ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

International Journal of Mechanical Engineering

SEPARATOR OF PARTS FOR TRANSPORTING TO PROCESSING MACHINES

A. M. Ahmed Alwaise*
University of Mosul, Collage of Petroleum and mining Engineering, Reservoir Engineering Department, Mosul 41002, Iraq

Omer Haitham Kanam
University of Mosul, Collage of Petroleum and mining Engineering, Mining Engineering Department, Mosul 41002, Iraq

Maher Obaid Ahmed
University of Mosul, Collage of Petroleum and mining Engineering, Petroleum and Refining Engineering Department, Mosul 41002, Iraq

Ahmed A. Aabid
University of Mosul, Collage of Petroleum and mining Engineering, Reservoir Engineering Department, Mosul 41002, Iraq

Mahmood Salman Ahmed
University of Mosul, Collage of Petroleum and mining Engineering, Reservoir Engineering Department, Mosul 41002, Iraq

Abstract.

In manufacturing area, prismatic or disk type parts are transported by sliding or rolling in the chutes, tranches, etc. simple mechanisms. Most of simple mechanisms transport the parts by gravity force in one chute. In many cases the parts transported must be separated for two flow chute branches and transferred to different processing machines. All known designs of chutes with flow part separators have a simple controlled mechanism in the form of a swing shield or pocket type that allows directing the flow of a part to the required branch of the transport chute. Nevertheless, such a simple swing shield creates problem due to its low reliability. The parts are clutched by the swing shield for some time making the automated transport system to stop. Such construction deficiencies reflect on decreasing the automatic machine productivity rate and the efficiency of its use. This paper presents new concept of a separator design, which works with the use of gravity force and has no lack of known mechanisms that is in industrial usage today. Calculation and limitation of working regimes of an automated separator for sliding prismatic and rolling disk type parts into a chute was considered.

Keywords: transport system, separator, part

1. INTRODUCTION

Integrated industrial systems and automation of production processes of mass parts is developing on the base of design of automated lines with complex machines and with transport facilities [1]. A prismatic and disk type part is moved by sliding and rolling, and action of gravitational force in inclined chutes. This is a typical construction of a transport system of automated lines for manufacturing different type work pieces. Most of such chutes are designed with the ability to transport parts and separate their flows for two or more parallel transport systems and to deliver parts to processing machines. The transport chute must have a design that can separate the flow of the discrete parts on two or more branches.

In industrial area, designers use a simple mechanism in the form of a shield (Fig. 1, I). The part 1 is moving in the chute 2 and if the shield 3 closes the main line 2, the part 1 moves to the chute branch 4. If the shield 3 closes (dotted line) the chute's branch 4, the part 1 moves in mail line 5. The opening and closing of the shield 3 is going on automatically according to the work program of an automated production line. However, the shield closing of the chute branch 4 some time can clamp the part in the chute 4 (Fig. 1, II). In such a case, the following running part cannot pass to the necessary branch chute and to a processing machine because the shield is clutched the part in the chute. This is a real situation of failure in transport systems with swing shields and always creates problems for manufacturers [2-6].

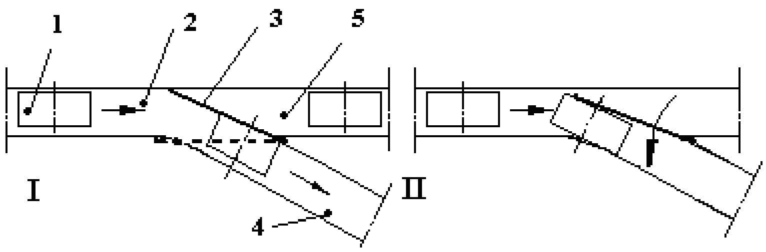

Figure 1. A transport system with a swing shield as a separator of a flow of a disk type parts

A new design of a separator enables to decrease the number of failures in transport systems and increase their work reliability. The new separator does not have a shield and designed in the form of a *Y* type swing lath on which the running part is located (Fig. 2). This separator has two branch laths located in the window at the bottom of the chute. The transported part is located on some branch of the *Y* type lath. The *Y* type lath has the straight branch 1 and the curved branch 2. If the part pass straight, the lath shifts to the right side of the chute (Fig. 2, I, A-A). The reaction force *C* of the part weight pushes the part 1 to the left board of the chute and the part finally takes position (E-E) to its straight pass. The part 1 can pass to the curved branch of the chute 2 when the separator shifted to the left side of the chute. (Fig. 1, II, B-B).

