welding process is determined by the sizes of the welded construction, possibility of its turn over, providing of the best terms of welding, access to the joints, possibility of automation and mechanization of process, present qualification of welders, present equipment and etc.

One of most difficult items is the choice of welding process and its technological modes. More frequent only the choice of welding process is dictated by minimum energy consumption.

We have conducted the analysis of welding methods on energy consumption for the welded connection of the type C4. For example, power input was determined on the joint single-pass welding of two sheets from construction steel (type of the connection C4) 4 mm thick (GOST 8713-79). 1 m adopted length of weld, production is single, for all arc methods of welding as a source of feed the semiconductor rectifier of the type VDU-1001-1001 is used. The modes of welding were adopted from help data. The results of decision of power input are represented on fig. 2.

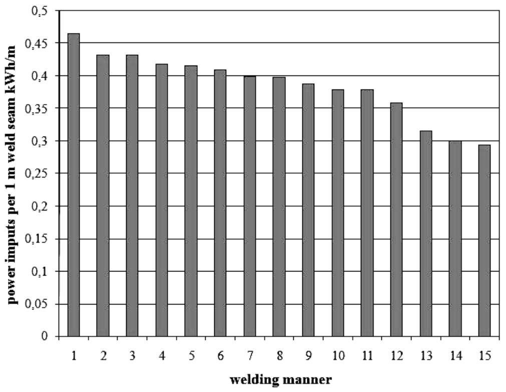

Fig. 2. Cost sharing of electrical energy per 1 m of weld of the connection C4 for various ways of the arc welding in protective gases [Druz O.N., Gitnaya S.V., 2011.]: 1 – automatic welding in the environment of inert gases (Ar); 2 – automatic welding under water by a bare wire without additional defense; 3 – automatic welding under water by the powder-like wire PPC-AN5; 4 – automatic welding under water by the powder-like wire PPC-AN1; 5 – automatic solvent sealing on copper-melt backing; 6 – automatic welding in the protective environment CO_2; 7 – automatic welding in a mixture by a $85\%CO_2+15\%O_2$ electrode wire with additions Ce and La; 8 – Automatic solvent sealing on melt backing; 9 – automatic welding in the mixture $85\%Ar_2+15\%CO_2$; 10 – automatic welding in the mixture $70\%CO_2+30\%O_2$; 11 – welding in the environment of aquatic steam; 12 – automatic welding in SO_2 on the layer of activator (melt); 13 – automatic welding in a mixture $85\%Ar+15\%CO_2$ on the layer of activator (melt); 14 – automatic welding in the protective environment Ar on the layer of activator (melt); 15 – automatic welding under water by a bare wire with the additional defense CO_2

However, not taking into account such distributing of consumption of energy and performance of welding methods (fig. 4), cost of 1 m of weld doesn't coincide with it, so it results in additional expenses on the receipt of the welded connection (cleaning, assembling under welding, pay-envelope of welders and auxiliary personnel, expenses on repair and maintenance of setting, welding materials and etc) [Gracheva K.A., 1984., Gretskiy Y.Y., 1995., Tereshenko V.I. and others, 1987., Shebeko L.P., Gitlevich A.D., 1986., Yurev V.P., 1972., Druz O.N., Gitnaya S.V., 2011.].

From a fig. 2 and fig. 3 we can see, that minimum energy consumption, while other things are equal, have the methods of welding in protective gases (and their mixtures) with activators, and also radial methods of welding. Welding under water and welding in the environment of aquatic steam can be considered welding in an active gas environment, consisting of products of decomposition of water (and steam) and gases selected at dissociation of powder-like wires charge.

