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INVESTIGATION OF FEEDING DEVICES AND DEVELOPMENT OF DESIGN CONSIDERATIONS FOR A NEW FEEDER FOR MICRO-SHEET-FORMING

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Abstract

Recent review in micro-forming research and technological development suggested that the trend of the development is more focused on the manufacturing processes, machines and tooling, and efforts on the methods and systems for integrated precision material handling are insufficient. Most of the developed micro-forming machines were based on standalone concepts which do not support efficient integration to make them fully automated and integrated. At present, material feeding in micro-forming is not of sufficient precision and reliability for high throughput manufacturing applications. Precise feeding is necessary to ensure that micro-parts can be produced with sufficient accuracy, especially in multi-stage forming, while high-speed feeding is a must to meet the production-rate requirements. Therefore, design of a new high-precision and high-speed feeder for micro-forming is proposed. Several possible approaches are examined with a view to establishing feasible concepts. Based on the investigation, several concepts for thin sheet-metal feeding for micro-forming are generated, they being argued and assessed with applicable loads and forces analysis. These form a basis of designing a new feeder.

***Keywords*: micro-forming, micro-handling, conventional press, gripper feed, roll feed, micro-tools, micro-punching.**

1.0 Introduction

Research in forming of miniature/micro-products [1] led to investigation into material feeding methods and devices as a part of the development of a machine system to transfer the laboratory-based forming processes to production [2]. Feeding the materials with higher rates and high accuracy in high speed micro-sheet forming is one of the challenges to be met in micro-forming research and development for engineering applications.

Conventional press feeders have to meet three main criteria to be successful. Firstly, the feeder must be flexible in terms of set up. Secondly, delivery of material must be with sufficient precision as required for forming. The feeders must also do the feeding at the correct time. All of these are particularly difficult to meet when forming thin sheet metals, such as the thickness is less than 100 microns, feeding distance larger than 10mm and the feeding rate higher than 500 stroke per minute (SPM). These are the requirements for the development of a machine system for micro-sheet-forming - Fig. 1 shows a 3D model of such a machine developed at the University of Strathclyde.

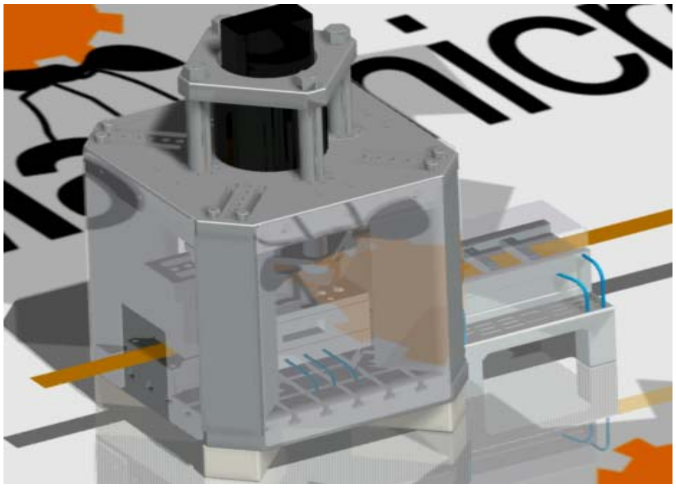


Fig. 1: 3D model of the micro-sheet-forming machine

Two conventional methods of feeding sheet-metals in stamping may be applied to micro-sheet-forming - roller feeding and gripper feeding [3-4]. As the name implies on the servo roll feeder, this type of the feeder uses electric servomotor while a gripper feeder mainly uses pneumatic actuation. Although the latter may exhibit limited flexibility in varying in travel distance and feeding speed, this type of the feeder is seen to have potential to compete with the servo roll feeder on positioning accuracy and precision. Higher accuracy is achievable due to that a gripper feeding mechanism may not have complicated mechanical transmission and hence, no backlashes, wear, tear, etc. which could contribute towards inaccuracies of feeding. An error on translational from angular rotation to linear motion in roll feeding does contribute towards inaccuracies. Nevertheless, this is not happened on linear gripper feeder. With possible use of a servo system, performance of a gripper feeder could be improved, regarding the flexibility on travel distances within the system length setup, and feedback and positional accuracy. The research reported in this paper is dedicated to a study of these issues, based on which consideration for a new feeder design is developed.

