032.897 | 6593.019 | 1503.062 | 250.5812 | -46.19763 | 204.3836 | 7125 | -1313.579 | 204.3836 | -46.19763 |
| 44 | 430 | 5700 | 24.6403 | 13.49589 | 568.6537 | -398.0576 | 1614.501 | 5542.311 | 6038.683 | 296.2362 | 201.2537 | -14.05448 | 187.1992 | 5700 | -398.0576 | 187.1992 | -14.05448 |
| 45 | 440 | 4275 | 30.27702 | 13.47636 | -639.9631 | 447.9742 | 1514.166 | 4959.756 | 5151.981 | -671.0266 | 144.5628 | 15.14863 | 159.7114 | 4275 | 447.9742 | 159.7114 | 15.14863 |
| 46 | 450 | 3460 | 35.805 | 12.98525 | -1686.167 | 1180.317 | 1513.036 | 4880.76 | 4640.317 | -1513.036 | 107.26 | 36.58983 | 143.8498 | 3460 | 1180.317 | 143.8498 | 36.58983 |

| | | | | | | | | | | | | | | | | | |
|----|-----|------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------|-----------|-----------|-----------|
| 47 | 460 | 3053 | 41.04321 | 12.09959 | -2528.994 | 1770.296 | 1546.329 | 5065.108 | 4238.623 | -2360.393 | 83.17052 | 48.22681 | 131.3973 | 3053 | 1770.296 | 131.3973 | 48.22681 |
| 48 | 470 | 2687 | 45.84555 | 10.9084 | -3152.012 | 2206.408 | 1490.098 | 5115.255 | 3623.219 | -3073.878 | 61.67547 | 50.64431 | 112.3198 | 2687 | 2206.408 | 112.3198 | 50.64431 |
| 49 | 480 | 2442 | 50.10375 | 9.502495 | -3562.708 | 2493.896 | 1375.631 | 5124.005 | 2949.482 | -3659.279 | 45.2363 | 46.19763 | 91.43393 | 2442 | 2493.896 | 91.43393 | 46.19763 |
| 50 | 490 | 2198 | 53.74611 | 7.965142 | -3789.081 | 2652.357 | 1185.752 | 4993.193 | 2234.822 | -4026.088 | 31.39486 | 37.88461 | 69.27947 | 2198 | 2652.357 | 69.27947 | 37.88461 |
| 51 | 500 | 2035 | 56.73269 | 6.364622 | -3873.906 | 2711.734 | 965.2106 | 4843.874 | 1602.01 | -4256.635 | 21.29101 | 28.37129 | 49.6623 | 2035 | 2711.734 | 49.6623 | 28.37129 |
| 52 | 510 | 1913 | 59.04804 | 4.749564 | -3867.444 | 2707.211 | 724.8934 | 4676.732 | 1069.727 | -4363.667 | 13.73055 | 19.43099 | 33.16154 | 1913 | 2707.211 | 33.16154 | 19.43099 |
| 53 | 520 | 1832 | 60.69255 | 3.14747 | -3819.543 | 2673.68 | 480.4283 | 4531.221 | 643.2128 | -4398.27 | 8.107398 | 11.8322 | 19.9396 | 1832 | 2673.68 | 19.9396 | 11.8322 |
| 54 | 530 | 1628 | 61.67393 | 1.566476 | -3772.135 | 2640.495 | 230.1107 | 4274.693 | 288.6439 | -4243.605 | 3.412744 | 5.535216 | 8.94796 | 1628 | 2640.495 | 8.94796 | 5.535216 |
| 55 | 540 | 1425 | 62 | 3.29E-15 | -3753.082 | 2627.157 | 4.62E-13 | 4052.157 | 5.66E-13 | -4052.157 | 6.17E-15 | 1.14E-14 | 1.75E-14 | 1425 | 2627.157 | 1.75E-14 | 1.14E-14 |
| 56 | 550 | 1140 | 61.67393 | -1.566476 | -3772.135 | 2640.495 | -203.8031 | 3785.984 | -255.6444 | -3758.451 | -2.389759 | -5.535216 | -7.924975 | 1140 | 2640.495 | -7.924975 | -5.535216 |
| 57 | 560 | 814 | 60.69255 | -3.14747 | -3819.543 | 2673.68 | -371.8818 | 3507.45 | -497.8872 | -3404.538 | -3.602305 | -11.8322 | -15.4345 | 814 | 2673.68 | -15.4345 | -11.8322 |
