УДК 621.98.044: 629.7 +620.17 +620. 22-4

M. TARANENKO, I. TARANENKO

INTERACTIVE CONTROLLINGATLARGE-DIMENSIONAL ARTICLESFORMING

Physical phenomenon of warping (springing) can be observed as a technological heritage after large-dimensional articles forming or curing and consequent cooling of composite articles. This phenomenon can be seen as gaps between ready article contour and forming jig contour. Deviation degree of ready article surface from theoretical contour and article dimensions has to be controlled during manufacturing. Application of auxiliary controlling jig leads to expenses and labor-manufacturability increasing.
Possibility of application forming jig with inserted jet gages is considered for articles shape controlling.
Such gages and realization of acoustic methods allow to control not only final article shape but also geometry on intermediate stages of manufacturing.
Key words: forming, controlling, controlling of shape and dimensions (gaps), air (pneumatic) jet gages, acoustic method of controlling of manufacturing process, forming jig.

М. Е. ТАРАНЕНКО, И. М. ТАРАНЕНКО

ИНТЕРАКТИВНЫЙ КОНТРОЛЬ ПРИ ФОРМООБРАЗОВАНИИ КРУПНОГАБАРИТНЫХ ДЕТАЛЕЙ

После формообразования крупногабаритных листовых деталей из листовых механических заготовок или полимеризации и охлаждения деталей из композитных материалов проявляется технологическая наследственность в виде коробления (пружинения). Это наблюдается в виде неприлегания готовой детали к формозадающей поверхности технологической оснастки. При контроле качества формоизменения необходимо измерять степень нарушения формы и размеров. Применение контрольной оснастки дорого и трудоемко.
Рассмотрена возможность использования для контроля формозадающей оснастки с установленными в ней воздушными струйными датчиками.
Такие датчики и применение акустических методов позволяют контролировать не только конечную форму заготовки, но и форму заготовки на предвариантных этапах формоизменения.
Ключевые слова: формообразование, контроль формы и размеров (зазоров), воздушные (пневматические) струйные датчики, акустический метод контроля протекания процесса, формозадающая оснастка.

М. Є. ТАРАНЕНКО, І. М. ТАРАНЕНКО

ІНТЕРАКТИВНИЙ КОНТРОЛЬ ПРИ ФОРМОУТВОРЕННІ БАГАТОГАБАРИТНИХ ДЕТАЛЕЙ

Після формоутворення багатогабаритних листових деталей з листових механічних заготовок або полімеризації і охолодження деталей з композитних матеріалів проявляється технологічна спадковість у вигляді викривлення (пружнення). Це спостерігається у вигляді неприлягання готової деталі до формозадаючої поверхні технологічного оснащення. При контролі якості формозміни необхідно вимірювати ступінь порушення форми і розмірів. Застосування контрольної оснастки дорого і складно.
Розглянуто можливість використання для контролю формозадаючої оснастки з встановленими в ній повітряними струминними датчиками.
Такі датчики і застосування акустичних методів дозволяють контролювати не тільки кінцеву форму заготовки, а й форму заготовки на попередваріантних етапах формозміни.
Ключові слова: формоутворення, контроль форми і розмірів (зазорів), повітряні (пневматичні) струменеві датчики, акустичний метод контролю протікання процесу, формозадаюча оснастка.

Nomenclature

P_{feed}	-	Feeding pressure	[Pa]
P_{out}	-	Output pressure	[Pa]
L_H	-	Level of sound pressure	[dB]

Introduction. Articles produced by sheet metal forming are generally considered as large-dimensional ones if their overall dimensions are more than 1.0 m. In majority of cases such articles have on their outer surface local stiffening elements like ribs, bevels, conjugated surfaces with low radii of curvature. To create such zones with required quality one has to apply elevated pressure or [illegible] geometry of an article. Typically to such articles one can relate car body panels, antenna mirrors for satellite and space communication, articles of skin and facings of aircrafts. Metal sheet articles are produced by mechanical presses, hydraulic presses by means of forming by elastic and liquid medium and by electrohydraulic presses with consequent local load application.

provided by Electronic National Technical University "Kharkiv Polytechnic Institute"...
View metadata, citation and similar papers at core.ac.uk
brought to you by CORE

Semi-finished composite articles after preliminary stages of forming are cured and cooled in contact with shape-creating surfaces of technological jig.

Necessity of interactive control of large-dimensional articles manufacturing, i.e. controlling of process or semi-finished articles state during manufacturing is stipulated by means of series of factors:

1. By high requirements to articles quality, precision of their radii and shapes. For some mentioned types of articles allowable deviation of shape of jig geometry doesn’t exceed 0.3…0.5 mm.