2.0 Linear Displacement Devices for Sheet Metal Feeding Applications

Three categories of devices have been widely used for high-precision feeding - electromechanical actuators [5-9], electrical actuators [10-12] and piezoelectric-actuators [13-14]. Table 1 shows a comparison study made on those devices. Proper selection of a high-precision system is a must in order to qualify high-precision/accuracy for high yield feeding applications. Linear motors are seen to have best characteristics among the others in terms of speed, acceleration, precision/accuracy, robustness, ease of maintenance, etc. as well as widely used by many researchers, as an alternative to conventional rotary machineries [10-18].

Table 1
Types of linear displacement devices and its suitability for micro-press feeding applications

Device Type	**Accuracy and precision**	**Acceleration rate (g)**	**Force (N)**	**Dimension**	**Reliability**
Solenoid	Inflexibility and uncontrollable on stroke distance, and hence, difficult to have accuracy and precision recorded.	Impressive response time and acceleration on short distance.	Fairly high force inversely proportional to stroke distance.	Small and compact and hence suitable for constrained space applications.	Reliable in terms of mean time between failure (MTBF).
Ball/lead Screw, belts & pulleys, gearboxes, rack and pinions, etc.	Flexibility with limited stroke distances and hence accuracy and precision is qualified at 6-7μm the best. Due to wear and tear, a greater inaccuracy develops with time.	Acceleration rate is low due to mechanical transmission involved.	High thrust force is qualified.	Fairly small depends on the applications.	Reliable as demonstrated by most of the devices.
Linear motors and stages	Stroke distance may be limited. Combined with air-bearing, the system could have very high positioning precision. No backlashes to contribute to inaccuracies.	Acceleration rate could be high - 5-10g acceleration is typical. 40g is available commercially.	High thrust force qualified, and it ranges from tenth up to thousands of Newton force.	Fairly small. Force is proportional to the coil size.	Reliable as demonstrated in many cases.
Piezoelectric-actuator (linear	Very accurate and precise as been used in photonics and high precision applications but	Response time is better over short distance and hence	Very low force ranging between 7-10N,	Depending on the travel distance	Reliable for low speed positioning. For high speed positioning, heat

motor)	with very limited travel distances.	reflecting high acceleration rate.	hence limits its application to very low force feed and positioning tasks only.	required.	may tend to build-up as well as wear and tear.

Linear motors are seen to have advantages over others in terms of achievable accuracy with impressive acceleration rates. Since there are no backlashes and plays which will contribute towards positioning inaccuracies to the system, higher accuracy is expected to be achieved. Therefore, a linear motor is seen to be a good platform for feeding design for sheet metal to achieve high precision and high rate feeding.

Selection of an appropriate motor for the feeder for micro-press among ironcore and ironless motors needs to consider several parameters - force density and magnetic attraction, stiffness and settling time in terms of dynamic and static characteristics, accuracy, velocity, stability, etc. Both ironcore and ironless motors have their respective advantages in terms of the said factors. The first parameter to be considered is the force density. As the name implies, due to the presence of iron laminations in the forcer of an ironcore motor, extra force may be generated by attraction force from the magnetic track on the forcer, on the top of the force generated by the electromotive force (emf). Magnetic attraction on the iron lamination in forcer also contributes to 'cogging' effect on the ironcore motor. 'Cogging' does affect smoothness and repeatability of an ironcore motor to achieve outstanding precision as what ironless motor might be able to achieve [12]. An ironless linear motor was used to study multi degrees of freedom error motions of a precision linear aerostatic bearings stage [19] and to qualify the achievable precision. Such a motor was used because a higher precision is achievable due to no 'cogging' effect existing, compared to an ironcore linear motor. In another study [20], an ironless linear motor was used to drive air bearings stage and to qualify the precision of the motor. Higher precision and repeatability were qualified with an ironless-linear-motor driven stage.

