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Status and prospects of fully mechanized mining technology in Vietnam coal mines from 2005 to 2020

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Abstract

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Keywords

Vietnam, underground coal mine, mechanized mining

Status and prospects of fully mechanized mining technology in Vietnam coal mines from 2005 to 2020

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Abstract

This paper analyzes the achievement and the failures of applying the mechanized mining method in underground coal mines by the Vietnam National Coal – Mineral Industries Holding Corporation Ltd. (VINACOMIN) for 15 years (from 2005 to 2020). It also proposes the recommendations for developing mechanized mining in order to improve coal production, productivity and safety management for the sustainable development of Vietnam's underground coal mining in the period 2021–2025.

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1. Introduction

For the last twenty years, coal output from the underground mines in Quang Ninh increased rapidly from 2.4 million tonnes in 1995 to 19.9 million tonnes in 2010 and 29.8 million tonnes in 2020 [1]. This achievement is the result of the broad expansion and application process of hydraulic supports (single hydraulic prop, movable frame beam, movable hydraulic beam) replacing the wooden props since 1999 and mechanized support since 2005 in longwall. The results of applying mechanized mining in the Vietnamese coal mines from 2005 to 2020 have shown the superiority in improving mining output, labour productivity as well as improving the safety level and working conditions over other technologies under the same conditions.

However, some underground coal mines currently are still applying mining methods with low mechanization levels in which coal is extracted by blasting and drilling methods, resulting in coal output in working faces and productivity being low; the working conditions and the safety management being still limited.

According to the Master Plan of Coal Industry Development in Vietnam by 2020, with perspective to 2030, which was adjusted in 2016 [2], and the mining plan of VINACOMIN, total coal output would reach the level of 41 million stonnes in 2022 and 49.3 million tonnesin 2025, in which, underground mining coal output will increase gradually year by year and achieve the largest share (to 73%) in the total output of the overall coal industry in 2025 [7]. Therefore, to achieve the set target, the application of mechanized mining technologies is the inevitable direction of VINACOMIN.

2. Materials and methods

The measurement of coal output and productivity of mechanized longwall in the underground coal mines will be made on the basis of available data from the VINACOMIN and the unpublished data from the 2005–2020. The statistical method was applied in the paper.

3. Analysis of coal reserves capable of mechanization application in Quang Ninh coalfield

In order to develop mechanization in underground coal mining, the analysis of coal reserves and geological conditions of twelve underground coal mining areas in Quang Ninh has been carried out (including deposits of mines such as Mao Khe, Nam Mau, Uong Bi, Vang Danh, Ha lam, Nui Beo, Duong Huy, Quang Hanh, Thong Nhat, Ha Long (Khe Cham II-IV), Khe Cham III and Mong Duong)

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with total estimated reserves of 630,645 thousand tonnes [3].

Based on the experience of mining in the developed countries of the world as well as in the Quang Ninh area, reserves are capable of mechanization application according to main elements, among others, as the seam thickness, the seam dip, variation of seam thickness, variation of the seam dip, the length along the strike, the length along the seam dip, partition rock ratio, stability of directly adjoining rock, stiffness of basic adjoining rock and stability of immediately roof or main roof were evaluated and classified. The result from the analysis showed that there are 231,126 thousand tonnes (accounting for 36.6%) in the total of 630,645 thousand tonnes in Quangninh coalfield that can apply the mechanization technology, which are mainly concentrated in some big mines such as Ha Long (about 51,009 thousand tonnes), Ha Lam (about 42,258 thousand tonnes), Khe Cham (about 27,222 thousand tonnes), Nui Beo (about 21,372 thousand tonnes). The summary of coal reserves which can apply the mining mechanization according to the thickness and seam dip at some deposits in the Quang Ninh area is presented in Table 1.

The chart on geological reserves distribution and reserves capable of mining mechanization application according to evaluated deposits, see Fig. 1.