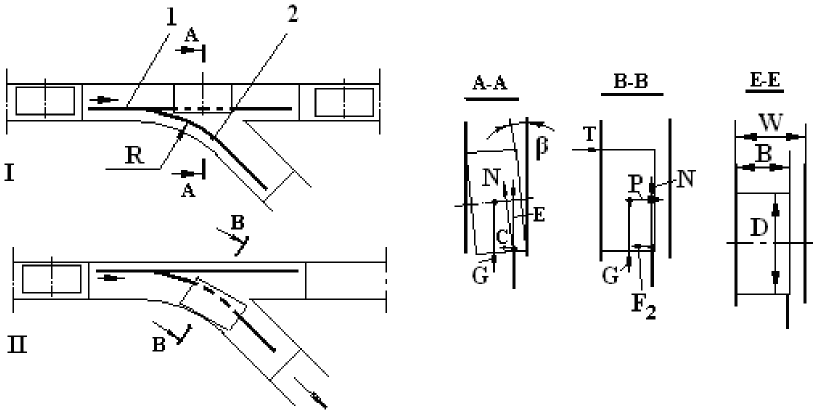

Figure 2. A transport system with a *Y* type separator of a disk parts flow.

This design of the part separator can work with high reliability only under certain conditions, which is the restriction of the part velocity motion. High velocity of a running part can create a situation when a part will not turn into the curved branch of the chute under the action of a centrifugal force. This is an important restriction and the reliable work of a transport system depends on the reliable work of the new design of separator. For such case, it is necessary to calculate the limited velocity of the running part at which the separator can work properly and should make reliable passes of the part to the necessary branch of the chute without jamming.

An analysis of the new separator work shows that there are some properties that are applicable to the new mechanism. The part is running on the curved branch of the chute will get a centrifugal force that depends on the size radius of the curved branch. It is known that the bigger radius, the lesser centrifugal force. It means that this design of the parts flow separator does not have too many restrictions and manufacturers can use it for a wide range of velocity for transporting disk type parts.

2. ANALYTICAL APPROACH

The parts can be prismatic or disc type that can move in the chute by sliding or rolling. The parts are running in an inclined chute according to the conformity of the gravity law. The velocity of a part is changing from zero value to some limited level depended on transport mechanisms design, which enables to use of the *Y* type lath separator of parts. It is very important to have a limited velocity a part that is acceptable for transporting processes and does not reflect on lowering the quality of machined parts and allow the reliable work of a separator mechanism in chutes [7-10].

2.1. Separator work for the rolling disc type part

The work of a parts separator is considered when a part is rolling in curved helical segments of a chute and based on the *Y* type lath (Fig. 3, 1). Fig. 3.2 shows all acting forces applied to a rolling part and geometrical parameters of a chute and a part.

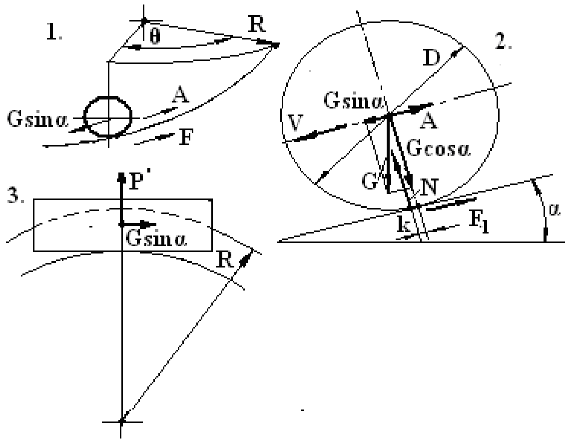

Figure 3. Computational scheme for a disk type part rolling in a helical branch of the chute.