Stiffness of the motor in terms of static and dynamic characteristics is to be considered due short settling time and rapid motion involved. Short settling time associated with high dynamics or high position stability requires stiff mechanics characteristics from the motor. The epoxy structure in an ironless motor may have low inherent stiffness. The rigidity of a motor may be enhanced by the copper coils inside the forcer which leads to better stiffness. However, steel structure in an ironcore motor makes it stiffer than an ironless motor. Nevertheless, according to previous reports [14]-[20], controlled ambient temperature within 1°C may be needed, which should greatly assist thermal reduction to avoid the linear motor structure from excessive thermal deformation. Higher stiffness in both motor structures and mounting could eliminate structural deformation which could cause backlashes and play during rapid operations. Therefore high accuracy process is feasible and qualified. Table II tabulates a comparison study of the ironless and ironcore linear motors.

Table II
Comparison study on ironless and ironcore linear motor

Micro-sheet forming feed application	**Description**	
	Ironless	**Ironcore**
Continuous force of 150N	Very suitable. Most of the ironless motor has continuous force ranging from 0 – 450N. It indicates that ironless motor is only suitable for low load demand, for example, in application of positioning and light weight feeding mechanism.	Very suitable. An ironcore motor usually has two times greater continuous force than an ironless one, which indicates suitability for higher force demand applications.
Peak force of 500N	Very suitable for the feeding. Highest peak force rated up to 1600Nm and normally last for a few seconds before the motor starts to overheat and burned.	Very suitable. Higher continuous force leads to higher peak force, compared to an ironless linear motor.
Smooth motion	Very suitable. No cogging effect and using air bearing (gap between forcer and U-channel magnetic tracks) make non-contact smooth, ultra-precision linear motion possible.	Iron lamination inside the forcer causes cogging effect. Non-smooth motion between forcer and magnetic way experienced. It is not recommended for high smooth motion applications.
Precision down to a sub-micron order	Sub-micron accuracy/precision and repeatability is qualified and recommended.	Sub-micron accuracy/precision and repeatability is feasible in slow speed and can be used as a cheaper alternative option.

Speed stability	Up to 0.1% error at 1kHz measurement - it is very stable in speed.	Speed stability is equal to ironless but recommended for a cheaper alternative.
Thermal dissipation	Not recommended due to no heat transfer medium. Only rely on air circulation to cool down motor temperature. Controlled ambient temperature might reduce thermal build-up.	Recommended for high heat build-up application due to this motor has water and air cooling mediums.
Dimensional constraint	Recommended due to compact sizes, e.g. a 200mm x 200mm sized feeder is qualified.	Not recommended due to large and bulky structure. A small and compact feeder is not feasible with this type of the motor.
Acceleration	Most of the motors have acceleration rate up to 40g (more than 115g theoretically).	Acceleration rates up to 10g are feasible.
Speed	Speed ranges from 0 – 10m/s.	High speed ranges similar to ironless are achievable.
Stroke < 50mm	Recommended. Moving magnet or moving forcer can be proposed.	Suitable, provided moving magnet motion is proposed.
Clean room applications	Very suitable due to no particle generation (if no moving cable is deployed).	Suitable if no moving cable motion is deployed.

3.0 Feasibility Study of a New Gripper Feeder

Correct sizing of the linear motor during the design stage is crucial as this will have impact on the entire system's performance and will contribute to the designated production rate. Associated considerations also include the designated load and push/pull force. Figure 2 shows applicable forces which are taken into account for a linear motor sizing analysis. Three types of forces contributing to total peak and continuous linear motor forces are identified for this particular application.

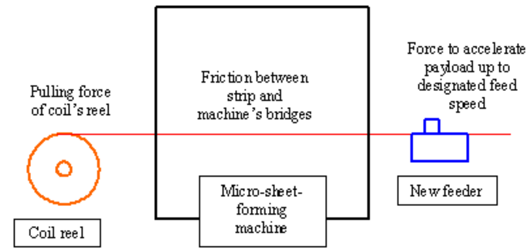


Fig: 2: Types of the related forces, friction between parts and payloads that contribute to total peak and continuous force requirements.