4. Status of mechanized mining in underground coal mines in Quang Ninh region from 2005 to 2020

Before 2005, most of the longwalls in Vietnam had been supported by wooden props, and the mining work was carried out with blasting works. Since 1998, hydraulic single props have been used in underground mines of VINACOMIN. Since 1999, a self-moving hydraulic frame type XDY-1T2/LY has been used. In Vietnamese coal history, their implementation was a kind of "technical revolution". In the next step, since 2006, the hydraulic frames type ZH1600/16/24Z, ZH1800/16/24 ZL and GK/1600/16/24/HTD have been used. The mining output of longwall using hydraulic support was from 140,000 to 250,000 tonnes per year, and labour productivity increased to 5.0–7.0 Mg/working day-shift [4]. Moreover, working conditions and safety have improved significantly. However, the blasting technique was still used to exploit coal.

In April 2005, the first mechanized longwall was put into operation in the Khe Cham coal mine, with mining output from 233,000 to 388,000 tonnesper year, the labour productivity from 9.9 to 11.4 Mg/working day-shift. Since 2005, coal output from mechanized longwalls in the Quang Ninh region has increased at a great rate, from 258,000 tonnes in 2005 to 639,200 tonnes in 2010 (an increase of 2.5 times compared to 2005) and 3,450,000 tonnes in 2020 (an increase of 13 times compared to 2005). The proportion of coal mining from mechanized longwalls in total underground mining output has enlarged swiftly; for example, in the period 2005–2015 reached 1.6–3.6%, increasing to 6.6% in 2016 and 14.2% in 2020 of total underground coal output. Furthermore, 14 mechanized equipment lines have been applied at underground coal mines: 11 for mining gently sloping and incline seams and 3 for steep mining seams. In 2022, 11 mechanized longwalls were operated in 9 underground coal mines (see Table 2).

Some mechanized mining methods were applied in Vietnam underground coal mines:

(1) The mining method applied for thin to medium thick seam (up to 3.5 m), dipping up to 35°

Table 1. Summary of coal reserves capable of mechanized mining in the Quang Ninh area (thousand tonnes).

No.	Name of company	Evaluated level	Name of coal seam	Coal reserves
1	Mao Khe	−150 to −400	9V; 9BT; 8T; 7V; 7T; 6V; 6T; 3; 2	21,182
2	Nam Mau	+125 to −200	9; 7; 7T; 6A; 6; 5; 4; 3	7315
3	Uong Bi	+30 to −150	24(59); 18(53); 12(47); 11(46); 10(45); 9BT(44BT); 9V(44V); 5(40); 1	13,137
4	Vang Danh	±0 to −175 (Vang Danh); +135 to −50 (Canh Ga)	8; 7; 6; 5; 4	14,612
5	Ha Lam	−50 to −300	11-2; 11-1; 10; 7; 6; 5	42,258
6	Nui Beo	LV − −525	11; 10; 9; 7	21,372
7	Duong Huy	+38 to −350	14; 13; 11; 10; 9; 8; V7; 6	20,650
8	Quang Hanh	−50 to −175	16; 13; 11; 7; 6	1839
9	Thong Nhat	−35 to −350	6B; 5C; 4C; 3C	3911
10	Ha Long (Khe Cham II-IV)	LV − −500	11; 10; 9; 8	51,009
11	Khe Cham III	LV − −350	14-5; 14-4; 14-2; 14-1; 13-2; 13-1; 12-1	27,222
12	Mong Duong	−100 to −250	G9; K(8); L(7); N(5)	6619
	Total of coal reserves capable of mechanized mining in the Quang Ninh area			**231,126**