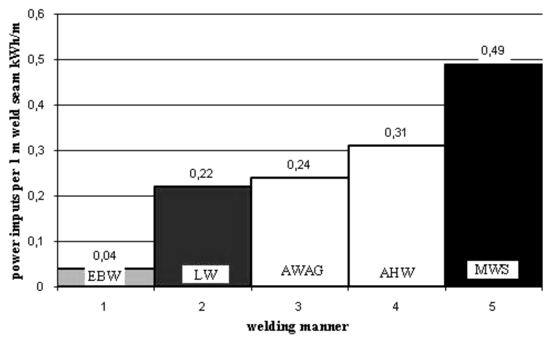

Fig. 3. Cost sharing of electrical energy per 1 m of weld of the connection C4 for various ways of the welding [Druz O.N., Gitnaya S.V., 2011.]: EBW – electron-beam welding, LW – laser welding, AWAG – automatic arc welding in active gases, AHW – automatic hidden arc welding, MWS – manual arc welding

Most localization of input of heat can be created at heating of the welded good by a laser and electronic ray. An arc with a consumable electrode is a relevantly high-localized source of heat. The less localizing heating is performed by the arc of indirect action. The least localized is entered warmly in the welded good by gas-welding flame.

Most maximal power is practically attained at the electroslag welding ~250 kW and electric arc welding ~100 kW. Electron-beam welding options are characterized the range of powers to 50 kW. Some less maximal power ~30 kW current is seen in setting for welding by a laser. Maximal power of the practically applied gas-welding flame is limited ~10 kW.

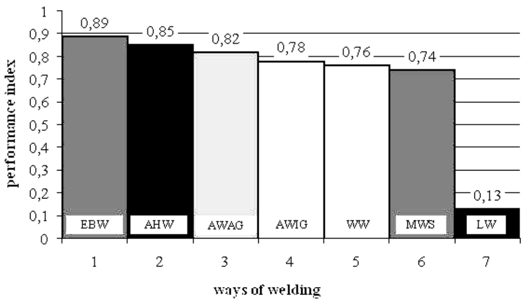

Fig. 4. Distributing of middle output-input ratio (performance index) of various ways of welding [Druz O.N., Gitnaya S.V., 2011.]: EBW – electron-beam welding; AHW – automatic hidden arc welding; AWAG – automatic arc welding in active gases (CO_2); AWIG – automatic arc welding in inert gases (Ar); WW – welding by a powder-like wire; MWS – manual arc welding by a stick electrode; LW – laser welding

Electronic ray, welding arc characterized by the use of energy (on the effective input of heat in the welded good) source by the most high value of performance. The power use of laser and gas flame is considerably less effective.

We can see from the above-mentioned data, that on the given stage of welding technologies development it is necessary to work above perfection, foremost in arc welding and the environment of protective gases and their mixtures, as one of most resource-saving and methods of receipt of unsectional connections that simple in realization (automations). Thus, the least energy consumption of welding process is not the basic criterion of innovative welding technologies choice.

On an example we will consider the choice of parameters of arc welding process, as most perspective for introduction of innovative technologies. One of economic indicators of arc welding methods is productivity of pad weld. On the fig. 6 we can see dependences of pad weld speed on the strength of welding current.

Prospects of further researches. Researches in area of arc welding methods in active gas environments theoretically and practically are most perspective. In East Ukraine National University there have been developed methods of welding in a complex protective environment, and also methods of the use of complex protective environment in different welding technologies, for example, forced concomitant cooling and reduction of concentration of welding aerosols in the working area of welder. On the received results of researches 8 patents of Ukraine have been gotten and candidate's dissertation prepares to defense.