3.1 Forces due to the Payload

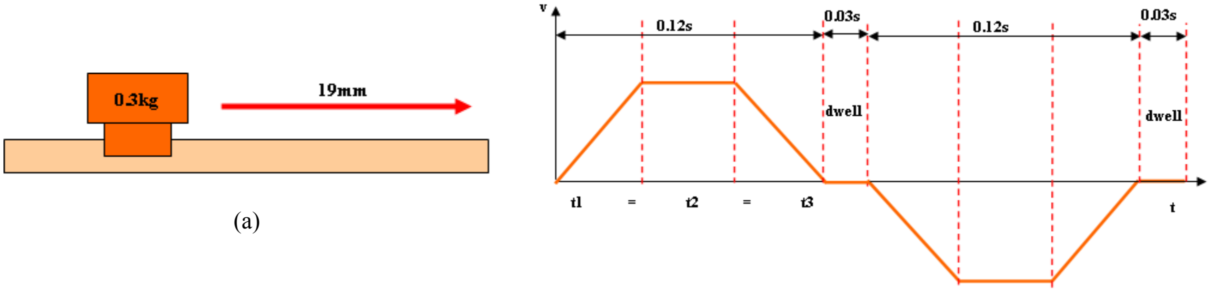
As depicted in Fig. 3a, for the case studied, about 0.3kg payload of the clamping mechanism and weight were needed to be moved. As designed, a 0.3kg payload, which is required to be moved for 19mm in 0.120s, dwell for 0.030s, move backward for 0.120s and dwell for 0.030s, and then repeat the cycle for a 3.33Hz operation. In this case, analysis and calculation of the required forces in order to determine the best linear motor and amplifiers are very much needed.

The first factor considered was the motion characteristics - the peak speed needed to accelerate the mass from the origin to the end point, time duration which the travel takes, and the dwell when the moves end. In general, for this type of motion characteristics which is from point to point, the basic profile is the trapezoidal move. With this move, the move time is divided equally into three parts. The first part is acceleration, second constant velocity, and third deceleration. Such a motion characteristic should ensure a balance between the speed and acceleration to give the best motor combination. Based on a trapezoidal motion, the time taken to accelerate is calculated as;

$$\frac{0.120s}{3} = 0.040s \tag{1}$$

Then the peak speed required to make the move was calculated and in this case because the move is symmetrical and divided into three parts, the formulae below was used. The load cannot accelerate instantaneously from 0 to

0.475m/s and as previous worked out; it will take 0.040s to reach this speed. Therefore accelerate rate then was calculated as shown in Fig. 3b.



(a)

(b)

Fig. 3: a) The exerted load on forcer, direction and distance of moving, and b) Trapezoidal profile representing acceleration of forcer in one cycle.

$$v = \frac{3s}{2t} = \frac{3 \times 0.019m}{2 \times 0.04s} = 0.7125m/s \tag{2}$$

$$a = \frac{v-u}{t} = \frac{0.7125m/s - 0}{0.04s} = 17.81m/s^2 \approx 1.8g \tag{3}$$

Newton's third law equation was used to determine the payload rating force, f_p, since the peak rating force considers frictional force, f_f, (with assumption of re-circulated ball bearing used to carry the load in the system, and has a coefficient of friction of about 0.002 up to 0.003) force for acceleration, f_a, and gravitational force for inclined plane, f_g, as well as external force, f_e,, caused by the cable management. Therefore, the payload rating force may be expressed as:

$$f_p = f_a + f_g + f_f + f_e \tag{4}$$

f_a represents the forces for load including forcer mass and is used to calculate final coil temperature rise, peak and continuous current and minimum bus voltage. In mechanical transmission linear stage, frictional value on the lead screw system also should be taken into account and usually does affecting the system positional accuracy.

$$f_a = ma = 0.3 \times 17.81 = 5.343N \tag{5}$$

$$f_g = \sin(\theta)mg = \sin(0) \times 0.1 \times 9.81 = 0 \tag{6}$$

$$f_f = mg\mu = 0.3 \times 9.81 \times 0.003 = 0.009N \tag{7}$$

$$f_e = 0 \tag{8}$$

$$\therefore f_p = 5.343 + 0 + 0.009 + 0 = 5.352N \tag{9}$$

By adding safety factor of 25% to compensate degradation of the motor efficiency, the new force to move the payload was calculated to be 6.7N. Due to the minimum pulling force required is almost 7N, piezoelectric actuator is seen as not the best option for this application. As for mechanical transmission linear stage system, carrying a low/light load is not recommended due to the uneven distribution on load that might also contribute towards positional inaccuracies as been studied and demonstrated by [9].