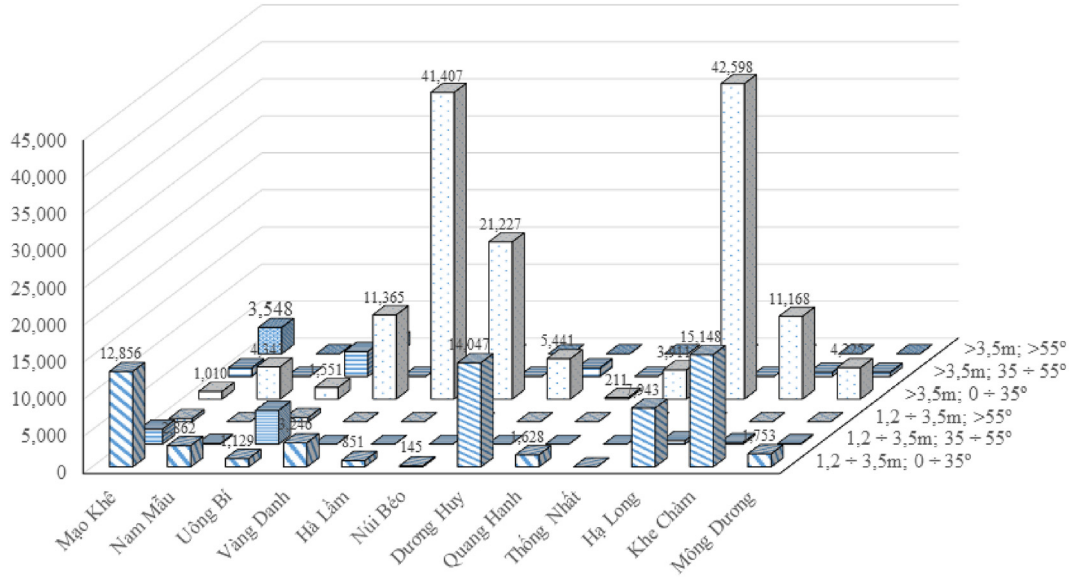

Fig. 1. The chart on geological reserves distribution and reserves capable of mining mechanization application according to evaluated deposits.

Since April 2005, the first mechanized longwall exploiting the full seam thickness was in the Khe Cham coal mine (see Fig. 2a). The success of the mechanized application in Khe Cham was expanded in the next longwalls in Duong Huy (see Fig. 2b) and Quang Hanh Company (Fig. 2c) since 2015 and in Ha Long Coal Company since 2020 (see Fig. 2d).

(2) The longwall top coal caving

The Vietnamese coal output obtains about 50% of the extraction from thick coal seams (with a thickness of more than 3.5 m). The large resources and high quality of coal in these deposits dictate the need for further development of their exploitation. The technical and economic results obtained in the exploitation of thick seams will significantly affect the effects of the functioning of the coal industry. Since 1999, the longwall supported by hydraulic supports has been applied in underground coal mines in Quang Ninh coalfield. In order to investigate the possibility of using powered support, in 2007, in the Vang Danh coal mine, the mechanized

Table 2. Mechanized equipment lines in underground coal mines in the Quang Ninh region.

No.	Name of mechanized longwall	Name of coal mine	Mechanized support		Mining shearer	Armoured face conveyor	
			Type	Number	Type	Type	Number
I	**The longwall mining method applied for seams having a thickness from thin to medium (up to 3.5 m), dipping up to 35°**						
1	KC 1	Khe Cham	ZZ 3200/16/26 ZT 3200/16/26	89	MG 150/375-W	SGZ 630/220	1
2	DH	Duong Huy	ZY 3200/16/36	102	MG 300/700-W	SGZ 730/220	1
3	QH	Quang Hanh	ZQY 3600/12/28	55	MG 132/320-W	SGZ 630/220	1
4	HL	Ha Long	ZY2400/14/32Q ZYG 2400/12/32Q	74	MG160/381-WD	SGZ 630/220	1
II	**The longwall top coal caving applied for seams with m ≥ 3,5 m, α ≤ 35°**						
1	HL 1	Ha Lam	ZF 4400/16/28 ZFG 4800/18/28	80	MG 150/375-W	SGZ 630/264	2
2	HL 2		ZF 8400/20/32 ZFG 9600/23/37	102	MG 300/730-WD1	SGZ 764/400 SGZ 800/630	2
3	KC 2	Khe Cham	ZFY 5000/16/28 ZFG 6200/17/30	100	MG 170/410-WD	SGZ 630/264	2
4	VD	Vang Danh	ZF 4400/17/28 ZFG 4800/20/32	84	MG 170/410-WD	SGZ 630/2 × 132	2
5	NB	Nui Beo	ZF 4400/17/28 ZFG 4800/18/30	86	MG 160/391-WD	SGZ 630/264	2
6	MD	Mong Duong	ZF 3000/15/24 ZFG 3200/19/31	96	MG 160/380-WD	SGZ 630/220	2
III	**The mining method applied to exploit seams with thickness from thin to medium, steep**						
1	2ANSH	Uong Bi	2ANSH	120	1ANSHM	–	–