| 58 | 570 | 732 | 59.04804 | -4.749564 | -3867.444 | 2707.211 | -539.599 | 3481.284 | -796.2878 | -3248.243 | -5.253927 | -19.43099 | -24.68492 | 732 | 2707.211 | -24.68492 | -19.43099 |
| 59 | 580 | 610 | 56.73269 | -6.364622 | -3873.906 | 2711.734 | -675.4482 | 3389.712 | -1121.076 | -2978.766 | -6.382072 | -28.37129 | -34.75336 | 610 | 2711.734 | -34.75336 | -28.37129 |
| 60 | 590 | 488 | 53.74611 | -7.965142 | -3789.081 | 2652.357 | -767.7137 | 3232.836 | -1446.932 | -2606.685 | -6.970287 | -37.88461 | -44.8549 | 488 | 2652.357 | -44.8549 | -37.88461 |
| 61 | 600 | 407 | 50.10375 | -9.502495 | -3562.708 | 2493.896 | -808.4776 | 3011.45 | -1733.452 | -2150.61 | -7.539383 | -46.19763 | -53.73701 | 407 | 2493.896 | -53.73701 | -46.19763 |
| 62 | 610 | 325 | 45.84555 | -10.9084 | -3152.012 | 2206.408 | -770.8423 | 2646.172 | -1874.327 | -1590.147 | -7.459817 | -50.64431 | -58.10412 | 325 | 2206.408 | -58.10412 | -50.64431 |
| 63 | 620 | 203 | 41.04321 | -12.09959 | -2528.994 | 1770.296 | -632.6306 | 2072.226 | -1734.096 | -965.6788 | -5.530172 | -48.22681 | -53.75698 | 203 | 1770.296 | -53.75698 | -48.22681 |
| 64 | 630 | 162 | 35.805 | -12.98525 | -1686.167 | 1180.317 | -437.6799 | 1411.871 | -1342.317 | -437.6799 | -5.022 | -36.58983 | -41.61183 | 162 | 1180.317 | -41.61183 | -36.58983 |
| 65 | 640 | 81 | 30.27702 | -13.47636 | -639.9631 | 447.9742 | -169.5869 | 555.4939 | -577.023 | -75.15513 | -2.739084 | -15.14863 | -17.88771 | 81 | 447.9742 | -17.88771 | -15.14863 |
| 66 | 650 | 40 | 24.6403 | -13.49589 | 568.6537 | -398.0576 | 109.0326 | -374.2904 | 407.8121 | -20.0058 | -1.412306 | 14.05448 | 12.64218 | 40 | -398.0576 | 12.64218 | 14.05448 |
| 67 | 660 | 0 | 19.10375 | -12.98862 | 1876.541 | -1313.579 | 366.0934 | -1363.64 | 1490.246 | -339.7431 | 0 | 46.19763 | 46.19763 | 0 | -1313.579 | 46.19763 | 46.19763 |
| 68 | 670 | 0 | 13.89327 | -11.92941 | 3203.482 | -2242.437 | 548.2019 | -2308.474 | 2402.401 | -1021.464 | 0 | 74.47444 | 74.47444 | 0 | -2242.437 | 74.47444 | 74.47444 |
| 69 | 680 | 0 | 9.237933 | -10.32889 | 4459.506 | -3121.654 | 634.7635 | -3185.538 | 2959.572 | -1983.308 | 0 | 91.74672 | 91.74672 | 0 | -3121.654 | 91.74672 | 91.74672 |
| 70 | 690 | 0 | 5.354462 | -8.235686 | 5553.611 | -3887.528 | 609.9382 | -3935.085 | 2987.44 | -3061.729 | 0 | 92.61065 | 92.61065 | 0 | -3887.528 | 92.61065 | 92.61065 |
| 71 | 700 | 0 | 2.431607 | -5.734964 | 6402.901 | -4482.031 | 477.9067 | -4507.437 | 2426.053 | -4048.277 | 0 | 75.20764 | 75.20764 | 0 | -4482.031 | 75.20764 | 75.20764 |
| 72 | 710 | 0 | 0.615848 | -2.943254 | 6941.093 | -4858.765 | 261.9317 | -4865.82 | 1358.872 | -4739.466 | 0 | 42.12504 | 42.12504 | 0 | -4858.765 | 42.12504 | 42.12504 |
| 73 | 720 | 0 | 1.15E-30 | -8.34E-15 | 7125.416 | -4987.791 | 7.58E-13 | -4987.791 | 3.96E-12 | -4987.791 | 0 | 1.23E-13 | 1.23E-13 | 0 | -4987.791 | 1.23E-13 | 1.23E-13 |