3.2 Friction Forces

Friction forces due to the contact between the sheet metal and the guide plates inside the machine (50µm thick strip, 50mm width and contact length 500mm) is analyzed as follows. The mass of material in contact was calculated as:

$$m = \rho V \tag{10}$$

$$V = 0.05 \times 0.5 \times 0.00005 = 1.25 \times 10^{-6}\, m^3 \tag{11}$$

$$\rho = 7.82 \times 10^3\, kg / m^3 \tag{12}$$

$$\therefore m = 1.25 \times 10^{-6} \times 7.82 \times 10^3 = 9.775 \times 10^{-3}\, kg \approx 10 gram \tag{13}$$

The coefficient of friction between the strip (carbon steel) and the tool-steel surfaces is given as 0.15 hence,

$$f_f = \mu ma \tag{14}$$

$$\mu = 0.15 \tag{15}$$

$$f_f = 0.15 \times 0.01 \times 9.81 = 0.02N \tag{16}$$

By adding 25% of safety factor, new frictional force value is found to be at 0.03N. This value will be added up for the calculation of the total peak force for linear motor sizing.

3.3 Coil's Reel Pulling Force

Another force which contributes to the total peak and continuous forces is force of pulling the material from its reel as illustrated in Fig. 4. It can be estimated and calculated as follows.

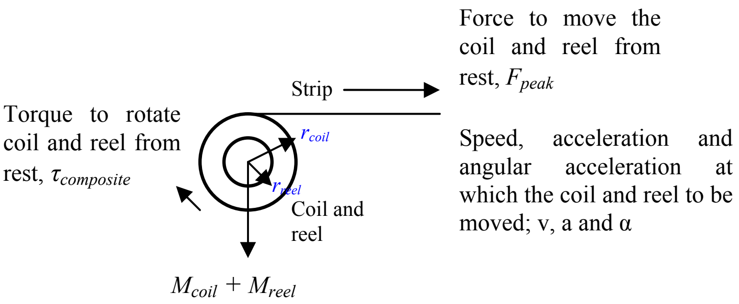


Fig. 4: Free-body diagram of the coil and reel producing a total of torque labeled as $\tau_{composite}$.

Known that:

$$s = 0.0190m \quad r = 0.0625m \quad t = 0.04s \quad u = 0 \;;$$

Suppose the followings,

$$\tau = fr = I\alpha \tag{17}$$

$$\alpha = \frac{a}{r} \tag{18}$$

$$I = mr^2 \tag{19}$$

$$a = \frac{v-u}{t}, v = \frac{3s}{2t}, u = 0 \tag{20}$$

From trapezoidal motion:

$$v = \frac{3 \times 0.0190}{2 \times 0.04} = 0.7125 m/s \tag{21}$$

$$a = \frac{0.7125 - 0}{0.04} = 17.8125 m/s^2 \tag{22}$$

$$\alpha = \frac{17.8125}{0.0625} = 285 rad/s^2 \tag{23}$$

Suppose that the coil (carbon steel) and reel (made of Perspex) outer diameter are 125mm and 110mm respectively, by assuming both coil and reel are solid, therefore inertia of the composite material can be calculated as:

Suppose the followings:

$$\rho = \frac{m}{v}, \rho_{coil} = 7820kg/m^3, \rho_{reel} = 1190kg/m^3 \quad (24)$$

$$length_{coil} = 50m \qquad width_{coil} = 0.05m \qquad thickness_{coil} = 0.00005m$$

$$v_{coil} = 50 \times 0.05 \times 0.00005 = 0.000125m^3 \qquad r_{reel} = 0.055m \quad (25)$$

$$m_{coil} = 0.000125 \times 7820 = 0.9775kg \qquad h_{reel} = 0.012m \quad (26)$$

$$v_{reel} = \pi \times 0.055^2 \times 0.012 = 1.14 \times 10^{-4} m^3;\ m_{reel} = 1.14 \times 10^{-4} \times 1190 = 0.1357kg \quad (27\ \&\ 28)$$