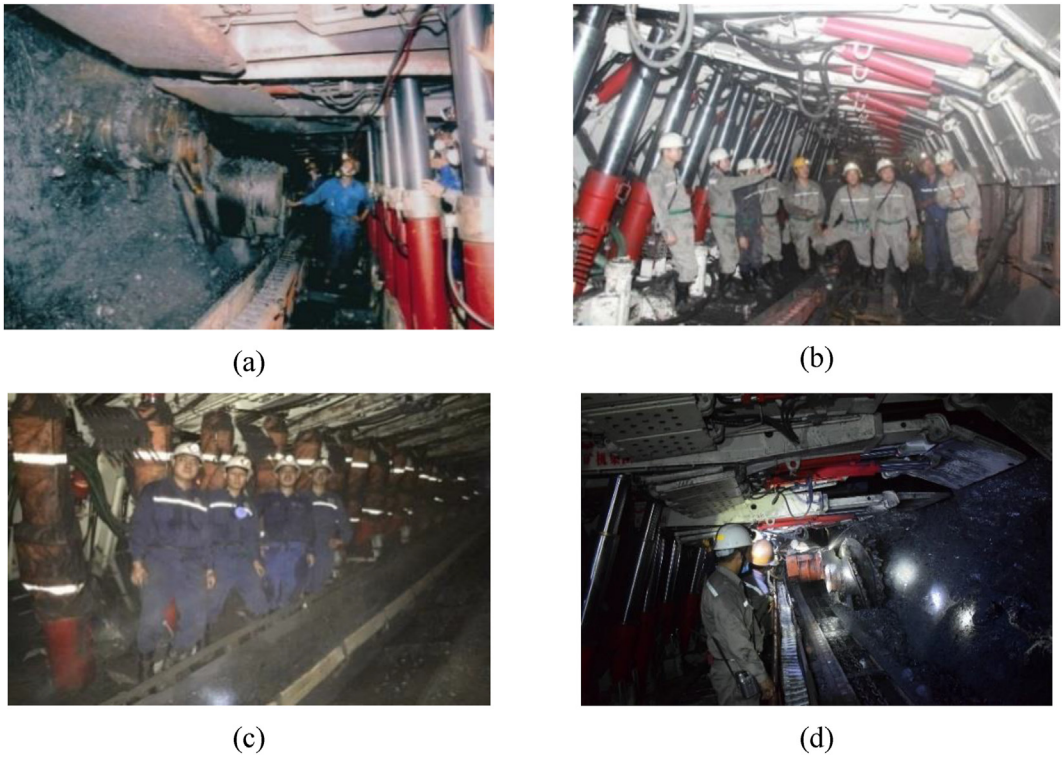

Fig. 2. Mechanized longwalls mining medium thick coal seam, dipping up to 35°: (a) longwall "KC 1" in Khe Cham coal mine since 2005; mining capacity 400,000 tonnes/year); (b) longwall "DH" in Duong Huy coal mine since 2015; mining capacity 600,000 tonnes/year); (c) longwall "QH" in Quang Hanh coal mine since 2015; mining capacity 180,000 tonnes/year); (d) longwall "HL" in Ha Long coal mine since 2020; mining capacity 300,000 tonnes/year.

longwall was implemented using support type VINAALTA-2.0/3.15 with front armoured face conveyor (AFC), mining seam with an average thickness of 7.2 m and dip of 14° (Fig. 2a). The annual coal output from the longwall was approximately 450,000 tonnes. In 2010, the same method of exploitation was implemented at the Nam Mau coal mine [5].