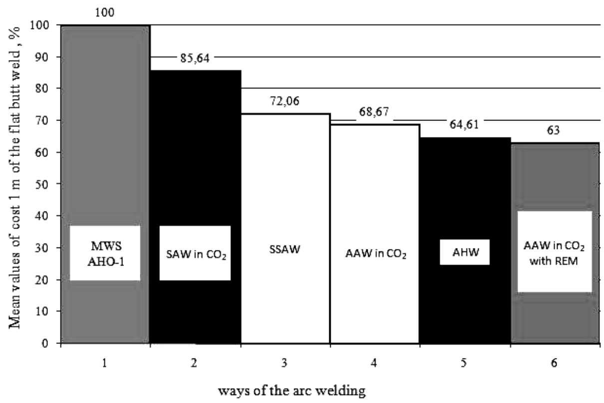

Fig. 5. Mean values of cost 1 m of the flat butt weld C4 at the thickness of sheet 4 mm in relative units (the hang-the-expense approach method of welding is accepted after 100%) on various ways of the arc welding [Druz O.N., Gitnaya S.V., 2011.]: MWS AHO-1 – manual arc welding by the custom-made electrode of the AHO-1 brand, SAW in CO_2 – semi-automatic arc welding in the protective environment CO_2, SSAW – semi-automatic submerged arc welding, AAW in CO_2 – automatic arc welding in the protective environment CO_2, AHW – automatic submerged arc welding, AAW in CO_2 with REM – automatic arc welding in the protective environment CO_2 with additions of rare-earth metals to the electrode

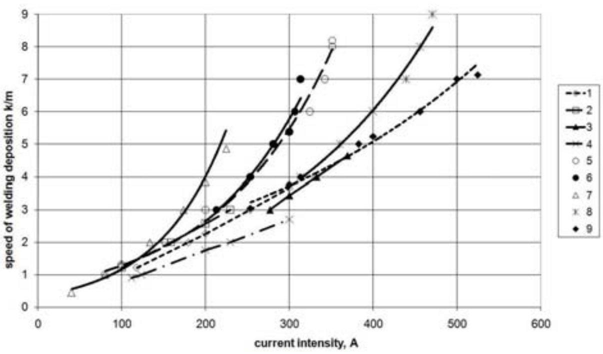

Fig. 6. Dependence of productivity welding deposition of arc methods of welding on strength of current [Druz O.N., Gitnaya S.V., 2011.]: 1 – manual arc welding, electrode with basic coverage; 2 – manual arc welding, electrode with cellulose coverage; 3 – manual arc welding, electrode with retile coverage and ferrous powder; 4 – manual arc welding, electrode with retile coverage; 5 – welding in a protective environment the CO_2 wire the diameter 1,2 mm; 6 – powder-like wire the diameter 1,6 mm (brands – FCW AWS E6XT5); 7 – welding in a protective environment the CO_2 wire the diameter 0,8 mm; 8 – powder-like wire the diameter 1,6 mm (brands – FCW AWS E6XT1); 9 – powder-like wire the diameter 2,4 mm (brands – FCW AWS E6XT1)

CONCLUSIONS

1. Introduction of innovative technologies in welding production requires the account of specificity of every welding process.

2. For introduction of innovative technologies the methods of welding in active gas environments are most perspective.

3. Application of plasma, electron-beam and laser methods of welding are justified only in case of impossibility of the use of other methods of welding.

4. From point of financial viability innovative technologies are not always justified (acceptable).

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УЧЕТ СПЕЦИФИКИ ПРОЦЕССА ДУГОВОЙ СВАРКИ В ИННОВАЦИОННЫХ ТЕХНОЛОГИЯХ

Олег Друзь, Светлана Житная

Аннотация. В данной статье изложены результаты исследований по внедрению в сварочное производство инновационных технологий. Рассмотрена роль в экономике сварочного производства конструкторов, металлургов и технологов производства при внедрении ресурсосберегающих технологий. Рис. 6, ист. 43.

Ключевые слова: сварка, экономия, инновационные технологии.

TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2012, Vol. 12, No.3, 30-39

AN INFLUENCE OF ADHESION MODEL ON THE RESULTS OF LOCOMOTIVES DYNAMICS SIMULATION

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S u m m a r y : The results of the locomotive dynamical behavior modeling with different wheel –rail contact sub – models are presented. It is shown, that the choice of wheel-rail contact model has significant impact on the simulation of locomotive motion in traction regime with high creep values, even when it's running on the straight track.
K e y w o r d s : wheel, rail, contact, creep, traction, dynamics

INTRODUCTION

A study on the wheel – rail frictional interaction brought the "adhesion coefficient (force) characteristics" concept – the dependence of the adhesion coefficient (force) on the creep vector inside the contact area. However the term "creep", its calculation method and its value is different in various sources.

The creep in wheel – rail contact arises by two different reasons:

- as the reaction on the tractive (braking) moment applied to the wheelset axle;
- kinematical parameters of movement

It is often met that the first term is ignored in the locomotive dynamics simulation, and this can lead to significant errors.

OBJECTS AND PROBLEMS

The scheme of wheelset running on the track is shown on fig. 1. Wheelset is moving with linear speed V, left and right wheels are rotating with angular speeds w_{left} и w_{right} thereafter. Let's denote by r_0 mean rolling radius of the wheel , and by r_{left} и r_{right} - left and right wheel contact radius. The distance between initial contact points is denoted by d .

The creep components are usually defines as ratio of projections of the relative movement speed of the wheel and rail points to the linear movement speed:

$$\xi_x^i = \frac{\Pr_x(\overline{V} - \overline{w}_i r_i)}{\overline{V}}$$
$$\xi_y^i = \frac{\Pr_y(\overline{V} - \overline{w}_i r_i)}{\overline{V}} \qquad (1)$$
$$\varphi^i = \frac{\Pr_z(\overline{w}_i r_i)}{\overline{V}}$$

where: ξ_x - longitudal creep, ξ_y - lateral creep, φ - spin, r - contact radius, i = *left, right*

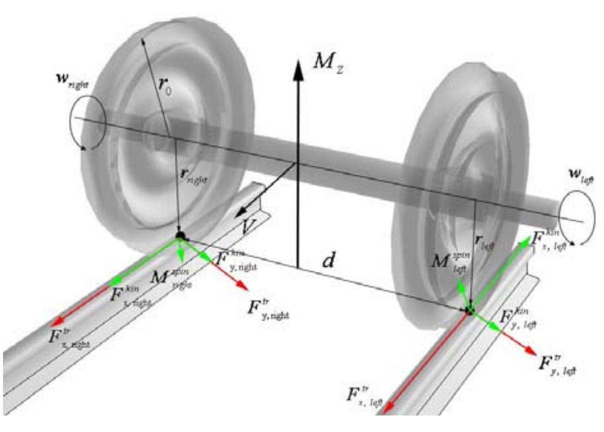

Fig. 1. Wheelset movement scheme

It is often met that creep, calculated with expression (1) is expressed in percents.

The schematic representation of adhesion characteristics is shown on fig. 2.

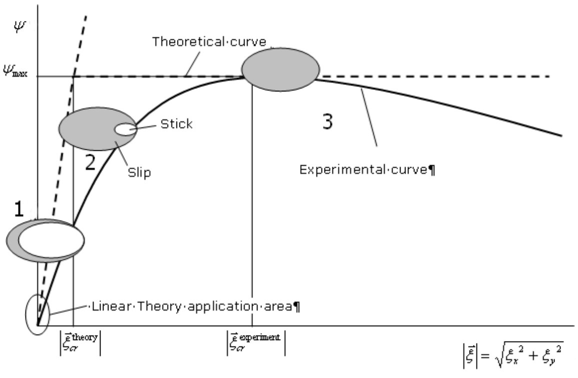

Fig. 2. Creep – adhesion coefficient curve

As it can be seen from fig. 2, creep force characteristics has maximum, which is reached at some value of creep – critical creep $\vec{\xi}_{cr}$. When the creep is lower then $\vec{\xi}_{cr}$, the adhesion process is stated as normal, and when the creep is higher then $\vec{\xi}_{cr}$ boxing is progressing.