$$I_{coil} = \frac{m}{2}(r_{outer}^2 + r_{inner}^2) \qquad I_{coil} = \frac{0.9775}{2}(0.0625^2 + 0.0555^2) = 3.41 \times 10^{-3} kgm^2 \quad (29)$$

$$I_{reel} = \frac{mr_{reel}^2}{2} \qquad I_{reel} = \frac{0.1357 \times 0.055^2}{2} = 2.05 \times 10^{-4} kgm^2 \quad (30)$$

$$I_{composite} = I_{coil} + I_{reel} \quad (31)$$

$$I_{composite} = 3.41 \times 10^{-3} + 2.05 \times 10^{-4} = 3.62 \times 10^{-3} kgm^2;\ \tau_{composite} = 3.62 \times 10^{-3} kgm^2 \times 285 rad/s^2 = 1.032Nm \quad (32\ \&$$

$$f_{composite} = \frac{1.032}{0.0625} = 16.5N \quad (34)$$

Therefore, the total force required rotating combination of coil and reel is found to be at 16.5N. By adding a safety factor 25% (to overcome internal frictional forces, etc), the total of the new force is calculated to be at 20.6N.

3.4 The Uncoil Braking Force

Study on the effect of the coil braking force towards strip tension during the stamping process was conducted previously [19]. Nevertheless the effort was only focused more on the punching hole quality instead of feed accuracy. Relation between the strip tensions and the feed accuracy still need to be studied in detail. As proposed previously [20], the strip tension should be kept at the same amount of the torque needed when coiling the metal strip in the first place. Adjustable braking force was proposed to make the uncoil process flexible in terms of adjusting torque in various value [19]. Suppose that the coil process requires the similar amount of torque as uncoiling the metal strip metal, given by the analysis in 3.3, the maximum force to uncoil is 20.6N. By taking f_{rms} of the rated force; therefore, the designated variable braking force for this application is as follows:

$$f_{brake} = \sqrt{\frac{20.6^2 \times 0.04}{0.15}} = 10.64N \quad (35)$$

Since 10.64N force acts during the whole cycle, therefore this value needed to be included into the peak force in linear motor sizing.

3.5 Influences of Other Interfacial Forces

Micro-forces which may be neglected in macro-world may no longer be neglected in micro-world. Proportion of micro-forces to micro-parts weight ratio is about at the same value where in most common situation, micro-forces is larger than the micro-parts weight for part with 100μm^3 size and smaller. Hence, this part will stick and stay on handling mechanism overcoming gravity reaction thus resulting problem in manipulation process. Three types of micro-forces which have significant influence on micro-parts are known and has been extensively studied nowadays; adhesion, van der waals and electrostatic forces. Usually, adhesion force between particle surfaces is due to the presence of van der waals and electrostatic force [23-24]. However, those forces do not have significant effect towards material handling for this application, since the handled material is larger than 100μm^3.

3.6 Qualified Peak and Continuous Forces

Based on the analysis presented above, peak force can be calculated as follows:

$$F_{peak} = f_p + f_f + f_{composite} + f_{brake} = 6.7 + 0.03 + 20.63 + 10.64 = 38N \tag{36}$$

The rms force is the average force, f_{rms} from the motor and helps to determine the final temperature that the coil will reach. Based on the above trapezoidal profile case, the calculation is as follows:

$$F_{rms} = \sqrt{\frac{F^2_{peak} \times t}{t_{cycle}}} \qquad \begin{array}{l} t = 0.04s \\ t_{cycle} = 0.15s \end{array} \qquad \therefore F_{rms} = \sqrt{\frac{38^2 \times 0.04}{0.15}} = 19.6N \tag{37}$$

New summation of the peak and continuous forces are 38N and 19.6N respectively. Both of these forces were considered when selecting a suitable linear motor. Ironless linear motor is chose due to demanded peak and continuous forces are relatively small. In addition, compact system is feasible by using ironless linear motor.

3.7 Coil Temperature, Peak and Continuous Current, and Minimum Bus Voltage

3.7.1 Final Coil Temperature Analysis

Final coil temperature represents the temperature at which the linear motor may be operated without adversely affecting the materials of construction. Therefore this final temperature can be as a guideline as to choose which servo controller is best suited to the designated linear motor. In order to determine the rise of coil temperature, the following formulae was used. With an assumption of ambient temperature is at 25°C, then the rise can be calculated as below with the data supplied from one of the ironless linear motor catalogues [25].