The most technologically advanced, intended for the exploitation of a thick seam, is longwall top coal caving using two AFC (rear AFC and front AFC) (see Fig. 3a, b). It has been used in Vietnamese mines since 2015. In the Ha Lam coal mine, there are two mechanized longwalls with a mining capacities of approximately 600,000 tonnes and 1,200,000 tonnes. The achieved mining efficiency is relatively high, on average labour productivity from 33.5 to 34.0 Mg/working day, which is 4–5 times more than in longwalls supported by hydraulic frame support. Some other underground mines have also applied the LTTC method, including Khe Cham Coal Company since April 2016 (capacity of 600,000 tonnes/year, Fig. 3c), in Vang Danh Coal Company since November 2018 (with a capacity of 450,000 tonnes/year, Fig. 3d), in Nui Beo Coal Company since 2020, mining capacity 500,000 tonnes/year, Fig. 3e and in Mong Duong coal mine since 2020, mining capacity 300,000 tonnes/year, Fig. 3f.

(3) The mining method applied to exploit steep, thin to medium thickness seam

Since 2008, Mao Khe and Hong Thai coal companies have been using mechanized technology to extract the high steep thin coal seams with the dip angle greater than 45°. The mining field is separated by main haulages (not longer than 120–150 m long and 60–80 m wide). The longwall is equipped with power support type 2ANSHA (made in Czech) and a plow. The obtained labour productivity is 5.6 Mg/working-day, and the annual coal output is 64,500 tonnes. Compared to the sublevel mining system, the efficiency of longwall supported by 2ANSHA support is twice as high, the roadway driving intensity index is seven times lower, and the coal loss index has decreased by two times.

(4) The shortwall mining technology using shield support applied for the steep thick seams

In 2007–2013, the mechanized sub-level caving method for extracting steep thick coal seams was