2. By high labor-intensity of dimensions and shape of non-rigid articles. Forming jig is the unique carrier of geometrically net parameters at conditions of such articles forming. This means that control can be conducted by [illegible] hape deviation from jig [illegible] mposite articles.

3. By relatively high warping of ready articles caused by residual stress action. Fore some prospective structural materials degree of warping ca reach values comparable with articles dimensions.

4. By not very precise applied load or pressure which depend on quite wide value of allowances on mechanical properties of article material. For some materials allowances on margin of strength and margin of yielding reach 20% of nominal value. Nominal value

© M. Taranenko, I. Taranenko, 2019

depends significantly on rolling direction or deviations of reinforcing fibers direction. Therefore, not precise loading leads to articles quality reduction.

All above-mentioned factors can be eliminated and get high-quality articles at correct composing of manufacturing process based on knowledge of deformable article state in processing and degree of semi-finished article contacting to forming jig surface.

The goal of paper is to research possibility of controlling methods application of semi-finished article position with respect to forming jig and equipment operation diagnostics, which don't require significant jig re-composing, used controlling and diagnostical equipment and in optimal case – application of contactless controlling methods.

To increase possibility of article spinning controlling with respect to forming jig different methods and structural solutions of different spaces measurements are considered. They are

To estimate controlling possibility of semi-finished article adjacency to forming jig surface different structures and methods of measuring typical distances have been analyzed. They include application of such methods as potentiometric, capacitive, inductive gages and static methods of measuring. Taking into account their advantages they have such disadvantages as necessity to provide electrical wires and contacts in operational zone. The contacts are subjected to contamination and have low reliability. Electrical contacts can be freely damaged by movable parts of jig or semi-finished article.

In such conditions the gages of distance most suitable for practical application are air jet gages of distance [1–3]. Their advantages are:

– the simplicity – gage consists of the single part – the nozzle exactly;

– high precision of distance measuring from 0 up to10 mm;

– low feeding pressure of compressed air;

– resistance to vibrations, electrical noise disturbance and contaminations;

The surface of forming jig is considered as reference surface that allows escape of auxiliary measuring devices.

Some variants of application and installation of gages are shown on the Fig. 1 and Fig. 2.

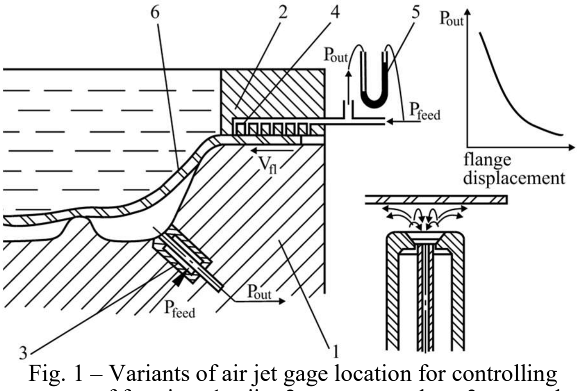

Fig. 1 – Variants of air jet gage location for controlling parameters of forming: 1 – jig; 2 – pressure plate; 3 – transducer for determination gapping between blank and die; 4 – gage for determination of flange drawing; 5 – micro-pressure gage; 6 – blank

It is recommended to install gages 4 (Fig. 1) in holding-down plate 2 and orient them in radial direction to register uniformity of flange material drawing over article perimeter.

In initial state a flange of a semi-finished article 6 overlaps holes for air exhausting and air consumption through gage is minimal. By the flange drawing process to female die cavity air consumption through gage increases that leads to reduction of pressure P_{feed} in feeding system. Feeding pressure is registered by pressure gage (shown as a U-like tube on the Fig. 1).

Such changing of pressure by signal value is proportional to the flange displacement. If signals got from several gages disposed uniformly by flange perimeter are compared one can determine easily location of zones with more intensive drawing. After several consequent recalculations of position of exact zone of a blank can be determined precisely.

It is recommended to use differential (double-channel) gage 3 to determine blank position with respect to jig 1 at zones where blank touches to a jig tightly in last turn. Feeding stream of air passes through outer channel. Air jets reflect from blank surface at nozzle leaving section. Pressure at the central zone of a gage increases and one can make conclusion about distance from the blank surface up to gage edge by means of this pressure changing. The dependence of transformer outer signal is proportional to the third degree of distance between blank and jig surfaces. This approach permits to find gaps between jig and blank quite precisely.

Possible arrangement of jet gages positioning at composite shells forming is shown on the Fig. 2.