Back Electro-motive force (BEMF) = 24.5 V/m/s; Force constant = 21.3 N/amp; Motor constant = 26.3 N/√W; Coil resistant = 0.7 Ω; Thermal Resistant, R_T = 0.64 W/°C; from the analysis, f_p = 38.0N; f_{rms} = 19.6N.

With the assumed ambient temperature, coil temperature rise may be calculated as blow:

$$T = R_T\left(\frac{f_{rms}}{M_C}\right)^2 = 0.64\left(\frac{19.6}{26.3}\right)^2 = 0.36°C; \quad \text{Therefore, Final Coil Temperature} = 25 + 0.36 = 25.36°\text{C}. \tag{38}$$

3.7.2 Sizing up the Amplifier

This analysis was conducted to determine the most appropriate servo controller size and type to be used so that the linear motor could perform up to the best performance without suffering from current and voltage drain-out. Based on the given value of the motor's force constant and calculated peak and continuous forces, the peak and continuous current and minimum bus voltage is calculated as follows:

Peak current= f_p/force-constant = 38/21.3 = 1.78A (39)
Continuous current= f_{rms}/force-constant = 19.6/21.3 = 0.92A (40)
Drive Voltage$_{min.}$ = (peak current x coil resistant) + (velocity x back EMF) = (1.78 x 0.7) + (0.7125 x 24.50) = 18.7V (41)

Therefore, the servomotor controller must be capable of supplying peak and continuous current minimum of 1.78A and 0.92A respectively.

3.7.3 Thermal Expansion due to Temperature Rise

Thermal effect due to temperature changes in micro-manufacturing may not be negligible [26-27]. Apparently, a small increment in temperature may significantly contribute to machine elements' performance. The heat generated by the motor coil, if it is not well controlled, can cause thermal deflection of mechanical parts. Aluminum alloys are often found to be used as linear stage material due to its good heat conductivity to dissipate heat efficiently from linear motor's coil [25]-[28-30]. The analysis below is conducted to understand how much deflection may experience by the parts of a gripper which is located on the top of the stage of the feeder. Suppose aluminum alloys 6061-T6 has 24.3µm/m°C [31], thermal expansion due to the heat generated by the motor during operation is [32]:

$$Exp_{thermal} = \Delta T \times 24.3\mu m = (25.36 - 25) \times 24.3 = 8.7\mu m \tag{42}$$

Suppose for 20mm travel distance, total expected thermal expansion is:

$$Exp_{thermal-20mm} = \frac{8.7\mu m}{1m} \times 0.02m = 0.174\mu m \tag{43}$$

Therefore, the thermal expansion due to the heat generated by motor's coil for the gripper is expected to be at the maximum of 0.174µm for 100% transferred heat. This small deformation due to 100% transferred heat can be negligible as the error is relatively low and not much contributing towards positional accuracy.

4.0 Conclusions and Further Considerations

Based on the studies described above, a linear actuation method which uses a linear motor is proposed as a strategy for developing a new feeder for micro-sheet-forming. Direct drive from linear motor ensures no mechanical transmission necessary which may contribute to play and backlashes that affects the accuracy of the feeding in micro-forming. For the strip materials and micro-stamping specifications defined, theoretically, 38.0N and 19.6N peak and continuous forces are respectively required to serve material feeding for this particular application. At least 2g of acceleration rate is needed to accelerate the payload, i.e. the gripper and strip for up to 200 parts per minute (ppm) in a high-precision operation. This level of precision is significantly greater than that with a servo roll feeder which may have 50µm accuracy.

Solenoid has been chosen to serve the clamping application for the gripper design due to impressive response time, holding force, easy to integrate, etc. Logic output from the servomotor controller is used to control the solenoid, and hence, giving peace of mind on the integration side by eliminating the necessity of using another type of controller. A new feeder is now being constructed.

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INVESTIGATION OF FEEDING DEVICES AND DEVELOPMENT OF DESIGN CONSIDERATIONS FOR A NEW FEEDER FOR MICRO-SHEET-FORMING