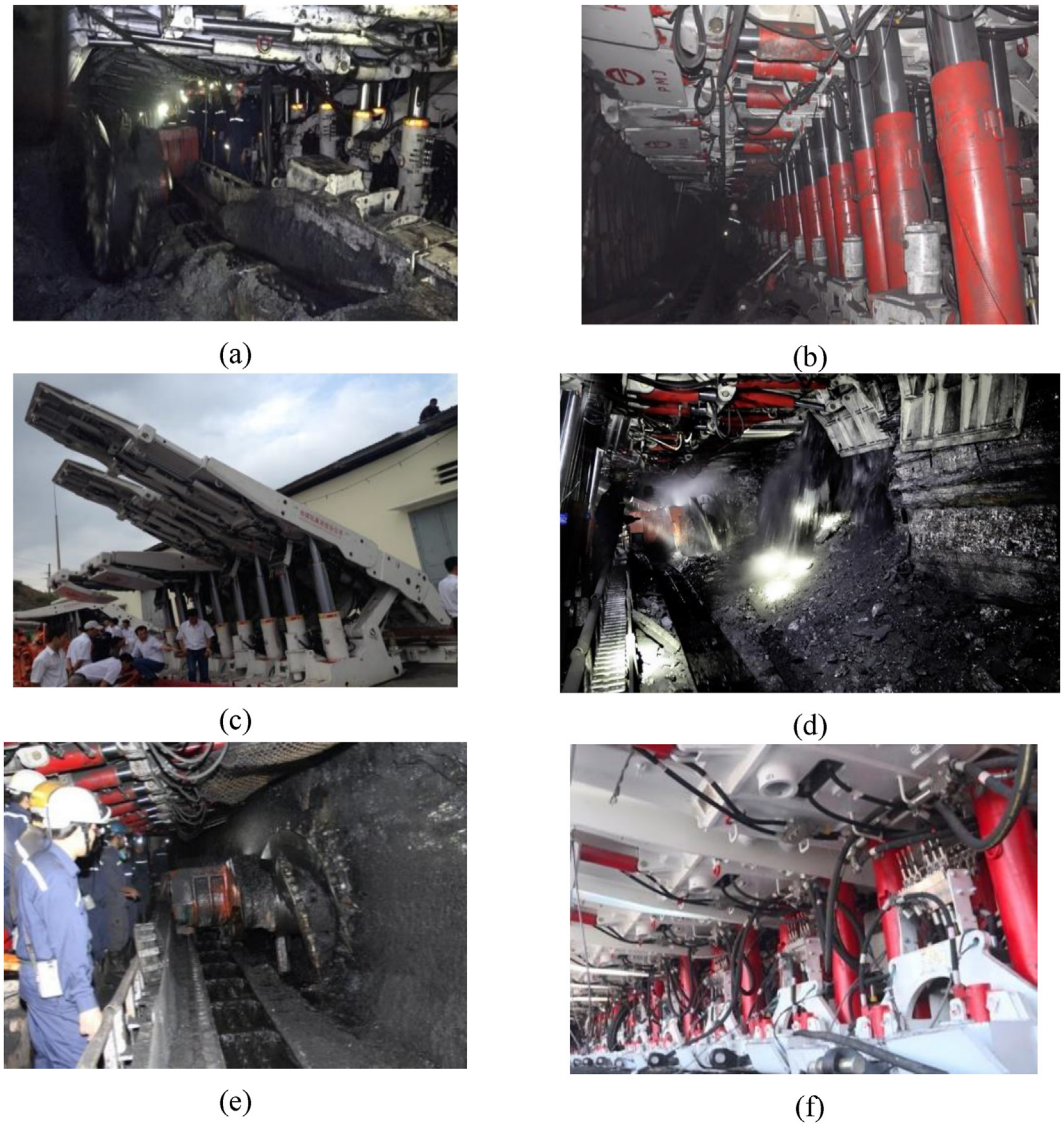

Fig. 3. Mechanized longwalls mining thick coal seam, dipping up to 35°: (a) longwall "HL 1" in Ha Lam coal mine; (b) longwall "HL 2" in Ha Lam coal mine; (c) longwall "KC 2" in Khe Cham coal mine; (d) longwall "VD" in Vang Danh coal mine; (e) longwall "NB" in Nui Beo coal mine; (f) longwall "MD" in Mong Duong coal mine.

introduced in the Vang Danh and Ha Long underground mines. The shortwall of the sub-level was equipped with two shield supports, a conveyor, a portable drilling machine type VPS-01 and blasting equipment. The mechanized support set is built on the basis of two sections of the KDT-1 powered support (at the Vang Danh mine) or KDT-2 (at the Ha Long mine) and top coal caving by blasting drilling in the long hole. Unfortunately, both shortwalls have not reached mining efficiency because of the complicated geology conditions (water flowing into the shortwall, fluctuation of seams, large mine pressure).

The results of mechanized mining application in underground mines in Quangninh coalfield in 2005–2020 are presented in Table 3 and Table 4.

The experiences of application in mechanized equipment in some underground coal mines in the Quang Ninh area showed that the mechanized mining method can increase the coal output more than the blast drilling method in longwalls [6]. The application of the mechanization can improve working conditions because the main activities in mining processes, understood as coal breaking and supporting, are performed by mechanized equipment, and decreasing number of workers work directly at the longwall face (from 1.5 to 2 times compared with manual longwall) [6].

In order to ensure stable development, one important factor is to increase labour productivity and decrease the number of workers working directly underground. It is supposed that the overall

Table 3. Coal output (in thousands of tonnes) of mechanized longwalls in underground coal mines in 2005–2012 [1].