For initialization of data of motion, an equation for a part by rolling is given by the following differential equations in Euler's form [11].

$$m\frac{d^2S}{dt^2} = G\sin\alpha - F - A,$$

$$J\,\frac{d^2\varphi}{dt^2} = F\,\frac{D}{2} - A\;\frac{D}{2} - kN \qquad (1)$$

where m is a mass of a part, $J = mD^2/8$ is the moment inertia of a part, $G = mg$ is a part weight, g is the gravity acceleration, D is the diameter of a part, S is the length of a part rolling on the curved lath, α is an angle of inclination of a chute, φ is an angle of a part rotation, t is time interval considered, k is a rolling friction factor between a part and a lathe, $N = G\cos\alpha$ is the normal reaction of a lath of a chute on acting a weight of a part, $F = G\cos\alpha * f$ is the friction force between a part and a lathe, and f is a sliding friction factor between a part and a lathe.

For analysis it is taken condition when a rolling part has full contact with a board of a chute (Fig. 2, II, B-B). The rolling part has permanent contact with the board of a chute by the action of a component of the normal reaction force T. The friction force between the part and the board of the chute is expressed by formula $A = T*f$, where f is a sliding friction factor between the part and the board of the chute. The normal reaction of the board of the chute T is defined from the equation of a moment, and forces in equilibrium around the contact point of the part with the branch of the lathe (Fig. 2, II, B-B)

$$TD - G\cos\alpha\left(\frac{B}{2}\right) + P\frac{D}{2} = 0, \qquad (2)$$

where $P = \frac{mV^2\cos^2\alpha}{R}$ is a centrifugal force, V is a speed of the part in the curvilinear chute. The followings are obtained after substituting and defining expressions and transformation

$$TD - G\cos\alpha\left(\frac{B}{2}\right) + \frac{D}{2}\frac{mV^2\cos^2\alpha}{R} = 0, \text{ or } T = \frac{G}{2D}B\cos\alpha - \frac{mV^2\cos^2\alpha}{2R} \qquad (3)$$

Then expression of the friction force has the following formula

$$A = \frac{f}{2}\left(\frac{G}{D}B\cos\alpha - \frac{mV^2\cos^2\alpha}{R}\right), \qquad (4)$$

where R is the radius of a curvilinear branch of a lathe; B is the width of the part; other parameters specified above.

To find expression of the part velocity in the chute, it is necessary produce some mathematical transformations and expresses the auxiliary of the part via its velocity

$$\frac{d^2S}{dt^2} = \frac{VdV}{dS};\;\; \frac{d^2\varphi}{dt^2} = \frac{VdV}{(D/2)/dS} \qquad (5)$$

The length of the part running on the curvilinear chute can be expressed by its radius and inclination,

$$S = R\theta/\cos\alpha. \qquad (6)$$

After substituting defined Eqs. (3) – (6) into Eq. (1), and following transformation the expression becomes

$$\frac{m\cos\alpha}{R}\frac{VdV}{d\theta}=G\sin\alpha-Nf\ -Tf\ ,$$
$$\frac{J\cos\alpha}{R(D/2)}\frac{VdV}{d\theta}=Nf\ \frac{D}{2}-Tf\ \frac{D}{2}-kN \qquad (7)$$

From second differential Eq. (7), the normal reaction N of the lath in the chute is expressed as

$$N=\left(\frac{J\cos\alpha}{fR(D/2)^2}\frac{VdV}{d\theta}+T+\frac{kN}{fD/2}\right) \qquad (8)$$

The expression $kN/f(D/2)$ is definitely a small value, which can be neglected. After substituting of expression of the normal reaction N , the normal reactions T, and other parameters mentioned above to the first differential Eq. (7), the system of Eq. (7) shall have the next expression

$$\frac{m\cos\alpha}{R}\frac{VdV}{d\theta}=mg\sin\alpha-\left(\frac{\left[mD^2/8\right]\cos\alpha}{fR\left[D/2\right]^2}\frac{VdV}{d\theta}+\frac{1}{2}\left[\frac{mg}{D}B\cos\alpha-\frac{mV^2\cos^2\alpha}{R}\right]\right)f-$$
$$\left(\frac{mg}{D}B\cos\alpha-\frac{mV^2\cos^2\alpha}{R}\right)\frac{f}{2} \qquad (9)$$

Transformation and separation of variables of Eq. (9) shall have the following formula

$$\frac{3VdV}{2\left[Rg*tg\alpha-f\left(\frac{RBg}{D}-V^2\cos\alpha\right)\right]}=d\theta \qquad (10)$$

