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Loewy filtration and quantum de Rham cohomology over quantum divided power algebra

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As a continuation of \cite{HU}, we explore the submodule structures of the quantum divided power algebra $\mathcal{A}_q(n)$ introduced in \cite{HU} and its truncated objects $\mathcal{A}_q(n, \mathbf{m})$. We develop an "intertwinedly-lifting" method to prove the indecomposability of a module when its socle is semisimple. We describe the Loewy filtrations for all the homogeneous subspaces $\mathcal{A}^{(s)}_q(n)$ or $\mathcal{A}_q^{(s)}(n, \mathbf{m})$, determine their Loewy layers and dimensions, and prove their rigidity. From our realization model for a class of indecomposable modules for $\mathfrak{u}_q(\mathfrak{sl}_n)$, we derive an interesting combinatorial identity. Furthermore, we construct the quantum Grassmann algebra $\Omega_q(n)$ over $\mathcal{A}_q(n)$ and the quantum de Rham complex $(\Omega_q(n), d^\bullet)$ via defining the appropriate q -differentials, as well as its subcomplex $(\Omega_q(n, \mathbf{m}), d^\bullet)$. For the latter, we decompose the corresponding quantum de Rham cohomology modules as the direct sum of some sign-trivial $\mathfrak{u}_q(\mathfrak{sl}_n)$ -modules.

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