An overwhelming majority of adhesion mathematical models, that explains the adhesion characteristics development, are based on the Osborne Reynolds "On Rolling-Friction" work, published in 1876. He has determined, that when the roller is rolling over the plain, the way passed by the center of the roller during one turn differs from it circle length. Osborne made a assumption that contact zone is split into stick area, where true slip is zero, and slip area, where true slip is higher then zero.

The followers of this approach [Chollet 2007, Kalker 1967, Kalker 1973, Kalker 1982, Kalker 1990, Kalker 1989, Pascal 1993, Piotrowski 2005, Piotrowski 2008, Polach 1999, Popovici 2010, Quost 2008, Vollebregt 2011 and others] state that with a small relative sleep ($\bar{\varepsilon} << \bar{\varepsilon}_{cr}$) almost all the contact zone is stick zone (see fig.2, first position). While the relative sleep grows, stick area becomes smaller, and the slip zone becomes bigger. (see fig.2, second position). When the $\bar{\varepsilon}$ exceeds $\bar{\varepsilon}_{cr}$, the whole contact area will be slip.area (see fig.2, third position).

A linear theory of the J.J. Kalker [Kalker 1967] is the most widespread rolling friction theory:

$$\begin{bmatrix} F_{tx} \\ F_{ty} \\ M \end{bmatrix} = -Gab \begin{bmatrix} C_{11} & 0 & 0 \\ 0 & C_{22} & \sqrt{ab}C_{23} \\ 0 & -\sqrt{ab}C_{23} & abC_{33} \end{bmatrix} \begin{bmatrix} \xi_x \\ \xi_y \\ \phi \end{bmatrix} \quad (2)$$

where: C_{11}, C_{22}, C_{33}, C_{23} are Kalker coefficients;

a, b –contact ellipse semiaxis;

G – shear modulus.

C_{11}, C_{22}, C_{33}, C_{23} coefficient values for different a/b ratios and elastic properties of the materials can be found in [Kalker 1967]. This solution has high computational speed, but it is limited by the vanishingly small creep (see fig.2). It is assumed, that $V \approx w_{left}r_{left} \approx w_{right}r_{right}$. Then the expressions (1) are then look like [Iwnicki 2006]:

$$\xi_x^{left} = -\xi_x^{right} = -\frac{\Delta r}{r_0}$$
$$\xi_y^{left} = \xi_y^{right} = -\alpha \quad (3)$$
$$\varphi^{left(right)} = \frac{\sin \gamma_{left(right)}}{r_0}$$

where: α - wheelset yaw angle, γ - wheel profile conicity; $\Delta r = r_{left} - r_{right}$ - rolling radius difference.

Another popular model of J.J. Kalker is simplified theory and it's program realization FASTSIM [Kalker 1982]. This model is used as standard for wheel - rail interaction simulation. It is widely used in railway vehicle dynamics simulation, including locomotive dynamics simulation. The last one is totally unacceptable, since the simplified theory is developed on the base of linear one, which has area of application limited by the vanishingly small creep as it was mentioned above.

For all the models mentioned above a critical creep values are lower the tenth of percent, and that is much less than experimentally measured once.

A review on the experimental studies given in work [Kostyukevich 1991], has shown that the critical creep, measured by different researches, is varying for 1 to 15% and even to 20%, depending on the frictional contact conditions.

Thus the usage of adhesion models, based on Reynolds theory, in locomotive dynamics simulations, especially in traction (braking) regimes can cause significant errors.

Having the aim to investigate the influence of friction model choice on the dynamical behavior of the locomotive, lets's examine a model of six axle locomotive (TE116), explicitly defined in [Gorbunov 2002]. The design model is shown on fig. 3.

The next premises were are made before the construction of the model:

- All bodies of the system (locomotive body, bogies' frames, traction motor, wheelsets and wheel treads are considered perfectly rigid.