The expression of the part velocity can be defined by taking integral of Eq. (10) at its corresponding limits

$$\frac{3}{2}\int_{V_1}^{V}\frac{VdV}{Rg*tg\alpha-f\left(\frac{RBg}{D}-V^2\cos\alpha\right)}=\int_0^{\theta}d\theta \qquad (11)$$

The left side of integral is a standard tabulated integral $\int\frac{dx}{x}=\ln x+c$. Consequently after taking integrals of Eq. (11) and its transformation, expression of a rolling part velocity on the helical branch lath in a chute will have the next expression

$$\frac{3}{4f\cos\alpha}\ln\left[Rg*tg\alpha-f\left(\frac{RBg}{D}-V^2\cos\alpha\right)\right]\Bigg|_{V_1}^{V}=\theta\Big|_0^{\theta} \qquad (12)$$

After transformation the expression of the velocity of rolling part on the curvilinear part of chute will have following expression

$$V=\sqrt{\left(e^{\frac{4\theta f\cos\alpha}{3}}-1\right)\left(\frac{Rg*tg\alpha}{f\cos\alpha}-\frac{RBg}{D}+V_1^2\right)+V_1^2} \qquad (13)$$

As mentioned earlier, the branch of the curvilinear lathe separator can have a velocity limitation for a rolling part due to design and reliable work of the separator. When a velocity of a part is exceeding some limits, the rolling part will not turn to the curvilinear branch of the lathe under action of the centrifugal force. It means the part will not be in contact with the board of the chute, i.e. condition when the friction force A is equal 0 (A = 0).

On a basis of this statement, Eq. (4) is presented in form

$$A=\frac{f}{2}\left(\frac{G}{D}B\cos\alpha-\frac{mV^2\cos^2\alpha}{R}\right)=0 \qquad (14)$$

From this equation we can find the velocity of the part on the curvilinear lathe when the part losses contact with the board of the chute under the action of centrifugal force.

$$\frac{mV^2\cos^2\alpha}{R}=\frac{mg}{D}B\cos\alpha \text{ , or } V=\sqrt{\frac{BRg}{D\cos\alpha}} \qquad (15)$$

The part can lose contact with the board of the chute but the lathe separator will work because the friction force F_2 between the part and the lathe surface will resist on action of the centrifugal force P (Figure 2, II, B-B). In such case the equation of the forces in equilibrium will have the following expression

$$P=F_2, \quad \text{or} \quad \frac{mV^2\cos^2\alpha}{R}=fmg\cos\alpha\,. \qquad (16)$$

Eq. (15) enables find the velocity of the part on the curvilinear lathe when the friction force resists the action of the centrifugal force

$$V=\sqrt{\frac{Rf\,g}{\cos\alpha}} \qquad (17)$$

Equalizing of Eq. (15) and Eq. (17) and after transformation gives following dependency

$$\sqrt{\frac{BRg}{D\cos\alpha}}=\sqrt{\frac{Rfg}{\cos\alpha}} \quad \text{or} \quad B/D=f. \qquad (18)$$

Eq. (17) enables to calculate the limit of the velocity of the part on the curvilinear lathe. If $B/D > f$, it is necessary to calculate the limited velocity by Eq. (16), because the limited velocity of the part is less than that calculated by the Eq. (14). If $f > B/D$, it is necessary to calculate the limited velocity by Eq. (14). When the limited velocity of a part defined, it is necessary to compare with the result calculated by Eq. (12). After that, it is necessary to find the curvilinear lathe radius of the *Y* type lathe separator.

2.2. Separator work for the sliding prismatic type part

The prismatic part, is sliding in an inclined chute according to the conformity of the gravity law. The height of a part is *D* and other parameters are same as for the disc part. The work of a parts separator is considered when a part is sliding in curved helical segments of a chute and based on the *Y* type lath (Fig. 4, 1). Fig. 4.2 shows all acting forces applied to a sliding part and geometrical parameters of a chute and a part.

