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A review on electromagnetic forming the recent trends

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I. Introduction

Electromagnetic forming (EMF) is a high velocity forming technique that uses electromagnetic forces to shape metallic work pieces. The process starts when a capacitor bank is discharged through a coil. The transient electric current which flows through the coil generates a time-varying magnetic field around it. By Faraday's law of induction, the time-varying magnetic field induces electric currents in any nearby conductive material. According to Lenz's law, these induced currents flow in the opposite direction to the primary currents in the coil. Then, by Ampere's force law, a repulsive force arises between the coil and the conductive material. If this repulsive force is strong enough to stress the work piece beyond its yield point then it can shape it with the help of a die or a mandrel.

Principal of electromagnetic forming

The equivalent circuit diagram for the setup of electromagnetic forming is shown in fig-3. To form highly electrically conductive material a magnetic field is required, which is achieved by pulse generator. There were so many circuit diagrams of this setup given in literature but fig-3 is the most descriptive design of circuit. In this circuit capacitor C, inductance Li and resistor Ri are in the series, representing as a forming machine. The tool coil Rcoil and its inductance Lcoil both are connected to the pulse power generator in series (see Fig-3). The reduced version of this circuit is shown in Fig-4. Fig.3. Detailed version of equivalent circuit diagram Fig.4. Reduced version Capacitor battery stores the energy. The charging energy Ec of this capacitor battery is calculated from the charging voltage U(t)and the capacity C (see eq-1).
$E_c(t) = ½ CU(t)^2$

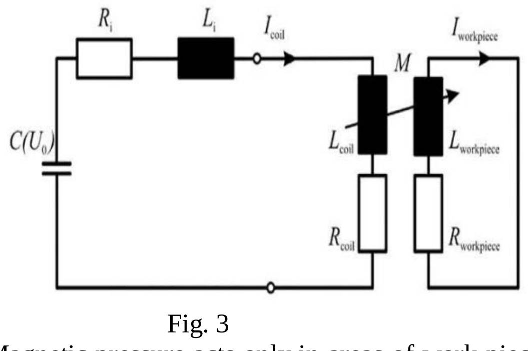

Fig. 3

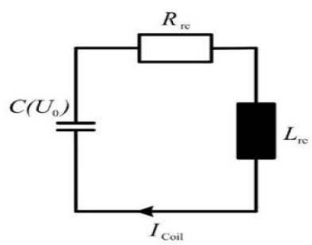

fig. 4

(1) Magnetic pressure acts only in areas of work piece close to coil. Therefore the deformation of work piece starts in these areas with velocity 10^2 m/s. The different directions of current, magnetic field lines, and magnetic pressure are shown in Fig-2. The setup is complimented by an additional component in tube compression process. This component is known as field shaper. In some publications it is called field concentrator. Firstly Babat and Losinsky Dhiraj Gayakwad et al. / Procedia Materials Science 6 (2014) 520 – 527 523 (1940) used field shaper to heat work piece inductively. In comparison to direct acting coil, the mechanical loading of tool coil can be significantly reduced by using field shaper, resulting in a higher coil tool life (Kim and Platner, 1959). Combination of inductive heating and electromagnetic forming can be used. To produce a more uniform magnetic field and pressure for sheet metal forming Kamal and Daehn (2007) used a field shaper. During electromagnetic tube compression to support the work piece a mandrel can be placed inside the work piece.

Application

The forming process is most often used to shrink or expand cylindrical tubing, but it can also form sheet metal by repelling the work piece onto a shaped die at a high velocity. High-quality joints can be formed, either by electromagnetic pulse crimping with a mechanical interlock or by electromagnetic pulse welding with a true metallurgical weld. Since the forming operation involves high acceleration and deceleration, mass of the work piece plays a critical role during the forming process. The process works best with good electrical conductors such as copper or aluminium, but it can be adapted to work with poorer conductors such as steel.

Comparison with mechanical forming

Electromagnetic forming has a number of advantages and disadvantages compared to conventional mechanical forming techniques.

Some of the advantages are;

- Improved formability (the amount of stretch available without tearing)
- Wrinkling can be greatly suppressed
- Forming can be combined with joining and assembling with dissimilar components including glass, plastic, composites and other metals.
- Close tolerances are possible as springback can be significantly reduced.
- Single-sided dies are sufficient, which can reduce tooling costs
- Lubricants are reduced or are unnecessary, so forming can be used in clean-room conditions
- Mechanical contact with the workpiece is not required; this avoids surface contamination and tooling marks. As a result, a surface finish can be applied to the workpiece before forming.

The principle disadvantages are;

- Non-conductive materials cannot be formed directly, but can be formed using a conductive drive plate
- The high voltages and currents involved require careful safety considerations

References

[1]. "Materials and Manufacturing: Electromagnetic Forming of Aluminum Sheet" (PDF). Pacific Northwest National Laboratory. Archived from the original (PDF) on 2005-12-18. Retrieved 2006-06-09.

[2]. "Electromagnetic Hemming Machine And Method For Joining Sheet Metal Layers". US Patent and Trademark Office. Archived from the original on 2018-05-18. Retrieved 2005-09-02.

[3]. "Resources on Electromagnetic and High Velocity Forming". Department of Materials Science and Engineering, Ohio State University. Archived from the original on 2005-12-19. Retrieved 2006-04-06.

[4]. "Electromagnetic Metal Forming Handbook". An English translation of the Russian book by Belyy, Fertik, and Khimenko. Archived from the original on 2006-09-05. Retrieved 2006-08-06.

[5]. "FEA of electromagnetic forming using a new coupling algorithm". Ali M. Abdelhafeez, M.M. Nemat-Alla and M.G. El-Sebaie. Retrieved 2013-01-15.