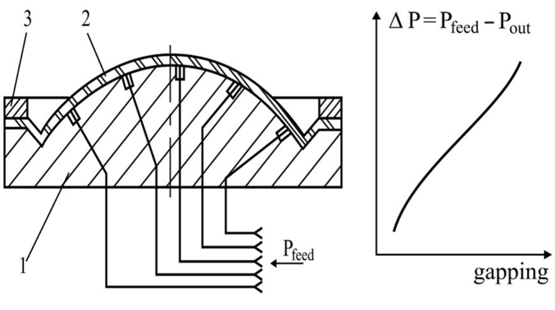

Fig. 2 – Variant of air jet-pipe gages location for determination gapping between shell and forming jig: 1 – forming jig; 2 – article; 3 – holding down element; transducer case; P_{feed} – feeding pressure; P_{out} – measuring parameter

Installation of air jet gages inside jig is not very complicated and required tooling for pressure measurement is relatively simple too. Air input to gaps between jig and blank makes ready article removing from jig to be easier and allows to escape of different kind of ejecting pins.

Above-described method of article position controlling allows to get results with high precision without article removing from the jig that make controlling got be easier. But at the same time jig structure has to be more complicated and special registration equipment (mainly, piping systems) is required. This fact doesn't simplify architecture of technological zone. Therefore, this method can be recommended is case contactless methods of measuring necessity.

Acoustic methods also belong to contactless measuring ones. These methods are widely used in industry for diagnostics of building and structures (bridges, big chemical columns etc). An object under analysis is preliminary loaded with short acoustic or mechanical signal of definite frequency and then the objectacoustic response on disturbing impulse is registered.

Short loading impulse can be used in case of research of impulse forming equipment as disturbing one. This impulse causes oscillations of a part of studying object (blank, chamber, discharger etc). The objective of studying was determination of correspondence of registered parameters of sound signals to changing parameters of entire process.

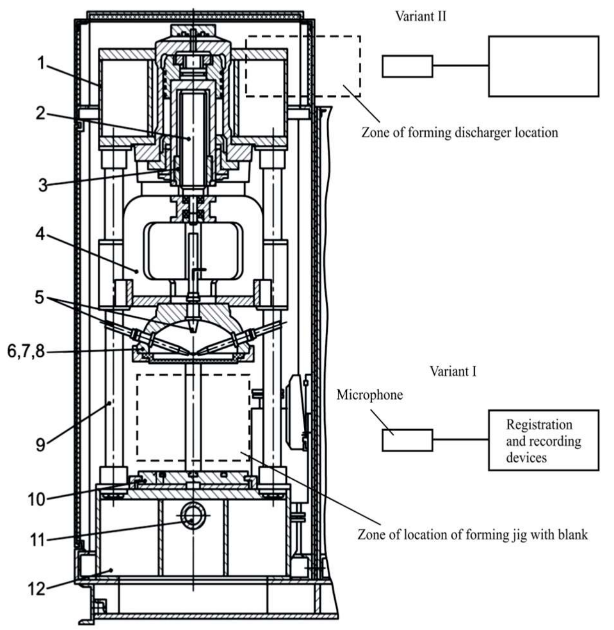

Fig. 3 – Scheme of arrangement of electrohydraulic press and location of microphones (two variants) for sound signals recording: variant I – at recording of sound signals from blank and total released energy; variant 2 – at recording of sound signals of energy feed to operational zone of press; 1 –upper crosshead with water tank; 2 –compressing hydro-cylinder; 3 – mechanism for regulation stroke of movable crosshead ; 4 – movable crosshead of frame type; 5 – side and upper operational electrodes; 6 – discharge chamber; 7 – elastic diaphragm; 8 – compressing ring of diaphragm; 9 – column; 10 – retractable table; 11 – hydro-cylinder of retractable table; 12 – lower crosshead

Acoustic method is suggested for determination degree of article forming and diagnostics of equipment operation at application of consequent local forming of large-dimensional sheet articles on electro-hydraulic presses [4]. The essence of the method is in registration and special processing of acoustic signals radiated by sheet article at impulse loading, blank interaction with jig at reciprocal impact and impulse signals of equipment elements. Blank as itself is a membrane, cases of discharge chambers, jig, cases of discharger and other elements release sound signals at impulse loading proportional to quantity of energy released at discharge on frequency determined by above-mentioned elements rigidity. Series of experiments were conducted in National Aerospace University "KhAI". The main objective of them was to establish correlation dependencies of acoustic indexes on degree of blank shape changing and state of energy releasing by electro-hydraulic press. Scheme of testing used is shown on the Fig. 3.