No.	Name of company	The mechanized mining method	Year							
			2005	2006	2007	2008	2009	2010	2011	2012
1	Khe Cham	(1)	208.6	388.2	67.9	358.4	275.4	276.3	232.9	237.8
2	Vang Danh	(2)	–	–	–	171.3	163.5	142.1	19.0	5.8
3	Ha Lam		–	–	–	–	–	–	–	–
4	Nam Mau		–	–	–	–	–	74.7	171.6	64.1
5	Mao Khe	(3)	–	–	–	34.9	63.5	59.3	49.5	19.2
6	Uong Bi		–	–	–	3.6	37.8	42.8	86.2	65.5

output of underground mines is mined by manual blast drilling, supported by a frame with the current mining capacity (180 thousand tonnes/year). According to the mining plan, it was necessary to increase the quantity from 130 longwalls to 345 longwalls in 2025, only by this way, can meet the demand on increasing the output. That means the number of workers will increase 2.86 times (about 50,400 workers) in 2025, compared with the current situation. While with the mining capacity of mechanized longwall (for example, 600 thousand tonnes/year in Ha Lam and 300 thousand tonnes/year in Vang Danh) required only 111 longwalls in 2021 and 175 longwalls in 2025, equivalent to 50% of longwalls, compared with movable frame beam longwall which can meet the demand of output as required. Therefore, to limit the mining workers increase and meet the demand for increasing the output, it is essential to deploy and apply mining and driving mechanization in the current period.

The other key issue of mechanization application is the possibility of ensuring stable development in terms of day by day increasing workers' salary level. According to the route, the coal industry take some more systems, and treatment policies for miners to facilitate stable living conditions for workers, and to minimize the difficulties on lack of labour sources. Therefore, the application of mechanized longwall with high labour productivity, and low labour consumption will be the essential long-term solution to stabilize labour and production of the mine.

5. Prospect of mechanized mining in underground coal mines in Quang Ninh region in the period 2021–2025, with a perspective to 2030

In order to maintain the coal industry development, it is necessary to promote the mining mechanization application work in areas with suitable mine technical geology conditions. According to general evaluation on mine technical geological conditions of coal seams to the exploration level and mining planning of some underground coal mines in Quang Ninh area, some following basic mining mechanization technological are proposed to research and deploy depending on the condition of seam thickness and slope angle the evaluation on mine technical geology characteristic of coal seams: (1) The longwall top coal caving, retreats along the strike, extracting at the bottom slice, top coal caving, applied for slope thick seam to 35°; (2) The single pass longwall mining method, retreats along strike, extracting the full seam thickness, applied for seams from thin to medium thick, slope angle to 35°; (3) The sublevel drift mining mechanization by shearer combined with blast drilling in long borehole, using non-electric differential detonator to increase sublevel height used in the seam with slope more than 45°; (4) The single pass longwall mining method, retreats along the seam dip, using the shield support compound of 2ANSH for thin and steep seams. Furthermore, the paper proposes a plan for applying mechanized mining,

Table 4. Coal output (in thousands of tonnes) of mechanized longwalls in underground coal mines in 2013–2020.

No.	Name of company	The mechanized mining method	Year								
			2013	2014	2015	2016	2017	2018	2019	2020	Total (2005–2020)
1	Khe Cham	(1)	267.5	229.6	346.3	168.9	92.9	153.3	111.1	98.7	**3513.7**
		(2)	–	–	–	184.8	359.7	178.0	13.6	–	**736.1**
2	Vang Danh	(2)	–	–	–	–	–	406.1	371.3	405	**1684.1**
3	Ha Lam		–	–	301.0	661.2	1658.9	1650.0	1567.3	1600	**7438.5**
4	Nam Mau		205.3	123.7	25.9	–	–	–	–	–	**665.3**
5	Mao Khe	(3)	–	15.2	–	–	–	–	–	–	**241.7**
6	Uong Bi		96.3	78.1	19.8	48.2	67.3	99.8	113.4	–	**758.8**
7	Duong Huy	(1)	–	–	23.1	200.0	289.2	402.3	432.8	104.8	**1452.3**
8	Quang Hanh	(1)	–	–	4.4	121.3	136.1	160.7	180.5	129.4	**732.4**
9	Ha Long	(1)	–	–	–	–	–	–	–	95.4	**95.4**

Table 5. Coal output of mechanized longwalls in underground coal mines from 2021 to 2025. Note: (1) The mining capacity of mechanized longwall, 1000 tonnes; (2) Number of mechanized longwalls; (3) Coal output of mechanized longwalls/total underground coal output (%).