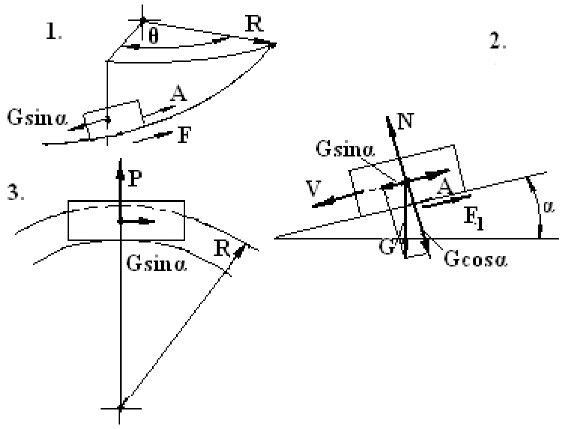

Figure 4. Computational scheme for a prismatic type part sliding in a helical branch of the chute.

For initialization of data of motion, an equation for a part by sliding is given by the first differential equations (1) in Euler's form [11]. All components of the first Eq. (1) are acceptable for presented case of consideration. Following substituting and transformations give the first formula of equations (7).

After substituting of expression of the normal reaction *N* , the normal reactions *T,* and other parameters mentioned above into Eq. (7), shall have the next expression

$$\frac{m\cos\alpha}{R}\frac{VdV}{d\theta} = mg\sin\alpha - \left[\frac{mg}{D}B\cos\alpha - \frac{mV^2\cos^2\alpha}{R}\right]f \tag{19}$$

Following transformation and separation of variables Eq. (19) shall have the following formula

$$\frac{VdV}{Rg\tan\alpha - \left(g\frac{RB}{D} - V^2\cos\alpha\right)f} = d\theta \tag{20}$$

The expression of the part velocity can be defined by taking integral of Eq. (20) at its corresponding limits similar of Eq. (11)

$$\int_{V_1}^{V_2}\frac{VdV}{Rg\tan\alpha - \left(g\frac{RB}{D} - V^2\cos\alpha\right)f} = \int_0^{\theta} d\theta \tag{21}$$

Consequently after taking integrals of Eq. (21) and its transformation, expression of a sliding part velocity on the helical branch lath in a chute will have the next expression

$$\frac{1}{2f\cos\alpha}\ln\left[Rg\tan\alpha - \left(g\frac{RB}{D} - V^2\cos\alpha\right)f\right]\Bigg|_{V_1}^{V_2} = \theta\Big|_0^{\theta} \tag{22}$$

After transformation the expression of the velocity of rolling part on the curvilinear part of chute will have following expression

$$V = \sqrt{\left(e^{2\theta f\cos\alpha} - 1\right)\left(\frac{Rg\tan\alpha}{f\cos\alpha} - \frac{RBg}{D\cos\alpha} + V_1^2\right) + V_1^2} \tag{23}$$

As mentioned earlier, the branch of the curvilinear lathe separator can have a velocity limitation for a sliding part due to design and reliable work of the separator. When a velocity of a part is exceeding some limits, the sliding part will not turn to the curvilinear branch of the lathe under action of the centrifugal force. The curvilinear lathe radius of the *Y* type lathe separator is calculated by Eq. (17). The conditions of the separator reliable work can defined as for disc type part. In such case, the magnitude of the reliable velocity of the part motion by sliding will be higher.

3. Working example

Assume that the machined steel part has parameters: m = 0.1 kg, J = 0.00017 kgm/sec^2, D = 100 mm, B = 25 mm, and the gravitational acceleration g = 9.8 m/sec^2. The initial velocity of the part is V_1 = 0.1 m/s. Find the graphs of dependency of the velocity of the part on the curvilinear lathe and in the chute by Eq. (12) as function of the chute inclination angle α=6^0, and the friction factor f_1 = f_2 = 0.1. Calculating of the limited velocity of the part allows the separator work at a reliable mode. Fig. 4 presents the graphs of dependency of the velocity of the part on the curvilinear lathe as function of some geometrical parameters of the chute and the lath.

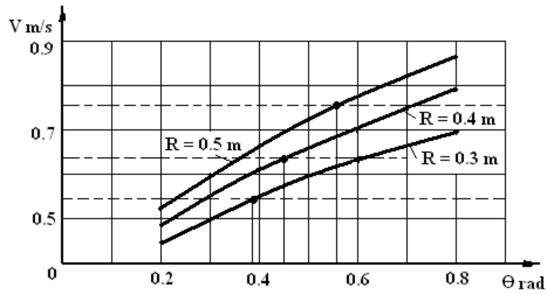

Figure 4. The graph of dependency of the velocity of the rolling part in the curvilinear chute of the separator.