Microphone of noise-measuring device connected to electronic oscillograph for visual signal recording was disposed very close to studying object, for example, discharge chamber with blank held down to jig (variant I). Electro-hydraulic discharges were conducted by press and acoustic signals from them were registered. Blank was deformed by consequent discharges with applied energy 13.5 kJ. Disturbance of energy releasing system was imitated by means of interelectrode spacing changing.

Dependences established by results of experiments are shown on the Fig. 4.

Following conclusions can be done. More released energy more level of sound pressure (Fig. 4, b). This dependence become more drastic with increasing frequency of octaves from 63.5 Hz to 250 Hz. Confidence interval of mentioned dependences at 95% reliability lay in rage of 2…5 % of registered value (shown on the diagram by vertical lines).

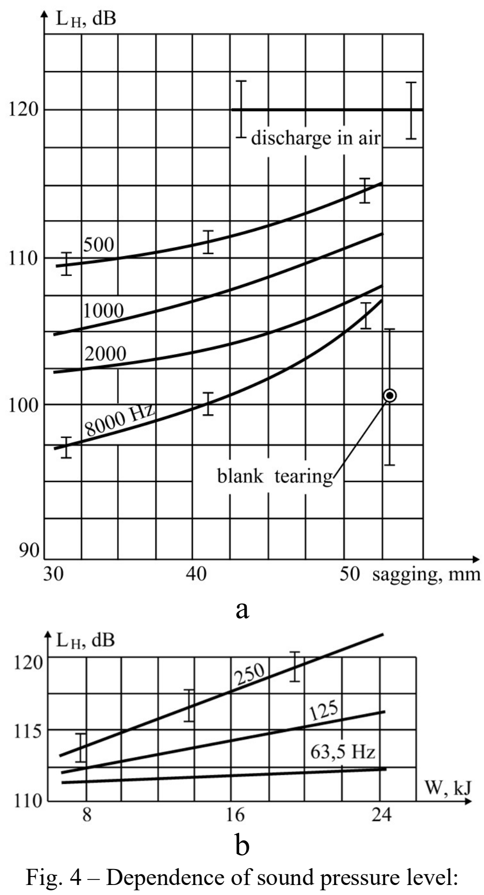

Fig. 4 – Dependence of sound pressure level: a – on blank sagging at different octaves; b – on saved energy at forming of bottoms of steel 08кп, thickness 1.0 mm

Dependence of sound pressure level on blank sagging (i.e. its rigidity) is established. It is shown on the Fig. 4 that, generally, more sagging more value of registered parameter generated at electro-hydraulic discharge. This dependence is quite weak at frequencies 63.5 and 125 Hz but more drastic at higher frequencies. The graph shows the points corresponding to blank tearing (L_H ≈101±4.5 dB) and to discharge in empty female-die (calibration of blank is simulated) – L_H ≈101±4.5 dB. Last two values are linearized by octaves values of L_H .

Dependencies obtained cab be explained by following reasons. At the beginning of deformation when blank is more compliant energy released is spent mainly on plastic forming of blank and its small amount is reflected from blank and causes oscillations of technological tooling. Then more sagging of blank more its rigidity and ratio of absorbed and reflected portions of energy changed to last one. Therefore, more blank sagging more level of sound pressure generated by blank. Blank rigidity reduces sharply at blank tearing that leads to reduction of L_H value. At blank calibration more portion of energy released transfers to acoustic mode.

Significantly drastic dependence of L_H on sagging at frequencies 2000…8000 kHz can be explained by higher oscillation frequency of deformed blank in comparison with flat one. Close frequency passed through registration channel to blank Eugen frequency more drastic dependence of sound pressure level on sagging observed in experiments.

Blank deformation under electro-hydraulic discharge happens by oscillations of more complicated form. Oscillations with two and more harmonics, corresponding to different forms of oscillations, are observed [4]. Analysis of oscillations of deformable blank in frames of S. P. Timoshenko's theory for experimental conditions gives two values of Eugen frequency: main one is 50…10 Hz and higher one – 1.0…2.0 kHz. Typical frequencies observed in experiment was 1.0…2.0 kHz. It can be seen that analytical and experimental values are quite close. Harmonics observed on oscillograms of less frequency can relate to oscillations of press structure and jig.

More thorough experimental dependencies can be also obtained for composite articles manufacturing.

Following conclusion by experimental studies. It was established experimentally that at forming of sheet blanks on electrohydraulic press:

1. There is the correlation dependence between depth of blank forming (sagging) and the value of sound pressure of generated signal. This dependence ismore drastic on frequencies corresponding to main frequency of oscillations for a blank considered as membrane.