No.	Name of company	Content	Year				
			2021	2022	2023	2024	2025
1	Mao Khe	*(1)*	–	–	–	–	50
		(2)	–	–	–	–	1
		(3)	–	–	–	–	*3%*
2	Vang Danh	*(1)*	540	450	450	580	710
		(2)	1	1	1	1	1
		(3)	*21.1*	*18.6*	*19.5*	*25.2*	*28*
3	Uong Bi	*(1)*	–	171	340	340	340
		(2)	–	1	2	2	2
		(3)	–	*7.8*	*15.9*	*19.5*	*18.7*
4	Nam Mau	*(1)*	–	–	150	250	250
		(2)	–	–	1	1	1
		(3)	–	–	*9*	*15*	*14.7*
5	Ha Lam	*(1)*	1403	1300	1350	1350	1450
		(2)	2	2	2	2	2
		(3)	*60.1*	*61.3*	*67.8*	*60.8*	*70*
6	Hon Gai	*(1)*	–	–	–	85	240
		(2)	–	–	–	1	1
		(3)	–	–	–	*4.7*	*12.9*
7	Nui Beo	*(1)*	300	420	450	510	700
		(2)	1	1	1	2	2
		(3)	*33.5*	*36.2*	*33.1*	*32.7*	*42.4*
8	Quang Hanh	*(1)*	100	180	86	0	60
		(2)	1	1	1	0	1
		(3)	*7.7*	*13.6*	*6.5*	*0*	*4.5*
9	Duong Huy	*(1)*	380	527	700	700	700
		(2)	1	2	2	2	2
		(3)	*24.2*	*31.4*	*34.6*	*34.6*	*34.6*
10	Ha Long	*(1)*	240	200	300	420	690
		(2)	1	1	1	2	3
		(3)	*16.9*	*13.1*	*14.4*	*16.7*	*20.8*
11	Thong Nhat	*(1)*	0	0	60	300	300
		(2)	0	0	1	1	1
		(3)	*0*	*0*	*3.7*	*16*	*16*
12	Mong Duong	*(1)*	300	300	300	300	300
		(2)	1	1	1	1	1
		(3)	*22.6*	*22.6*	*22.6*	*22.6*	*22.6*
13	Khe Cham	*(1)*	435	460	504	520	520
		(2)	2	2	2	2	2
		(3)	*28.9*	*32.3*	*33.6*	*32.2*	*32.2*
	Total	***(1)***	**3698**	**4008**	**4690**	**5355**	**6310**
		(2)	**10**	**12**	**15**	**17**	**20**
		(3)	**17**	**18**	**21**	**24**	**29**

which is presented in Table 5. According to this plan, the rate of coal output from mechanized longwalls has increased, in 2022 reach to 18% and will achieve 29% of total underground coal output. Besides, the number of mechanized longwalls increased from 12 to 20 longwalls.

6. Conclusions

A summarized evaluation of 12 typical mines of VINACOMIN showed that total coal reserves, which are possible to apply the mining mechanization technology accounts for 240 million tonnes. The application of mechanized technology in Vietnam's underground coal mines is essential in the period 2021–2025 due to the demand for increasing the coal output and mining productivity, solving difficulties for underground employees and improving the working environment. In order to orient the mechanization development at underground mines in Quang Ninh coalfield, it is necessary to carry out some solutions including promotion of the additional exploration work to enhance the reliability level of deposit reserves in the mining plan for the period 2021–2025 of VINACOMIN; To make the domestic mechanized equipment in order to master the design, manufacturing and production process step by step which is suitable with mine technical and geological conditions of Vietnam, reducing reliance on the import; the underground coal companies need to follow the mechanized master plan of the VINACOMIN.

Ethical statement

The authors state that the research was conducted according to ethical standards.

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Conflict of interest

The authors declare no conflict of interest.

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