The limited velocity of the part calculated by Eq. (17) is V = 0.76 m/s for the lath radius R = 0.5 m. This velocity can be reached at θ = 0.56 radian or at the length of the curvilinear lath $S = \theta R$ = 0.56*0.5 = 0.28m. This is more than the disk diameter D = 0.1m, $S > D$, i.e. 0.28 > 0.1. It means the part will turn and run in the curvilinear chute. The ratio B/$D > f_1$ (0.025/0.1 > 0.1) follows the accepted rule.

The limited velocity of the part calculated for the radius of the lath R = 0.4m is V = 0.63m/s. This velocity can be reached at θ = 0.45 radian or at the length of curvilinear lath $S = \theta R$ = 0.45*0.4 = 0.18m, that is more than the disk diameter D = 0.1 m, $S > D$, i.e. 0.18 > 0.1. It means the part will turn and run in the curvilinear chute.

The limited velocity of the part calculated for the radius of the lath R = 0.3m is V = 0.54m/s. This velocity can be reached at θ = 0.38 radian or at the length of curvilinear lath $S = \theta R$ = 0.54*0.3 = 0.16m, that is more than the disk diameter D = 0.1 m, $S > D$, i.e. 0.16 > 0.1. It means the part will turn and run in the curvilinear chute.

4. RESULTS AND DISCUSSION

A design scheme of a *Y* type lath separator in a chute for the flow of disk type parts of discrete transport motion mode is presented. This design can be embedded into automated transport units of production lines as the separator for the flow of parts with discrete motion. Integrated manufacturing systems for production of this type of parts can work properly because this type of separator has appropriate technical characteristics. Eqs. (12), (14) and (17) for calculating of a velocity for a moving part in a chute on a curvilinear lathe of the separator consists all basic parameters of a chute, and a transported part. The calculation of the working modes for the separator enables to find trustworthy technical characteristics and optimal geometrical dimensions of a mechanism of a separator for discrete parts transported by a flow mode.

5. CONCLUSION

The new design of the automatic separator for parts with a discrete mode motion in helical chutes and equations of the velocity of a rolling disk type part in a helical chute has been developed. The equations of a velocity of a part and its limitation in a chute were obtained. These equations will be useful in modeling the geometrical parameters of a new separator as a function of a limiting velocity of a part moving in a curvilinear chute. The presented equations of calculating the velocity of a part moved by rolling in helical chutes and geometrical characteristics of the separator enables to predict more reliable design and can be used at a preparatory stage of design of transport systems for automated lines for production of disk type parts.

References:

[1] Benhabib B. (2003). *Manufacturing. Design, Production, automation, and Integration*, Marcel Dekker Ink.

[2] Boothroyd G. (2008). *Assembly Automation and Product Design*. 2nd ed. Taylor and Francis, 512 p.

[3] Crowson R. 2006, *Assembly Processes: Finishing, Packaging, and Automation.* 2nd ed., Taylor & Francis Group; 168 p.

[4] Ireson R. F. J., (1996), *Assembly automation : a management handbook,* 2nd ed. New York Industrial Press,.

[5] Chua P.S.K. (2007), Novel design and development of an active feeder, *Journal Assembly Automation,* Vol.: 27, Number: 1, p. 31-37

[6] Murphey T. D., Lynch K. M. (2008), Case Studies in Planar Part Feeding and Assembly Based on Design of Limit Sets. *The International Journal of Robotics Research*, Vol. 27, No. 6, p. 693–708

[7] Hitakawa H. (1988), Advanced parts orientation system has wide application. Assembly Automation, 8(3): p.147-150

[8] Shafer, D. A. (1998), Successful assembly automation : a development and implementation guide. *Dearborn: Society of Manufacturing Engineers*.

[9] Glyn J. (2001), *Modern Engineering Mathematics*, 3rd ed. Pearson, Prentice Hall.

[10] Hibbeler R.C. (2007), *Engineering Mechanics. Dynamics*. Pearson. Prentice Hall, 720 p.