[6]. Babat, G., Losinsky, M., 1940.Concentrator of Eddy currents for zonal heating of steel parts, Journal of Applied Physics 11, 816–823

[7]. Bahmani, M., Niayesh, K., Karimi, A., 2008.3Dsimulation of magnetic field distributionin electromagnetic forming systems with field-shaper, Journal of Materials Processing Technology, doi:10.1016/j.matprotec.2008.05.024.

[8]. Bahmani, M., Niayesh, K., Karimi, A., 2009.3D Simulation of magnetic field distribution in electromagnetic forming systems with field-shaper, journal of materials processing technology 2 0 9, 2295–2301

[9]. Brower, 1969. Metals Handbook, vol. 4. ASM, Metals Park.

[10]. Brower, D.,1966. Forming Device and Method, US Patent 3, 279-228.

[11]. Chu, Y., Lee, R., Psyk, V., Tekkaya,E., 2012.Determination of the flow curve at high strain rates using electromagnetic punch stretching, Journal of Materials Processing Technology 212, 1314– 1323

[12]. Correia, J., Siddiqui, M., Ahzi, S., Belouettar, S., Davies, R., 2008.A simple model to simulate electromagnetic sheet free bulging process, International Journal of Mechanical Sciences 50, 1466–1475

[13]. Furth, H., Waniek, R., 1962. New ideas on magnetic forming. American Machinist/Metalworking Manufacturing, vol. 106, pp. 92–95

[14]. Gourdin, 1989.Electromagnetic ring expansion: experiment, analysis and application to high-strain-rate testing, Journal of Applied Physics 65 , 411–422.

[15]. Haiping, Y.,Chunfeng,L., Jianghua, D., 2009.Sequential coupling simulation for electromagnetic–mechanical tube compression by finite element analysis, journal of materials processing technology 2 0 9, 707–713.

[16]. Kamal, M.,Daehn, G., 2007.A uniform pressure electromagnetic actuator for forming flat sheets, Journal of Manufacturing Science and Engineering 129, 369–379.

[17]. Kim,Y., Platner, E.,1959.Flux concentrator for high-intensity pulsed magneticFields, The Review of Scientific Instruments 30 (7), 524–533. Livshitz, 2004.PulsedPowerForming, Proceedingsof the 1st International Conference on High Speed Forming—ICHSF2004 Dortmund, pp. 221– 228.

[18]. Mamalis, A.,Manolakos, D.,Kladas, A., Koumoutsos, A., 2004.Electromagnetic forming and power processing: trend and developments, Appl. Mech. Rev. (ASME) 57 (4), 299-324

[19]. Maxwell,1873.A Treatise of Electricity and Magnetism, Macmillan and Co

[20]. Okoye, C., Jiang, J., Hu Z., 2006.Application of electromagnetic-assisted stamping (EMAS) technique in incremental sheet metal forming, International Journal of Machine Tools & Manufacture 46, 1248–1252.

[21]. Psyk, V., Beerwald, C., Henselek, A., Homberg, W., Brosius, A., Kleiner, M., 2007.Integration of electromagnetic calibration into a deep drawing process of anindustrial demonstrator part. Key Engineering Materials 344, 435–442

[22]. Psyka, V., Rischa, D., Kinseyb, B., Tekkayaa, A., Kleinera, M., 2011. Electromagnetic forming -A review, Journal of Materials Processing Technology 211, 787–829.

[23]. Rajiv, S., 2012.finiteeliment analysis of electromagnetic compression forming of steel tube, procedia engineering 38, 2520-2524.

[24]. Seth, M., Vohnout, V., Daehn G.,2005.Formability of steel sheet in high velocity impact, Journal of Materials Processing Technology 168, 390– 400.

[25]. Thomas, J., Triantafyllidis, N., 2009.On electromagnetic forming processes in finitely strained solids: Theory and examples, Journal of the Mechanics and Physics of Solids 57 : 1391–1416.

[26]. Unger, J., Stiemer, M., Brosius, A., Svendsen, B., Blum, H., KleineM., 2008. “Inverse error propagation and model identificationfor coupled dynamic problems with applicationto electromagnetic metal forming, International Journal of Solids and Structures 45, 442–459.

[27]. Unger, J., Stiemer, M., Brosius, A., Svendsen, B., Blum, H., KleineM., 2008. “Inverse error propagation and model identificationfor coupled dynamic problems with applicationto electromagnetic metal forming, International Journal of Solids and Structures 45, 442–459.

[28]. Unger, J., Stiemer, M., Brosius, A., Svendsen, B., Blum, H., KleineM., 2008. “Inverse error propagation and model identificationfor coupled dynamic problems with applicationto electromagnetic metal forming, International Journal of Solids and Structures 45, 442–459.

[29]. Yu, H., Li, C., Zhao, Z., Li, Z., 2005.Effect of field shaper on magnetic pressure in electromagnetic forming, Journal of Materials Processing Technology 168, 245–249

[30]. Zhong, L., Chun-feng, L., Hai-ping, Y., Zhi-heng, Z.,2007.Effect of tube size on electromagnetic tube bulging, Trans. Nonferrous Met. SOCC. hina 17, 705-71 0.

[31]. J.D. Thomas , M. Seth , G.S. Daehn, J.R. Bradley, N. Triantafyllidis (2007), “Forming limits for electromagnetically expanded aluminum alloy tubes: Theory and experiment”, ActaMaterialia 55 , 2863–2873.

[32]. Kapitza, 1924. A method for producing strong magnetic fields, Proceedings ofthe Royal Society Serine A 105, 691∴710