Supplementary Material

# Supplementary Figures and Tables

**Supplementary Table 1.** Parameter definition table

|  |  |
| --- | --- |
| Name | Definition |
| *O*1 | Center of the sun gear |
| *O*2 | Center of the idler gear |
| *O*3 | Center of the elliptical planetary gear |
| *J* | Center point of the middle sucker of the labeling actuator |
| *M* | Center point of the right sucker of the labeling actuator |
| *N* | Center point of the left sucker of the labeling actuator |
| *J*0 | Center point of the sucker after the end of the labeling actuator is displaced after *O*1*O*3 rotation |
| *l* | Distance from the intersection of the concentric lines of *O*3 and *J* and the base circle of the cam to *J*. |
| *l*1 | Distance between the solar gear center *O*1 and the planetary gear center *O*3 |
| *l*2 | Distance between the planetary gear center *O*3 and point *J* |
| *l*3 | Distance between the center point *J* of the middle sucker and the center point *M* |
| *l*4 | Distance between the center point *J* of the middle sucker and the center point *N* |
| *θ*0 | Initial angle between *O*1*O*3 and the *x*-axis |
| *θ*1 | The angle of the idler gear |
| *θ*2 | The angle of the elliptical planetary gear |
| *σ*1 | The angle between the short half axis of the elliptical idler gear and *O*2*O*3 |

**Supplementary Table 2.** Comparison of motion performances after adding cam

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | distance error (mm) | Maximum velocity  (mm s-1) | Maximum acceleration  (mm s-2) | Minimum acceleration  (mm s-2) |
| E labeling  mechanism | 2.3 | 1668 | 12660 | 8222 |
| E&C labeling  mechanism | 1.3 | 1552 | 12384 | 7528 |
| difference Value | 1 | 116 | 276 | 1694 |
| Percentage | 43% | 7% | 2% | 18% |

**Supplementary Table 3.** Information entropy and entropy weight of each evaluation index

|  |  |  |
| --- | --- | --- |
| Evaluation index | Information entropy | Entropy weight |
|  | 0.968 | 39.247 |
|  | 0.951 | 60.753 |

**Supplementary Table 4.** The relative closeness between each scheme and the ideal solution

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Ranking |  |  | *S* | Projects |
| 1 | 0.464 | 0.650 | 0.584 | 67 |
| 2 | 0.472 | 0.660 | 0.583 | 40 |
|  |  |  |  |  |
| 79 | 0.775 | 0.626 | 0.447 | 2 |
| 80 | 0.779 | 0.626 | 0.445 | 1 |

**Supplementary Table 5.** Comparison of optimization results

|  |  |  |
| --- | --- | --- |
|  | Distance error  (mm) | Labeling velocity  (m s-1) |
| Before optimization | 1.30 | 0.10770 |
| After optimization | 0.12 | 0.0037 |

# Supplementary Figures



Supplementary Figure 1. Cam-elliptical gear combined labeling mechanism: 1.rotating bracket 2.sun gear 3.spur idler gear 4.elliptical idler gear 5.elliptical planet gear 6.cam 7.labeling actuator 8.fixed shaft 9.spring.



Supplementary Figure 2. The work flow of cam-elliptical gear combined labeling mechanism: (A) 1.rotating bracket 2.sun gear 3.spur idler gear 4.elliptical idler gear 5.elliptical planet gear 6.cam 7.labeling actuator 8. hypocycloid trajectory 9.label tray 10.label 11.conveyor 12.label object; (B) a-f is the gear train at different points in its travel.



Supplementary Figure 3. Structure diagram of C&E labeling mechanism 1.sun gear 2.circular idler gear 3.elliptical idler gear 4. elliptical planetary gear 5. cam 6. rotating bracket



Supplementary Figure 4. Hypocycloid trajectory



Supplementary Figure 5. (A) Cam profile; (B) Track curve; (C) Velocity comparison; (D) Acceleration comparison



Supplementary Figure 6. Pareto sets



Supplementary Figure 7. (A) Optimized trajectory comparison; (B) Optimized velocity comparison



Supplementary Figure 8. Pitch curve and tooth profile of elliptical gear



Supplementary Figure 9. Three-dimensional model of cam-elliptical gear combined labeling mechanism: (A). The back of mechanism, 1.sun gear 2.idler gear 3.elliptical idler gear 4.rotating bracket 5.elliptical planetary gear 6.fixed shaft 7.cam; (B). The front of mechanism, 8.cam lever, 9.sliding sleeve.



Supplementary Figure 10. Simulation trajectory



Supplementary Figure 11. Comparison between simulation trajectory and theoretical trajectory



**Supplementary** **Figure 12**. Cam-Elliptical Gear Combination Vegetables Curved Surface Labeling Mechanism



Supplementary Figure 13. Actual trajectory