2. There is the correlation dependence between level of sound pressure of generated signal and quantity of energy released at discharge. Such dependence can be used for interactive control of released energy at electro-hydraulic discharge. This dependence is well defined at frequencies more than 250 kHz. One can assume that more drastic dependencies can be observed at frequencies corresponding to oscillation frequency of discharge chamber.

It can be considered that further development of the method is quite prospective for interactive controlling of blank state and diagnostics of equipment operation.

Conclusions. Two methods of interactive control of processes happened at sheet forming are suggested. These methods differ by precision of estimation of forming articles of different shape and dimensions, by complexity of technological zone organizing and by presence or absence of mechanical contact between technological jig and measuring or registering devices.

More auxiliary methods of interactive control of forming of large-dimensional articles are also studied in National Aerospace University "KhAI".

Список литературы

1. Залманзон, Л. А. Теория элементов пневмоники [текст]:/ Л. А. Залманзон. – М. : Физматгиз, 1969, 568 с.
2. Дылев, В. И. Применение струйных датчиков в комплексах оборудования с промышленными роботами [текст]: / В. И. Дылев. А. С. Шаров. – Минск, Вестник машиностроения, № 6, 1978. – С. 18–20.
3. Баселаев, В. Н. Исследование струйных датчиков расстояния [текст] / В. Н. Баселаев, В. К. Даниленко и М. П. Чайко / В сб. «Вопросы струйной техники». – Минск, 1975, – С. 164 – 177.
4. Тараненко, М. Е. Электрогидравлическая штамповка: теория, оборудование, техпроцессы [текст]: монография в 2 ч. [текст] / М. Е. Тараненко. – Х. , Национальный аэрокосмический университет им. Н. Е. Жуковского «Харьковский авиационный институт», 2011, 272 с.
5. Горюнов В. А. Разработка метода повышения эффективности струйных управляющих устройств систем автоматического управления технологическим оборудованием [текст]: автореферат дис. ... кандидата технических наук : 05.13.06 / Волгогр. гос. техн. ун-т. – Волгоград, 2001. – 19 с.
6. Рачков М. Ю. Технические измерения и примеры : учебник и практикум для вузов [текст] / М. Ю. Рачков / — 3-е изд., испр. и доп. — Москва : Издательство Юрайт, 2019. — 151 с. — ISBN 978-5-534-07525-0.

References (transliterated)

1. Zalmanzon L.A. Theory of pneumatic elements. Phizmatgiz, Moscow, 1969, 568 p.
2. Dylev V.I., Sharov A.S. Application of jet-pipe transducers in complexes with industrial robotic equipment. Herald of Machine-building: Collection of Scientific Papers. Minsk, No.6, 1978, pp. 18–20.
3. Baselayev V.N., Danilenko V.K., Chaiko M.P. Studying of jet-pipe transducers of distances. Problems of jet engineering: Collection of Scientific Papers. Minsk, 1975, pp. 164 – 177.
4. Taranenko M.Ye. Electro-hydraulic forming: theory, equipment, manufacturing processes: monograph (in 2 parts). Zhukovsky National Aerospace University "KhAI". Kharkiv, 2011, 272 p.
5. Gorunov V.A. Developin gofthemethod of improving efficiency of jet control systems for automatic controlling of manufacturing facilities. The sisonc and idate of science degree, 2001, Volgograg, 162 p.
6. Rachkov M.Yu. Technical measurements and equipment: textbook and practical book. Moscow, 3rd edition, Urait Publishing. – 2019, 151 p. — ISBN 978-5-534-07525-0.

Надійшла (received) 29.05.2019

Відомості про автора / Сведения об авторе / AbouttheAuthor

Тараненко Михаил Евгеньевич (Тараненко Михайло Євгенович, Mykhaylo Taranenko) – доктор технических наук, профессор, Национальный аэрокосмический университет им. Н. Е. Жуковского «Харьковский авиационный институт, зав. кафедрой автомобилей и транспортной инфраструктуры; ул. Чкалова, 17, 61070, г. Харьков, Украина; тел.: (057) 788-41-70, m.taranenko@khai.edu

Тараненко Игорь Михайлович (Тараненко Ігор Михайлович, Igor Taranenko) – кандидат технических наук, профессор, Национальный аэрокосмический университет им. Н. Е. Жуковского «Харьковский авиационный институт, кафедра композитных структур и авиационных материалов; ул. Чкалова, дом. 17, 61070, г. Харьков, Украина; тел.: +38-097-448-34-25, igor.taranenko@khai.edu